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The Link Between Sleep and Weight Gain

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We all need to get a good night's sleep. When we sleep well, we feel refreshed, energized, and ready to take on the world. When we don't, we feel fatigued, sluggish, and irritable. And if we're chronically sleep deprived, we can develop daytime sleepiness that can lead to accidents and errors both on and off the job.

According to the National Sleep Foundation, adults should get between seven and nine hours of sleep each night.[1] Yet the average American adult sleeps just six hours and 30 minutes per night during the workweek.[2]

Adequate sleep restores us physically, mentally, and emotionally. It facilitates learning, helps us concentrate and retain information, and gives our brains a much-needed rest from the hustle and bustle of our hectic lives. In a nutshell, sleep is essential to our short- and long-term health.[1]

Research shows that sufficient sleep plays an important role in weight management and decreasing the risk of metabolic disorders such as insulin resistance and diabetes as well as other sleep-related problems.[3]

Because of this correlation between sleep and weight control as well as metabolic disorders, dietitians are in the perfect position to begin evaluating the sleep habits of clients and patients who are battling overweight or obesity and are at high risk of developing chronic disease. Such an intervention can mean the difference between patients continuing down a path of weight struggles and poor health and finding a solution that will put them on the road to better health.

This continuing education activity will help dietitians assess the current research on the association between sleep quantity and quality on weight management and diabetes risk in adults and children, and develop strategies to evaluate their patients' sleep habits to improve their overall health and well-being.

The Scope of Sleep Issues

In its 2006 consensus report, the Institute of Medicine (IOM) identified the effects of sleep disorders and sleep deprivation as "an underrecognized public health problem."[4] The report estimates that 50 to 70 million Americans suffer from sleep disorders that compromise their quality of life and adversely affect their health and longevity.[4]

The Centers for Disease Control and Prevention (CDC) has a Sleep and Sleep Disorders Team[5] that oversees the collection of sleep-related survey data that are part of its public health surveillance systems. These data are incorporated into studies that seek to establish

associations between sleep quantity and quality and health outcomes linked to obesity, diabetes, hypertension, heart attack, stroke, depression, and all-cause mortality. Unfortunately, much of the data collected in national surveys are based on self-reported or subjective responses, so many of these relationships remain unclear.

In November 2011, the National Institutes of Health (NIH) updated its Sleep Disorders Research Plan, which aims to promote and protect sleep health. The plan increases awareness among health professionals and others about the association between sleep problems and physical and mental health as well as safety issues. Highlighting the significant need to improve education in these areas, one of the plan's five research goals calls for the "translation of sleep and circadian rhythm research findings, [which] could help stem the rising tide of obesity and associated metabolic disorders…"[6] Clearly, sleep is an issue of great relevance to nutrition professionals that deserves attention.

Sleep Basics

The timing, duration, and quality of sleep can affect endocrine, metabolic, and neurohormonal functions related to health. Sleep is an active time in which distinct brain wave patterns with unique physiologic functions spring into action in a progressive series. Sleep follows a pattern of alternating rapid eye movement (REM), known as stage R, and non-REM (NREM) sleep throughout the night in a cycle that repeats itself roughly every 90 minutes.[7] We spend 75% of the night in NREM sleep and 25% in REM sleep.

When we first fall asleep, we enter NREM stages N1 and N2 and, later, N3, which is also known as slow-wave sleep (SWS). During stages N1 and N2, brain waves begin to slow down; we become disengaged from our surroundings; and our body temperature drops. During N3, or SWS, the deepest and most restorative stage of sleep, our heart rate, breathing, and blood pressure decrease; our muscles relax; and our energy is restored. SWS is responsible for the restorative functions of sleep that lead to our feeling rested and energetic upon waking. As the night progresses, we experience longer periods of REM sleep, during which our eyes dart back and forth; our breathing, heart rate, and blood pressure increase; our brain becomes active; and dreams occur.[7]

