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Research Article

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The Relationship between Sleep, Depression, and Traumatic Brain Injury: A Study of Ontario Workers with Head Trauma

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Abstract

While current literature reports associations between psychiatric illnesses and sleep dysfunction, traumatic brain injury (TBI) and sleep dysfunction, and TBI and psychiatric illnesses, the relationship between all three variables has not been examined. The aim of this cross-sectional study was to investigate the relationship between brain injury, sleep complaints, and other clinical variables in individuals presenting with work-related head injury. A medical record review of a consecutive sample of 106 head injured workers was performed. Abstracted data included that related to occupation, cause of head injury, diagnoses of TBI and sleep disorders, self-reported sleep complaints, mental health diagnoses, and demographic characteristics. The majority of workers with head trauma were diagnosed with mild TBI or concussion. Diagnosis of TBI was associated with increased odds of post-injury worsening of sleep (odds ratio 5.8, 95% confidence interval: 1.8–18.9). Among those with TBI, those with worsened sleep were significantly more likely to experience depression (p=0.003). A primary sleep disorder was established in 37.8% of our TBI sample, including new diagnoses and diagnoses in those with history of a sleep disorder. The potential implications of our findings are significant: self-perceived worsening of sleep after head trauma is strongly associated with brain injury. A diagnosis of depressive disorder was significantly related to self-perceived sleep quality in those with TBI. Therefore, when faced with sleep complaints in persons with head trauma, the clinician's first task must be identification of underlying abnormalities for proper differential diagnosis and treatment.

Keywords

Sleep; Head trauma; Traumatic brain injury; Workers; Rehabilitation

Introduction

Head injuries are frequent in industrialized countries and have significant health consequences [1]. In 2003-2004, head injuries comprised 8.6% of hospitalisations due to trauma in Canada [2]. Of these, it is estimated that at least 20% were serious enough to cause a traumatic brain injury (TBI) [3,4]. The terms 'head injury' and 'brain injury' are not descriptive, but they have specific medical definitions. Head injuries are trauma to the scalp or skull which may, or may not result in traumatic brain injury (TBI). Traumatic brain injury is defined as an alteration in brain function, or other evidence of brain pathology, caused by an external force [5]. Recently, there has been growing support for the view of TBI as a chronic disease starting at the time of the head injury event, with the potential to affect other organ systems and cause or expedite disease development [6,7]. Most debated of all is mild TBI, centered on the anatomic disruptions underlying it, often viewed as insufficient to account for the observed duration and severity of post-morbid symptoms.

The leading causes of TBI in the fiscal years 2002/03-2006/07 years in Canada's largest province Ontario, were falls (41.6%) and being struck by or against an object (31.1%); most of the injuries were unintentional [8]. TBI can be a serious workplace issue [9], particularly in the construction industry, through incidents involving falls from elevation, contact with equipment or operation of a vehicle [10]. An estimated half of all workplace fatalities in the working population in Ontario are associated with head injury [11]. Workplace head injuries resulting in even mild TBI are associated with increased long-term use of healthcare services for issues related to accidents, violence, diseases of the nervous system, and mental disorders [9]. Moreover, from 2005-2012, there was a doubling of compensation claims in Ontario, Canada by workers who sustained occupational traumatic brain injury, mostly of mild severity [12, 13]. Possible explanations for the spike include increased public awareness and thereby diagnosis, and susceptibility [14].

While the general prognosis for mild brain injury is considered good [15], newer research presents evidence suggesting persistence of long-term sequelae years after the injury, resulting in significant occupational and social disability [7,16].

