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## The Cost of Sleep Lost: Implications for Health, Performance, and the Bottom Line

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### The Importance of Sleep for Workplace Health

Alongside healthy diet, sufficient physical activity, smoking cessation, and moderation of alcohol intake, healthy sleep has emerged as a key element in health. Getting at least 7 hours of quality sleep per night (or 7–9 hours if there is an upper limit) is a recommendation put forth by the American Academy of Sleep Medicine and Sleep Research Society,<sup>1–4</sup> NSF,<sup>5,6</sup> American Thoracic Society,<sup>7</sup> and American Heart Association.<sup>8</sup> These recommendations have been adopted by the Centers for Disease Control and Prevention (CDC; <https://www.cdc.gov/sleep>) and the National Institutes of Health (<https://www.nhlbi.nih.gov/health-topics/sleep-deprivation-and-deficiency>). Increasing the number of Americans who achieve adequate sleep was a goal of Healthy People 2020.<sup>9</sup>

Still, American society demonstrates unhealthy sleep practices. Regarding sleep duration, recent data suggest that just 56% of US adults get 7 to 8 hours of sleep on a regular basis, with about 36% getting about 6 hours or less.<sup>10</sup> In addition to insufficient sleep duration, insomnia symptoms are also prevalent in the US population. It has been well documented that about 30% of the population experience significant insomnia symptoms, with approximately 10% likely meeting criteria for insomnia disorder.<sup>11</sup> Sleep apnea (SA) is also highly prevalent. As can be seen in data from the Wisconsin Sleep Cohort, prevalence of SA is high, especially in men and especially in adults who are obese.<sup>12</sup> Nationally representative data from National Health and Nutrition Examination Survey also suggest that nonrestorative sleep is experienced “often” or “almost always” by approximately 29% of the US population and excessive daytime sleepiness is experienced “often” or “almost always” by about 19% of the population.<sup>13</sup> Although insufficient sleep, insomnia, and SA are the most prevalent sleep problems, they are not the only ones. Taken together, it is estimated that approximately 70 million Americans suffer from some sort of disordered sleep.<sup>14</sup>

The reasons for these unhealthy sleep practices are still unclear. But modern society tends to promote the idea that sleep is unproductive time. The purpose of this review is to demonstrate how sleep is not only time well spent in terms of health, but also for productivity.

### Sleep and Health

For over 50 years, and across over 50 studies, habitual sleep has been known to be associated with mortality risk.<sup>15,16</sup> Overall, there is a U-shaped relationship such that sleep outside the normative range (typically 7–8 hours) is associated with increased mortality. All of the reasons for why those experiencing shorter or longer sleep die sooner are not fully

explicated. The hypotheses regarding long sleep have been articulated, but this issue still remains controversial.<sup>2,17,18</sup> Regarding insufficient sleep, though, much more evidence has accumulated.

A growing literature has shown that insufficient sleep is associated with a number of factors closely related to health. For example, many studies have now shown that short sleep is associated with higher body mass index (BMI)/obesity.<sup>19</sup> Further, a meta-analysis of longitudinal studies shows that short sleep is associated with an approximately 55% increased likelihood of developing obesity.<sup>20</sup> Laboratory studies have shown that sleep deprivation leads to increased caloric intake,<sup>21–26</sup> resulting in up to 1 kg of weight gain in just 1 week. Other studies have shown in real-world samples that less sleep is associated with incident weight gain.

Several studies showed that insufficient sleep was associated with increased likelihood of cardiovascular risk factors,<sup>27,28</sup> including hypercholesterolemia,<sup>29,30</sup> coronary artery calcification,<sup>31</sup> and other cardiovascular risk factors, including hypertension.<sup>32</sup> A meta-analysis found that short sleep was associated with a 21% increased incidence of hypertension.<sup>33,34</sup> Diabetes has also been associated with insufficient sleep in a number of studies<sup>10</sup> and is supported by meta-analyses showing an approximately 30% increased likelihood of developing diabetes in the presence of short sleep.<sup>35–37</sup>

