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ARE FATIGUE AND SLEEPINESS THE SAME? A BRIEF INTRODUCTION TO THE DIFFERENCES AND SIMILARITIES AND THEIR IMPLICATIONS FOR WORK SAFETY

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DISCLAIMER

ABSTRACT

Fatigue-related risk is a persistent safety concern for the mining industry. However, fatigue and sleepiness are often treated interchangeably, which can lead to confusion and potentially less effective reduction of safety risk. To provide clarity, we present an overview of similarities and differences between work-related fatigue risk and sleepiness including definitions, theories, measurements, and mitigation strategies. As a supplement, a summative visual model which highlights these similarities and differences is presented. Expanding industry knowledge in this area will assist safety professionals in crafting more targeted risk management practices appropriate for work-related fatigue risk, sleepiness, or both.

INTRODUCTION

Fatigue and sleepiness impact the health and safety of many workers across a variety of industries. An estimated 130 million workers are at increased risk for occupational injury due to fatigue [1]. It is also estimated that insufficient sleep costs the U.S. economy $411 billion annually due to worker injury, lost time, and negative impacts on worker's health and wellbeing [2]. Approximately 17.7 % of the U.S. labor force works nonstandard shift work schedules outside of the normal 6 am to 6 pm daytime shift [3], typically obtaining 4-6 hours of sleep per 24 hours [4] which is below the 7 hours of sleep recommended for adults by the American Academy of Sleep Medicine and Sleep Research Society [5]. Insufficient sleep, long working hours, shift work, and various job characteristics all increase the risk of fatigue and sleepiness [6], putting workers in industries that are heavily characterized by these factors at increased risk for occupational injuries.

Although the prevalence of work-related fatigue risk in mining is not well established, there is some evidence to suggest that the nature of the work done in the mining industry is characterized by factors that contribute to mine workers being uniquely susceptible to fatigue [7]. Compared to other manual labor industries, mine workers are more likely to report inadequate sleep [8]. Mine workers are also more likely to work shift schedules than the general population with 24.5% of mine workers and 17.7% of U.S. workers working a nonstandard shift schedule [3]. Data from the U.S. Bureau of Labor Statistics indicate that workers in the mining industry work longer hours per day (9.6 compared to 8.8) than the general U.S. labor force [9]. Moreover, approximately 17.3% of the mining population works more than 60 hours per week, while only 7.3% of U.S. workers work more than 60 hours per week [10]. This is cause for concern as longer working hours and inadequate sleep are associated with fatigue and sleepiness, likely increasing safety risk within the mining industry from injuries and adverse events linked to a fatigued and sleepy workforce [1, 11].

While there is limited knowledge regarding U.S. mineworkers' experiences with fatigue [12], there are a few international sources which demonstrate that fatigue and sleepiness have a negative impact on the mining industry. In a report based on lost-time injuries in Australian open pit coal mining, it was estimated that over a five-year timeframe, worker fatigue likely contributed to 83 of 91 total lost-time injuries, and the economic cost of fatigue over those five years was at least $3,345,000 [13]. In Iranian industrial mining group workers, the rate of fatigue and number of safety incidents were higher in shift workers when compared to nonshift workers [14]. These findings paired with the widespread utilization of shift work and night work within in the mining industry [15] illustrate part of what puts mine workers at increased risk for injury due to fatigue and sleepiness. Given the prevalence of long work hours, shift work schedules, and fatigue within the mining workforce, there is a critical need to identify effective ways to intervene, manage, and mitigate mine worker fatigue and sleepiness wherever present. One barrier to this is the complexity and lack of consensus around the operational definitions for fatigue and sleepiness.