One of the most commonly reported symptoms of TBI is disturbed sleep, characterized by inability to fall asleep or maintain uninterrupted sleep. Post-injury poor sleep can be the result of a complex relationship between sleep disorders and psychological, psychosocial, and/or behavioural factors associated with TBI [17-19]. The impact of sleep dysfunction in individuals with TBI has received little dedicated attention. Ouellet et al. [20], in their study of insomnia post-TBI, suggested the scarcity of literature on the topic is related to views of the nature of sleep dysfunction post injury as physiological, with transient impact and likelihood to subside with time. However, poor sleep after TBI can indicate primary or secondary sleep disorders, which must be diagnosed and treated to prevent a cascade of serious negative health effects [21,22]. Moreover, if left untreated, these symptoms can compromise a person's ability to engage in vocational pursuits and resume work, even after a mild TBI [19]. Therefore, addressing sleep complaints institutes potential for effecting positive changes in the level of functional ability and quality of life of those impacted [23].

Studies also show that the incidence of psychiatric conditions is significantly higher in mild TBI patients with sleep disturbances than in those without [24-28]. The presence of insomnia in the acute period following TBI has been shown to be related to anxiety, as evaluated with the structural clinical interview for the Diagnosis and Statistical Manual of Mental Disorders-IV (DSM-IV) text revision [29-31]. Many symptoms of depression overlap those associated with

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poor sleep and TBI, including decreased energy, fatigue, difficulty concentrating and with memory recall, as well as irritability [32]. Therefore, recognition of symptoms and accurate diagnosis is imperative to ensure appropriate, prompt and effective intervention [33,34].

While there is currently literature exploring the impact of sleep disturbances on brain injured individuals' ability to return to work (RTW) [35,36] as well as the prevalence of sleep disturbances following TBI [17,19,37-46], investigation of sleep dysfunction and work-related disability following TBI is missing in the scientific literature [23]. In addressing this gap, a necessary point of study is the significance of sleep dysfunction post-TBI in relation to other clinical factors that impact RTW post injury. Although there are some reports of an association between psychiatric illnesses and sleep dysfunction [24,47-49], TBI and psychiatric illnesses [24,31,50], and between TBI and sleep dysfunction [22,25,51], the relationship between all three variables has not been analysed.

The objectives of this study were to: (1) identify the extent and nature of sleep complaints in Ontario workers with head injury; (2) compare the rates of self-perceived worsening of sleep in head injured workers with an established diagnosis of TBI and those without and (3) explore associations between self-perceived worsening of sleep post injury and mental health conditions in workers with TBI. We sought to provide insight on the impact of sleep dysfunction on post-morbid health and functional ability.

Materials and Methods

This study was a retrospective medical record review of a consecutive sample of individuals with head injury sustained at the workplace who presented for a non-voluntary third party evaluation of readiness for return to work at an outpatient neurology clinic at Canada's largest rehabilitation hospital in 2003. The clinic has a contractual agreement with a worker's compensation insurer to provide diagnostic opinions, recommendations for treatment and continued case management for workers who sustained, or are suspected to have sustained a TBI at work, and have not returned to work within six weeks of the head injury event. This research is part of a larger study, ongoing since May 2006. Individuals eligible for this study met the following criteria: (a) older than 18 years of age at the time of injury; (b) injured at work; (c) identified as having sustained a head injury. This study was approved by the research ethics board at the institution where the study was carried out.

Data was collected from medical records from a rehabilitation hospital's neurology clinic. Two data abstractors worked collaboratively. Ten percent of the data were re-abstracted (i.e. reviewed a second time) and an agreement statistic was obtained to determine concordance between abstraction and re-abstraction. There was excellent agreement (≥ 0.75) between the two abstractions on core variables related to demographics, sleep, events leading to injury and mechanisms of injury, and substantial agreement (≥ 0.60) for variables related to incident typology and occupation.

Demographic information, including age, sex, and occupation at the time of injury, was collected. For data analysis, occupations were collapsed into four categories: (1) managers/professionals/technicians and associate professionals; (2) clerical support workers/service and sales workers; (3) skilled agricultural, forestry and fishery workers/ plant and machine operators and assemblers and (4) elementary occupations.

Injury-related data included clinical diagnosis of brain injury, injury severity, time since injury, and mechanism of injury. Injury severity was categorized as mild and moderate/severe. Mechanism of injury was classified as (1) struck by; (2) struck against; (3) falls; (4) motor vehicle crash and (5) other.