Several potential mechanisms of these relationships have been explored. A number of studies have shown that insufficient sleep is associated with a pro-inflammatory state,<sup>38</sup> both in the laboratory and in population samples. In addition, sleep loss has been shown to alter insulin sensitivity and promote insulin resistance,<sup>39,40</sup> as well as alterations in metabolic hormones leptin and ghrelin,<sup>41,42</sup> cannabinoids,<sup>43</sup> testosterone,<sup>44,45</sup> cortisol,<sup>46–48</sup> and other biomarkers of metabolic processes associated with metabolic risk.<sup>49</sup> Behavioral risk factors have also been explored. Insufficient sleep has also been associated with smoking<sup>50–54</sup> and alcohol use,<sup>54–56</sup> as well as unhealthy dietary patterns<sup>21,57–59</sup> and increased sedentary behaviors.<sup>52,60–62</sup> Mental health has also been shown to be related to insufficient sleep, which has been shown to be related to depression and anxiety.<sup>63–65</sup>

To conceptualize these relationships, the Social Ecological Model of Sleep Health has been described.<sup>2,15,27</sup> Briefly, this model describes how sleep plays an important role at the interface of upstream social, environmental, and behavioral influences and downstream health outcomes. Briefly, the model (summarized in Figure 1) describes how an individual's sleep health is a product of that individual's own characteristics, status, and choices. But, the model describes that the individual is embedded within a social level that includes work, home, neighborhood, and other factors that exist outside of the individual and exert a powerful influence. The model describes how these factors are still embedded within a larger context of societal factors such as globalization, technology, and 24/7 society, which influence the factors at the social level and, eventually, an individual's behavior around sleep. For example, an individual may make a choice to stay up late or have an attitude about sleep being something that is a low priority or that an individual may have a health condition that physiologically influences their sleep. But those beliefs, attitudes, practices, and choices (and to some degree the health conditions) are highly influenced by factors such as work

(which can dictate commute times, shift schedules, workplace culture) and even larger societal issues, such as globalization (which can influence work schedules); and technology (which can influence mobile device and e-mail use). Recognizing that these issues exist on multiple levels is important for understanding the multidimensional influences on sleep health and developing interventions that are likely to work in real-world situations.

## Sleep Disorders

In addition to insufficient sleep, sleep disorders such as insomnia and SA are important to consider. Insomnia (which represents difficulty sleeping irrespective of sleep quantity) is itself associated with cardiovascular disease,<sup>28</sup> as well as both obesity and diabetes.<sup>66</sup> An extensive literature describes the role of insomnia as a key risk factor for anxiety and depression.<sup>67,68</sup> In addition, a growing literature has identified insomnia as a key risk factor for suicide.<sup>69–75</sup> Sleep apnea is also a well-characterized health risk factor. It is a major risk factor for cardiovascular disease<sup>76–78</sup> and is strongly related to obesity.<sup>12</sup> Sleep apnea, through intermittent hypoxia and/or sleep fragmentation, has been shown to be related to oxidative stress,<sup>79,80</sup> neuronal injury,<sup>81</sup> inflammation,<sup>76,82–84</sup> and other adverse outcomes.

## Sleep and Cognitive Functioning

Many previous studies have documented the effects of sleep loss on aspects of cognitive functioning. Several have especially salient applicability to workplace situations, such as sleep propensity, vigilant attention, and decision-making. Sleep propensity refers to the homeostatic sleep pressure that can lead an individual to be able to fall asleep quickly or sometimes inadvertently. It is well documented that sleep loss leads to increased sleep propensity.<sup>85–87</sup> Functionally, this means that less sleep places an individual at risk of being unable to maintain wakefulness. This is a critical safety concern and is a major source of accidents and errors, including motor vehicle accidents.<sup>88–91</sup> A previous study at the population level found that not only did shorter sleep duration predict drowsy driving, but this persisted in individuals who reported that they felt completely well rested.<sup>92</sup> This suggests that the increased sleep propensity that could lead someone to doze in even a safety-sensitive scenario is not always perceived by the individual.

Many studies have evaluated the role of sleep loss in impaired vigilant attention.<sup>93–101</sup> This refers to the ability of an individual to maintain their attention over time, in the absence of stimulation, like a guard on duty.<sup>96</sup> The psychomotor vigilance task is the gold-standard assessment tool for vigilant attention and has been shown to be sensitive to sleep loss. It has demonstrated a dose-dependent relationship to sleep, such that as sleep duration decreases, attentional lapses increase.<sup>102</sup> In addition, deficits in attention are cumulative over time<sup>103,104</sup> and do not seem to stop increasing. This is in contrast to self-reports of impairment, which show a levelling off after a few days.<sup>97,105</sup> Thus, impairments increase over time, even if the individual believes that they are acclimating to less sleep. This has profound workplace safety implications. Not only attentional lapses and errors more likely in the context of sleep loss, but the individual is often unaware of their impairments, leading to some potentially unsafe situations.