FATIGUE AND SLEEPINESS USED INTERCHANGEABLY

Fatigue and sleepiness are interrelated complex constructs that are studied across a wide variety of disciplines, such as biology, nursing, pulmonology, psychology, neurology, and so on. While an assortment of expertise is useful in the study of sleep and fatigue, many voices can tend to instead highlight differences in preferred scientific methodologies and nomenclature. This can result in confusion as different disciplines have differing definitions for various terms. For example, in 2008 during a fatigue and safety conference, a group of world-renowned experts on the subject were tasked with coming to consensus on a precise definition of fatigue. However, due to a wide variety of views on the nature of fatigue, the experts were unable to come to a singular definition [16]. This may be due to aspects of fatigue such as its complicated etiology, multidimensionality, and imprecise quantification [16]. Given this level of complexity as well as the overlap between fatigue and sleepiness, some researchers have instead opted to refer to fatigue and sleepiness interchangeably to facilitate communication of their research [17]. This appears to be a practical solution to disseminate information pertaining to fatigue and sleepiness given the interconnectedness of the two terms. Indeed, sleepiness is even listed as a synonym for fatigue in the thesaurus, further conflating these two separate constructs.

When it comes to managing occupational health and safety, at first glance differentiating between fatigue and sleepiness may not appear to be necessary. On the surface, a worker experiencing fatigue may be indistinguishable from a worker experiencing sleep deprivation. In both cases, the risk for safety-related incidents can increase. Compared to the more subjective aspects of fatigue, sleep and wake are more readily measurable and concrete [18]. For this reason, sleep may be one of the primary or sole focal points of some fatigue risk management strategies. This may appear to be a somewhat more efficient approach, as implementing risk management strategies that primarily focus on sleep likely encompass a large portion of risk as sleep loss is fairly common [19] and can have a relatively immediate and profound effect on alertness [18]. However, focusing exclusively on sleepiness and leaving the specific factors of fatigue out of risk management strategies may underestimate the overall risk of nonsleep-related fatigue, given that performance decrements associated with sleep deprivation symptomology cannot fully be accounted for by sleepiness alone [20]. This approach also overlooks the likelihood that the effectiveness of interventions for fatigue and the interventions for sleepiness are dependent upon the context in which fatigue or sleepiness developed. For example, sleepiness resulting from inadequate sleep the night before may not be alleviated by work breaks, whereas work-related fatigue may be mitigated by breaks [21]. Ultimately, treating fatigue and sleepiness as completely interchangeable, regardless of context, makes it difficult to assess and mitigate safety risk in the absence of clear operational, measurable differences.

To provide some clarification on the issue, this paper offers an introductory overview of similarities and differences of work-related fatigue and sleepiness. Ultimately, the paper attempts to distinguish between these two highly similar constructs by referencing guiding materials to assist practitioners in better managing sleepiness and/or fatigue at their respective places of work. To supplement the information presented in this paper, a visual model which highlights critical, operational similarities and dissimilarities between sleepiness and fatigue through a review of relevant literature is presented. Ideally, this model can serve as a reference for the mining industry and increase the general awareness of differences between fatigue and sleepiness among personnel and leadership. It is important to note that these terms and their interrelationship are complex, and it is beyond the scope of this paper to solidify a singular definition for the scientific community. Rather, differences and similarities between fatigue and sleepiness are highlighted while simultaneously pointing out that it is important to identify differences between the two constructs in the workplace.

FATIGUE AND SLEEPINESS DEFINITIONS

As previously stated, there is currently no universal definition of fatigue across the scientific community. In general, most definitions include psychomotor or physiological decreases in performance due to increased demands, exertion or waning resources. Frone and Tidwell [22] describe fatigue as extreme tiredness accompanied by reduced functioning capacity. The authors use this definition in the context of physical, mental, and emotional fatigue and suggest that fatigue can be a result of a lack of resources in the presence of demands from work itself or factors outside of the workplace [22]. They also assert that work-related fatigue is not a persistent state but is instead temporally tied to the fatiguing factor. For instance, once an individual receives adequate time away from the fatigue-eliciting factor associated with the workday, their symptoms should begin to subside. Fatigue also has a physiological component to it and has been conceptualized as a state produced by a biological drive for recuperative rest [23]. Another definition of fatigue that complements these perspectives is Phillips [20]definition, "…fatigue is a suboptimal psychophysiological condition caused by exertion…" [20]. While there are many definitions of fatigue, a common theme is that exertion is a key causal component for fatigue that is experienced both psychologically and physiologically.

