Concurrent Validity and Cross-Validation of the Child SCAT3 PCSS-C Sleep Cluster

by

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Abstract

Objective: The Post-Concussion Symptom Scale (PCSS) has been used to evaluate impaired sleep, despite not being validated for this purpose. The objective of this study was to examine the concurrent validity of the Post-Concussion Symptom Scale-Child (PCSS-C) sleep items/cluster with a validated measure of sleep functioning and the effect of sleep problems on baseline performance in children. **Design:** The study design was retrospective and cross-sectional. **Participants:** Participants included male children (*n* = 80), between 10 to 12 years of age who were enrolled in a comprehensive concussion study and completed pre-season testing. **Assessment of Risk Factors**: Athletes were divided into 2 groups: (1) Sleep Problems (i.e., defined as PCSS-C sleep cluster ≥ 1) and (2) Control (i.e., defined as PCSS-C sleep cluster = 0). **Main Outcome Measures:** The Child Sport Concussion Assessment Tool 3 (Child SCAT3) and the Sleep/Wake Problems Behaviour scale (SWPB). **Results:** The reliability coefficients of measures by Ordinal alpha were .62 and .70, respectively. Individual PCSS-C sleep items were moderately associated with the validated sleep measure (i.e., SWPB). A large effect ($r_s = .58$, $p < .001$) was observed between the SWPB total score and the PCSS-C sleep cluster. Sleep difficulties did not affect the Child SCAT3 Standard Assessment of Concussion (SAC-C) or Balance Error Scoring System (BESS-C) scores. In contrast, the effect of sleep difficulties on symptom reporting was significant. Large effect sizes ($d = 1$) were found between the sleep groups for symptom total, $t(78) = -4.72$, p < .001 and symptom severity score, $t(78) = -5.31$, p < . 001. Participants in the Sleep Problems group reported both a greater number of symptoms and higher symptom severity score. Supplementary analyses indicated that sleep difficulties were associated with Post-Concussion Symptom clusters of the PCSS-C. Medium effect sizes were observed between the PCSS-C sleep cluster and the PCSS-C cognitive cluster ($r_s(80) = .34$, p

=.002) and PCSS-C somatic cluster ($r_s(80) = .40$, $p < .001$). **Conclusions:** If the data is not normally distributed, the Ordinal alpha is a more accurate coefficient for testing reliability. Although the PCSS-C of the Child SCAT3 was never designed to thoroughly assess sleep problems, the sleep items on the PCSS-C may be useful when other sleep measures are not available. **Clinical Relevance**: The subjective measures of the Child SCAT were all significantly affected by self-reported sleep problems. Sleep problems may be an important confound when assessing post-concussion symptoms.

Keywords: sleep, concurrent validity, children, baseline assessment, Child SCAT3

Dedications

This thesis is dedicated to my family. My family has always been a significant part of my identity and have always been a source of great strength, pride and joy. Thank you for dealing with my perpetual status as a student with optimism and encouragement. I would not have gotten nearly this far without your ongoing support and compassion throughout my years in academia.

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Table of Contents

List of Tables

List of Abbreviations

PCSS	Post-Concussion Symptom Scale
SWPB	Sleep/Wake Problems Behaviour
mTBI	Mild Traumatic Brain Injury
SCAT	Sport Concussion Assessment Tool

Chapter 1

In Canada, participation in sports is a common activity for children and adolescents. Sports participation can enhance a youth's physical and psychosocial health (Strong et al., 2005), by improving their self-efficacy, learning behavioural skills that underlie the ability to interact with peers their own age and family members, as well as performing better in school (Bloom, Grant, & Watt, 2005). Participation in sports also exposes youth to an increased risk of sports-related injuries, with concussions being the most commonly reported sports injury among children and adolescents (Browne & Lam, 2006). For instance, 25% of youth admitted to the hospital for concussions are related to a sports injury (Anstey et al., 2004; Browne & Lam, 2006). This risk increases in youth that play contact sports (Coghlin, Myles, & Howitt, 2009), such as ice hockey (McKinlay et al., 2008). Particularly among youth ice hockey players concussions are a commonly reported injury (Emery & Meeuwisse, 2006). It is estimated that the rate of sports-related concussion in ice hockey players aged 11-12 years old, is 78 concussions per 85,077 exposure-hours (Emery et al., 2010). A recent meta-analysis (Pfister, Pfister, Hagel, Ghali, & Ronksley, 2016) reported that the highest incidence rate of concussion for ice hockey was 1.20 per 1000 athlete exposures (AEs).

Concussions are defined as a complex pathophysiological process that affects the brain and psychological symptoms such as behaviour, emotion and cognition and is caused by biomechanical forces (McCrory et al., 2013). Similar to adults, children and adolescents following concussion can experience varying levels of neurobehavioral deficits that includes combinations of somatic symptoms (e.g., headache, nausea, fatigue, dizziness, balance deficits, sensitivity to light/noise etc.), cognitive symptoms (e.g., reduced processing speed, poor attention/concentration, problem solving/planning difficulties, memory deficits etc.), and emotional/behavioural symptoms (e.g., irritability, feeling more emotional, anxiety, and depression) (Kirkwood, Yeates, & Wilson, 2006). Concussions are a subset of mild traumatic brain injury (mTBI) and are considered to be on the less-severe end of the brain injury spectrum (Harmon et al., 2013); however, some concussed athletes can experience enduring long-term altering sequelae. For instance, select studies suggest that somatic symptoms of concussion (i.e., headaches, dizziness, etc.) often resolve within weeks to months of injury (Cunningham, Brison, & Pickett, 2011), whereas emotional and cognitive symptoms may persist beyond 1 year (Barlow et al., 2010).

The developing brain is particularly vulnerable to concussion, which results in delayed recovery and exposes children to a greater risk for persistent functional deficits, and that such insult may have long lasting consequences that might not become apparent until the brain is fully mature (Coghlin et al., 2009). Children and adolescents function in a social and scholastic environment on a routine basis where mild difficulties in cognitive and behavioural functioning can potentially affect their performance in school and their social relationships. As a result, there has been increased attention to the problem of establishing guidelines for assisting youth when returning to school following a concussion (Iverson & Gioia, 2016). Thus, there are direct implications for school and clinical psychologists working with this population.

The Problem

The incidence of mTBI in youth with its short-term and potential long-term consequences has led to an increased emphasis on proper evaluation, assessment and management. One component of recommended standards of care in the treatment of concussions in the pediatric population is the use of baseline neuropsychological and cognitive tests. Essentially, this involves the administration of standardized tools to athletes at the start of a competitive season.

Should an athlete suffer a concussion, repeated assessments with these tools in conjunction with a clinical examination are used to formulate decisions for return to play (RTP) (Dessy, Rasouli, Gometz, & Choudhri, 2014; McCrory et al., 2013).

Post-concussive RTP guidelines recommend symptom resolution and return to cognitive baseline levels, therefore, clinical decisions rest in part on the interpretation of modifiers of baseline performance (McClure, Zuckerman, Kutscher, Gregory, & Solomon, 2014). The recent expert Concussion in Sport Group (CISG) identified several modifying factors that can create difficulties when assessing, recognizing and managing concussions (McCrory et al., 2013). These include both situational (i.e., testing environment) and dispositional factors (i.e., the effects of prior concussions, age, athlete's sex, effort/motivation, and difficulty/failure to follow test instructions) (Iverson, 2006; Landre, Poppe, Davis, Schmaus, & Hobbs, 2006; McCrory et al., 2013), both of which have been found to affect the reliability and validity of baseline assessment scores.

Of the existing pre-injury vulnerabilities, sleep-related factors have been identified as potential modifiers that influence assessment testing (McClure, Zuckerman, Kutscher, Gregory, & Solomon, 2014; Mihalik et al., 2013; Silverberg, Berkner, Atkins, Zafonte, & Iverson, 2016; Sufrinko et al., 2015; Sufrinko, Johnson, & Henry, 2016). Disrupted sleep patterns in youth are common and poor sleep quality has the potential to disrupt a child's daily functioning. Similar to adults, poor sleep in children affects a number of domains related to cognitive processes (i.e., reaction time and attention) (Millman, 2005). In fact, the correlation between poor cognitive outcomes and poor sleep is generally consistent across the developmental age span, with the understanding that younger children are particularly vulnerable to the effects of reduced sleep compared to older children (Sadeh, Gruber, & Raviv, 2003). In addition, researchers have found that poor sleep in youth can be associated with psychological symptoms, such as anxiety, emotional problems and depression (Forbes et al., 2008).

Rationale

To assist in the evaluative process, concussion assessment tools have been developed within the last decade and each is designed to assess specific aspects of a concussion or a combination of potential deficits. Two tools commonly used as a measure of baseline functioning and post-concussion status are, the Immediate Post-Concussion Assessment and Cognitive Test (ImPACT) and the Sports Concussion Assessment Tool (SCAT). One component of these tools is the Post-Concussion Symptom Scale (PCSS), which includes items that assess symptoms of cognition, emotion, somatization, and sleep. Although the PCSS is not a measure designed specifically for the assessment of sleep problems, select researchers have used the PCSS sleep-related items to investigate the relationship between sleep problems and other variables on concussion tools (i.e., symptoms, cognition, etc.) Using the sleep disturbance symptoms (grouped in various ways) that were self-reported as part of the PCSS of the ImPACT or SCAT has led to important findings. For example, sleep problems identified with the self-reported PCSS sleep items was associated with increased total scores on the PCSS at pre-injury (Sufrinko et al., 2016) and at post-injury (Kostyun, Milewski, & Hafeez, 2015; Sufrinko et al., 2015; Tkachenko, Singh, Hasanaj, Serrano, & Kothare, 2016) evaluations. However, it has not yet been established whether the PCSS sleep items can evaluate sleep problems. Because of its extensive use in the pediatric population, the self-report sleep items, a part of the Post-Concussion Symptom Scale-Child (PCSS-C), a component of the Child SCAT3, may serve as a potential screening measure when focused sleep measures are not available or possible.

Underlying Assumptions

The research questions for this study are derived from certain assumptions. For example, it is assumed that the PCSS-C sleep-related items of the PCSS-C, a component of the Child SCAT3, will be positively associated with the items of the Sleep/Wake Problems Behaviour scale (i.e., a validated sleep measure). This assumption is based on the fact that both tools use a self-report Likert scale and are specifically designed for school-aged children.

The second assumption is that the baseline Child SCAT3 scores will be affected by the presence of sleep problems (i.e., defined as participants with PCSS-C sleep cluster scores of ≥ 1). This assumption is supported by previous research which has shown that self-reported sleep problems had a statistically significant effect on scores for PCSS Total Symptom (McClure et al., 2014; Mihalik et al., 2013; Sufrinko et al., 2015; Sufrinko et al., 2016), and the PCSS clusters, somatic and cognitive (McClure et al., 2014) in adolescent and collegiate-aged athletes.

The Present Study

The purpose of this study was to create a three-item sleep scale of the PCSS-C and to evaluate its psychometric properties (i.e., internal consistency and concurrent validity) in children. The PCSS-C sleep cluster will be compared to a validated sleep tool commonly used in research involving children, the Sleep/Wake Problems Behaviour scale (SWPB). The secondary purpose of this study was to examine the effects of sleep problems on baseline symptoms (i.e., PCSS-C Total Symptom, PCSS-C Symptom Severity, and PCSS-C clusters) and Child SCAT3 cognitive (i.e., Standardized Assessment of Concussion-Child version) and balancing scores (i.e., Balance Error Scoring System-Child version) in minor ice hockey players. Athletes who endorsed at least one of the PCSS-C sleep items were grouped together to form the ‘Sleep

Problems' group and were compared to control athletes (i.e., those who did not endorse any of the PCSS-C sleep items).

This thesis is comprised of five chapters, including this introductory chapter. Preceding each chapter is a brief summary of the chapter's contents, and a description of how the chapter relates to this project's inquiry. Chapter two consists of a review of the literature on current knowledge of sports-related concussions (i.e., definition, symptoms, incidence rates, assessment and management) with a focus on youth ice hockey players. The review also includes information on factors modifying baseline testing, with an emphasis on sleep problems. Chapter three will consist of details outlining the methodology of this project (i.e., data collection, tools, etc.) and the results section will be presented in Chapter four. Lastly, in Chapter five, the results will be analyzed and compared to the current literature. This Chapter will end with a discussion of the practical implications for healthcare professionals, the limitations encountered and suggestions for future studies.

Chapter Two – Literature Review

The Sport Concussion Assessment Tool (SCAT) is a measure commonly used for the assessment of symptoms related to concussions. Recently, a couple of items from the Post-Concussion Symptom Scale (PCSS) of the SCAT and Immediate Post-Concussion Assessment and Cognitive Test (ImPACT) have been used to measure sleep problems. The objective of this study was to examine the reliability and validity of the PCSS-C sleep/cluster. Given the extensive use of this diagnostic tool (i.e., Child SCAT3) in children and adolescents, the PCSS-C sleep items/cluster may serve as a potential screening tool when specific sleep measures are unavailable. In addition, the effect of sleep problems on self-reported symptoms and Child SCAT3 scores at baseline was examined. The PCSS, a section of the SCAT and ImPACT has been used to assess sleep problems in adolescents and adults; however, whether the presence of sleep problems (defined by the PCSS-C sleep items) affects self-reported symptoms and the objective scores of the Child SCAT3 remains unknown.

