SLEEP DEPRIVATION AND EATING HABITS: A LITERATURE REVIEW OF THE IMPACTS LATE NIGHT SNACKING HABITS ON HEALTH

By

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Abstract

Many adults in the United States have dysregulated sleep schedules, often staying awake late into the night and not getting quality sleep. Sleep deprivation and nocturnal wakefulness have been shown to cause negative effects on the mind and body, leading to an increased risk of dysregulated behaviors and impulsivity. [1] This, in turn, can have an impact on a person's eating habits, specifically what and when they eat. Late-night snacking can be a result of nocturnal wakefulness, which can ultimately lead to excess weight gain due to a positive energy balance. [1] With the obesity epidemic that also plagues the United States, it is important to determine the link between sleep deprivation and obesity to lead people toward living a healthy lifestyle. Both obesity and sleep deprivation have been linked to a plethora of chronic diseases, such as cardiovascular disease, kidney disease, hypertension, mental health issues, and diabetes. [2] This review aims to determine how the effects of nocturnal wakefulness and sleep deprivation can affect one's eating habits and risk of weight gain.

Background

Eating and sleeping are two key components of living a healthy lifestyle. However, many Americans do not get proper sleep and do not follow healthy eating patterns. According to the Centers for Disease Control and Prevention, 33% of adults report not getting adequate sleep or rest every day. [2] Furthermore, 30.7% of adults are overweight, 42.4% are obese, and 9.2% are severely obese. [3] According to past literature, it has been shown that there is a link between lack of sleep and obesity, namely that obesity can cause disruptions to proper circadian rhythm functioning and hormone signaling. [4] It is critical to determine how these issues are interconnected to help the United States population lead a healthier lifestyle.

The Physiology of Wakefulness and Sleep

An adequate sleep/wake cycle is critical to the overall health and functioning of the human body, adjusting its internal environment to the external environment. The circadian rhythm is the 24-hour cycle that dictates behavioral and physiological activity and function throughout the day, typically synchronizing internal sleep/wake cycles with the external day-night cycle. [5] To generate wakefulness, the circadian rhythm implores an ascending arousal system of the brain, and maintains wakefulness with the activation of the forebrain. [5] Two different pathways in the central nervous system allow for wakefulness. One pathway begins with cholinergic neurons of the upper pons which activate the thalamus, allowing for the transmission of sensory information to the cerebral cortex. [5] The other pathway relies on the releases of monoamine neurotransmitters, such as dopamine, histamines, norepinephrine, and serotonin, from

the upper brain stem to the hypothalamus; this allows nerves cells to pick up inputs that ultimately also enter the cerebral cortex via the basal forebrain, activating it to be able to interpret sensory information. [5] To prepare the body for sleep, neurons of the preoptic area of the hypothalamus begin to turn off these arousal systems, which then allows the brain to fall asleep. [5]

Sleep Deprivation and The Mind After Midnight Hypothesis

Sleep deprivation, specifically in the form of nocturnal wakefulness, can affect different areas of a person's physiological and psychological well-being, including executive functioning, food intake, and mental health. [1] The Mind After Midnight Hypothesis states that when a person is awake during day hours, usual behavior is supported by normal neuronal activity and molecular levels; thus, allowing for proper eating behaviors, locomotor activity, and cognitive function. [1] At night, the body begins to prepare for sleep by reducing molecular/cortical activity and synaptic downscaling. [1] However, when a person is awake during night hours, whilst the body is preparing for or expecting sleep, behavior dysregulation occurs, causing decreased executive functioning, errors with reward processing, and reduced cognitive control, while also causing increased emotionally-driven motivations and rumination. [1] Ultimately, this causes an increase in risky or dangerous behaviors, such as an increased risk of suicidality, violence, substance use, and dysregulated eating behaviors, such as late-night snacking. [1]

The Obesity Epidemic and Its Associated Risks

The obesity epidemic is a worldwide public health crisis, affecting both developed and developing countries. [6] As defined by the World Health Organization (WHO), obesity is a chronic disease characterized by “abnormal or excessive fat accumulation that presents a risk to health,” which has a multitude of comorbidities that increase the risk of mortality. [6] Obese individuals have been shown to have a 5-10 year life expectancy decrease, compared to healthy adults. [6]

Obesity affects numerous areas of a person’s physiology, specifically the cardiovascular, gastrointestinal, endocrine, musculoskeletal, neurological, integumentary, respiratory, and reproductive systems of the body. [6] Furthermore, being overweight or obese has been shown to increase a person’s risk for developing cancer, due to the increased metabolic activity of adipose tissue. [6] As a person gains weight, phenotypic changes to adipose tissue cause the advancement of low-grade inflammation. [6] This in conjunction with dyslipidemia, characterized by increased circulation of small, dense low-density lipoproteins (LDL) and triglycerides coupled with decreased amounts of high-density lipoproteins, causes damage to vascular networks in the body. [6] Ultimately, this leads to an increased risk of cardiovascular disease, stroke, and atherosclerosis formation. Furthermore, chronic inflammation also causes impedances to normal insulin function, leading to insulin resistance, a defining pathophysiology of type 2 diabetes.