Comparatively, sleepiness has received less nuanced debate concerning its defining features, and a singular definition is more widely used. Throughout the research literature, sleepiness is defined as sleep propensity [24], or the inclination to fall asleep. In order to quantify sleepiness, measures such as the Multiple Sleep Latency Test (MSLT) are used to calculate the time it takes for participants to fall asleep [25]. The less time it takes to fall asleep, the greater the sleepiness. Other studies aimed at measuring the consequences of sleepiness use sleep deprivation methodology to measure decreases in performance on prolonged reaction-time tests such as the Psychomotor Vigilance Task (PVT) [26, 27]. Typical countermeasures for sleepiness involve recovering from sleep debt (i.e. sleeping), proper treatment of any underlying sleep disorders, and obtaining restorative sleep [28]. Across measures, countermeasures, and definitions used in the literature, sleepiness is consistently characterized by time spent awake and the resulting propensity to fall asleep.

FATIGUE AND SLEEPINESS THEORY

Much like the definitions there are similarities and differences in the theories between fatigue and sleepiness. Definitions inform what sleepiness and fatigue *are*, theories provide the *hows* and *whys* that ground the abstract constructs in reality. Drawing from these *how* and *why* theoretical perspectives provides further insight into the differences between fatigue and sleepiness. One of the major theories explaining work-related fatigue is the job demands-resource model, which theorize that two processes work together to maintain worker health: job demands and job resources [29]. A job demand is an aspect of work that requires sustained physical or psychological effort that can accumulate and result in the worker taking compensatory actions, such as narrowing attention to a single element in the environment [29]. An example of job demands could be jackleg drilling for a long period of time in a hot environment (i.e., physical strain and heat stress), or pressure to meet quarterly production goals (i.e., anxiety and time pressure). Job resources, on the other hand, may decrease detrimental effects of job demands by providing a reduction of physical and psychological costs to the worker. Some examples of job resources include a supportive work culture, opportunity for personal growth, or a workplace offering extended breaks for their employees. When these two processes become imbalanced and a job is characterized by excessive demands with minimal resources, workers can experience job strain, leading to fatigue and potential injuries, among other things. There are myriad other fatigue-related theories that suggest workplace fatigue prevention requires an adequate balance between demands and resources in the workplace. Based on these theories, it appears that overexertion beyond one's resources is a key risk factor for fatigue [21, 22, 29].

To explain sleepiness, the two-process model of sleep regulation remains the most scientifically applicable model [30]. This model posits that two processes interact with each other continuously to regulate sleep and sleep propensity. One is the homeostatic process, driven by sleep debt. As time awake increases, so does sleep debt until sleep propensity is great enough for sleep to occur. The other process is the circadian process, which is the "biological clock" that entrains sleep to the 24-hour period through mechanisms such as core body temperature and release of melatonin [31]. The two-process model of sleep focuses on the interaction between this biological clock and the balance between time awake and time asleep to determine the magnitude of sleepiness [32]. Other models have added working hours as an additional third process to predict alertness [33], but the two-process model remains the foundation on which most sleep models are based.

In sum, sleep and circadian disruptions appear to be the primary predictors of sleepiness, while fatigue can be elicited by a larger number of risk factors that align with the job demands-resource model [29] as well as exertion-related factors [20]. One of the main differences between these two sets of theories is that sleepiness is a state that persists and increases in magnitude until adequate sleep is attained, while fatigue is a more transient state alleviated by either the removal of the fatigue-eliciting stimuli, the provision of relevant resources to adequately cope with the fatigue-eliciting stimuli, and/or recuperative rest, which notably could include sleep. These distinctions are important as they reveal areas that measurement and intervention can be used as a beginning in distinguishing between fatigue and sleepiness among workers.