These cycles are different for infants and children. Children spend more time in the deeper stages of sleep compared with older adults. Sleep requirements vary from person to person and throughout the life cycle. Generally, most adults need between seven and nine hours of sleep per night, while school-aged children need 10 to 11. Most teens need 8 1/2 to 9 1/4 hours of sleep per night.[1]

Sleepiness is regulated by the physiological need for sleep combined with the body's circadian rhythm (also known as the biological clock). The latter generally causes a natural increase in sleepiness between midnight and 7 AM and then again between 1 and 4 PM. Factors that can cause a shift in normal circadian patterns include sleep patterns (eg, sleeping during daylight hours), light, exercise, meal times, temperature, and exogenous melatonin. Circadian disruptions can lead to various hormonal and metabolic changes that can result in obesity, diabetes, and even decreased life expectancy.[8]

If either the hormonal or metabolic systems are disrupted, daytime sleepiness, which may impair quality of life, can occur. The most common causes of such disruptions are primary sleep disorders such as obstructive sleep apnea (OSA), insomnia, restless leg syndrome (RLS), periodic limb movements in sleep (PLMS), and narcolepsy. Other causes include chronic medical conditions such as congestive heart failure, rheumatoid arthritis, and chronic bronchitis or their related medications; caffeine, alcohol, nicotine, and over-the-counter cold and cough medicines; shift work; nicotine or alcohol abuse; and other poor sleep hygiene practices. (See “Factors That Disrupt Sleep” and the “Sleep Hygiene Checklist” below.)

The Sleep/Weight Connection

Research on the association between sleep quantity and quality and their effects on weight gain has shown that there may be a genetic connection. Studies of identical and fraternal twins suggest that sleep deprivation may promote the expression of genes related to obesity.[9] Several studies have indicated that both insufficient sleep (less than five or six hours) and excessive sleep (more than nine or 10 hours) are associated with weight gain, but not all studies define insufficient and excessive sleep the same way. Further, there’s evidence that the relationship between insufficient sleep and overweight is bidirectional. Some researchers propose that a vicious cycle exists in that sleep deprivation may cause weight gain, inducing sleep disturbances that further reduce sleep duration.[10] This cycle exists because of various factors that impact weight regulation, including the fact that excess weight increases the risk of medical conditions that may interfere with sleep such as gastroesophageal reflux, osteoarthritis, and OSA.[11]

Researchers who have conducted studies on the effects of sleep duration on weight gain in various populations found inconsistencies between genders. For example, some studies have shown a relationship between short sleep and weight gain only in women, while others have found this association only in men. Additional studies are needed to clarify this issue.[12]

Moreover, research has found that a higher BMI is strongly linked to short sleep in children, whereas study findings on BMI and sleep duration in adults are inconsistent and often demonstrate a U-shaped relationship, meaning that both short and long sleep duration may be associated with a higher BMI.[10] In two recent studies, short sleep was linked with an increased risk of weight gain or obesity and increased fat mass after a five to seven year follow-up in both children and adults, although this association was particularly strong in children.[10,11] The first studies to evaluate whether increasing sleep duration and quality may be an effective strategy for weight loss or weight maintenance are under way. It also remains to be seen whether reduced physical activity related to daytime sleepiness plays a significant role in weight gain associated with sleep insufficiency.

Appetite Regulation

In other research, sleep quantity and quality have been shown to play a role in regulating the hormone ghrelin, known as the hunger hormone that controls appetite. Discovered in 1999, this amino acid peptide is the only known peripherally produced and centrally acting hormone that influences the desire for food. Since 1999, researchers have discovered additional peptides derived from ghrelin, some of which have a similar orexigenic effect, while others have an inhibitory effect on food intake. To date, the regulation and gene expression involved

in ghrelin's actions is only partially understood. It's become apparent that plasma ghrelin levels in the body vary with response to meal timing, and that fat mass and body weight influence its levels. Moreover, ghrelin appears to function through direct brain action and vagal nerve pathways and be involved in the long-term homeostatic control of weight (via increased appetite and fat storage and reduced energy expenditure), gastrointestinal motility, and the food reward system.[13]

Some evidence suggests the circadian system regulates ghrelin, but this is uncertain. Ghrelin levels decrease after eating in proportion to caloric intake and rise between meals as hunger increases. Ghrelin is suppressed by daytime exercise but increased by evening exercise. Researchers speculate that circadian changes in other hormones may be the cause of the differences in ghrelin levels seen following exercise at different times of the day and evening.[14] However, no increase in hunger has been associated with the exercise-induced rise in ghrelin.