The Physiology of Hunger and Appetite

To regulate energy homeostasis, leptin and ghrelin are hormones the body produces to regulate appetite. Leptin, mainly produced by adipose tissue, regulates appetite through satiety signaling, regulating energy balance by diminishing feelings of hunger, which is indicative of reaching a normalized energy balance. [7] Ghrelin, produced in the stomach, stimulates feelings of hunger, thus indicating to increase food intake and decrease energy expenditure. [8] In the case of a negative energy balance, ghrelin inhibits insulin secretion and initiates glucose-generative pathways in the body, such as gluconeogenesis and glycogenolysis. [8] However, in overweight and obese individuals, leptin and ghrelin signaling is compromised, leading to improper signaling of hunger and satiety. [9] Overweight and obese individuals tend to have a high leptin/ghrelin ratio, which causes impedances to satiety and dysregulated hunger signaling. [9] In turn, this causes overeating and a positive energy balance, leading to more weight gain. [9]

The Consequences of Late-Night Snacking

When one cycle of the circadian rhythm is altered, it affects other cycles as well. For example, if someone changes their feed/fast cycle, it influences their sleep/wake cycle, and vice versa. This is the main issue with late-night snacking – eating later into the night affects the sleep/wake cycle and thus alters normal physiological processes, such as energy expenditure and hormonal regulation, that affect psychological behaviors in response.

Effects on Energy Expenditure and Caloric Intake

Late-night snacking habits may contribute to a positive energy balance, and thus weight gain. [10] Since the body is in an awake state for longer, daily energy expenditure increases, causing a physiological response to increasing food intake as well; however, this increased intake is often more than is physiologically needed. [10] In a study from 2013, participants' food intake, energy expenditure, and weight were studied whilst transitioning between getting 5 hours of sleep (sleep deprivation state) and 9 hours of sleep (adequate sleep control state). [10] During the study, the participants had unlimited access to meals and snacks to determine what they wanted to eat and how much they consumed throughout the day. [10] The results showed that, when the participants were sleep deprived, they increased their caloric intake by 6%, causing a positive energy balance and weight gain. [10] Specifically, participants increased their consumption of post-dinner snacks by 42% compared to when they were able to get adequate sleep. [10] These snacks tended to be high in carbohydrates, protein, and fiber. Also, the morning following the sleep deprivation, participants ate smaller breakfasts, due to being awake

at an earlier point of their circadian rhythm, which delayed their feed/fast cycle further. [10] Interestingly, during the transition between sleep deprivation and adequate sleep, the participants' intake decreased, specifically of carbohydrates and fats, indicating that with proper sleep, dysregulated eating behaviors can be corrected. [10] This study demonstrates how sleep deprivation ultimately can cause an increased risk of eating later into the night to compensate for increased energy expenditure, potentiating weight gain.

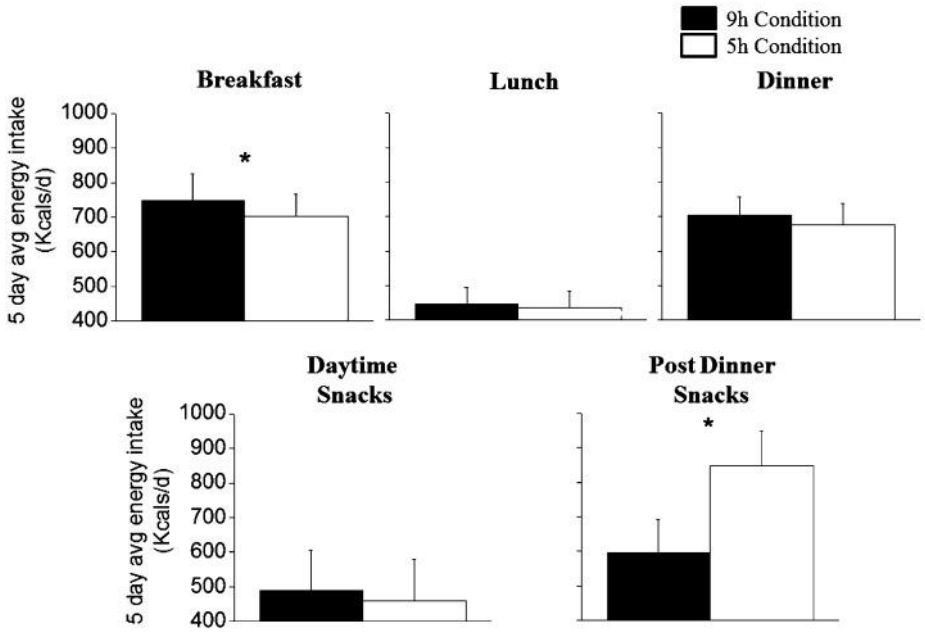

Figure 1: Energy intake, in kilocalories, by meal and timing between the 9-hour and 5-hour sleep conditions.[10]

