Concussion

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Abbreviations

ImPACT	Immediate post-concussion assessment and cognitive testing
MSLT	Multiple sleep latency test
mTBI	Mild traumatic brain injury
PSG	Polysomnogram

Case Vignette

Laurie, a 15-year-old female soccer player is knocked down by a ball kicked at her head. She falls and hits the back of her head on the field. She does not lose consciousness. She is able to get up and immediately complains of a headache. She is assessed by her coach and advised to sit out the rest of the game. She goes home and feels exhausted. Her parents assume it is her usual exhaustion after a game and allow her to go to sleep early that night. She sleeps in late the next morning and follows up with her primary care doctor in the afternoon, who diagnoses her with a concussion. "Complete brain rest" is recommended, and she is advised to rest in the dark. She is advised not to use electronics or do any physical activity and is excused from attending school. She follows up with her doctor after a week and is still having headaches, sleeping during the day, and complaining of difficulty falling asleep at night. She is sensitive to light and does not complete her usual schoolwork due to headaches and tiredness. When she goes to school, she tolerates a couple of hours of time there before recurrence of headaches. Her parents report that she is more irritable than usual and does not engage in her usual social activities with her friends.

Introduction

Traumatic brain injury (TBI) is the leading cause of death and disability in children and adolescents in the United States. According to the Center for Disease Control, more than 248,000 children were treated in emergency rooms in 2009 for sports and recreation-related injuries that included a diagnosis of concussion or TBI. Mild traumatic brain injury (mTBI), otherwise known as concussion, accounts for 70–90% of all traumatic brain injuries [1].

According to the Concussion Consensus Statement [2], concussion is defined by one or more of the following clinical domains:

1. Somatic symptoms (e.g., headache), cognitive (sometimes described as mental fogginess) and/or emotional symptoms (such as anxiety or depression)
2. Physical signs (e.g., loss of consciousness, amnesia)
3. Behavioral changes (notably irritability)
4. Cognitive impairment (e.g., slowed reaction times)
5. Sleep disturbance

Sleep disturbances commonly include difficulty initiating and maintaining sleep (insomnia), excessive daytime sleepiness, and altered sleep-wake cycles. Surveys indicate that up to 38% of children with concussion reported poorer sleep

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during the first month post-injury [3]. The presence and persistence of sleep disturbances over the longer-term recovery period is not clear. A longitudinal study of all levels of traumatic brain injury found that sleep disturbances were present up to 24 months after injury in moderate and severe cases [4]. This study only followed patients for 24 months, so it is possible that sleep disturbances may persist even longer.

Understanding and recognizing sleep problems after concussion is important because sleep disturbances can affect cognitive, emotional, and physical functioning. For instance, insomnia has been shown to exacerbate psychiatric problems, memory, mood, and social functioning [5]. Mood disorders can be comorbid with sleep disorders in patients following concussion. In some cases, a pre-injury history of sleep difficulties or mood disorders may have been present and exacerbated by injury or disruption of routine. Greater anxiety and depression were associated with greater daytime sleepiness, poorer sleep quality, and more naps in patients with brain injury vs controls [6]. Tham et al. [7] found a correlation between depressive symptoms and sleep quality, but their findings were not specific to concussion since both adolescents after concussion and healthy controls were affected.

A commonly used web-based clinical and research assessment tool in the field of sports concussion management is the Immediate and Post-Concussion Assessment and Cognitive Testing (ImPACT: ImPACT Applications Inc., Pittsburgh, PA). This computer-based task typically takes 25 min for administration and includes a demographic section, symptom rating, and six subtests that assess attention, memory, processing speed, and reaction time. Kostyun et al. found that ImPACT neurocognitive test scores for visual memory, visual-motor speed, and reaction time indicated poorer performance in adolescents reporting sleeping more than typical (i.e., 9 or more hours) compared to adolescents who did not report sleeping more than usual [8]. During recovery from concussion, increased sleep may suggest active recovery and decreased neurocognitive functioning during acute recovery.

Adolescents, in particular, are at greater risk of developing sleep problems due to the physiologic changes in their sleep that promote delayed sleep phase, combined with academic and social demands that compete for time with adequate sleep [7]. Tham et al. [4] followed adolescents after concussion and found that they experienced higher rates of sleep disturbances compared to healthy peers at 5 and 12 months post-injury. They reported poorer sleep quality, which was supported with actigraphy data. They had shorter sleep durations (average 6 h), increased wake time at night, and poorer sleep efficiency. Early management of sleep problems may lead to shorter recovery time and reduction of symptoms.