Clinical data collected included diagnosed psychiatric conditions categories (i.e. mood disorder, anxiety disorder, and substance-related disorder) according to the DSM-IV criteria [52]; diagnosis of sleep disorders in accordance with the International Classification of Sleep Disorders-2 [53], and self-perceived worsening of sleep.

Data Analysis

All variables analysed in the study were categorical with the exception of age and time since injury. Student's t-test was used for the continuous variables, to detect statistically significant differences between workers with a diagnosis of TBI and those without. Pearson's chi-square test was used for categorical variables when expectant frequency counts in all cells in a 2×2 table were equal to or greater than five. In the case of a cell with an expectant frequency count of less than five, the Fisher's exact test was used. Odds ratio was computed to compare the prevalence of self-perceived worsened sleep in workers with and without a TBI diagnosis. SAS software version 9.2 (SAS Institute, Inc., Cary, NC, 2008) was used for data analysis.

Results

The medical chart review of 106 workers with head trauma indicated 90 workers (84.9%) with a TBI diagnosis on assessment, with the remaining 16 workers having only a head injury diagnosis. Table 1 displays the demographic, injury-related and clinical

Table 1: Comparison of study participants with head injury who had endured TBI and those who had not

Variable	No TBI (n=16)	TBI (n=90)	p-value
Mean age (SD)	38.2 (10.8)	41.1 (11.4)	0.342
Sex			
Male	9	66	0.232†
Female	7	24	
Median days since injury (Q3-Q1)§	320 (911-186)	308 (915-142)	0.692
Mechanism of injury			
Struck by	*	30	0.511‡
Struck against	*	22	1.000†
Falls	*	49	0.002‡
Motor vehicle crash	*	11	0.440†
Other¶	5	*	0.004†
TBI category			
Mild		66	N/A
Moderate/Severe		12	
Loss of consciousness			
None		42	NA
Brief		13	
Yes, time not specified		11	
Missing		24	
Post-traumatic amnesia			
None		38	NA
Brief to < than 1 hour		16	
Yes, time not specified		17	
Missing		19	

*Cell size <5
†p-values derived from Fisher's exact test for all categories except mean age (Student's t-test) and median days since injury (Wilcoxon-Mann-Whitney test)
‡Chi-square test p-value
§n=89 for TBI group
¶Includes contact with electrical current; caught, jammed or pinched in, under or between objects

characteristics associated with TBI-positive and -negative diagnosis groups. There were no statistically significant differences between the two groups with respect to age, sex, time since injury, or occupational category. A statistically significant difference was observed in the proportion of head injuries sustained due to falls between the two groups, higher in the TBI diagnosed group (p=0.002). Likewise, there was a significant difference between the groups in prevalence of injury by other mechanisms, including contact with electrical current and being caught, jammed or pinched in/under/between objects, higher in the head injury only group (p=0.004). Conversely, prevalence of injury caused by being struck by/against or in a motor vehicle crash did not differ significantly between the TBI diagnosed and the non-TBI diagnosed head injured groups. The time since injury distribution was highly skewed to the high end; the median days since injury were similar for the two groups (320 days and 308 days for the non-diagnosed and diagnosed TBI groups, respectively).

Reported sleep functioning in workers with and without TBI is presented in Figure 1. Seventy-four of the 84 workers with TBI (88.1%) reported worsening of sleep after head trauma compared to nine of 16 workers with head injury only (56.3%). The odds for self-perceived sleep worsening were 5.8 times greater in workers with a traumatic brain injury than in workers with a head injury only (95% CI: 1.8-18.9, p=0.006).

