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The impact of sleep quality and disorders on the risk of obesity – physiological mechanisms and health implications

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ABSTRACT

Introduction and Purpose: Sleep is a biological process essential for immune function, brain development, memory consolidation and emotional regulation. Sleep restriction affects metabolic processes, hormone regulation and coagulation processes and is implicated in various diseases, including for example type 2 diabetes, hypertension, stroke and heart disease. The purpose of our study is to examine the impact of sleep quality on obesity and related diseases. We aim to understand how improving sleep habits can reduce the risk of obesity and its related health issues**.**

Brief Description of the State of Knowledge: Sleep deprivation disrupts hormonal regulation, reducing leptin and increasing ghrelin, leading to overeating and weight gain. Circadian rhythm disturbances also promote insulin resistance and fat storage. Obesity further impairs sleep quality, increasing the risk of metabolic disorders, including type 2 diabetes and hypertension. In pediatric populations, inadequate sleep is associated with higher BMI and an elevated risk of obesity.

Summary: Insufficient sleep alters hormonal regulation, promoting overeating and increasing obesity risk, which exacerbates metabolic dysfunction. Addressing sleep disorders and promoting healthy sleep and diet are essential for prevention.

Keywords: obesity, sleep disorders, obstructive sleep apnea, metabolic health, sleep quality

Introduction and purpose

Sleep is a biological process essential for immune function, brain development, memory consolidation and emotional regulation [1,2]. Sleep requirements change with age. Adults should aim for 7 or more hours of sleep each night for optimal health. Extended sleep durations exceeding 9 hours may be beneficial for young adults or people with certain medical conditions. However, the association between extended sleep and potential health risks is still unclear for the general population [3]. Sleep restriction affects metabolic processes, hormone regulation and coagulation processes, and is implicated in various diseases, including for example type 2 diabetes, hypertension, stroke and heart disease [1,4,5]. This study will examine the influence of sleep quality on obesity and conditions associated with obesity. Excess weight and obesity is linked to negative health outcomes. Obesity is a condition characterized by abnormal gathering of fat within the adipose tissue and is evaluated through the use of the Body Mass Index (BMI). The measurement is obtained by dividing the body mass in kilograms by the square of the individual's height in meters. A BMI of 30 kg/m^2 or more classifies an individual as obese, whereas overweight is defined as a BMI between 25 and 29.99 kg/m^2 [6]. The purpose of our study is to examine the impact of sleep quality on obesity and related diseases. We aim to understand how improving sleep habits can reduce the risk of obesity and its related health issues.

Description of the state of knowledge:

Recent findings indicates a significant two-way connection between obesity and the quality of sleep. People with inadequate or disrupted sleep often exhibit hormonal imbalances that promote increased appetite and decreased physical activity, facilitating weight gain and the onset of obesity. On the other hand, excess body fat, especially around the abdomen and upper airways, may interfere with sleep by raising the risk of conditions like obstructive sleep apnea.

Sleep physiology and body weight regulation

Sleep is a fundamental pillar of health and is its foundation [7]. It has many essential functions for the proper functioning of the body, one of them is the production of hormones and proteins in the body. Additionally, it reduces oxidative stress, strengthens the immune system, supports the removal of unnecessary metabolic products and saves and distributes energy. During sleep, anabolic processes predominate over catabolic processes, the body saves energy and repairs damaged cells at this time. Thanks to these functions, sleep participates in maintaining homeostasis and helps maintain the efficiency of systems in the body [7,8].

Sleep requirements vary with age. Children need more sleep than adults. In adults, the required amount of sleep is estimated to be between 7-9 hours, while young children need around 11-14 hours [1]. There are more and more reports that emphasize that insufficient sleep affects the level of appetite hormones. Shorter sleep increases the ghrelin to leptin ratio, which implies a greater appetite. Excessive energy intake occurs, which is not spent, and a positive energy balance is created [7,9]. NREM sleep is a phase of sleep in which physiologically a slowed metabolism occurs. During this time, the demand for glucose decreases due to reduced glucose uptake by the brain. During the REM phase, the brain's metabolism is similar to that during wakefulness [8]. Studies on rodents have shown that eating at night causes greater weight gain than eating the same food during the day [7]. Sleeping less than 6 hours a day has been shown to be associated with a 38% increased risk of obesity [7]. Scientists have shown that sleep deprivation lasting at least 24 hours reduces the body's sensitivity to insulin, reduces postprandial insulin secretion, and increases the concentration of cortisol - a stress hormone in the body. Sleep disorders lead to impaired glucose management in the body and loss of control over appetite, which may contribute to complications such as unmeasured weight gain and the development of type 2 diabetes [8,9].