Several studies have examined the role of sleep loss in decisionmaking. In a now classic study, Killgore and colleagues showed that sleep loss impaired function on a decision-making task with a monetary component (participants had to maximize the amount they were paid by strategically completing a task).<sup>106</sup> The study found that under sleep deprivation conditions, participants were much less able to make the optimal decisions and ended up with less money at the end of the task. Further, when given stimulants including caffeine, amphetamines, or modafinil, performance was not rescued. This is especially relevant to the workplace, where caffeine is often seen as a solution to impaired decision-making due to sleep loss—the existing studies suggest that though these stimulants increase speed and focus, they do not mitigate these impairments. Other studies have examined sleep and decision-making and have shown that sleep loss leads to a number of alterations in executive function,<sup>93,94,107–116</sup> such as more hedonic decision-making, difficulty planning, increased risky decisions, and difficulty managing complex tasks.

## Sleep and Workplace Factors

Healthy sleep is increasingly recognized as an important aspect of workplace health and functioning. Several domains in which this is relevant are injuries/disability, absenteeism, presenteeism/productivity, and health-care expenditures. A meta-analysis by Uehli and colleagues showed that sleep problems were associated with a 62% increased likelihood of workplace injuries.<sup>117</sup> In a recent study,<sup>118</sup> data from a large organization were used to show that poor sleep quality was associated with absenteeism—compared to those that reported good quality sleep, those who reported frequent poor sleep (comprising 11% of the total sample) were 171% more likely to miss 1 to 2 of the past 30 days of work, 548% more likely to miss 3 to 6 of the past 30 days of work, and 1052% more likely to miss 7 or more of the past 30 days of work. Similarly, poor sleep was associated with comparable increased likelihood of missed partial days of work.

Regarding presenteeism/productivity, a study by Rosekind and colleagues showed that a typical company loses \$1293 per year of productivity per employee, but this increases by 79% for employees who are at risk for poor sleep, by 116% for employees who are getting insufficient sleep, and by 144% for employees with insomnia.<sup>119</sup> Another study found that poor sleep was associated with worse self-rated work performance, as well as lower performance relative to a typical person in that position.<sup>118</sup> The study by Rosekind and colleagues found that productivity was lost due to increased problems with time management, mental/interpersonal demands, output/performance demands, and physical job demands.<sup>119</sup> A recent study expanded on this work examining productivity loss across all sources relative to sleep characteristics.<sup>120</sup> Compared to individuals sleeping 7 to 8 hours, those sleeping 4 hours or less reported 29% more productivity loss, while sleeping 5 to 6 hours reported 19% more productivity loss, and those sleeping 9 hours or more reported 24% more productivity loss. Compared to those without insomnia, those with mild insomnia reported 58% more productivity loss and those with moderate-severe insomnia reported 107% more. Daytime sleepiness was associated with a 50% more lost productivity than those without sleepiness, and those that reported snoring (a possible SA risk factor) reported 19% to 34% more productivity loss, across all sources.

Hui and Grandner also examined health-care dollars spent as a result of poor sleep.<sup>118</sup> They found that poor sleep quality was associated with approximately \$3400 to \$5200 additional dollars spent per person on health care. When participants were followed up after a year, if sleep quality worsened, health-care expenditures increased.

In another study, Hui and Grandner showed that sleep quality impacted the stages of change associated with other health behaviors, including stress management, weight management, physical activity, alcohol use, and smoking.<sup>56</sup> This refers to whether an individual is likely to make a change in a behavior related to their health and is conceptualized as precontemplation (has not yet considered change), contemplation (considered change but has not yet chosen to act), preparation (chose to act but has not taken the first step), action (currently engaging in behavior), and maintenance (maintaining healthy behavior). Overall, it was found that generally, poor sleep quality was associated with increased likelihood of being in a contemplation or preparation or action stage of behavior change, relative to precontemplation; however, poor sleep quality was generally associated with a decreased likelihood of being in a maintenance stage. This may be because poor sleep may help motivate an individual to decide to act on health but may—through functional limitations—make it more difficult to maintain healthy behavior. This is particularly relevant for workplace wellness programs that wish to promote healthy behavior change.