This chapter provides a brief overview of the current knowledge on sports-related concussions and includes the definition, symptoms, incidence rates and guidelines of assessment as well as the management of concussions with a focus on youth ice hockey players. This review also provides a summary on factors that may influence performance test scores at baseline, specifically sleep difficulties. Lastly, this review intends to evaluate the validity and reliability of measuring sleep difficulties using items found on concussion tools (i.e., ImPACT and SCAT3). The rationale leading to the development of research objectives and hypotheses will conclude the chapter.

Sports-related Concussions

History. Participation in sports is a common activity for many children and adolescents in Canada. Fifty-one percent of children aged 5 to 14 years of age regularly participated in sports in 2005 (Clark, 2008), and it has been estimated that 43% of children aged 12 to 15 years old participate in organized sports at least once a week (Bloom et al., 2005). Specifically, compelling to Canadian youth is the sport of ice hockey. Ice hockey is recognized as Canada's national winter sport (Branch, 2002) with 11% of youth (5 to 14 years old) regularly taking part in ice hockey (Clark, 2008) at the recreational level. Over 570,000 youth players (under 18 years) are registered with Hockey Canada ("Hockey Canada Annual Report," 2016). Regular participation in physical activity (i.e., sports participation) can result in enhanced physical and psychosocial health, and has been reported to help youth feel better about themselves, make friends, perform better in school and to be more active within their families (Bloom et al., 2005). Despite the numerous benefits of playing sports, participation in sport activity also exposes youth to an increased risk of sports injury, with concussion being one of the most commonly reported sport injuries in children and adolescents (Browne & Lam, 2006).

Concussions occur more frequently in contact sports with the highest prevalence in sports such as ice hockey. Reportedly, among youth ice hockey players it is the most common specific injury (Emery & Meeuwisse, 2006). Several risk factors have been identified which include, the player's age, position, their physical size and a previous history of injury and/or concussion. Other factors (Emery et al., 2010) include the session-type (i.e., a practice vs. a game) and level of play (i.e., Peewee, Bantam, etc.) Based on the session-type, the estimated injury risk ratios range between 2.45 to 6.32, with an increased risk of injury being reported in games relative to practices (Benson & Meeuwisse, 2005; Emery et al., 2010; Emery & Meeuwisse, 2006).

Epidemiology. Concussions represent 5.8% of all college and 8.9% of all high school athletic injuries (Gessel, Fields, Collins, Dick, & Comstock, 2007). School-aged children are six times more prone to suffer a concussion during organized sport participation compared to any other physical leisure activities (Browne & Lam, 2006). Among youth ice hockey players, the reported incidence of concussion range between 12% (Gerberich et al., 1987) to 15% (Brust, Leonard, Pheley, & Roberts, 1992) of all injuries. For children aged 11-12 years old, the rate of concussion in hockey has been estimated at 78 concussions per 85,077 exposure-hours (Emery et al., 2010), with an annual incidence rate estimated to be as high as 20% of players per team (Tator, 2009). For game-related injuries (Emery et al., 2010), the incidence rate ratio per 1000 game hours, is 1.37 for all injuries, 0.39 for concussion, 0.31 for severe injury (i.e., 1 week of time loss), and 0.08 for severe concussion (i.e., time loss of > 10 days). However, the actual number of concussions in youth ice hockey may be higher as concussions are considerably underreported by both coaches and team personnel as well as players (Williamson & Goodman, 2006).

Definition. A concussion is the result of bio-mechanical forces transmitted to the head caused by a direct or indirect blow to the head, face or neck, or anywhere else on the body. Concussions are considered a subset of traumatic brain injury (TBI), also known as a mild traumatic brain injury (mTBI) and are defined as a complex pathophysiological process affecting the brain and psychological symptoms such as behaviour, emotion and cognition (McCrory et al., 2013). There are several varying hypotheses and theories regarding the pathophysiological processes related to concussion (Blume & Hawash, 2012; Choe, Babikian, DiFiori, Hovda, & Giza, 2012; Cohen, Gioia, Atabaki, & Teach, 2009; Davis & Purcell, 2014; Guskiewicz & Valovich McLeod, 2011; Karlin, 2011; Kirkwood et al., 2006; Schnadower, Vazquez, Lee, Dayan, & Roskind, 2007). As a result, there are numerous definitions of concussion in the literature. The absence of an accepted definition has been problematic for establishing recommendations for the assessment and management of concussions. For the purposes of this paper, the terms ‘concussion’ and ‘sports-related concussion’ will be used interchangeably and this paper will use the definition explained by McCrory and colleagues (2013).

There are several common features that incorporate clinical, pathologic, and bio-mechanical injury constructs that may be utilized in defining the nature of a concussive head injury include:

1. Concussion may be caused either by a direct blow to the head, face or neck elsewhere on the body with an “impulsive” force transmitted to the head;
2. Concussion typically results in the rapid onset of short-lived impairment of neurologic function that resolves spontaneously. However, in some cases, symptoms and signs may evolve over a number of minutes to hours;
3. Concussion may result in neurological changes, but the acute clinical symptoms largely reflect a functional disturbance rather than a structural injury and, as such, no abnormality is seen on standard structural neuroimaging studies;
4. Concussion results in a graded set of clinical symptoms that may or may not involve loss of consciousness. Resolution of the clinical and cognitive symptoms typically follows a sequential course. In a small percentage of cases; however, post-concussive symptoms may be prolonged (McCrory et al., 2013).

Pathophysiology and symptomatology. Similar to adults, youth following concussion can experience varying levels of neurobehavioral deficits that includes combinations of somatic symptoms (e.g., headache, nausea, fatigue, dizziness, balance deficits, sensitivity to light/noise etc.), cognitive symptoms (e.g., reduced processing speed, poor attention/concentration, problem solving/planning difficulties, memory deficits, etc.), and emotional/behavioural symptoms (e.g., irritability, feeling more emotional, anxiety, depression, etc.) (Kirkwood et al., 2006). Both adults and children commonly report symptoms related to cognitive (e.g., attention, verbal and visual memory and executive functioning), behavioural and emotional functioning (McKinlay, Grace, Horwood, Fergusson, & MacFarlane, 2010). The onset of symptoms can appear immediately or signs of injury can be delayed for days or even weeks (Mooney, Speed, & Sheppard, 2005). Symptoms and related performance deficits can persist for several weeks to months post-injury and have been reported in both adult (Willer & Leddy, 2006) and youth (Gagnon, Galli, Friedman, Grilli, & Iverson, 2009) athletes. Typically, adults return to baseline functioning within 5-7 days, whereas adolescents return to baseline within 10-14 days (Field, Collins, Lovell, & Maroon, 2003). For children younger than 12 years old, there is a paucity of data available concerning concussion outcomes for this age cohort (Purcell, 2009). Data from clinical reports suggests that these athletes usually require 30 days to be asymptomatic (Lovell & Fazio, 2008). The rate of recovery varies and is often dependent on both the severity of the injury and a history of concussion. Although most athletes do recover from a concussion, some concussed athletes can experience life altering long-term sequelae. Further, evidence on the outcomes of concussion in children, suggests a long-term association between concussions and deficits in social-adaptive behaviour (McKinlay et al., 2010) and neurocognitive functioning (Hessen, Nestvold, & Anderson, 2007). Therefore, efforts at preventing concussions in youth are very important.

Assessment and Management of Sports-related Concussions

Several guidelines have been developed to assist clinicians in the assessment and management of concussions (Aubry et al., 2002; Kirkwood et al., 2006; McCrory & Davis, 2005; McCrory et al., 2009). The recommended guidelines for managing a concussed athlete's ability to return to play, are physical and cognitive rest until acute symptoms resolve, which is then followed by a graded program. For the athlete to progress to the next level, they must be asymptomatic and if symptoms return they must return to the previous level (Halstead et al., 2013; Lee & Perriello, 2009). With respect to school-aged children, the guidelines recommend combining RTP with Return to Learning (RTL) (Lee & Perriello, 2009). The priority is to return the athlete back to their regular school attendance before allowing any physical activity (e.g., return to play).

Numerous concussion assessment tools have been developed within the last decade to assist in this process. These tools are designed to assess specific aspects of concussion or a combination of potential deficits. The evaluation of a concussion is comprehensive, multi-faceted and includes four components: defining symptoms of injury, identifying symptom status and cognitive impairment, establishing symptoms reported at post-injury are greater than symptoms reported before injury; and evaluating the impact on the individual's life (i.e., school, work, or social) (Gioia, 2012).

The diagnosis of a concussion is based on the clinical judgment of medical professionals (McCrory et al., 2013a); however, the use of normative data and individualized neuropsychological and cognitive testing of athletes has attempted to add to the accuracy of post-injury assessments. Although there is evidence for normative values in adults, collegiate and high-school aged athletes; there is limited normative data for concussion tools in children. The generalization of adult normative values to children is not recommended. Children are still in the process of developing and the guidelines for adults and adolescents do not account for the developmental changes children experience. Given these circumstances, the guidelines for the concussion-management of pediatric athletes suggests annual baseline assessments for children, particularly for those involved in high-contact sports (Gioia, 2015; Rose, Weber, Collen, & Heyer, 2015). This makes accurate baseline assessments vitally important, especially when such data are used to make clinical decisions regarding cognitive and symptom recovery following a concussion (Vaughan, Gerst, Sady, Newman, & Gioia, 2014). Typically, baseline assessments include measures that assess areas of functioning that are particularly vulnerable to injury so that ipsative comparisons can be made following an injury. This method (i.e., a serial model) is intended to improve clinical decision making regarding the presence and severity of insult after injury and recovery, in order to guide a safe return to sports or other activities that increase the risk of concussion. Therefore, clinicians must understand the potential factors that may influence an athlete's baseline test scores, to make the best use of these data.

Modifying factors. Previous research has reported several factors that may affect the self-report of psychological symptoms and cognitive performance. These factors have been reported in the recent expert consensus (i.e., CISG) as 'modifiers' that may affect baseline scores and consequently influence the assessment and management of concussions (McCrory et al., 2013). These modifiers include temporal factors associated with the recency and timing of other injuries (Landre et al., 2006), history of concussions, age (i.e., < 18 year olds) (McCrory et al., 2013), medication use (i.e., psychoactive drugs and anticoagulants), sport played (i.e., high-contact sports), and premorbid conditions (i.e., learning disabilities (LD), attention deficit hyperactivity disorders (ADHD), and mental health disorders) (Iverson, 2006). There is also some preliminary evidence that suggests sleep problems may be a significant premorbid factor (Everhart, Loveless, & Stephenson, 2016).

Sleep and baseline assessments. The current evidence suggests that sleep problems are a modifying factor that affects neuropsychological symptom reporting; however, the evidence for sleep problems affecting cognitive and balancing testing is limited and inconsistent. Further, most studies are conducted in adolescent or adult populations; thus, applying the evidence to children is not advised. Although generalizing these results to children is not recommended, the identified studies are included to discuss issues that will inform clinical practice and research in younger athletes.

There is a paucity of published research that focuses on the effect of sleep problems on domains commonly tested on concussion tools. Of these studies only a handful have used a concussion assessment tool, with even fewer researchers using a validated measure of sleep functioning. This in part can be explained by the inconsistency in the operational definitions of "sleep problems," and the acceptability, feasibility and efficacy of sleep measures (Wickwire et al., 2016). As a result, investigators have used self-report data, clinician ratings, and actigraphy to assess sleep functioning in patients with mTBI (Wickwire et al., 2016). With respect to subjective measures of sleep, only the Pittsburgh Sleep Quality Index (PSQI) (Fictenberg, Putnam, Mann, Zafonte, & Millard, 2001; Masel, Scheibel, Kimbark, & Kuna, 2001) and Epworth Sleepiness Scale (Masel et al., 2001) have been partially validated with objective measures of sleep in participants with TBI (Wickwire et al., 2016). With respect to the field of concussion research, only one study has used a validated measure of sleep (i.e., PSQI), whereas the remaining studies have used the sleep-related items of a domain (i.e., the Post-Concussion Symptom Scale) a part of concussion assessment tools to evaluate sleep problems.