MEASURING FATIGUE AND SLEEPINESS

From a measurement perspective, the observed effects of fatigue and sleepiness look very similar. Both sleepiness and fatigue are not directly observable, so to measure either state, indirect indicators are used—such as observing changes in biological homeostasis (equilibrium) by measuring heart rate variability. Additionally, both fatigue and sleepiness result in a decline in attributes such as biological homeostasis, cognitive stability, emotional regulation, and physical vigor. Because of this overlap, simply measuring variables such as reaction time, which indicates a decline in cognitive stability and biological homeostasis, will not be sufficient to distinguish between fatigue or sleepiness. Therefore, distinguishing between fatigue and sleepiness requires examining the context in which the changes in these indicators occur. In other words, when it comes to differentiating between sleepiness and fatigue, knowing that a delayed reaction time or other symptoms are present is less important than knowing *why* symptoms are present (e.g., sleep deprivation, overexertion, etc.). This does not mean that fatigue and sleepiness cannot occur at the same time and confound efforts to distinguish between the two. However, it does suggest that both fatigue and sleepiness operate and manifest independently, and a better distinction between the two can contribute to more effective risk management.

In the absence of unique indicators to clearly distinguish between fatigue and sleepiness, it is necessary to measure the risk factors that are co-occurring alongside these indicators and potentially leading to the observed changes. Fatigue and sleepiness have a variety of distinct and shared risk factors that provide some context for determining which state is most likely the dominant condition. Some factors that can be measured and are relatively sensitive to the unique factors underlying fatigue, as opposed to sleep, are time on task [34], task complexity, work load [35], and job characteristics such as physically strenuous work, frequent overtime, and fast-paced work [6]. These risk factors are unique to fatigue as they primarily fall under the criteria within the job demand-resource model and are exertion-based risk factors [21, 29]. For example, long monotonous or complex tasks are job-specific demands that require cognitive exertion and can lead to fatigue if proper resources such as work breaks are not utilized.

Distinct factors predicting sleepiness include poor sleep quality, an inadequate amount of sleep, windows of circadian low (WOCL; usually between 2:00 a.m. and 6:00 a.m.), or anything that could disturb one's sleep [36], such as sleep disorders. Some of the shared risk factors for sleepiness and fatigue include work schedules (especially numerous consecutive work shifts), long commutes, and long working hours [6, 37]. These shared factors can have a draining effect on workers while potentially disrupting optimal sleep schedules and providing less than adequate opportunity for recuperative rest and sleep. For example, a long commute can determine how early one must wake up and potentially shorten sleep while also increasing pre-work fatigue levels due to a long and monotonous drive. Contextual information such as this can provide additional insight into whether fatigue or sleepiness is more pronounced and which condition could better account for symptoms such as slowed reaction time.

WHY DISTINGUISHING BETWEEN FATIGUE AND SLEEPINESS MATTERS

Although outcomes for fatigue and sleepiness are similar, interventions to address the two can look very different. Treating fatigue and sleepiness as interchangeable can potentially result in misuse of interventions and the perception that the problem is being managed while it may still persist unnoticed. For example, through focus group interviews with train drivers, Filtness and Naweed [38] found that train drivers' answers to alleviating fatigue were sometimes incongruent with the actual source of the problem. In this study, caffeine consumption and talking to someone were suggested as countermeasures for fatigue. While caffeine can increase alertness via chemical stimulation, it may not be an effective long-term solution for mitigating fatigue if the source of the fatigue was a particularly high vigilance (e.g., boring) task. Similarly, conversational engagement may temporarily decrease the symptoms of sleepiness; however, this countermeasure may be less effective if used in response to low sleep quality and quantity. One of the first steps to mitigating work-related fatigue risk in this instance relies on improving the understanding of how alertness can vary throughout the workday along predictable patterns and in response to different work and sleep schedules.

Including considerations for both sleep and fatigue is critical in a fully effective safety management system aimed at mitigating work-related fatigue risk. If a worker is obtaining minimal sleep at night, then focusing on working hours or task-based fatigue will likely have minimal impact. Likewise, after adequate sleep duration and quality has been obtained, work factors can still produce fatigue amongst even the most well-rested workers. Having a risk management system in place that considers both fatigue and sleepiness as distinct yet related risks is one potentially effective method for more comprehensively accounting for risk workers encounter throughout their shift. Effective risk management strategies can aid having a plan in place to identify both problems by their distinct factors and knowing what to do based on the context in which they are occurring is paramount.