As mentioned earlier, several satiety peptides exist that have anorexigenic effects. For example, leptin, known to inhibit food intake, increases energy expenditure and promotes fat utilization. Leptin levels increase during daytime hours and peak at night. Circulating leptin is secreted by adipose tissue, whereas the stomach primarily secretes ghrelin. Glucagonlike peptide (GLP-1), peptide YY (PYY), cholecystokinin (CCK), and insulin also are involved in producing signals to stop eating. Currently, only one study has documented a decrease in PYY levels following sleep loss.[10]

Orexins A and B (also known as hypocretins) are intricately involved in the regulation of eating and sleeping. The orexins are peptides produced by neurons in the central hypothalamus of the brain that also interact with the neurons that respond to leptin. In animals, sleep deprivation overactivates the orexin system.[10]

Sleep deprivation studies have shown that sleep loss can cause an increase in the ratio of ghrelin to leptin, enhancing appetite and, specifically, increasing cravings for carbohydrate foods. A large majority of studies have found that sleep restriction leads to increased caloric consumption (greater than 250 kcal/day). Energy expenditure studies indicate that sleep loss doesn't cause a significant change in energy expenditure, and consequently the increased calorie intake should lead to weight gain over time.[10] A recent study from the Mayo Clinic showed that healthy young adults whose sleep was shortened by about one-third ate more than 500 extra calories per day compared with controls, while their leptin levels increased and ghrelin levels slightly decreased. It was suggested that the increased energy intake may have been responsible for the changes seen in leptin and ghrelin levels in this study.[15] Because leptin and ghrelin studies have yielded inconsistent results, there's a need for further research to determine if the findings are related to differences in populations, sample sizes, or study design.

Nonetheless, the majority of current evidence suggests that under conditions of sleep insufficiency the levels of orexigenic and anorexigenic hormones and the associated increase in hunger and caloric intake are the primary determinants of energy balance rather than alterations in energy expenditure.[10]

Sleep-Disordered Breathing

Another factor that influences weight control is sleep-disordered breathing (SDB). SDB is a group of disorders characterized by pauses in breathing or pulmonary abnormalities during sleep. Obesity is a significant risk factor for the development of SDB, but weight loss has been shown to improve symptoms.[3]

SDB affects 20% to 40% of older adults and many children—especially those of African American descent or low socioeconomic status. Untreated SDB significantly increases heart attack, stroke, and overall mortality risk in adults, and it can lead to difficulties in school, metabolic abnormalities, and heart disease risk in children. OSA, a form of SDB, affects about 17% of the general population[10] and is an independent risk factor for stroke[15] and diabetes.[8]

OSA and obesity both are associated with hyperleptinemia and leptin resistance, whereas obesity is associated with hypoghrelinemia and OSA with hyperghrelinemia. Consequently, both weight (normal weight, overweight, obesity) and the presence or absence of OSA must be accounted for in future studies that seek to evaluate relationships between sleep, appetite, and weight.[10]

Children

Research in children as it relates to sleep and weight gain is limited, but the studies that have been done have raised important concerns. It's unclear if insufficient sleep is independently associated with obesity in children or if sociodemographic variables have more of an influence. Adolescents often experience sleep deprivation, and this has been found to hinder clinic-based weight-loss interventions.[16,17] One recent study showed that peer pressure to be thin may contribute to decreased sleep in adolescent girls.[18] Television watching, including passive viewing and observing adult-targeted programming, has been linked with sleep disturbances in young children aged 5 to 6.[19]