Preliminary work on sleep problems and baseline test scores was undertaken by Mihalik et al. (2013). They investigated the relationship between sleep problems (i.e., either sleep quality or sleep quantity) and baseline measures commonly used in concussion evaluations in a population consisting of the National Collegiate Athletic Association Division 1 student-athletes (*n* = 155). Athletes with low sleep quality, which was measured using the PSQI (global score ≥ 5), reported a higher number of post-concussion symptoms as evaluated by the Graded Symptom Checklist (GSC), and reported more severe somatic and neurobehavioral symptoms compared to athletes who had high sleep quality. Low sleep quality had no effect on neurocognitive function as evaluated by the CNS Vital Signs battery (computerized neurocognitive test) or balance performance as measured by the Sensory Organization Test (SOT) or other symptom clusters (i.e., Cognitive). A significant effect was observed between sleep quantity (i.e., percentage of athlete's normal sleep duration that was divided into 3 groups: greatest, moderate and least sleep quantity) and the number of post-concussion symptoms and somatic symptoms endorsed. Athletes who received moderate amounts of sleep the night prior to testing reported more somatic symptoms than those who slept the least, and performed worse on the neurocognitive test 'Visual Memory' than those who slept the most and those who slept the least. Differences in sleep quantity had no discernible effect on other symptom clusters (i.e., Cognitive and Neurobehavioral), the remaining CNS Vital Signs domains, as well as the balance performance. Sufrinko and colleagues (2015) used a different measure for sleep problems (i.e., the sleep-related items on the PCSS) but reached similar conclusions. Athletes (*n* = 348) were divided into groups of two: sleep difficulties (i.e., those who endorsed both sleep items, difficulty falling asleep and sleeping less than usual) and no sleep difficulties (i.e., those who scored 0 on both sleep symptom items). No significant differences were found between groups (i.e., athletes with and without pre-injury sleep difficulties) across the composites of neurocognitive testing on the ImPACT. Similar to Mihalik et al. (2013), athletes with sleep difficulties were highly symptomatic at baseline. In another study, McClure and colleagues (2014) evaluated the effect of sleep quantity on ImPACT baseline metrics in non-concussed high school and college-aged athletes (*n* = 3686). In this study, sleep quantity was defined by the total hours (i.e., short, < 7 hours; intermediate, 7 - 9 hours; and long, ≥ 9 hours) of sleep the night before testing (McClure et al., 2014). Athletes in the short duration group performed significantly worse on 3 of the 4 neurocognitive composite scores (i.e., reaction time, verbal memory, and visual memory scores, but not visual-motor speed scores) and reported more symptoms on the PCSS composite relative to the intermediate sleep group. Significant differences were observed between the groups for the PCSS symptom clusters (i.e., cognitive, somatic, and emotional); however, no differences were reported for the neurobehavioral cluster. Conversely, Silverberg and colleagues (2016) reported no significant differences on the neurocognitive composites of the ImPACT between the sleep duration conditions (i.e., grouped into 4 levels according to hours slept: ≤ 5 hours, 5.5 - 6.5 hours, 7 - 8.5 hours, and ≥ 9 hours). Consistent with previous studies, a significant effect was observed for symptom reporting, athletes with severe insufficient sleep (≤ 5 hours) endorsed more items on the PCSS.

The evidence presented in this section suggests that sleep problems (i.e., defined as sleep quality or sleep duration) affects post-concussion symptoms, whereas the evidence concerning the effect of sleep problems on neurocognitive tests are inconsistent and contradictory. The differences between the reviewed studies may reflect differences concerning the study protocol (i.e., measures used for sleep problems, concussion tools, and criteria for sleep groups) and definitions. However, there is a caveat. The study (McClure et al., 2014) that found a significant difference was not clinically significant.

In a recent study (Sufrinko et al., 2016), clinically significant differences did emerge when the effects of poor sleep duration and sleep symptoms were examined concurrently. This suggests that the differences observed between studies are attributable to the individual variations in sleep need (Jenni & Carskadon, 2007). In a large sample (*n* = 7,150) self-reported symptoms and neurocognitive performance domains of the ImPACT were compared across three groups derived from total sleep duration (i.e., sleep restriction, ≤5 hours; typical sleep, 5.5-8.5 hours; and optimal sleep, ≥9 hours). Athletes with reduced sleep duration performed worse across the domains of the neurocognitive battery (i.e., verbal and visual memory domains, visual motor speed and reaction time) and endorsed more PCSS items. Athletes were then compared across two combined factors, sleep quantity, either sleep restriction (≤5 hours) or optimal sleep (≥9 hours) and endorsement of PCSS sleep symptoms (either at least one or no sleep symptoms, respectively). Athletes in the symptomatic sleep restricted group performed significantly poorer on their neurocognitive test performance and endorsed more symptoms than athletes reporting optimal sleep (i.e., control).

The studies reviewed thus far present evidence for the effect of sleep problems on symptom reporting at baseline. Recognition of this effect is important as select researchers recommend annual baseline testing for children to account for their developmental differences (Gioia, 2015) and intra-individual neurocognitive strengths and weaknesses (Arnett, Meyer, Merritt, & Guty, 2016). Therefore, we need a better understanding of the effects of modifying factors (i.e., sleep problems) on baseline measures in child athletes. Although the majority of these studies have focused primarily on adults or adolescents (14 years and older), there is a preponderance of evidence in the literature that supports the concept that sleep problems affects cognitive and psychological functioning in children.

This literature review also revealed several methodological limitations across all studies reviewed. In the author's opinion (Sufrinko et al., 2015), the most significant limitation was that the reliability and validity of the measures used to evaluate sleep has not been evaluated. Consequently, the inability to address this limitation may obfuscate the findings to date (Sufrinko et al., 2015). Therefore, the current study intends to address this limitation.

Psychometric properties of the PCSS sleep cluster. Reliability and validity are often used as evidence to establish the validity of scores on measures (Kane, 2013; Zumbo, Gadermann, & Zeisser, 2007) in order to make inferences. Mihalik and colleagues (2013) were the only researchers who used a reliable and valid scale for measuring sleep problems (i.e., the PSQI), whereas the remaining researchers (Kostyun et al., 2015; Sufrinko et al., 2015; Sufrinko et al., 2016; Tkachenko et al., 2016) have used a domain that is a part of concussion tools (i.e., ImPACT and SCAT3) to assess sleep problems at baseline or during the recovery period. These concussion tools contain several domains that measure various symptoms and signs of concussions. The symptoms scale is called the PCSS and includes items that assess symptoms of cognition, emotion, somatization and sleep. To investigate the effect of sleep problems on other domains of concussion tools (i.e., total symptoms, symptom clusters, cognition, etc.), select researchers (Kostyun et al., 2015; Sufrinko et al., 2015; Sufrinko et al., 2016; Tkachenko et al., 2016) have used the PCSS sleep items (e.g., questions about the athlete's sleep quality and sleep-related symptoms) as a measure of sleep disturbance.

Although some studies (McClure et al., 2014; Silverberg et al., 2016) have found that athletes with poor sleep (i.e., sleep duration) were more likely to endorse PCSS sleep items more compared to control athletes, the PCSS was not designed to assess sleep problems and the psychometric properties (i.e., validity and reliability) of the PCSS sleep items have not been evaluated.

There are various kinds of reliability (e.g., internal consistency, re-test, inter-rater) and validity (e.g., concurrent, convergent, etc.), and there are several formulas for computing these coefficients or indices (e.g., correlations or covariance matrices). Concurrent validity is used to compare the performances of measures, known to be valid and reliable. Whereas internal consistency is used is to measure the consistency within the measure and questions how well a set of items measures a particular characteristic within the measure. Conventionally, the psychometric measure that continues to be used for calculating the reliability is Cronbach's alpha (Cronbach, 1951; Sijtsma, 2009). The computation of the coefficient alpha involves the matrix of correlations or covariances among all items on a scale. For Cronbach's alpha, the Pearson covariance is often used in studies and requires the assumption of continuous data. If this assumption is violated, the Pearson covariance matrix can be significantly distorted (Flora & Curran, 2004), leading to an inaccurate estimate of internal consistency (Gadermann, 2012; Maydeu-Olivares, Coffman, & Hartmann, 2007) that will be misinterpreted (Cronbach & Shavelson, 2004; Garrido, Abad, & Ponsoda, 2013; Sijtsma, 2009) and researchers might discard a measure because of its apparently low reliability (Gadermann, 2012). Likert-type ordinal data (i.e., commonly used in the social sciences) often violates the assumptions of Cronbach's alpha (Zumbo et al., 2007). For this reason, Zumbo and colleagues (2007) recommend using the Ordinal alpha, which has been shown to accurately estimate reliability, compared to Cronbach's alpha to estimate the reliability of ordinal response scales.

Conceptually, the Ordinal alpha is similar to the Cronbach's alpha. The Cronbach's alpha uses the Pearson covariance matrix, whereas the Ordinal alpha uses the polychoric correlation matrix. The polychoric correlation has been found to more accurately estimate the relationship of the underlying variables. A recent paper (Gadermann, 2012) provides a theoretical rationale supporting the use of the Ordinal alpha as a reliability coefficient for Likert data; for a detailed analysis, see Gadermann (2012).

Zumbo and colleagues (2007) recommend using the Ordinal alpha as the reliability coefficient for measures that use Likert-type items with 2 to 7 responses, which was similar to the response format used in the present study. Further, the use of the Ordinal alpha is in line with current opinion in the field (Gadermann, 2012; Zumbo et al., 2007) and has been used by different researchers in different fields (Lopes et al., 2016; Ortuño-Sierra et al., 2017). For these reasons, the current study used the Ordinal alpha as a reliability coefficient for internal consistency.

Although the PCSS-C is inadequate for the assessment of sleep problems, the PCSS-C sleep items, may be useful to coaches, health professionals and parents who do not have access to validated sleep measures. The PCSS-C sleep items might be optimal to assess specific factors of sleep functioning, whereas the PCSS-C sleep cluster might be optimal to examine overall sleep functioning (Becker, Ramsey, & Byars, 2015). The present study aimed to assess the reliability and validity of the PCSS-C sleep items/cluster in order to examine its clinical utility.

The Effect of Sleep on Cognitive and Somatic factors in Children

The current literature supports the effects of sleep problems on cognitive functioning and academic performance in children and adolescents. Numerous studies (i.e., observational and experimental) have found that sleep problems significantly affects a child’s functioning across many domains (i.e., learning, emotion, behaviour, and health) (Paruthi et al., 2016), and have documented associations between a decline in cognitive performance (i.e., memory, attention, and executive functioning) and sleep problems. These findings have been confirmed by reviews

(Araújo & Almondes, 2014; Curcio, Ferrara, & De Gennaro, 2006; Kopasz et al., 2010) longitudinal studies (Buckhalt, El-Sheikh, Keller, & Kelly, 2009; Friedman, Corley, Hewitt, & Wright, 2009), and by a meta-analytic study (Dewald, Meijer, Oort, Kerkhof, & Bögels, 2010), which have found associations between aspects of sleep problems and academic performance, the effects of sleep loss on memory, attention, and other cognitive domains, as well as, the impact of sleep quality and daytime sleepiness on a child's cognitive functioning.

The term cognition refers to cognitive abilities that facilitate processes related to memory, planning, inhibition, and problem-solving. These processes range from lower-level functions such as response-inhibition and sustained-attention tasks, to higher-level cognitive functions, such as executive functioning. Sleep quality (i.e., measured with objective or subjective measures) appears to be correlated with poorer performance on complicated neurocognitive tasks that require sustained attention for extended periods of time and working memory (Anderson, Storfer-Isser, Taylor, Rosen, & Redline, 2009; Calhoun et al., 2012; Gradisar, Terrill, Johnston, & Douglas, 2008; Sadeh, Gruber, & Raviv, 2002; Sadeh et al., 2002; Steenari et al., 2003; van der Heijden, de Sonneville, & Swaab, 2013; Wolfe et al., 2014). Whereas sleep duration appears to be associated with simple neurocognitive tasks that require motor skills and short-term memory (Paavonen et al., 2010).

Over the past decade most research on cognitive functioning and sleep in children and adolescents has been derived from correlational research. These studies have found that poor sleep efficiency and short sleep duration negatively impacts aspects of cognitive performance in a number of age groups. In a study (Sadeh et al., 2002) consisting of 135 second, fourth, and fifth graders, higher sleep fragmentation, irregular sleep (i.e., more night awakenings) and lower sleep efficiency was associated with poorer performance on neurobehavioral (NBF) measures, in particular complex neurobehavioral tasks (i.e., require higher executive control), such as the continuous performance task (CPT) and symbol-digit substitution test (SDS). No association was found between simple tasks (i.e., motor speed and reaction time) with any of the sleep measures (Sadeh et al., 2002). For children aged 6-13 years old, Steenari et al. (2003) reported an association between working memory performance (i.e., both auditory and visual) and sleep efficiency. More errors were associated with children who had lower sleep efficiency and longer sleep latency, and short sleep duration was only associated with tasks at the highest load. They observed that poor sleep quality greatly affected auditory tasks relative to visual tasks, as auditory tasks were more difficult than visual ones. Paavonen et al. (2010) found an association between children (aged 7.4 to 8.8 years old) who had short sleeps and poorer performance in visuospatial skills and processing speed tasks, but not with actigraphy-measured sleep quality. Similar to prior research (Steenari et al., 2003), short sleep duration was associated with a poorer performance on visuospatial tasks, whereas poor performance on verbal reasoning tasks, a much more complex task, was associated with poor sleep quality. Anderson et al. (2009) reported an association between lower sleep efficiency and poorer scores on a measure for executive functioning, the Children's Colour Trails Test 2 (CCTT-2). Similar to previous studies, no association was found between sleep efficiency and the less complex measures of memory and attention, and no associations were found between sleep duration and the performance on the cognitive tasks. Likewise, Vriend et al. (2012) using the CCTT-2 found a significant association between sleep efficiency and poor performance. Consistent with other studies (Gruber et al., 2007; Sadeh et al., 2002), no relationships were found between sleep duration and the cognitive measures used, and sleep efficiency and the remaining less complex cognitive tasks. Interestingly, Wolfe et al. (2014) found a negative association between sustained attention performance and sleep duration in older children (aged 15-20 years old). In comparison with previous studies, no relationship was found between sleep duration and the working memory tasks. In a slightly older population of adolescents (13-18 years old), Gradisar et al. (2008) found that adolescents who self-reported insufficient sleep (less than 8 hours) performed worse on the working memory tasks (i.e., letter-number sequencing (LNS) and operation span task). Similar to Steenari et al. (2003), they found a larger effect for the more complex task, operation span task (Op Span). Adolescents with insufficient sleep also reported going to bed later, taking longer to fall asleep and experiencing greater daytime sleepiness. In a study conducted by van der Heijden and colleagues (2013), they found that the subjective feeling upon awakening was the most important sleep characteristic associated with the neurocognitive measures (i.e., faster simple reaction time and sustained attention reaction time, more sustained attention stability, and faster working memory). In a recent study by Könen et al. (2015), a significant association was reported between subjective sleep measures (i.e., sleep quality and daytime tiredness) and working memory performance in elementary school-aged children. Sleep quality was predictive of performance in the morning and daytime tiredness was related to performance in the afternoon. More recent evidence suggests that higher-order thinking abilities are more associated with sleep efficiency/quality. In a recent study (Erath, Tu, Buckhalt, & El-Sheikh, 2015), an association was found between intelligence and academic achievement in children with lower sleep efficiency (i.e., more long wake episodes) relative to children with higher-quality sleep.