Another study, titled "Elevated ghrelin predicts food intake during experimental sleep restriction" had similar findings. Participants of this study were also able to have unlimited amounts of food and snacks, where their intake was compared between under sleep restriction (5 hours of sleep) and adequate amounts of sleep (9 hours of sleep). [11] Under sleep restriction, participants ate roughly 340 ± 131 kilocalories (kcals) more than

under normal sleeping conditions. [11] Additionally, they found that participants ate significantly more carbohydrates when sleep deprived. [11] During baseline sleep protocols, participants typically gravitated towards sweet and salty snacks; however, when sleep deprived, their intake of these snacks increased by 283 ± 130 kcals. [11] Again, this demonstrates how healthy adults tend to snack more when sleep-deprived, due to an increase in energy expenditure necessary to stay awake.

Effects on Hormonal Regulation

Hormone regulation of appetite and hunger in healthy individuals is altered when participants are under sleep restriction. Under sleep deprivation conditions, leptin concentrations do not significantly change compared to baseline sleep conditions. [11] However, this is not the case for ghrelin concentrations; ghrelin levels increase significantly with sleep deprivation. [11] In fact, when participants had unlimited access to food or followed a standardized diet, ghrelin levels increased throughout the day under sleep restriction compared to baseline sleep conditions. [11] This was associated with a higher caloric intake throughout the day, especially regarding snacking behaviors. [11] Again, this increases the risk of late-night snacking habits, which can lead to weight gain.