Short sleep duration appears to have negative metabolic consequences in this population, including abnormal insulin sensitivity and the development of cardiovascular disease markers such as LDL and high-sensitivity C-reactive protein levels.[20] A clear link exists between obesity and SDB and metabolic syndrome in children and adolescents.[21] And some evidence suggests that weight loss should be considered first-line treatment for SDB in children. Consistent data support the association of short sleep duration with increased weight in pediatric populations, although this relationship isn't as clearly established in adults.[22]

Impairment of Glucose Metabolism

Further evidence shows that sleep duration, sleep quality, and the timing of sleep may affect the 24-hour patterns of hormone production, including insulin, cortisol, glucagon, catecholamines, growth hormone (GH), leptin, and ghrelin. Energy homeostasis is regulated by the combination of circadian rhythms and sleep-wake homeostasis as well as environmental factors such as food intake and exercise. The brain and peripheral tissues reduce glucose utilization during the early stages of sleep. GH pulses, particularly during SWS, plus diurnal fluctuations in cortisol mediate these changes in glucose metabolism.[10]

Sleep deprivation, specifically insufficient SWS, can cause impaired glucose tolerance. This is because during SWS brain glucose utilization decreases, GH release is stimulated, and cortisol secretion is inhibited. Numerous studies have shown insufficient sleep (short duration and poor quality) is positively associated with impaired glucose tolerance and diabetes.[8] Prospective epidemiologic studies find that both insufficient sleep (less than five or six hours) and excessive sleep (greater than nine hours) as well as other sleep disturbances are associated with diabetes risk. In a sleep-deprived state, markers of beta-cell function (disposition index) may decrease as much as 50%. The disposition index is a validated marker of diabetes risk, as it evaluates beta-cell function relative to insulin resistance.[10]

Clinical Practice Recommendations

Knowing that sleep quantity and quality may be associated with overweight and obesity as well as diabetes risk in adults and children, it's important to evaluate how well your patients are sleeping while taking patient histories. Here are some guidelines dietitians can follow while counseling patients:

• **Inquire about sleep quality.** Ask patients what time they go to bed and what time they awake rather than how many hours of sleep they get each night. Compare work days and off days. Is shift work an issue? Does the patient snore or experience restless legs at night? Is learning, memory, attention span, or behavior affected by lack of sleep? Is fatigue interfering with their ability to exercise? Are certain eating behaviors associated with sleep habits? Include caffeine-containing foods and beverages in a food recall, noting the times these items are consumed. Also evaluate tobacco and alcohol use as well as prescription and nonprescription medications they take. Ask about conditions in their bedroom (light, noise, etc) and their napping schedules. Determine if patients have been evaluated for sleep problems in the past. If so, what was the diagnosis and treatment prescribed?

• **Suggest patients keep a sleep journal.** Just as you may advise clients to keep a food or physical activity journal, recommend they keep a sleep journal for one week. Have them record the hours they sleep each night; their quality of sleep; use of medications and dietary supplements; consumption of alcohol, caffeinated products, or nicotine; and timing and length of exercise and naps. Recommend they describe the physical characteristics of their sleep environment and how sleepy they feel during the day. You can review the journals with patients during a follow-up visit, or they can take it with them to their next appointment with their primary care physician.[23]

• **Give them the facts.** Discuss with overweight clients the reciprocal relationship between excess weight and sleep insufficiency. Explain that weight loss can potentially decrease the risk of OSA, SDB, and other breathing disorders or decrease their severity.[24] Describe the inverse relationship between sleep duration and BMI and establish goals related to both. Refer patients who snore for further testing if a physician hasn't evaluated them for OSA.