Several studies that have examined neurocognitive functioning following acute sleep restriction (i.e., restricted sleep for 2-5 hours in bed for one or several nights), total sleep deprivation, and chronic sleep restriction (i.e., 1 hour over 3-6 nights) suggest that sleep deprivation/restriction leads to increased ratings of subjective sleepiness and impaired performance on certain aspects of cognitive functioning tasks. Working memory and attention have been found to be particularly vulnerable to sleep deprivation (Carskadon & Dement, 1981) and chronic (Beebe et al., 2008; Lo, Ong, Leong, Gooley, & Chee, 2016; Voderholzer et al., 2011) rather than acute sleep restriction (Carskadon & Dement, 1981; Fallone, Acebo, Arnedt, Seifer, & Carskadon, 2001), and improve following sleep extension (Gruber, Cassoff, Frenette, Wiebe, & Carrier, 2012; Sadeh et al., 2003). Whereas executive functioning tasks are likely susceptible to the effects of acute (Randazzo, Muehlbach, Schweitzer, & Walsh, 1998) and chronic sleep disruption (Lo et al., 2016).

With respect to sleep deprivation, in a pair of complementary studies, children (aged 11 to 14 years old) were either deprived of a full night of sleep or permitted to sleep for 4 hours (Carskadon & Dement, 1981). Only children who were deprived of a full night of sleep had compromised functioning and were observed to make fewer attempts on an addition task. Most studies that have partially restricted sleep in children and adolescents have reduced their sleep by only 1 hour for a few nights (Sadeh et al., 2003), or have restricted their sleep to 4 to 5 hours for only 1 night (Carskadon & Dement, 1981; Fallone et al., 2001). A study by Fallone et al. (2001) failed to observe differences on low level psychomotor tasks (i.e., response inhibition and sustained attention tasks) in a group of children aged 8-15 years old who were either in the sleep-optimized group or a group with only 4 hours of sleep. Likewise, in a similar aged group of children (7 to 14 years old) those who had 5 hours of sleep performed comparably on tasks which measure low-level psychomotor and simple memory abilities, but performed worse on a task of executive control (i.e., Wisconsin Card Sorting Task) (Randazzo et al., 1998). Several studies (Beebe et al., 2008; Beebe, Difrancesco, Tlustos, McNally, & Holland, 2009; Lo et al., 2016; Voderholzer et al., 2011) have revealed that it is not just acute sleep restriction that acts on cognitive performance. For example, Beebe and colleagues (2008) found that adolescents (*n* = 16) who had their sleep restricted to 6.5 hours for 5 nights led to an increase in subjective reports of inattention and problems with metacognitive skills. In a complementary study, Beebe et al. (2009) observed that the adolescents who had their sleep restricted had greater activation in brain regions responsible for attention-demanding and working memory tasks, and brain regions that are normally suppressed during these tasks showed even greater suppression. Likewise, children aged 6 to 12 years old who had their sleep restricted to 6.5 hours for 7 nights reported more attention problems and their teachers reported more academic difficulties, compared to children who slept at least 9 hours (Fallone, Acebo, Seifer, & Carskadon, 2005). Vriend et al. (2013) found similar results with 4 days of sleep restriction to 8 hours. Compared to the control group, the children who had their sleep restricted resulted in impaired performance on memory and attention tasks. However, no significant differences were found between the sleep conditions for the attention constructs – alerting, orienting, and executive control. In a recent study (Lo et al., 2016), the effect of partial sleep deprivation (i.e., sleeping 5 h a night for a week) on cognitive performance was investigated. A week of partial sleep deprivation resulted in impaired cognitive functioning (i.e., sustained attention, processing speed, working memory and executive functioning), with some measures not returning to baseline even after 2 nights of recovery sleep. One area of memory that is probably not influenced by sleep quality or sleep quantity is declarative and procedural memory. For example, Voderholzer et al. (2011) assessed declarative and procedural memory across five different sleep restriction protocols (5, 6, 7, 8, 9 h) for 4 nights. No differences were found between the groups for declarative or procedural memory consolidation.

The evidence presented in this section suggests that deficits in neurocognitive abilities are more strongly associated with chronic sleep difficulties rather than acute sleep difficulties in children. With difficulties in executive functioning and attention/working memory being more commonly reported in studies assessing sleep problems on neurocognitive functioning. The studies reviewed also suggest that insufficient sleep in children is associated with deficits in higher-order and complex neurocognitive functions (Astill, Van der Heijden, Van IJzendoorn, & Van Someren, 2012). General sleep difficulties as well as fragmented sleep, short sleep latency, poor sleep efficiency, and sleep restriction can all impact executive functioning and attention/working memory in children and adolescents.

Sleep is important for health and is related to a child's emotional and physical well-being. Select studies have revealed that sleep problems are not only linked to cognitive sequelae, but have also been linked to somatic complaints (i.e., nausea, headaches, stomach aches, etc.) (Quach, Hiscock, Canterford, & Wake, 2009; Simola, Liukkonen, Pitkäranta, Pirinen, & Aronen, 2014). Using the Child Behaviour Checklist (CBCL), which evaluates psychosocial and somatic complaints in 6-to 18-year old children (Achenbach & Rescorla, 2001), Simola and colleagues (2014) found that children with current sleep problems without a history of sleep difficulties and those with persistent sleep problems had significantly more somatic complaints relative to children with no sleep problems and those with sleep problems only at pre-school age. Children with persistent sleep difficulties is associated with increased risk (6 vs. 16-fold risk) of somatic complaints compared to children presenting with current sleep difficulties.

Sleep continues to be an area of great importance for parents and their children, especially for those who participate in sports. Numerous studies have found that sleep deprivation negatively effects an athlete's performance in sports, and sleeping more can improve performance in sports. Sleep deprivation also increases a child's risk of injuries while playing sports. In a recent survey (Milewski et al., 2014), the risk of injury for children in middle or high-school were nearly two times greater for those who slept less than 8 hours per night. Children who slept 9 hours per night had the lowest injury rates, whereas children who slept 5 to 7 hours per night had the highest injury rates. In another study, researchers investigated the rate of injury in school-aged athletes and found a correlation between injury during games and athletes who slept fewer than 6 hours the night before the game (Luke et al., 2011). Poor sleep affects risk of injury directly, but also indirectly, by increasing decision-making errors (Fullagar et al., 2015). Overall, the aforementioned studies highlight the importance to screen and evaluate problems related to sleep in school-aged children.

The effect of sleep on PCSS clusters. Many of the symptoms relating to cognitive, somatic and sleep complaints are a part of PCSS-C. Following a concussion, these complaints are often a part of a constellation of other complaints or symptoms. However, certain symptoms can be a prominent component of a concussion and can assist in the assessment and management of athletes with these injuries (Kontos et al., 2012). For example, "a concussed athlete presenting predominately with cognitive symptoms (e.g., difficulty concentrating, memory problems) may benefit from different management and treatment programs relative" (Kontos et al., 2012) to an athlete presenting with post-injury migraine or affective complaints.

Conceptualizing symptoms into clusters comprising of several related symptoms (e.g., somatic factor = headache, nausea, vomiting) can better inform and provide a more targeted approach to the assessment and management of concussions (Kontos et al., 2012). It can also help professionals understand how the endorsement of symptom clusters might impact other symptoms following a concussion. For example, "adolescent athletes with a high initial somatic symptom loading (e.g., headache, nausea, vomiting, etc.) is associated with increased odds of symptoms beyond 28 days post-injury" (Howell, O'Brien, Beasley, Mannix, & Meehan, 2016).

A study conducted by Kontos & colleagues (2012) found that symptoms that were comorbid at baseline do not necessarily group together following a concussion. This suggests the presence of one or more moderator variables that affects the endorsement of symptoms.

Only a few published studies have evaluated the effect of sleep problems on concussion symptom clusters (McClure et al., 2014; Mihalik et al., 2013). Mihalik et al. (2013) used the GSC to assess the presence of 18 concussion related symptoms, and grouped the total number of symptoms endorsed by the athletes into somatic, cognitive and neurobehavioral clusters. Athletes with low sleep quality reported a higher number of somatic and neurobehavioral complaints. With respect to sleep quantity, statistically significant differences were found between the least and moderate sleep quantity groups, with the later endorsing more somatic and neurobehavioral complaints than the former (Mihalik et al., 2013). No significant differences were found between sleep quality and sleep quantity groups and the GSC cognitive cluster. McClure et al. (2014) found significant differences between sleep quantity and ImPACT PCSS clusters (i.e., cognitive, somatic and emotional). No significant differences were found between sleep quantity and the ImPACT PCSS neurobehavioral cluster. This differential finding is not uncommon, as two studies have previously reported associations between the Pre-Sleep Arousal (PSAS) questionnaire (however, cognitive rather than somatic) and symptoms of insomnia in both children and adolescents (Alfano, Pina, Zerr, & Villalta, 2010; Gregory, Willis, Wiggs, Harvey, & STEPS Team, 2008).

The scale (i.e., GSC) used by Mihalik & colleagues (2013) is one of the four commonly used concussion symptom checklists that has been analyzed by factor analysis. From these studies emerged four symptom clusters that have been identified in the Zurich consensus statement (McCrory et al., 2013). The four symptom clusters are cognitive-sensory, vestibular-somatic, sleep-arousal and affective. These clusters have been identified on the 22-item PCSS in samples of high school and collegiate-aged athletes at baseline and post-concussion evaluations. In contrast, the factor structure of the 20-item PCSS-C of the Child SCAT3 has yet to be evaluated. That said, Porter & colleagues (2015) in a recent study grouped the symptoms of the Child SCAT3 into three of the four clusters: cognitive, physical-somatic and sleep. Therefore, in addition to the PCSS-C Total Symptom and PCSS-C Symptom Severity scores, this study will also analyze the subjective PCSS-C clusters by grouping the PCSS-C symptoms into three of the four clusters outlined in the Zurich consensus statement — somatic/physical (e.g., headache), cognitive/behavioural (e.g., attention problems) and sleep (McCrory et al., 2013).

Research Objectives

The increase in sports-related concussions in youth has made assessment and management an extremely important field of study, however, complications and difficulties continue to persist with the assessment process. Further, it has been suggested that the assessment and management of concussions in children might be more complicated than adult assessments, making the need for reliable and valid concussion tools essential. Sleep is just one factor that might modify concussion assessment scores in adults and adolescents and more research is needed to investigate how sleep difficulties affect baseline assessment scores in children.

This review also revealed several methodological limitations across the reviewed studies. As noted above, the inability to address this issue (i.e., the measures used to assess sleep disturbance, specifically the PCSS sleep items are not a validated sleep measure), could obfuscate the findings to date, and is believed to be a significant limitation. Therefore, the current study intends to address this limitation. This study also adds to the current body of literature on the assessment and management of youth athletes.

Objective 1. The first objective is to establish concurrent validity of the Child SCAT3 PCSS-C sleep items with the Sleep/Wake Problems Behaviour (SWPB) scale items.

Alternate hypothesis. There is a statistically significant positive correlation between the PCSS-C sleep items and the SWPB scale items.

Null hypothesis. There is no statistically significant relationship between SWPB scale items and PCSS-C sleep items.

Objective 2. The second objective is to establish concurrent validity of the Child SCAT3 PCSS-C sleep cluster with the SWPB scale total.

Alternate hypothesis. There is a statistically significant positive correlation between the PCSS-C sleep cluster and the SWPB scale total.

Null hypothesis. There is no statistically significant relationship between SWPB scale total and PCSS-C sleep cluster.

Objective 3. The third objective is to investigate the effect of sleep problems on baseline assessment scores.

Alternate hypothesis. There is a statistically significant difference between the groups of student-athletes formed by self-reporting sleep problems (i.e., ≥1 on PCSS-C sleep cluster), with respect to PCSS-C Total Symptom, PCSS-C Symptom Severity, PCSS-C clusters (i.e., cognitive and somatic), SAC-C and BESS-C scores, as measured by the Child SCAT3.

Null hypothesis. There is no statistically significant difference between the groups of student-athletes formed by self-reporting sleep problems (i.e., ≥1 on PCSS-C sleep cluster), with respect to PCSS-C Total Symptom, PCSS-C Symptom Severity PCSS-C clusters (i.e., cognitive and somatic), SAC-C and BESS-C scores, as measured by the Child SCAT3.