Another risk factor in developing sleep problems is a prior history of sleep problems. Sufrinko et al. [9] found that adolescent and adult athletes who had pre-injury sleep difficulties had decreased cognitive performance and increased symptoms after concussion compared with those who did not have pre-injury sleep problems. They hypothesized that pre-injury sleep problems may increase susceptibility to already compromised cerebral blood flow and metabolism, leading to more severe injury [10]. In related work using animal models of the adolescent brain, structural brain changes in hippocampal volume occurred after chronic sleep deprivation [11]. These changes may be associated with the cognitive and emotional problems displayed with lack of sleep. Sufrinko et al. [9] conclude that there is a cumulative effect of sleep deprivation, brain injury, and affective/cognitive difficulty that results in poorer outcomes after concussion.

Multiple concussions are associated with an increased incidence of insomnia and severity of sleep disturbance [12]. More specifically, the incidence of insomnia increased from 5.6% in patients with no history of concussion to 22.4% after a single concussion to 47.5% for patients after multiple concussions. The frequency and severity of sleep-onset insomnia, sleep-maintenance insomnia, and early morning awakening were all increased after TBI. Sleep-onset insomnia is most prevalent after a first concussion, while maintenance insomnia intensifies after an additional concussion. The number of concussions was found to be a significant predictor of overall insomnia severity. Therefore, as one gets older, the risk for more concussions and also more sleep problems may increase.

Surprisingly, the complaint of sleep disturbances is more common in mild brain injury compared to severe traumatic brain injury. It is unlikely that sleep disturbances are not present in severe injury. Rather, it may be that sleep problems receive less attention compared to the focus on survival and emergency management of a severe injury and the devastating sequelae of long-term physical and cognitive deficits.

There are several challenges to the management of sleep problems after concussion. First of all, the underrecognition of sleep problems and their impact on functioning may result in a lack of guidance or therapy for these problems. Secondly, the belief that complete brain rest is needed until symptoms resolve may lead clinicians to assume that excessive sleep is necessary for recovery for a prolonged period of time, which may actually impair a return to normal functioning. This challenge may relate to a worsening of symptoms in an iatrogenic manner in which a well-intentioned recommendation to rest and sleep during the day may have unintended consequences on sleep and other domains of functioning. Thirdly, sleep problems may become refractory when addressed too late and may prolong recovery and resumption of normal activities.

Evidence Base

Evidence that sleep is impacted after concussion is found from studies using electroencephalography (EEG). A study of infants and toddlers after acute injury showed a reduction of slow-wave sleep and an increase of the sleep spindles found in stage N2 sleep. Rapid eye movement (REM) sleep was not affected [13]. Enomoto [14] found slowing in the occipital area with either delta waves alone or alpha waves mixed with delta or theta waves. These EEG findings have been replicated in adult studies. Schreiber et al. report a higher proportion of stage 2 sleep and lower proportion of REM, as well as shorter total sleep time. The authors hypothesized that these EEG changes correlate with memory difficulties. The level of tiredness after concussion may be so intense as to mimic narcolepsy, with sleep-onset REM periods found on multiple sleep latency tests (MSLT), used to objectively measure sleepiness. Gosselin et al. [15] also report increased delta activity and reduced alpha activity which was correlated with poor sleep quality and daytime impairment.

While the exact etiology of sleep disturbance after a concussion is not well defined, several theories on the mechanism of injury may explain how sleep becomes impacted. For example, the impact of a head injury may result in damage to areas of the brain, such as the hypothalamus and mid and basal forebrain, which regulate sleep. This is supported by alterations in neurotransmitter levels that modulate the sleep-wake cycle [16]. The neuropeptide hypocretin, which is essential for maintaining consolidated sleep and is affected in narcolepsy, may be reduced after concussion [17]. One hypothesis is that injury to the posterolateral hypothalamus results in hypersomnolence since those cells synthesize hypocretin-1, which is important in maintaining a wakefulness state [18].