Diabetes patients or those at risk of developing the disease may be interested in learning about the relationship between adequate sleep and glucose metabolism. Discuss relationships between sleep patterns and weight and appetite. Look for opportunities in which changing meal times, exercise, and sleep may help improve metabolic control. And suggest patients with

diabetes get tested for OSA even if they claim snoring isn't present since OSA is an independent risk factor for diabetes.[10]

Final Thoughts

Hectic lifestyles cause many people to sleep fewer hours than they should. Combined with the increasing prevalence of medical disorders that interfere with sleep, we're faced with a new public health crisis in sleep insufficiency. As rates of obesity, diabetes, SDB, and other diseases characterized by metabolic abnormalities—and linked directly with sleep loss—continue to rise, health professionals, including dietitians, will need to follow emerging research and apply new findings to practice.

At a minimum, a discussion about sleep should be part of a routine assessment with new patients. When appropriate, goal setting can include lifestyle changes, including those regarding diet, exercise, and sleep patterns. As additional research clarifies existing inconsistencies between populations and further elucidates the complex metabolic processes that control hunger, sleep, and weight, dietitians can anticipate even greater opportunities for involvement in improving patient care and helping stem the tide of the existing obesity epidemic.

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Consequences of Insufficient Sleep

• Interferes with memory, learning, attention, and mood.

• Triggers the release of adrenaline, cortisol, and other stress hormones, leading to an increased risk of cardiovascular disease.

• Interferes with the release of the growth hormone affecting muscle mass development, tissue repair, puberty, and fertility.

• Reduces the immune response to infection by reducing cytokine production.

• Alters blood glucose and insulin metabolism, increasing the risk of developing diabetes.

• Changes the ratios of leptin and ghrelin production, leading to the overconsumption of carbohydrate and high-calorie foods and weight gain.

— Source: ***Your Guide to Healthy Sleep*** *by the National Heart, Lung, and Blood Institute, August 2011*

Factors That Disrupt Sleep

1. Caffeine: It may take six to eight hours for the effects of caffeine to wear off completely. Caffeine is believed to interfere with sleep signals by blocking adenosine receptors.

2. Nicotine: This is a stimulant that causes lighter-than-normal sleep patterns.

3. Alcohol: It often has an initial sedating effect, but it can prevent rapid eye movement (REM) sleep and the deep stages of non-REM sleep during the night.

4. Psychological disorders: They can disrupt REM and deep sleep. Depression may cause insomnia as well.

5. Nighttime exercise: Daytime exercise is associated with improved nighttime sleep, but evening exercise can delay the release of melatonin that helps someone fall asleep at night. The National Sleep Foundation recommends leaving three hours between exercise and sleep, if possible.

6. Large meals: They can make it tough to fall asleep because they can cause indigestion. Excessive fluid intake can cause you to awaken frequently to urinate.

7. Chronic pain: Painful conditions such as fibromyalgia and arthritis can interfere with sleep.

8. Medications: Many pain relievers contain caffeine; decongestants and steroid medications can disrupt sleep; and beta-blockers can make it difficult to fall asleep and cause frequent nighttime awakenings.

9. Environment: Noise, lighting, and uncomfortable temperatures also can interfere with a good night's sleep.

Sleep Hygiene Checklist

Share these tips with clients who have difficulty falling asleep and staying asleep:

• Go to bed the same time each night and wake up the same time every morning—even on the weekends.

• Exercise early in the day for 30 to 60 minutes on most days of the week.

• Avoid caffeine, alcohol, and nicotine after noon. These substances stimulate the nervous system, interfering with falling asleep and staying asleep by increasing heart rate, blood pressure, and adrenaline levels.[1]

• Limit eating and drinking to small quantities before bedtime.

• Discuss with your doctor or pharmacist alternatives to medicines that interfere with sleep.

• Get 30 minutes of sunlight exposure, preferably in the morning hours, most days of the week.

• Keep your bedroom quiet, dark, and cool (between 54˚F and 75˚F).

• Avoid watching TV or sitting in front of a computer for at least one hour before bedtime.

• Take a nap if needed, but not for more than 20 minutes or after 3 PM.

• Don't lie awake in bed for more than 20 minutes. If you can't sleep, get up and do something relaxing such as reading a book until you feel sleepy again.