For example, suppose that as part of its fatigue risk management system, a particular mine keeps a record of workers' self-reported sleep and work history and implements appropriate control measures for workers at increased risk (e.g., less than 5 hours of sleep in the previous 24 hours, etc.). Additionally, this mine may also administer symptom checklists (e.g., head nodding, slowed reaction time, difficulty focusing, etc.) for workers identified at higher risk levels based on their sleep and work history. These are both sound approaches based on existing guidelines [39]. However, even among workers with a sleep and work history considered to be lower risk, symptom checklists can still indicate fatigue prevalence—for example, with particular job tasks (fast paced, physically strenuous) or worker characteristics (underlying medical conditions, working through breaks). If the sole focus is given to sleep and work histories, many other fatigue-inducing factors can be missed and could therefore lead to injuries and safety incidents. For this reason, it is important to rely on a variety of metrics and contexts to determine safety risk due to either sleepiness, fatigue, or both. One of the first steps in the right direction is disseminating the differences between fatigue and sleepiness and why it matters for mitigation throughout the mining workforce.

VISUALLY MODELING FATIGUE VS SLEEPINESS

A result of this literature overview is the ability to distinguish meaningful differences between fatigue and sleepiness for the purposes of generating awareness and actionable information to the industry. Figure 1 (see APPENDIX) shows the Work Safety Visual Model of Fatigue and Sleepiness that represents a summary of the distinctions and similarities highlighted in this paper. This model is not necessarily meant to be utilized as a robust analytical model or theoretical synthesis, but simply as an aid that can help illustrate the interconnectivity of these two constructs, highlight pathways by which these constructs interdependently impact safety outcomes, and facilitate meaningful solution-based discussions among workers, supervisors, and health and safety practitioners.

As stated, the aim of this model is to provide a visual representation of the relationship between fatigue and sleepiness from which mine safety managers can identify general differences and how fatigue and sleepiness might be mitigated differently at different levels or stages. The model in Figure 1 starts at the top-left by illustrating that the origin of risk factors for work-related fatigue primarily fall into the category of excess demands and limited resources (vis-à-vis the Job Demands-Resources Model cited previously), which leads to a state of overexertion or working beyond one's mental or physical capabilities. Meanwhile, on the bottom-left side of the model, a primary risk factor for sleepiness is decreased opportunity for sleep, which leads to increased time spent awake and decreased time spent asleep. Some shared risk factors between sleepiness and fatigue include long working hours and long commutes—both of these can be physically and mentally exerting (fatigue) while also potentially increasing the time spent awake (sleepiness). For prevention at this level, more specific and targeted interventions can be implemented to potentially mitigate the severity of fatigue or sleepiness. On the fatigue side, this may consist of methods like analyzing the work environment and work tasks to ensure adequate resources are being provided to meet demands (e.g., decrease noise, heat, vibration, etc.) and improving work/life balance. When it comes to sleepiness, interventions at this level may consist of approaches such as more efficient shift-scheduling practices to increase opportunity for restful sleep and improving sleep hygiene (e.g., sleep-promoting habits and behaviors, like keeping a consistent bedtime routine). If not prevented, these risk factors can lead to increased sleepiness or fatigue but could potentially be mitigated by work breaks or work rearrangements (for fatigue), planned (prophylactic) naps or sleep disorder screening (for sleepiness), or caffeine, exercise, and adequate lighting (for both fatigue and sleepiness). Once fatigue and sleepiness occur, there are shared symptoms or indicators that manifest such as brain fog, difficulty in the regulation of emotions, poor reaction time, and an inability to focus. From this point, symptom monitoring strategies are typically used to monitor fatigue and sleepiness symptoms (i.e., head nodding, eye closure, poor reaction time) once they reach a higher level of severity to prevent these symptoms from potentially leading to safety incidents.

CONCLUSION

In brief, fatigue and sleepiness are similar yet distinct in many ways, and in some instances, it may be difficult to decipher which state is exerting greater influence over observed performance decrements. However, we feel that this overview which highlights the differences between the two states and included visual aid can help bring clarity to an otherwise complex topic, and perhaps assist with the development of risk management plans and systems to mitigate work-related risk due to sleepiness and fatigue.

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APPENDIX

Figure 1. The Work Safety Visual Model of Fatigue and Sleepiness.