Table 2 depicts demographic and other baseline characteristics of workers with a TBI diagnosis who reported worsening of sleep and those who did not. There were no statistically significant differences for any of the demographic or injury-related measured variables between the two groups. With respect to psychiatric diagnoses, approximately 70% of the workers with TBI who reported worsening of sleep were diagnosed with mood disorder category, compared to the 30% frequency of depressive disorder diagnosis in those with a TBI diagnosis without worsening of sleep, representing a significant difference (p=0.003). Fifty-one per cent of the TBI-diagnosed workers with self-perceived worsening of sleep were diagnosed with anxiety disorder relative to 40% without, however, not at a level of statistical significance (p=0.514). Similarly, no significant difference was observed for substance-related disorder between the sleep-worsened TBI group and the TBI group without self-perceived worsened sleep (p=0.330).

Of the 74 workers with TBI who reported worsening of sleep, 20 (27%) had an established sleep disorder diagnosis prior to their assessment at the neurology clinic, including pre-injury and post-injury cases. An additional eight workers (10.8%) with no prior sleep disorder diagnosis underwent a sleep study during their assessment

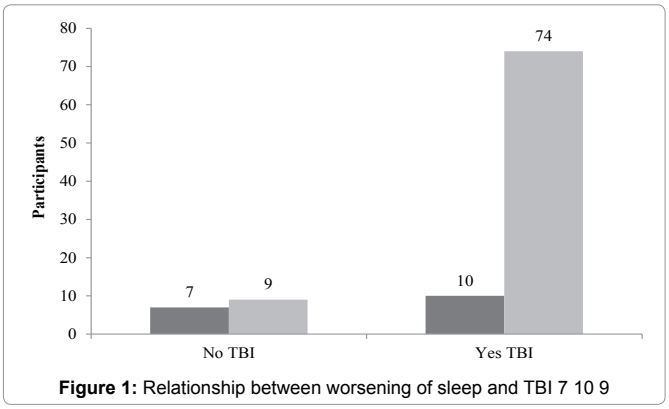

Figure 1: Relationship between worsening of sleep and TBI 7 10 9

Table 2: Comparison of study participants (all TBI cases) who had reported sleep worsening and those had not

Variable	Without sleep worsening (n=10)	With sleep worsening (n=74)	p-value†
Mean age (SD)	38 (10.2)	41.6 (11.3)	0.346
Sex			
Male	**	53	0.720
Female	*	21	
Median days since injury (Q3-Q1)‡	304.5 (509-304.5)	298.0 (915-142)	0.961
Mechanism of injury			
Struck by	*	26	1.000
Struck against	5	16	0.112
Falls	*	40	0.509
Motor vehicle crash	*	11	0.346
Other‖	*	*	0.478
Psychiatric status post-injury, DSM-IV***			
Mood disorders	*	51	0.029
Anxiety disorders	*	38	0.514
Substance-related disorders	*	*	0.330

*Cell size <5
**Not given to protect confidentiality
***Mood disorders include depressive disorders, dysthymia; Anxiety disorders include panic disorder, generalized anxiety disorder, obsessive-compulsive disorder, post-traumatic stress disorder; Substance-related disorders include alcohol, opioids, cocaine, cannabis.
†p-values derived from Fisher's exact test for all categories except mean age (Student's t-test) and median days since injury (Wilcoxon-Mann-Whitney test)
‡Chi-square test p-value

to establish the aetiology of their self-reported sleep complaints and were subsequently diagnosed with a sleep disorder.

Figure 2 shows the sleep disorder diagnoses in workers with TBI. Of the 28 workers with TBI who were diagnosed, 15 (53.6%) had a sleep-related breathing disorder (SRBD) and nine (32.1%) had insomnia. Among the remaining diagnoses were polysomnographic features of fibromyalgia (i.e. increased alpha EEG activity), restless legs syndrome/periodic leg movements in sleep, narcolepsy, and circadian rhythm sleep disorder.