Objective 4. The fourth objective is to investigate the association between the PCSS-C sleep cluster and the remaining PCSS-C clusters (i.e., cognitive and somatic).

Alternate hypothesis. There is a statistically significant positive relationship between the PCSS-C sleep cluster and the remaining PCSS-C clusters (i.e., cognitive and somatic).

Null hypothesis. There is no statistically significant relationship between the PCSS-C sleep cluster and the remaining PCSS-C clusters (i.e., cognitive and somatic).

The following chapters will outline the methodology for this study, including participant characteristics, instrumentations, and data collection, the results will be discussed in Chapter 4, lastly, Chapter 5 will discuss the results further within the context of the current literature and the resulting practical and clinical applications.

Chapter Three – Methods

This chapter provides an overview of research methods used in the study including the participants, instrumentation, sampling, and data and collection procedures.

Participants

A convenience sample was used to recruit male minor hockey participants (between the ages 10-12 years old) within the Edmonton area to participate in this study. There were 8,699 athletes enrolled in minor hockey within the Greater Edmonton area for the year 2014 to 2016 (personal communication, Edmonton Minor Hockey Association, 2016). Within the Southwest District, there were 498 registered players spanning 5 age divisions (Atom, Peewee, Bantam, Midget, Junior) with ages ranging from 8 to 17. Players in the Peewee division are between ages 10 to 14 and there were 8 teams from the Southwest District during the 2014 to 2016 hockey year with a total of 102 players. Players in the Bantam division range from age 14 to 16. There were 240 Bantam players from 18 teams during the 2014 to 2016 hockey year.

All 8 Peewee teams and 2 Bantam within the Southwest District were recruited for participation. This district was selected because of its previous relationship with Dr. Martin Mrazik from the Department of Educational Psychology at the University of Alberta. Dr. Mrazik had conducted research regarding concussion outcomes with the Southwest District from 2009. Thus, this was a convenience sample of male participants who played hockey. Individual teams were recruited as opposed to individual participants to ensure compliance. For this study, 80 male participants from 6 Peewee teams participated in this study. Participants reported that they had played hockey from a range of 0 to 10 years (mean = 5.79 ± 1.28).

Instrumentations

The child sport concussion assessment tool 3. The Child SCAT3 was used to assess the presence of concussion related symptoms and signs across several components (i.e., symptom checklist, a brief neurocognitive screen, and a balance examination). The Child SCAT3 was revised from the previous SCAT2 adult version by the International Concussion Group in 2013. It has two versions, a child version and parent version.

The Child SCAT3 consists of several subsections. First, the background information section includes demographics (e.g., age, gender, and dominant hand), and health history information (i.e., history of concussion, history of headaches or migraines, history of a psychiatric disorder diagnosis and learning disability). The second section is a subjective symptom report (i.e., PCSS-C) completed separately by both the participant and their guardian/parent. The questions have the participant subjectively rate current cognitive, physical and sleep-related symptoms. The symptom evaluation has 20 symptoms that are based upon a four-point Likert scale (i.e., 0 is never; 1 is rarely; 2 is sometimes; and 3 is often). The third section involves objective testing and includes the adapted child versions of the Standard Assessment of Concussion (SAC-C) and the Balance Error Scoring System (BESS-C). The SAC-C is a neurocognitive screener and includes the subtests, Orientation, Concentration, Immediate Memory and, Delayed Recall. The physical component, the BESS-C includes two trials of stances with eyes closed for 20 seconds. The first trial requires the participant to stand with their feet together with their hands on their hips (i.e., the double leg stance). The second trial requires the participant to stand with their non-dominant foot behind their dominant foot with their hands on their hips (i.e., the tandem stance). The number of errors or deviations from the predetermined stance are recorded. A maximum of 10 errors per stance is permitted for children aged ≤12 years old. Following this, a tandem gait test is performed where the participant is required to walk heel-to-toe down a 3-m line and back as accurately and quickly as possible. The participant is timed based on how long it took them to complete 1 lap, with their best time over four trials being used as their final score. Finally, the last physical assessment is a finger-to-nose coordination task. Five correct consecutive finger-to-nose trials within 4 seconds are scored as 1 point.

The Child SCAT3 was selected for several reasons. Firstly, the Child SCAT3 is a widely-used measure to assess athletes, and has been adapted to children while retaining the major components of the SCAT3 (e.g., symptom ratings, cognitive and postural stability assessment) (Ayr, Yeates, Taylor, & Browne, 2009; McCrory et al., 2013). Secondly, the Child SCAT3 allows for parental input which can be compared to their child's responses and provide assistance when recalling information about their medical history or to understand the questions. Thirdly, the Child SCAT3 is an inclusive and cost-effective tool that can be quickly and easily administered by coaches, parents or health professionals. Lastly, it has recently been shown that the Child SCAT3 is a reliable and valid measure (Nelson, Loman, LaRoche, Furger, & McCrea, 2016). Nelson and colleagues (2016) reported that the Child SCAT3's reliability of symptom ratings was excellent for children aged 10 to 13 years old (alpha = 0.90). Whereas the stability was modest for SAC-C (Pearson $r = 0.77$) and tandem gait scores ($r = 0.46$) and poor for BESS-C scores ($r = 0.02$).

A further analysis was also conducted to explore the effect of sleep problems on the PCSS-C symptom clusters. The PCSS-C items was grouped into three of the four clusters identified in the Zurich consensus statement (McCrory et al., 2013) – somatic/physical (e.g., headache), cognitive/behavioural (e.g., attention problems) and sleep. Table 1 shows the categorization of the PCSS-C items according to McCrory et al. (2013), Porter et al. (2015) and the Centers for Disease Control and Prevention (2016).

Table 1

Post-Concussion Symptom Scale Items by Post Concussion Symptom Scale Cluster

Cognitive/Behavioural	Somatic/Physical	Sleep
I have trouble paying attention	I have headaches	I daydream too much
I get distracted easily	I feel dizzy	I get tired a lot
I have a hard time concentrating	I feel like the room is spinning	I get tired easily
I have problems following directions	I feel like I am going to faint	
I get confused	Things are blurry when I look at them	
I forget things	I see double	
I have problems finishing things	I feel sick to my stomach	
I have trouble figuring things out		
It's hard for me to learn new things		
I have problems remembering what people tell me		

Note. Items were grouped based on criteria from the CDC (2016), Injury Prevention & Control: Traumatic Brain Injury & Concussion. (2016, January 22). Retrieved January 06, 2017, from www.cdc.gov/traumaticbraininjury/symptoms.html.

Sleep/wake problems behaviour scale. The Sleep/Wake Problems Behaviour (SWPB) scale was used to measure self-reported sleep/wake behaviours and problems. Participating athletes were asked to fill out the SWPB form and return it to their coach. The SWPB includes 15 items rated on 5-point Likert-type scale that are graded from 1 to 5 (i.e., 1, never; 2, once; 3, twice; 4, several times; and 5, every day/night). Participants had to indicate how often in the last 2 weeks they had experienced some related sleep problems. The total score, ranging from 10 to 50, was computed by summing the items (i.e., b, c, d, f, g, h, i, j, k and m), with a high score indicating impaired sleep quality.

The SWPB scale was chosen for several reasons. First, the scale is a part of a standardized and validated measure, the School Sleep Habits Survey (SSHS), which has been widely used in the sleep literature with child and adolescent populations. Secondly, it has also been found to highly correlate with sleep-diary reports and actigraphy data in boys (Wolfson et al., 2003). Thirdly, the scale has good internal consistency (Cronbach's α =.75) (Wolfson & Carskadon, 1998). Lastly, this instrument specifically addresses sleep habits of school-aged children, which is the age of the participants in this study.

Sampling and Data Collection Procedures

Sleep problems group. Sleep problems were measured using the sleep items on the PCSS-C, a component of the Child SCAT3. This method is essentially the same as that used by Sufrinko et al. (2015; 2016) and Tkachenko et al. (2016) with some modifications. For this study, athletes were divided into two groups: (1) those with sleep difficulties (i.e., defined as participants with a score of ≥ 1 for PCSS-C sleep cluster; Sleep Problems) and (2) those with no sleep difficulties (i.e., defined as participants with a score of 0 for PCSS-C sleep cluster; Control). The items of the PCSS-C sleep cluster to some extent were based on the selection criteria proposed by Tkachenko and colleagues (2016). Tkachenko et al. (2016) defined 'sleep disturbances' using 3 of the sleep-related items (i.e., Drowsiness, Difficulty falling asleep, and Fatigue/Low energy) of the PCSS a part of the adult version of the SCAT (i.e., SCAT3). Thus, balancing concerns for internal structure and content validity, select studies (Porter et al., 2015; Sufrinko et al., 2015; Sufrinko et al., 2016; Tkachenko et al., 2016), the fourth Zurich consensus statement (McCrory et al., 2013), and the ICD-10 Post-Concussion Symptom (PCS) domains were used to identify a subset of items of the PCSS-C to form the PCSS-C sleep cluster. Using the above method two PCSS-C sleep-related items were identified (i.e., I am tired easily and I am tired a lot). The item “I daydream too much” was also included based on research that shows an association between higher frequencies of mind wandering and daydreaming with poorer sleep quality, in particular those with poor subjective sleep quality, increased sleep latency, night-time disturbance, daytime dysfunction and daytime sleepiness (Carciofo, Du, Song, & Zhang, 2014). Thus, the PCSS-C items, “I daydream too much,” “I am tired easily,” and “I am tired a lot” formed the PCSS-C sleep cluster.

Procedure. Data were collected from 42 participants during the 2014-2015 ice hockey season. An additional cohort of 38 participants were recruited during another season (i.e., 2016-2017). At the start of each season, a letter of recruitment was forwarded by the Southwest District’s president to the 8 coaches. Coaches who chose to have their teams participate contacted Dr. Mrazik. Recruitment letters were sent home to participants from these areas. Assent from the participant and informed consent from the parent/legal guardian were obtained prior to the player participating in the study. Each participant’s parent also completed a demographic background questionnaire. The background portion consisted of the participant’s name and date of the assessment as well as questions on previous concussion history including the number, date and length of recovery of the previous concussion, family history and other relevant medical history.

Communication with coaches set a specific date and time for participants and their parents to complete baseline testing. All testing procedures were explained by Dr. Mrazik to coaches, participants, and parents thoroughly to ensure both the player and their parent understood the procedures. Following the completion of the informed consent and assent, as well as the demographic form by each parent or legal guardian, the background section of the Child SCAT3, including injury history and concussion co-morbidity questions, was then completed.

The Child SCAT3 was administered to participants within the Peewee division. All testing using the Child SCAT3 was administered in accordance with the guidelines included on page 3 of the corresponding Child SCAT3 protocol document. The standard instructions listed within the Child SCAT3 protocol were read to each participant, by a trained University of Alberta undergraduate or graduate student, to ensure no bias was introduced by the trained students. As aforementioned, the baseline Child SCAT3 did not include the sideline assessment portion of the test. Participants were also asked to fill out the SWPB scale and return it to their coach.

The completion rates of the sleep survey were high (99%), with only one participant returning an incomplete form (1%) and was removed from the sample. Two other participants returned a partially completed sleep questionnaire form (2%). The University of Alberta Ethics Review Board approved this project.

Statistical Analysis

The data was analyzed using Statistical Package for the Social Sciences (SPSS) version 20.0 (IBM Corp., Armonk, N.Y., USA). Demographic results were reported as frequencies, whereas the variables of interest were analyzed using descriptive statistics. To assess the reliability of the PCSS-C sleep cluster and the SWPB scale, both Cronbach's alpha and Ordinal alpha were calculated. Reportedly, the Ordinal alpha is an alternative to Cronbach's alpha that is more accurate with Likert-scale responses. Generally, values above .70 are considered to indicate good reliability and scores below .60 are undesirable (Churchill & Peter 1984; Nunnally 1978). However, an alpha value of .60 is considered acceptable for measures that are new, but .70 should be considered the threshold for determining acceptability for developed measures (Nunnally 1978). Therefore .60 was set as an acceptable alpha value for the PCSS-C sleep cluster and .70 was set for the SWPB scale.

Correlations were used to validate the PCSS-C sleep cluster. The correlations between the PCSS-C sleep items and SWPB items; and the PCSS-C sleep cluster and SWPB scale were tested. Pearson correlation was used for parametric data and Spearman correlation for non-parametric data. To understand the magnitude of relationships, Cohen's classification of correlations (Cohen, 1992) was used. Large correlations included those whose magnitudes were ≥ .50, medium correlations included magnitudes between 0.30 and 0.49, and small correlations included magnitudes from 0.10 to 0.29.

Independent-sample t-tests were used to determine whether there was a difference in baseline performance based on sleep problems. To understand the relationship between the PCSS-C sleep cluster and the remaining PCSS-C clusters (i.e., cognitive and somatic), correlations were tested. To determine if the sleep groups differed on any demographic variables, including history of concussion, migraine, etc., independent t-tests and chi-square analyses were run. Univariate distributions of variables were evaluated for normality, and correlations were computed following the inspection of scatterplots to confirm linearity and to identify potential outliers. Cohen's classification (Cohen, 1988) for magnitudes expanded by Sawilowsky (2009), was used to determine the effect size for the t-test analyses. Very Large effects included magnitudes that were ≥ .81, large effects included magnitudes between 0.51 and 0.80, medium effects included magnitudes between 0.21 and 0.50, and small effects included magnitudes from 0.01 to 0.20 (Sawilowsky, 2009). Significance level was set at $p < 0.05$.