• See your family doctor or a sleep specialist if you continually feel sleepy during the day despite sleeping enough hours at night, consistently need more than 30 minutes to fall asleep at night, snore loudly or frequently, or awaken frequently or for long periods most nights of the week.

• Ask your doctor about prescription and over-the-counter sleep medications. They may be helpful in the short term, but they won't resolve biological issues interfering with sleep. Plus, they may cause side effects.

• Consider melatonin only if you're a shift worker who must sleep during the day instead of at night. Melatonin appears to promote sleep only during the day.[2]

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Examination

1. Which of the following is not a recommendation for good sleep hygiene?
A. Keep bedroom quiet, dark, and cool.
B. Take over-the-counter sleep aids as needed.
C. Avoid watching TV right before bed.
D. Exercise earlier in the day whenever possible.

2. Which of the following is most problematic with regard to the quality of the current research on sleep and weight associations?
A. Many measures are based on self-reported and subjective data.
B. Many studies include only a small sample size.
C. Many studies use only heterogeneous populations.
D. The researchers are inexperienced.

3. Which of the following associations between short sleep and weight gain are best supported by existing evidence?
A. Energy expenditure increases.
B. Energy expenditure decreases.
C. Altered ratios of leptin and ghrelin production increase appetite.
D. Fatigue leading to decreased physical activity causes weight gain.

4. Which stage of sleep is most closely associated with abnormalities of glucose metabolism?
A. Slow-wave sleep
B. Rapid eye movement (REM) sleep
C. N1 non-REM (NREM) sleep
D. N2 NREM sleep

5. Which sleep duration is not associated with increased diabetes risk?
A. Less than six hours
B. Six to eight hours
C. More than nine hours
D. None of the above

6. Which of the following questions would be important to include in an assessment of sleep sufficiency?
A. At what times do you go to sleep and wake up?
B. Do you know whether you snore?
C. How would you describe your energy level on an average day?
D. All of the above

7. Jane, 48, reports poor success with attempts to lose weight. Her BMI is 28. She doesn't exercise regularly, although she says she tried to make this more of a priority. Jane explains that she tries to eat healthful foods and watch portion sizes, but cravings for carbohydrate-based foods often derail her efforts. Which of the following recommendations would you make as you begin to counsel Jane?
A. Keep a sleep diary for one week.
B. Schedule 10- to 15-minute periods of physical activity before dinnertime at least three days per week.
C. Begin weighing and measuring portions of foods eaten at home.
D. a and b

8. Joe, 62, presents with sleep apnea and diabetes. Which of the following entries in his food diary would most concern you?
A. Five cups of black coffee with breakfast
B. 12 oz of caffeine-free diet soda at lunchtime
C. One glass of wine with dinner
D. 20 oz of brewed unsweetened iced tea at bedtime

9. Allison, 8, is referred to you because her weight is above the 95th percentile for her age. As you question her, you discover she has trouble falling asleep most nights and often awakes several times per night. Her parents restrict her caffeine intake and are sticklers about her set bedtime. She's often sleepy during the day and therefore avoids physical activity in favor of sedentary activities. Allison would like to lose weight, but she doesn't know what to do. Which of the following actions would you take?
A. In your note to Allison's pediatrician, you'd express your concern that she may have a sleep disorder that's contributing to her overweight.
B. Teach Allison and her parents how to keep an accurate food diary. Ask them to keep the diary for one week and bring it in at her next follow-up visit.
C. Review with Allison and her parents the importance of minimizing light and noise in her bedroom at night and set the thermostat at a cool temperature.
D. All of the above

10. Which of the following statements is known to be true?
A. Although many of the exact mechanisms are unknown, it's clear that sleep insufficiency is a public health problem, contributing to the current epidemic of obesity.
B. Insufficient sleep is a major cause of today's obesity epidemic.
C. If everyone slept six to eight hours most nights, the prevalence of obesity and diabetes would be greatly reduced.
D. b and c