Discussion

The purpose of this study was to explore the relationship between sleep and TBI in workers who sustained trauma to the head. The results show that workers who were diagnosed with TBI were more likely to report worsening of sleep after head injury compared to workers without a TBI diagnosis. Our findings are consistent with several studies that although did not focus specifically on the working population, reported greater dissatisfaction with sleep in persons with TBI relative to non-injured controls [54-56]. Similar findings were outlined in Orff et al.'s [57] review, concluding that self-perceived sleep disturbance is one of the most common problems associated with TBI. In our consecutive sample of TBI-diagnosed workers, over 88% reported deterioration of sleep after head injury. This is higher than reported by Colantonio et al. [58], who examined post-injury symptoms after work-related TBI and found 55% of 431 TBI participants reported sleep difficulties. Sex, age distribution and injury severity were comparable to this study. The median time since injury, however, was longer in our study at 10.2 months compared to Colantonio et al.'s 6.8 months. Whether this implies a time-dependent effect on quality of sleep requires further investigation. By Masel & Dewitt's [7] depiction of TBI as a chronic disease process with disease causing and accelerative capacity, it is expected that sleep

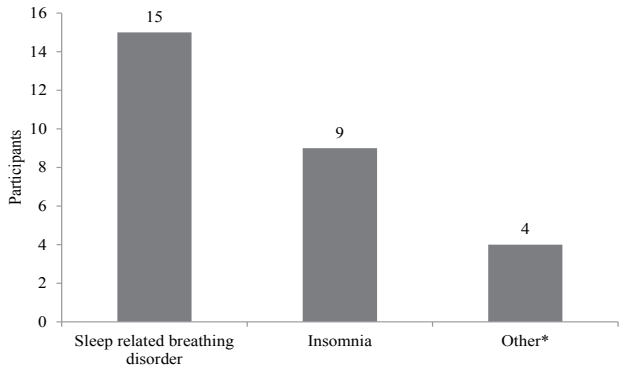

Figure 2: Sleep disorder diagnoses in workers who had sustained TBI

dysfunction, just as other conditions that develop after injury, will be subject to change with time as the person ages and more comorbid clinical conditions accumulate, many of which impact sleep.

In our sample of 74 workers with TBI who reported worsening of sleep, a sleep disorder diagnosis was established in 37.8%, including new and pre-assessment diagnoses. These findings indicate that a large number of TBI-diagnosed workers in our sample (62.2%), who reported worsening of sleep, did not undergo medical investigation to determine the nature of their sleep complaints. Those with a previously established sleep disorder diagnosis did not have their diagnosis revisited for evaluation and optimization of treatment effectiveness. This is significant as many of the self-perceived sleep symptoms that workers with TBI are experiencing and which impact their functioning in daily life, may be stemming from undiagnosed, yet, treatable sleep disorders [22].

Our study found an association between mechanism of injury, specifically falls, and TBI diagnosis. This finding is consistent with previous research studies that reported falls to be the most frequent cause of TBI at the workplace [34,59]. Wei et al.'s [60] research on work-related TBI in Ontario showed 54.2% of work-related falls occurred in construction, manufacturing and the transportation and storage industry. Although our study did not examine the relationship between mechanism of injury and occupational category, the large proportion of our sample that identified as working within type 3 and type 4 occupational categories, together with the significant number who specified falls as the mechanism of injury, lends indirect support for Wei et al.'s findings.

This study's results indicate a higher prevalence of mood disorder diagnosis in TBI subjects with worsened post-injury sleep compared to TBI subjects who did not report sleep worsening after their injury. These findings corroborate those of Huang et al. [61], where depression score one year post injury was higher in participants with persistent sleep complaints compared to those without. Although the scientific literature has established a strong association between sleep alterations and major depression [62], the cause-and-effect relationship between them is not clear [63]. With respect to a relationship between TBI, sleep dysfunction, and depression, studies show high rates of psychiatric comorbidity in persons with TBI and sleep problems [64,65]. A longitudinal study that followed TBI participants one to two years after the injury found higher rates of depression and anxiety disorders in participants with sleep difficulties compared to those without [64]. A recent finding by Rao et al. [26] established that sleep problems experienced in the acute TBI period predicted symptoms of depression, anxiety, and apathy one year after injury. Although our study was not longitudinal in nature, the findings add to the literature supporting a relationship between TBI and mood disorders through a possible sleep deterioration pathway.