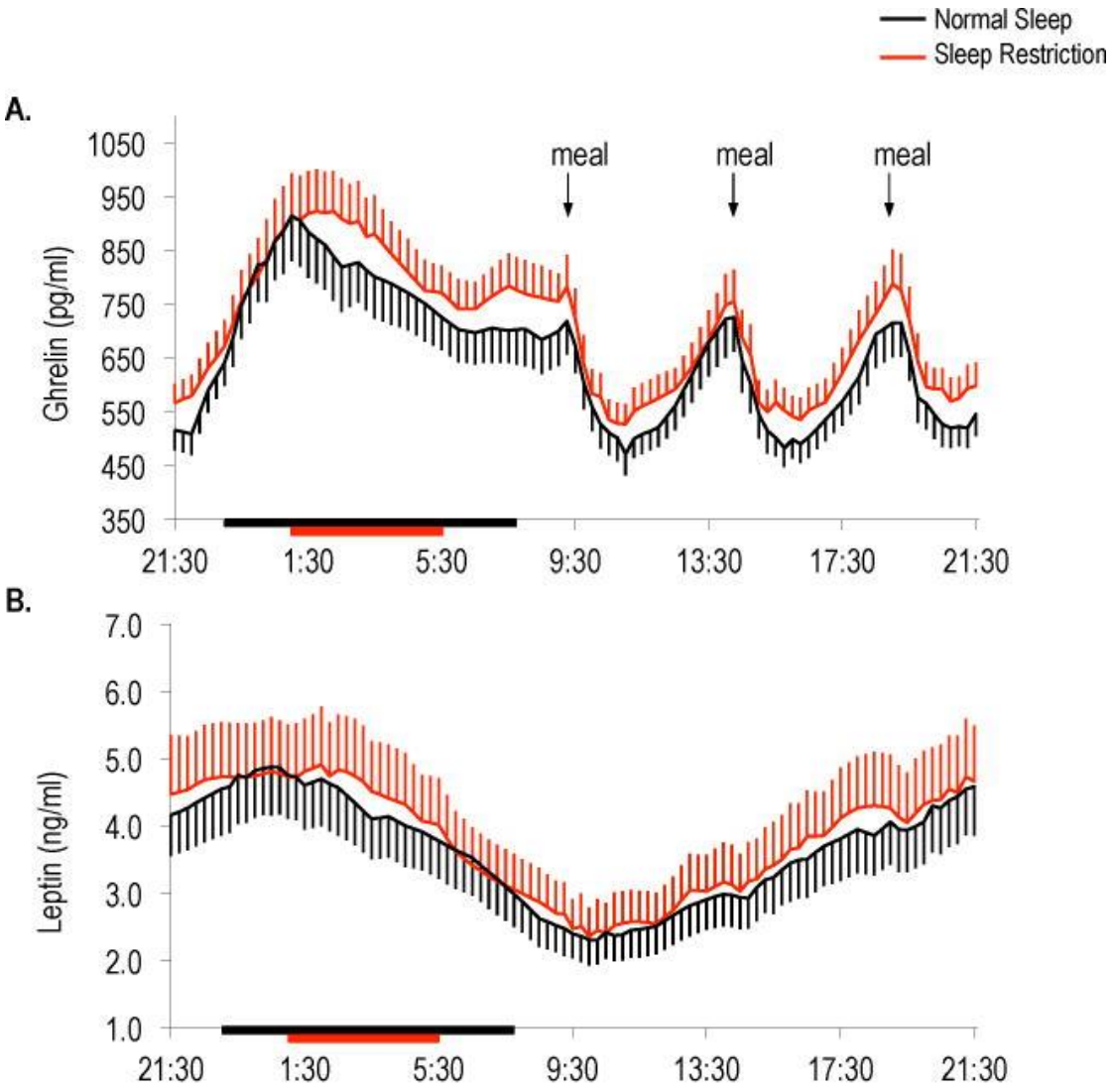

Figure 2: Levels of circulating ghrelin (A) and leptin (B) across the 24-hour day under normal sleep conditions and sleep restriction.[11]

In overweight and obese individuals, hormonal regulation of leptin and ghrelin is already compromised; even with adequate amounts of sleep, having later meal times may propagate this issue further. [12] In a study comparing the relationship between sleep and eating times, overweight and obese participants followed a schedule of getting adequate sleep at normal sleeping hours (0000-0800) or late sleeping hours (0330-1130) and had either normal meal times (1, 5, 11, and 12.5 hours after waking up) or

late meal times (4.5 8.5, 14, and 16 hours after waking up). [12] Results show that there was no significant impact on the amount of overnight leptin, regardless of the sleep or eating schedule. However, having late mealtimes leads to higher amounts of circulating ghrelin during night hours and lessened ghrelin response to test meals. [12] Furthermore, levels of ghrelin were significantly increased when participants had normal sleeping times but late mealtimes, demonstrating that eating later within the circadian rhythm disrupts proper hunger signaling, and increases the risk of weight gain. [12]

Future Directions

With the heightened prevalence of shift work and social jetlag, nocturnal wakefulness increases the risk of developing dysregulated eating behaviors, namely eating snacks late into the night. [1] However, research on this connection is limited, as many of these studies have a limited number of participants and cannot replicate normal living conditions or external influences. Also, more research needs to be done on sleep deprivation in overweight and obese individuals, as most of the literature studies participants with normal body weight. Therefore, more research needs to be done to explore this connection between late-night snacking and disrupted circadian rhythms.

The IN-BeD Study

The Investigating Neurocognitive Behaviors after Dark (IN-BeD) study aims to further determine how sleep deprivation affects eating habits throughout the day. This study is currently in progress, officially beginning data collection in July 2023. This study

aims to determine how different forms of sleep deprivation affect food intake. Throughout the course of the study, participants' food intake, sleep, and activity levels are monitored using food diaries, sleep diaries, and a wearable Fitbit, respectively. Percipients are sleep deprived under two different conditions, allowing them to sleep for 5 hours. The first condition allows participants to go to sleep at a normal time (2300), but they are woken up during night hours (0300). Under the second condition, participants are kept up until late night hours (0300) and are then allowed to sleep until normal morning hours (0800). During their time in the sleep lab, participants have access to three standardized meals, which account for 90% of caloric intake, that they can eat at any time. They also have unlimited access to snack foods, which include healthy and unhealthy options. We expect to see differences in what and when participants choose to eat dependent upon the form of sleep deprivation they face. We hope to study overweight and obese individuals as well during this pilot study, to hopefully determine the effect of excess weight on eating behaviors under sleep deprivation. The IN-Bed study will allow us to further understand how different types of sleep deprivation will affect people's eating behaviors.

Conclusion

Proper nutritional and sleep practices are key to proper physiological and phycological function; however, more than ever, people face issues with healthy eating behaviors and sleep hygiene practices. There has been shown to be a link between obesity and dysregulated sleep, causing a downward spiral into increased weight gain and disturbed circadian rhythms, further propagating both issues. With increased

energy expenditure and ghrelin signaling, nocturnal wakefulness and sleep deprivation heighten the risk of overeating and having a positive energy balance, and thus weight gain. [10,12] Therefore, to lead a healthy lifestyle, it is critical to maintain a proper eating and sleep schedule, as to sustain proper circadian rhythm functioning.

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