Chapter Four – Results

This chapter presents the results of the data analysis. The characteristics of the sample data will be described first followed by the results that are organized by the study's objectives. Under the first and second objectives, the psychometric properties (i.e., internal consistency and concurrent validity) for the PCSS-C sleep cluster and SWPB scale will be presented. The third and fourth objectives compares the sleep groups across the Child SCAT3 metrics. For the third objective, descriptive and frequency statistics for the items are provided, followed by inferential statistics which address the hypothesis. The chapter concludes with a supplementary analysis between the PCSS-C items concerning concussion signs and symptoms (i.e., cognitive and somatic clusters) and the PCSS-C sleep cluster.

Psychometric Analyses

Sample characteristics. Table 2 summarizes the demographics of the participants (*n* = 80), who participated in this study. According to participants' self-reported information, the average hours of sleep per night within the last 2 weeks was 9 hours, which is within the recommended range (i.e., 9 – 12 hours) that was recently reported in a consensus statement of the American Academy of Sleep Medicine (Paruthi et al., 2016). Seventy-five percent of the sample reported sleeping less than the recommended hours of sleep (less than 10 hours) required for optimal functioning. None of the participants in this sample reported significant sleep restriction, or sleeping 7 hours or less. Table 3 summarizes the descriptive data for the subsections of the Child SCAT3.

Table 2

Demographic Characteristics of the Participants

Variable	*M*	*SD*
Age	11.45	.57
Years Played	5.79	1.28
	n	%
Concussion History	13	16.00
Headache/Migraine	1	1.20
Hospitalization	1	1.20
Learning Disorder	2	2.50
Mood Disorder	0	0.00
Family History	9	11.10
Medications	3	3.70

Descriptive statistics and frequencies of PCSS-C sleep items. Table 4 shows the data of the PCSS-C sleep items. Consistent with expectations of a baseline sample, most participants indicated "never" for the PCSS-C sleep items "I daydream too much," "I am tired a lot," or "I am tired easily." Sixty-three percent of participants endorsed at least one or more of the PCSS-C sleep items, with 31% (n = 25) endorsing one, 24% (n = 19) endorsing two and 8% (n = 6) endorsing all three items. Only 37% (n = 30) of participants did not endorse any of the PCSS-C sleep items. Table 4 shows the frequency data on PCSS-C sleep items.

Table 3

Descriptive Statistics of the Child SCAT3

Child SCAT3 Domain	Range	M	SD	α
Symptoms				
Total	0-17	6.52	4.11	.81
Severity	0-25	8.05	5.48	.84
Cognition				
Orientation	3-4	3.90	0.30	
Memory	10-15	13.78	1.25	
Concentration	3-6	4.23	0.88	
Delayed Recall	0-5	4.32	0.96	
SAC-C Total	21-30	26.23	2.00	.20*
Balancing				
BESS-C Total	0-4	1.10	1.02	

Note. * = Low score is attributed to low variability among participants' raw scores.

Table 4

Descriptive Statistics and Frequencies of the PCSS-C Sleep Items

			Frequency of Item Endorsement *n* (%)			
PCSS-C sleep item	*M* (*SD*)	Range	Never	Rarely	Sometimes	Often
I daydream too much	.35 (.59)	0-3	56 (70.0)	21 (26.3)	2 (2.5)	1 (1.3)
I am tired a lot	.51 (.71)	0-3	47 (58.8)	27 (33.8)	2 (5.0)	2 (2.5)
I am tired easily	.46 (.82)	0-3	56 (70.0)	15 (18.8)	5 (6.3)	4 (5.0)

Internal consistency of the PCSS-C sleep cluster and SWPB scale. Table 5 shows the internal consistencies of the measures used. The Cronbach's alpha for the PCSS-C sleep cluster and SWPB scale was .42 and .56, respectively. The Ordinal alpha for the PCSS-C sleep cluster and SWPB scale was .62 and .70, respectively. The Ordinal alpha and Pearson covariance based (Cronbach's/raw) alpha are substantially different for both the PCSS-C sleep cluster (.62 versus . 42, respectively) and the SWPB scale (.56 versus .70).

Table 5

Internal Consistencies of the PCSS-C Sleep Cluster and SWPB Scale

				Alpha	
Sleep Measure	Range	*M*	*SD*	Cronbach	Ordinal
PCSS-C Sleep Cluster	0-6	1.33	1.46	.42	.62
Sleep/Wake Problems Behaviour	10-25	15.40	3.62	.56	.70

Objective 1. The first objective is to establish concurrent validity of the Child SCAT3 PCSS-C sleep items with the SWPB scale items.

Hypothesis. The sleep items on the PCSS-C will positively correlate with the sleep items on the SWPB scale.

Spearman's bivariate correlations of the individual PCSS-C sleep items with the SWPB items are displayed in Table 6. The PCSS-C sleep item "I am tired a lot" was significantly correlated (small-to-medium effect sizes) with the SWPB item's b (arrived late to class because you overslept?) ($r_s = .25, p = .026$), c (fallen asleep in a morning class?), ($r_s = .30, p = .007$), f (stayed up until at least 3 am?) ($r_s = .23, p = .041$), g (stayed up all night?) ($r_s = .39, p < .001$), h (slept in past noon?) ($r_s = .24, p = .036$), and i (felt tired, dragged out, or sleepy during the day?) ($r_s = .25, p = .029$). The PCSS-C sleep item "I am tired easily" was significantly correlated (small-to-medium effect sizes) with the SWPB item's b (arrived late to class because you overslept?) ($r_s = .46, p < .001$), h (slept in past noon?) ($r_s = .31, p = .005$), and m (gone to bed because you just could not stay awake any longer?) ($r_s = .24, p = .035$). Lastly, the PCSS-C sleep item "I daydream too much," was significantly correlated (small-to-medium effect sizes) with SWPB items f (stayed up until at least 3 am?) ($r_s = .28, p = .013$), i (felt tired, dragged out, or sleep during the day?) ($r_s = .26, p = .023$), and j (needed more than one reminder to get up in the morning?) ($r_s = .38, p = .001$).

No correlations were found between the PCSS-C sleep items and the SWPB items, a (felt satisfied with your sleep?); d (fallen asleep in an afternoon class?); e (awakened too early in the morning and couldn't get back to sleep?); k (had an extremely hard time falling asleep?); l (had nightmares or bad dreams during the night?); and o (had a good night's sleep?), except for n (done dangerous things without thinking?).

Objective 2. The second objective is to establish concurrent validity of the Child SCAT3 PCSS-C sleep cluster with the SWPB scale.

Hypothesis. The PCSS-C sleep cluster will positively correlate with the SWPB total.

As shown in Table 6, the PCSS-C sleep cluster is significantly correlated (large effect size) with the SWBP total score ($r_s = .58, p < .001$). Medium correlations were observed for the individual PCSS-C sleep items "I daydream too much," "I am tired a lot," and "I am tired easily" with the SWBP total score, ($r_s = .34, p = .002$; $r_s = .38, p = .001$ and $r_s = .40, p < .001$, respectively).

The PCSS-C sleep cluster was more strongly correlated with the SWBP total score than any of the individual PCSS-C sleep items. For example, the effect size of the correlation between the PCSS-C sleep cluster and SWPB total was large ($r_s = .58, p < .001$), whereas the correlations between the individual PCSS-C sleep items and the SWBP items ranged from small-to-medium effect sizes (*r_s's* = .23 to .46). Thus, the PCSS-C sleep cluster showed concurrent validity with a validated sleep measure used with school-aged children.

Table 6

Correspondence Between the PCSS-C Sleep Items/Clusters and SWPB Items/Scale

	PCSS-C Sleep Item			PCSS-C Sleep Cluster	
SWPB Item	I daydream too much	I am tired a lot	I am tired easily	Total	Severity
a	-.15	-.01	-.03	-.12	-.10
b[a]	.13	.25*	.46**	.34**	.38**
c[a]	.22	.30**	.19	.30**	.35**
d[a]	.06	.02	.10	.10	.11
e	.05	.07	.00	.07	.11
f[a]	.28*	.23*	.20	.35**	.39**
g[a]	-.07	.39**	.22	.23*	.28*
h[a]	-.17	.24*	.31**	.15	.22*
i[a]	.26*	.25*	.11	.34**	.36**
j[a]	.38**	.01	.12	.30**	.26*
k[a]	.02	.16	.11	.14	.18
l	.05	.11	.09	.18	.17
m[a]	.13	.17	.24*	.27*	.25*
n	.11	.24*	.27*	.31**	.33**
o	-.14	-.13	-.19	-.24*	-.25*
SWPB Total	.34**	.38**	.40**	.54**	.58**

Note. * = Correlation is significant at the 0.05 level (2-tailed). ** = Correlation is significant at the 0.01 level (2-tailed). [a] = Items included in the SWPB Total.

Cross-validity Analysis

Sample characteristics. Participant data are summarized in Table 1 and Table 2. For this analysis, the sample (*n* = 80) was divided into two groups. Thirty-eight percent of (*n* = 30) participants were in the Control group and 62% (*n* = 50) were in the Sleep Problems group. As shown in Table 7, the results of a series of t-tests indicated that groups did not differ on age or number of competitive years.

The frequency data for the Child SCAT3 demographic variables are summarized in terms of frequencies and percentages in Table 2. There were lower than expected cell counts in the cross-tabulation analyses, therefore Fisher's exact test was used.

The results of the Fisher's exact test analyses showed that the groups did not differ with respect to the demographic variables, history of hospitalization ($p = 1.00$), history of migraines ($p = 1.00$), history of learning disorders ($p = .524$), history of family diagnosis ($p = .725$), use of medications ($p = .286$), of the Child SCAT3. In contrast, a difference was observed between the groups for the demographic variable, history of concussions ($p = .025$). An independent *t*-test was run to determine whether participants with a history of concussions differed on the PCSS-C sleep total and severity clusters. No significant difference was found between the groups for the PCSS-C sleep total ($t(78) = 1.87, p = .065$). As for the PCSS-C sleep cluster, Levene's test indicated unequal variances ($F(2, 15) = 4.24, p = .043$) so the degrees of freedom was adjusted from 78 to 15. No significant differences were found between the groups, for the PCSS-C sleep cluster, $t(14.65) = 1.87, p = .082$.

Objective 3. The third objective is to investigate the effect of sleep problems on baseline concussion assessment scores.

Hypothesis. There is a statistically significant difference between the groups of student-athletes formed by self-reporting sleep problems (i.e., ≥1 on PCSS-C sleep cluster), with respect to PCSS-C total symptoms, PCSS-C symptom severity, PCSS-C clusters (i.e., cognitive and somatic), SAC-C and BESS-C scores, as measured by the Child SCAT3.

As expected and shown in Table 7, the groups did not differ for any of the Child SCAT3 objective measures (i.e., SAC-C total and BESS-C total). With respect to the subjective measure of the Child SCAT3, an independent samples t-test indicated that the total symptom scores of the PCSS-C were significantly greater for the Sleep Problems group ($M = 8$, $SD = 3.95$) than for the Control group ($M = 4$, $SD = 3.15$), $t(78) = -4.72$, $p < .001$, $d = 1$. An independent samples t-test indicated that the severity symptom scores of the PCSS-C were significantly greater for the Sleep Problems group ($M = 10.20$, $SD = 5.37$) than for the Control group ($M = 4.40$, $SD = 3.50$), $t(78) = -5.31$, $p < .001$, $d = 1.21$.

Table 7

*Differences Between Sleep Group*s on *Child SCAT3 Components*

	Control		Sleep Problems			
Variable	*M*	*SD*	*M*	*SD*	*t*	*p*
Age	11.47	0.51	11.44	0.61	0.20	.841
Years Played	5.93	1.14	5.70	1.37	0.78	.437
Child SCAT3						
Symptom Total	4	3.15	8.00	3.95	- 4.72	<.001
Symptom Severity	4.40	3.50	10.20	5.37	- 5.31	<.001
SAC-C Total	25.90	2.31	24.46	1.80	- 1.21	.230
BESS-C Total	1.17	1.21	1.04	0.90	- 0.50*	.621

Note. * = Levene's test for equality of the variances was statistically significant. Owning to this violated assumption, a *t* statistic not assuming homogeneity of variance was computed

The independent samples t-test indicated that the PCSS-C cognitive cluster mean scores were significantly greater for the Sleep Problems group (*M* = 6.62, *SD* = 4.71) than for the Control group (*M* = 3.80, *SD* = 3.32), *t*(75.90) = -3.13, *p* = .002. The Levene's test indicated unequal variances (*F*(2, 75.90) = 4.34*, p* = .041), so the degrees of freedom was adjusted from 78 to 75.90. The PCSS-C somatic cluster mean scores was significantly greater for the Sleep Problems group (*M* = 1.48, *SD* = 1.43) than for the Control group (*M* = .60, *SD* = .97), *t*(76.79) = -3.27, *p* = .002). The Levene's test indicated unequal variances (*F*(2, 76.79) = 4.42*, p* = .039), so the degrees of freedom was adjusted from 79 to 76.79.