## Conclusions and Recommendations for Workplace Health Promotion

In summary, healthy sleep has been increasingly recognized as an important aspect of health. Workplace health interventions should address sleep, especially if they address other dimensions of health such as diet, physical activity, smoking, or stress. Sleep has been shown to be a key predictor of shorter lifespan, as well as weight gain and obesity, hypertension, hypercholesterolemia, atherosclerosis risk, diabetes, poor mental health, smoking, alcohol misuse, unhealthy diet, and sedentary activity. In addition, sleep is an important factor in brain functions that are important for the workplace, including sleepiness, attention, and decision-making. For these reasons, insufficient sleep in workplace settings has been shown to be related to workplace injuries, absenteeism, presenteeism/ productivity loss, and health-care costs.

Workplace health initiatives should promote the idea that sleep is not unproductive time. Rather, it is an investment of time that has been shown to produce improved productivity and less productivity loss. The available evidence shows that rather than more productive, individuals who are sleeping less are actually less productive, even with more time. The culture of sleep being only “rest” and therefore a sign of weakness or lack of endurance needs to change. In addition, workplace health programs should recognize that needs assessment regarding sleep should reflect 3 layers: (1) assessment of sleep disorders that need treatment by a licensed professional, since sleep disorders are often undiagnosed, (2) assessment of sleep deficiencies that are associated with poor outcomes, and (3) assessment of ways in which otherwise healthy sleep might be optimized. These 3 pathways are each important, since (1) sleep disorders such as SA and insomnia should be addressed with evidence-based therapies, (2) poor sleep quality and insufficient sleep duration—even if they are not sleep disorders—should be addressed as important workplace factors, and (3) even

those with otherwise healthy sleep may be able to benefit from a sleep optimization program.

The importance of a sleep intervention has relevance beyond reducing health-care spending, improving morale, and improving productivity. Because it is known that sleep loss leads to workplace injuries and accidents, the issues of shift work, fatigue, and overscheduling are important from a liability perspective. These are often inherent in business operations, but because they carry known risks, it is often up to the employer to mitigate these risks as much as possible in the context of workers' compensation and other legal matters. A single accident or injury can prove very expensive. These issues and others should be considered when weighing the cost of a workplace sleep health program.

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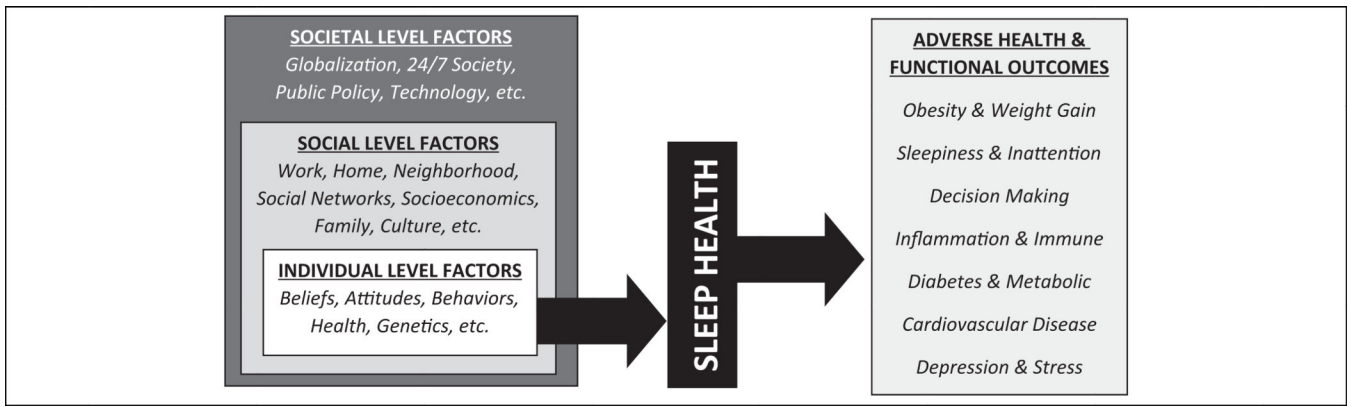
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**Figure 1.** Social-ecological model of sleep and health.

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