Diagnosis

The diagnosis of sleep problems in the context of concussion is largely based on history and self-report of symptoms. Symptom checklists, such as the Post-Concussive Symptom Inventory (PCSI) [19], include sleep symptom questions. Given that the reliance on symptom report of children may be difficult to elicit, Sady et al. [20] modified the PSCI to be developmentally appropriate for children of all ages, and different forms have been adapted for different age groups (ages 5–7, ages 8–12, and ages 13–18). A more objective assessment of sleep can be made through the use of actigraphy, which can determine sleep-wake cycles and daytime napping. Though not the standard of practice, a multiple sleep latency test (MSLT) can be used to evaluate the level of daytime sleepiness. If concerns of central or obstructive sleep apnea arise, a polysomnogram can be done.

One must be cautious in overtreating insomnia complaints. Gosselin et al. [15] found that poor sleep quality on the Pittsburgh Sleep Quality Index reported by athletes after TBI was not supported by findings on polysomnogram. Concussed athletes had a normal sleep stage distribution, normal sleep efficiency (>91%), and a mean sleep latency of 15.8 min. However, they found objective findings on waking quantitative EEG which supported symptoms of daytime fatigue. During the waking EEG, there was an increase in the relative delta power and decrease in alpha power, indicating prolonged sleep inertia after waking. Discrepancies between sleep quality perception and objective measures may be partially attributed to central nervous system (CNS) hyperarousal, which is demonstrated by high levels of beta and gamma activity during sleep [15].

Management

The management of sleep problems after a concussion is an important early intervention because sleep disruption is associated with slowed recovery and continued functional impairment [21]. Sleep problems that are not treated may become more persistent and refractory over time. Addressing sleep problems may have a positive effect on recovery and result in a quicker return to physical activity. This is of particular value to student athletes.

Unfortunately, there is a paucity of literature regarding evidence-based management of sleep disorders in children who have suffered a concussion. In a review article by Williams et al. [22], amantadine was recommended for pediatric concussion patients with decreased alertness, decreased arousal, and difficulties with executive function. Melatonin, which can treat insomnia, has been found to protect against focal and global brain injury in animal models [23, 24]. Hypnotic sedatives may also be helpful for insomnia.

Non-medication approaches to managing sleep problems include cognitive behavioral therapy to improve insomnia and light therapy to improve circadian misalignment. Good sleep hygiene, which includes consistent bedtime and wake time, no electronics in bed, and minimizing daytime napping, should be encouraged.

Other comorbidities which contribute to sleep problems include anxiety, depression, and headaches. Medications used to manage these conditions may in and of themselves interfere with the sleep-wake cycle, and their use needs to be monitored carefully.

Areas of Uncertainty

The management of sleep problems related to concussion is often not addressed because it is underrecognized. Studies hypothesize that addressing sleep problems may lead to earlier resolution of symptoms and that ongoing sleep problems may be associated with persisting symptoms.

The role of hypersomnia or excessive daytime sleepiness in recovery from concussion is unknown. Kostyun et al. [8] hypothesize that the brain requires increased sleep to restore its neurometabolic homeostasis to the preinjury level. In animal models, the neurometabolic changes resolve in 7–10 days [25]. They also hypothesize that hypersomnia is a protective mechanism to prevent the brain from engaging in exertional activities that can exacerbate symptoms and prolong the healing process. Further research is needed to define what an appropriate amount of sleep is needed during the recovery process and when total sleep time is expected to revert back to baseline. Certainly, if daytime sleep negatively impacts sleep onset or reduces nighttime sleep, it should be limited.

Future Directions

Given the need to treat sleep disorders which can in turn improve recovery, research is needed on management of sleep problems within the context of concussion. It is not known whether the same sedative hypnotics used to treat sleep problems have a different effect in the context of concussion. It is not clear what effect these agents have on recovery of the metabolic derangements that occur with a concussion.

The pathophysiology of post-traumatic sleep-wake disturbances remains unclear. It is likely a complex interaction between brain lesions, neurotransmitters and hormonal changes, hypocretin level, aging, pain, and genetic predispositions [26]. Even without a clear pathophysiological explanation, sleep problems need to be addressed because they impact recovery. The treating clinician needs to include a careful interview about pre-injury sleep concerns, symptom constellation of sleep problems (i.e., daytime fatigue, delayed sleep onset, fragmented sleep), and sleep patterns.

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