Objective 4. The fourth objective is to investigate the association between the PCSS-C sleep cluster and the remaining PCSS-C clusters (i.e., cognitive and somatic).

Hypothesis. There is a statistically significant positive correlation between the PCSS-C sleep cluster and the remaining PCSS-C clusters (i.e., cognitive and somatic).

Spearman's bivariate correlations revealed positive correlations with medium effect sizes, between the PCSS-C sleep cluster and the PCSS-C cognitive cluster, $r_s(80) = .34$, p = .002 and the PCSS-C somatic cluster, $r_s(80) = .40$, p < .001.

Chapter Five – Discussion

This chapter presents the key findings of the results presented in the preceding chapter. In the following discussion, the results will be interpreted and summarized. This Chapter ends with a discussion of the theoretical and practical implications of these results for researchers and healthcare professionals, the limitations of this study, and identifies avenues for future research.

A recent CISG report identified several different factors that have the potential to affect the evaluation and management of sports-related concussion. Recent evidence suggests that among these factors, the presence of sleep problems may affect baseline test scores. This area of research, specific to concussion, has received considerably less attention and a paucity of studies are available that have investigated the relationship between sleep problems and baseline assessment metrics. Of these studies, only one (Mihalik et al., 2013) has used a validated sleep measure, whereas the remaining studies have used the PCSS to assess sleep functioning in adolescent and collegiate-aged athletes. The PCSS is a scale that is a part of concussion tools, such as the ImPACT and SCAT. It includes items that assess symptoms of cognition, emotion, somatization and sleep. It is the sleep-related items of the PCSS, that select studies have used as a measure of sleep problems. However, to the authors knowledge there have been no studies published that have evaluated the validity and reliability of the PCSS sleep items and it remains unclear as to whether the PCSS-C cluster is a valid measure of sleep.

Although the three measures of sleep (i.e., sleep diary, actigraphy and polysomnography) are considered to be standards of care, they are more time consuming, costlier than rating scales, and are often used in sleep-specific studies (Markovich, Gendron, & Corkum, 2015). In contrast, the PCSS is an open source tool, is extensively used in the child population, and may serve as a potential screening measure when specific sleep measures are not available or possible.

Therefore, the primary purpose of this study was to evaluate the psychometric properties of the PCSS-C sleep items/cluster of the Child SCAT3 to examine its clinical utility.

Several previous studies have investigated the effects of sleep problems on baseline measures in adolescent and collegiate-aged athletes. Collectively, these studies suggest that sleep problems have an adverse effect on post-concussion symptom scores. These findings are important, especially because some researchers recommend yearly baseline assessments for children to account for their developmental differences (Gioia, 2015). However, it remains unknown whether sleep problems affects baseline test scores in school-aged athletes. Although trends are similar for children, with respect to poor sleep and cognitive performance, there are notable differences between the age cohorts (i.e., required hours of sleep to function), and generalizing these findings to children is not advised. Therefore, the secondary purpose of this study was to examine how self-reported sleep problems, as measured by the PCSS-C sleep items affect Child SCAT3 test scores at baseline.

Taken together, findings of this study are important as they will provide descriptive and psychometric data (i.e., reliability and validity) of the PCSS-C sleep items/cluster for school-aged athletes. This study also extends the utility of the PCSS-C sleep items/cluster for identifying sleep problems in children, and contributes to the research on factors modifying baseline test performance.

Summary and Discussion of Findings: Objectives 1 & 2

Psychometric properties. The purpose of this study was to evaluate the psychometric properties (i.e., internal consistency and concurrent validity) of the PCSS-C sleep items/cluster in children. The internal consistency reliability of the PCSS-C sleep cluster and SWPB scale, using the Ordinal alpha was found to be acceptable, and the PCSS-C sleep items/cluster correlated reasonably well with the SWPB items/scale.

The present study supports the current literature with respect to the Cronbach’s alpha significantly underestimating the internal consistency of the measures compared to the Ordinal alpha (Gadermann, 2012). For example, the Pearson correlation coefficient for both measures were considered a small effect, whereas the effect size of the Ordinal alpha value for the same measures was considered to indicate a large effect.

As previously discussed in the literature review, Cronbach’s alpha usually increases as the inter-correlations among test items increase, thus a low reliability coefficient indicates that the items are less related to each other in the scale and suggests that the items are possibly not measuring the same trait. Validity is the degree to which a scale measures what it is purported to measure, therefore, a low Cronbach’s alpha coefficient raises concerns about the validity of a measure (Hatch, Burg, Naberhaus, & Hellmich, 1998), and thereby raises questions regarding the validity of the findings.

According to the researchers, Nunnally (1978) and Churchill and Peter (1984) an alpha value below .60 is undesirable. However, Nunnally (1978) indicated that an alpha value of .60 is acceptable for measures that are new, but .70 should be considered the threshold for determining acceptability for developed measures. The PCSS-C sleep cluster could be considered a ‘new scale’ whereas the SWPB is a developed measure. Taking this into consideration, the PCSS-C sleep cluster and SWPB scale’s reliability was interpreted to be acceptable. The results are similar to the results of previous studies, that is, interpreting the reliability of the measures “by using Ordinal versus Cronbach’s alpha would make a difference with regard to conventional recommendations” (Gadermann, 2012).

Despite the relatively low score for the Cronbach's alpha, the correlation between the PCSS-C sleep cluster and the SWPB scale indicated reasonable concurrent validity (*rs* = .58). Further, all of the PCSS-C sleep items were significantly associated with the SWPB scale items, except for items d and k. Small-to-medium correlations (*rs* = .23 to .46) were observed between the items of the PCSS-C sleep cluster and the SWPB scale, and pairs of PCSS-C sleep items were found to be associated with several of the SWPB items.

This differential finding is particularly noteworthy, since it suggests the possibility that the PCSS-C sleep items can delineate different sleep complaints. Similar findings have been reported by Becker and colleagues (2015) who reported positive associations between CBCL sleep items and sleep disorder diagnoses. The CBCL item "sleeps more" was positively associated with hypersomnia and the CBCL item "overtired" was positively associated with psychological insomnia. Similarly, the results of the current study demonstrated the ability of the PCSS-C sleep items to delineate tiredness linked to different sleep complaints and behaviours. For example, the correlation between PCSS-C sleep items "I get tired easily" and "I get tired a lot" and SWPB items could be related to "hypersomnia," or "excessive sleepiness." Whereas "I daydream too much" and "I get tired a lot" could be related to either "behavioural insomnia" or "delayed sleep onset." Delayed sleep onset, otherwise known as "Delayed Sleep Phase syndrome" (DSPS), is a common form of insomnia found in adolescents that cannot fall asleep until midnight or later, and subsequently have difficulty awakening for school or staying awake in early morning classes. Poor sleep habits or sleep hygiene often influence this. Students with DSPS are likely to sleep through early morning classes (Wolfson et al., 2003). In one study, it was found that adolescents with DSPS reported "daydreaming" and had maximal sleepiness mostly during the morning classes with a greater tendency towards alertness as the day progressed (Thorpy, Korman, Spielman, & Glovinsky, 1988). Whereas "hypersomnia" is more associated with chronic sleepiness and is found in adolescents who take naps at inconvenient times (i.e., such as during school) and experience trouble waking from long sleeps (Wolfson & Carskadon, 1998). In some individuals, the sleep disturbance may contribute to impulsivity and risk-taking behaviour (i.e., the SWPB item "done dangerous things without thinking"). Overall, these distinctions (Bodkin & Manchanda, 2011) are important as they have important implications for assessment and treatment of sleep problems in children.

A current challenge within the sleep disorder literature is evaluating a patient with a symptom of "tiredness" and determining whether it means "tired or sleepy," "fatigue or lack of energy," or "weak" which are often used interchangeably (Bodkin & Manchanda, 2011). Understanding the distinction between these terms is important as each term refers to a different type of sleep problem, and the corresponding evaluation and treatment differ according to what is meant (Bodkin & Manchanda, 2011). For example, one patient may use the term "tired" to describe their fatigue, while another patient may be describing hypersomnia. Determining what is actually meant by the sleep complaint is a crucial step to the evaluation and management of the patient (Bodkin & Manchanda, 2011). That said, this finding should be interpreted cautiously and considered exploratory. Although more research is needed, these findings indicate the potential usefulness of the PCSS-C sleep items to distinguish different sleep complaints which is important for treatment.

In sum, a statistically significant medium correlation between the items of the PCSS-C sleep cluster and SWPB scale was found in this study. Again, no correlations emerged between the items not included on the SWPB scale (i.e., a, e, l, and o) and the PCSS-C sleep items, with the exception of SWPB item n. Interestingly, a small negative correlation was observed between the PCSS-C sleep cluster and the SWPB item o (had a good night's sleep?). Returning to the hypothesis posed at the beginning of this study, it is now possible to state that the PCSS-C sleep items/cluster is a valid measure of sleep problems in children.

Summary and Discussion of Findings: Objectives 3 & 4

Cross-validity. The secondary purpose of this study was to investigate the effect of sleep problems across the psychological, cognitive and balancing domains measured by the Child SCAT3. As hypothesized, significant differences were observed between the sleep groups for PCSS-C total and PCSS-C severity, with the sleep problems group reporting more symptoms and indicating greater symptom severity. With respect to the PCSS-C cluster analysis, the sleep group reported higher scores in both PCSS-C clusters, cognitive and somatic, with medium effect sizes. Likewise, positive correlations were found between the PCSS-C sleep cluster and the PCSS-C clusters, cognitive and somatic. Lastly, no significant differences were found between the athletes with and without sleep problems for the SAC-C total and BESS-C total scores.

The results are consistent with the present study's hypotheses and previous research (Mihalik et al., 2013; Sufrinko et al., 2015; Sufrinko et al., 2016) in which athletes with sleep difficulties reported more concussion-related symptoms (i.e., symptom total, symptom severity and somatic symptoms). In contradiction with earlier findings (Mihalik et al., 2013), this study did find a significant difference between sleep groups for cognitive-related symptoms, in which athletes with sleep problems reported more cognitive-related symptoms.

Even though these results differ from those reported by Mihalik et al. (2013), this finding has been reported in children who experience sleep deficiency (Brooks, Iverson, Atkins, Zafonte, & Berkner, 2016; Kostyun et al., 2015). For example, Brooks and colleagues (2016) found that male athletes with attention problems reported more symptoms in the sleep-related arousal domains than those without attention problems. The symptoms more commonly reported by boys with attention problems were difficulty concentrating (38%), trouble falling asleep (30%), sleeping less than usual (28%) and drowsiness (25%) (Brooks et al., 2016). It has been hypothesized (Meerlo, Koehl, van der Borght, & Turek, 2002) that these effects are associated with neuropsychological processes (e.g., hypothalamic-pituitary-adrenal axis activation), and that sleep problems interferes with the restorative functions of sleep (Brown, Basheer, McKenna, Strecker, & McCarley, 2012), resulting in disruptions in breathing, emotional reactivity changes, and cognitive impairments (i.e., inattention, memory and decision making).

Consistent with the hypothesis and previous studies (Mihalik et al., 2013; Sufrinko et al., 2015), athletes with sleep difficulties performed similarly on baseline cognitive and balancing composites compared to athletes without sleep difficulties. Although hypothesized, the failure to find a link between sleep problems and the cognitive and balancing domains, might depend on the method chosen for this study. The present study measured sleep quality, however ‘sleep problems’ can also be evaluated by sleep duration.

Sleep quality and sleep duration are often seen as two separate sleep domains. Although there are some similarities between the domains, qualitative differences do exist between them. Sleep quality often refers to the subjective experience of sleep, and these measures focus on the feeling of being rested when waking up and satisfaction with sleep (Reynolds & Banks, 2010). Whereas sleep duration is an objective domain and focuses on objective indices namely, the actual time during which the individual is asleep.

Based on the literature, sleep quality appears to be associated with poorer performance on complex neurocognitive tasks that require sustained attention and working memory, relative to sleep duration. Therefore, one possible explanation for the lack of significant results may be related to the interactions between the sleep domain (i.e. sleep quality or sleep duration), sleep measure (i.e., subjective or objective) and neurocognitive tasks (i.e., complex or simple) of the SAC-C. For example, it has been suggested that sleep quality measured subjectively (i.e., self-reported sleep problems like tiredness) is more associated with subjective measures of cognitive functioning compared to objective measures, whereas short sleep duration is associated with both objectively assessed and subjective reports of decreased cognitive functioning (Kronholm et al., 2009).

Compared to the literature on concussions, the results of the present study corroborates with some published studies (McClure et al., 2014; Mihalik et al., 2013), but not all (Silverberg et al., 2016). However, researchers that have observed significant effects of sleep duration on objective neurocognitive measures, reported small effect sizes ($d = .10$) and the results are not clinically meaningful. A more recent study (Sufrinko et al., 2016) also reported a small effect of sleep duration on neurocognitive tasks; however, when poor sleep (i.e., sleep duration) and sleep problems were examined concurrently the differences became clinically significant.

The difference in results can be explained, in part, by methodological differences between the current study and the study by Sufrinko et al. (2016); specifically, the concussion tool used and the inclusion and exclusion criteria. Sufrinko et al. (2016) used the PCSS sleep items of the ImPACT and sleep duration, whereas the current study used only the PCSS sleep items of the Child SCAT3. Therefore, it is likely that the sleep group in this study, may represent heterogeneity, and such that the differences in results between studies may in part be attributable to the homogeneity of the sleep group in the Sufrinko et al. (2016) study, as athletes in the sleep restricted group also had to report poor sleep (i.e., ≤ 5 hours of sleep).