In contrast to findings from studies by Hou et al. [25] and Fogelberg et al. [66], this study found no significant difference in the prevalence of anxiety between TBI participants that reported worsened sleep post injury and those that did not. This disparity in findings may be related to the method by which anxiety was diagnosed. While the aforementioned studies utilized standardized self-report measures (hospital anxiety and depression scale [67] by Hou et al. and generalized anxiety disorder scale-7 [68] by Fogelberg et al.), our study employed clinical psychiatric diagnoses by the DSM-IV criteria. Furthermore, although depression and anxiety frequently coexist in persons with TBI [69], following differential association between various psychiatric disorders and region of brain trauma, Jorge and colleagues [70] commented that depression with and without anxiety post-TBI may have different aetiologies. Further research on the subject of depression and anxiety after work-related TBI is timely.

To summarize, it is critical that sleep complaints in persons with head injury are thoroughly investigated and the nature established in order to apply appropriate intervention, given this study's finding that those who complained of worsening of sleep were more likely to be diagnosed with TBI. Moreover, we observed a significant difference in prevalence of clinical diagnoses of depressive disorder in those with TBI who reported sleep worsening and those who did not report sleep problems.

Limitations

There are several limitations to this study. Given the cross-sectional design, we were unable to explore interactions of the variables associated with brain injury longitudinally. Another issue is that the study's small sample size increases the probability of Type II error (i.e. undetected differences between TBI groups reporting post-injury sleep worsening and those not). Furthermore, the underpowered nature of the study may inflate the discovered effect sizes (i.e. strength of associations).

While comprehensive head injury evaluation was instituted by a multidisciplinary neurology services team, it is not always possible to reliably disentangle the nature of the diagnoses of depression, sleep disorder, and brain injury. This is particularly relevant to our study given that the sample was largely represented by mild TBI (i.e. concussion), the symptoms of which include insomnia [71].

External validity may be an issue in our findings as well. The data were drawn from admissions to a rehabilitation hospital's outpatient neurology clinic that has an agreement with a worker's compensation insurer to assess workers with mild to moderate head trauma and persistent symptoms. The lack of a non-insured group to examine whether the estimates of symptoms/ disorders in our insured sample are elevated limits generalizability of our results to the entire working population who sustained a head trauma.

Although only depression was found to have an association with reported worsening of sleep in workers with TBI, it is important that future studies examine other variables such as pain, fatigue, cognitive functioning, as well as pre-morbid sleep functioning more comprehensively. While this study did seek to collect data pertaining to workers' pre-morbid schedules (e.g. shift work, night shifts and

alternating shifts), this information was not available in the medical charts. The variables mentioned above could impact self-perceived sleep quality and functioning after the injury. The pitfalls associated with self-reported data must be noted as well.

To conclude, reported worsening of sleep is a common finding following TBI in the working population and may go uninvestigated. This can leave many workers post-TBI with undiagnosed sleep disorders that could result in the exacerbation of existing TBI symptoms, development of post-concussive syndrome or psychiatric symptomatology. The results of this study add to the literature supporting an association between sleep dysfunction, mental health issues, and brain injury. Despite the limitations of the study, the findings may serve in generating hypotheses for larger studies that intend to investigate the effect of sleep dysfunction in workers with head injury and TBI. Subsequent findings may be relevant for healthcare providers, specifically the professionals within occupational therapy and medicine who assess workers' ability to return to work after the injury. An increase in claims related to mild TBI in recent years calls for an effective strategy that addresses all symptoms associated with the injury, including those sleep-related, so that complete return to work can be achieved at the earliest time possible. Clinicians can serve a vital role, investigating the circumstances of the injury, evaluating an injured worker's ability to perform employment duties, and implementing safe strategies in the return to work process.

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