Unfortunately, it was not possible to investigate the concurrent effect of sleep problems and poor sleep in the current study, because the majority of participants reported getting at least 9 hours of sleep. This is noteworthy given that the average amount of sleep reported in adolescent samples is between 7 and 7 ½ hours (National Sleep Foundation, 2006). That said, it is well known in the literature (Lauderdale, Knutson, Yan, Liu, & Rathouz, 2008) that adults and children tend to over-estimate their sleep by at least one hour. In a supplementary analysis (not included in the results section) participants were grouped according to whether they endorsed the SWPB item "stayed up all night?" (i.e., Sleep Deprivation group). Significant differences with medium effect sizes were found for SAC-C and BESS-C total scores. Athletes who reported "stayed up all night?" within the last 2 weeks performed worse on both domains. These results are consistent with those of other studies and suggest that cognitive and physical performance is affected by extreme sleep deprivation (Wolfson & Carskadon, 1998). Indeed, it has been reported that short-term memory was degraded in participants who slept an average of 21.4% of their normal sleep compared to those with moderate sleep loss (71.42%) (Matthews, Deary, & Whiteman, 2009). Given that the SWPB scale directs the respondent to indicate when they usually go to bed and wake-up, and does not differentiate between acute and chronic sleep duration patterns, it is uncertain when this night of sleep deprivation occurred. It is understood that it occurred sometime within the last 2 weeks, which shows the significance and lingering effects of extreme sleep deprivation. This finding is consistent with the existing literature which has shown a link between chronic sleep restriction (e.g., > 2 nights of less than 8 hours of sleep) and neurophysiological changes, that requires several nights of recovery sleep to reverse the neurocognitive deficits in healthy individuals (Alhola & Polo-Kantola, 2007). Interestingly, the Sleep Deprivation group was comprised of participants from both groups (i.e., Sleep Problems and Control). This finding is in accord with the literature, which has shown that there is individual variability in sleep need (Jenni & Carskadon, 2007).

Overall, the literature suggests that poor sleep duration, not poor sleep quality, is associated with poorer neurocognitive scores, and when examined concurrently results in more clinically meaningful differences. Although not conclusive, the results suggest that sleep duration and sleep quality should be combined and considered as modifying factor of baseline test scores.

Lastly, although hypothesized, the failure to find a link between sleep problems and BESS-C scores, might be explained in part by the composition of this sample. The sample for this study consisted of male athletes, and previous studies have shown that male athletes are not as affected by sleep on neurocognitive tasks and often perform better than female athletes on psychomotor vigilance tasks, under equivalent sleep conditions (Ballester, Huertas, Yuste, Llorens, & Sanabria, 2015; Sufrinko et al., 2016).

In summary, the results of this study are consistent with those of other studies and suggest that sleep problems affect PCSS-C scores (e.g., total and severity) and PCSS-C clusters (e.g., cognitive and somatic), and have no discernible effect on cognitive and balancing scores. This study produced results which corroborate the findings of a growing body of literature that provides evidence that insufficient sleep in children is more likely associated with deficits in higher-order and complex neurocognitive functions, as well as subjective well-being (Astill et al., 2012; Dewald et al., 2010).

Implications for Practice

In accordance with previous literature, the results of the current study highlight the importance of evaluating sleep problems at baseline testing in children. In a recent short communication article, in the International Journal of Neurorehabilitation, Everhart and colleagues (2016) discussed the importance of evaluating pre-injury sleep characteristics among adolescents afflicted with mTBI. Select studies have found that athletes presenting with sleep problems at baseline, reported more symptoms following a concussion than athletes who did not have sleep problems. Neuroscience studies (Vanderploeg, Curtiss, Luis, & Salazar, 2007) have suggested that there is a shared mechanism between sleep deprivation and concussions, such that premorbid sleep problems may interact with a concussion and influence the rate of recovery, report of residual symptoms and long-term morbidities. Therefore, the results of this study have both practical and theoretical implications.

Problems with sleep and sleep disorders are common in athletes, however may go unrecognized (Malhotra, 2017). Given the adverse effects of poor sleep, there is an increasing necessity to educate athletes on adequate duration, quality, and timing of sleep (Malhotra, 2017). Part of this process includes the screening of sleep problems. The authors of the communication article (Everhart et al., 2016) proposed adding another instrument, the short version of the Adolescent Sleep Wake Scale (ASWS) to measure sleep problems at baseline testing. Although a multi-item measure would allow for a robust evaluation of sleep problems, this might not be an option to healthcare providers or other professionals who work with athletes. In fact, researchers have identified time for completion, scoring, and analysis as barriers to the implementation of other measures (Valier, Bacon, Bay, Houston, & Valovich McLeod, 2016; Valier, Jennings, Parsons, & Vela, 2014). This study provides evidence that the PCSS-C sleep cluster of the Child SCAT3 offers a valid alternative to the lengthy multi-item and comprehensive measures, reducing concerns pertaining to participant and clinician burden, but still provide coaches and clinicians with a reliable and valid measure of sleep problems in children at baseline testing.

Although most athletes do recover, a subset can experience symptoms that persist for longer than 1 month (Barlow et al., 2010). Investigations into predictors of prolonged recovery have identified several factors, one of which is acute post-concussive symptom burden (Erlanger et al., 2003; Nelson et al., 2016). According to the literature, non-concussed athletes endorse concussion-like symptoms (Alla, Sullivan, & McCrory, 2012; Kirkwood et al., 2006; McCrory et al., 2013). For example, McCrory et al. (2013) found that the mean symptom report scores of non-concussed collegiate athletes ranged from 3.7 to 18.1 and mean symptom severity scores ranged from 4.2 to 27.5, at baseline. Given that symptoms are state dependent (Matthews et al., 2009), it is intuitive that non-injury related factors, specifically pre-injury symptoms, may affect young athletes' report of symptoms following concussion and can provide a context for interpreting post-injury symptoms (i.e., acute post-concussive symptom burden).

The present study provides evidence that sleep problems reported at baseline testing effected PCSS-C scores (i.e., total and severity). This is significant given the fact that preliminary evidence has been published showing an association between pre-injury sleep problems and post-injury PCS scores. For example, Sufrinko et al. (2015), using the sleep items on the PCSS of the ImPACT found that athletes with sleep problems endorsed more symptoms on the PCSS at 5-7 days and 10-14 days following a concussion relative to athletes with concussions who did not report pre-injury sleep problems. In another study (Theadom et al., 2015), it was reported that pre-injury sleep quality was predictive of sleep difficulties at one year, and that post-injury sleep difficulties were predictive of a prolonged recovery. When considering the effects of sleep problems and poor sleep practices often adopted by adolescent athletes (Taylor, Chrismas, Dascombe, Chamari, & Fowler, 2016), it might be wise to consider sleep as a modifying factor. In doing so, we can speculate that return to play and return to learning decisions could be complicated by the perceived differences in baseline and post-concussive sleep scores (McClure et al., 2014).

Post-concussive athletes often report more sleep items than their recorded baseline levels, particularly when sleep is recommended as a first-line therapy (McClure et al., 2014). Sufrinko et al. (2015) observed that athletes with pre-injury sleep difficulties following a concussion had worse sleep-related symptoms when compared to controls; however, the pattern of symptom scores across time were similar between groups, regardless of sleep difficulties at baseline. Similar to Sufrinko and colleagues (2015), in the present study, it was observed that athletes in the control group reported baseline symptom scores that were consistent with published norms (Nelson et al., 2016; Porter et al., 2015). This is important for clinicians to be aware of, as pre-existing sleep problems may potentially inflate the overall symptom score when managing these athletes (Sufrinko et al., 2015).

This study also found evidence of sleep problems effects on the PCSS-C clusters, cognition and somatization. This is particularly noteworthy as Kontos and colleagues (2012) outlined the need for understanding whether the endorsement of cognitive symptoms is caused by a general (i.e., trait) deficiency in cognition or if endorsement of these symptoms was more temporally related to a state, such as sleep problems. Further, the presence of somatic symptoms (e.g., headache, nausea and faint) is important as clinicians often question more about these symptoms during an initial concussion assessment as these symptoms are commonly associated with concussions and increase the odds of symptoms beyond 28 days post-injury (Howell et al., 2016). Essentially, if baseline levels of sleep and its adverse effects on related symptoms are not accounted for, “post-concussive symptoms may appear to be solely a result of the injury rather than a partial function of premorbid status” (Solomon, Kuhn, & Zuckerman, 2016).

Determining what is meant by the sleep complaint is a crucial step to the evaluation and management of the athlete. In a supplementary analysis (not included in the results section) it was found that the PCSS-C items “I daydream too much” and “I am tired easily” were associated with different symptomatic clusters: cognitive and somatic, respectively, with medium effect sizes. This is consistent with a study in adults (Lau, Lovell, Collins, & Pardini, 2009) that found that the PCSS items “sleeping more than usual” and “sleeping less than usual” fall into different symptomatic clusters: cognitive and sleep, respectively. The present study provides evidence for parsing the effects of the PCSS-C sleep items of the Child SCAT3.

School-aged athletes are particularly vulnerable to poor sleep. Compared to non-athletes, they often sleep less than 8 hours per night (Milewski et al., 2014), and report poorer sleep quality (Fullagar et al., 2015). Poor sleep can lead to poor performance, slower recovery, and a higher risk of injury in athletes (Malhotra, 2017). Given these risks, coaches and clinicians might consider educating athletes about proper sleep hygiene (i.e., regulated sleep schedule, sleep rituals, and no naps) (Sufrinko et al., 2015).

Research Implications, Limitations & Future Directions

The strengths of this study include the use of a pediatric population, it provides psychometric evidence for the use of the PCSS-C sleep items/cluster to assess sleep problems, and it is the first to evaluate the effect of sleep problems on baseline test scores measured by the Child SCAT3. Nonetheless, several limitations should also be noted.

One downside regarding the methodology is the use of the Child SCAT3, which makes comparisons to other studies difficult. Although the ImPACT is similar to the SCAT there are important differences between the two measures. For example, the SCAT assesses long-term and short-term memory using word lists, whereas the ImPACT uses both words and shapes for its memory tasks (i.e., verbal memory and spatial memory). In addition, the sleep items used on the ImPACT and SCAT PCSS differ from the PCSS-C sleep items used on the Child SCAT3. Despite the limitations of this method, the findings do correspond with other researchers within and out of the concussion literature.

Secondly, objective measures of sleep were not used. Assessing sleep exclusively using the PCSS-C sleep items/cluster is far from optimal; however, this measure may be useful for understanding sleep problems and how they influence the assessment and management of youths with concussions. Further, the sleep scale used in this study, the Sleep/Wake Problems Behaviour scale is a part of the School Sleep Habits Survey, and although widely used and has moderate reliability, no empirical research has been published on the validity of the scale with other sleep scales nor have cut-off criteria been established. It is recommended that future studies consider using a validated sleep scale, such as the PSQI or the Epworth Sleepiness Scale, both of which have been validated with objective measures of sleep in participants with mTBI (Wickwire et al., 2016).

The generalizability of this study should also be considered a limitation. The current sample included children from 10 to 12 years of age who are ice hockey players in Edmonton, Alberta and therefore may not be generalizable to youths in different sports, age, or gender cohorts. It is important to note that other related, comorbid conditions were not controlled for in this study (e.g., mood disorder, migraine) and may have accounted for worse PCSS-C scores in the sleep difficulties group (Dewald et al., 2010). Moreover, this study used a moderate sample size, future research should use a larger sample size, ideally with athletes who play high-contact sports, as these individuals are more likely to have a concussion. With a larger sample size, it is advisable to group athletes who endorse the PCSS-C sleep items into more than one group, in an attempt to address the heterogeneity of sleep problems including sleep severity, frequency of sleep problems, and individual differences in sleep need.

Lastly, the reporting period for the PCSS-C is the day of the assessment whereas the reporting period for the SWPB scale is within the last 2 weeks. It is recommended that subsequent studies follow-up with a clinical interview with families to clarify any inconsistencies across the measures and corroborate the athlete's self-reported sleep duration. The sleep data included in this study was self-reported, future studies should examine parent-reported sleep functioning in relation to the PCSS-C sleep items/cluster.

Conclusions

In conclusion, although the PCSS-C sleep cluster is not a sleep-specific measure and was not intended to be developed to assess sleep problems in children and adolescents, the correspondence between the PCSS-C sleep items/cluster scored reasonably well with a validated measure of sleep functioning in children. Although there are limitations due to the reliability, which limit the validity of the research findings, this study does provide support for the use of the PCSS-C sleep items/cluster to be used in research studies, as well as a potential screening measure for sleep problems in young athletes, when specific sleep screening is not available or possible. Lastly, the results of this study support current literature regarding the effect of sleep problems on baseline performance. That is, athletes that self-report sleep problems as measured by the PCSS-C sleep items endorse more symptoms on the PCSS-C and PCSS-C clusters (i.e., cognitive and somatic). Although this is a pilot study, this is the first project to examine the Child SCAT3's potential at assessing sleep difficulties and the effect of sleep problems on metrics for this tool in school-aged male ice hockey players at baseline.

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