The role of circadian rhythm in the development of obesity

The circadian rhythm, or biological clock, plays an important role in regulating many physiological processes, including metabolism, hormone secretion, and the sleep-wake cycle [1,10]. Disturbances of the circadian rhythm, resulting from shift work, irregular sleep and meal

times, and exposure to artificial light at night, can lead to dysregulation of the mechanisms responsible for the body's energy management [1,5,10]. Adequate sleep duration is crucial for maintaining full efficiency during the day and maintaining well-being [1,5,10]. One of the key mechanisms is disruption of the synchronization between the central biological clock in the suprachiasmatic nucleus of the hypothalamus and peripheral clocks in metabolic tissues such as the liver, adipose tissue, or pancreas [10]. Such desynchronization can lead to improper regulation of glucose and insulin. During the day, the body is more sensitive to insulin, which allows for the efficient use of energy from food. At night, this sensitivity decreases, which means that eating meals late in the evening or at night leads to higher blood glucose levels and increased insulin secretion. Long-term disruptions to this rhythm can lead to insulin resistance, which promotes the storage of fat tissue and, consequently, the development of obesity [1,5,8,10].

Circadian rhythm disorders can also lead to dysregulation of the secretion of hormones responsible for controlling appetite, such as leptin and ghrelin. Leptin, which is secreted mainly by fat cells, signals the brain about satiety and suppresses appetite. In conditions of sleep deprivation or disruption of the circadian rhythm, its level decreases, which weakens the satiety signal. Ghrelin, produced mainly in the stomach, stimulates the feeling of hunger (its level can be observed to increase in people who are sleep-deprived), increasing the need to eat, especially high-calorie products. The result of these disorders can be obesity [1,5,8,10].

Studies also indicate that people with an evening chronotype (i.e. preferring late hours of activity) are more likely to have unhealthy eating habits and a higher body mass index (BMI) [1,10]. In addition, people with circadian rhythm disorders show less spontaneous physical activity, which further limits energy expenditure and promotes weight gain [10].

Eating behaviors - impact on the quality and quantity of sleep

Sleep is strictly regulated by internal mechanisms of the body, but it also depends on external factors such as diet [11]. Incorrect nutrition contributes to poor sleep quality. Not only choosing inappropriate food products, but also eating in a hurry, irregularly eaten meals or skipping them, as well as too large portions can cause poor sleep quality. Additionally, you should pay attention to hot spices and stimulants such as caffeine [12]. Caffeine keeps us in a state of arousal because it does not allow adenosine to work, blocking its receptors [1]. The ingredients from which we prepare meals can affect the production of hormones that affect our sleep and wakefulness

rhythm. These include melatonin, serotonin, growth hormone or prolactin [12]. For example, in order to produce tryptophan, cofactors are needed, which we can obtain from appropriate food products such as tuna, avocado or lentils [1]. Studies show that a deficiency of omega-3 acids negatively affects melatonin levels. In teenagers, it was found that a higher level of DHA acids in the body affected falling asleep easier and sleeping longer [11]. Special attention should also be paid to stimulants. Alcohol completely changes the rhythm of the biological clock and significantly affects the deterioration of sleep quality. Nowadays, it is becoming more and more common to eat the main meal before going to bed. This disrupts digestion, makes falling asleep more difficult and causes a decrease in the number of hours of sleep. It is worth paying attention to food intolerances in patients, because eating intolerant products can contribute to the release of neurotransmitters, which can also cause sleep problems [12].

There is increasing evidence in the medical literature that shows that reduced sleep affects food preferences. People who sleep less or have ineffective sleep choose mainly products with high caloric value. Then, the entrenched incorrect eating patterns worsen the quality of sleep and deepen the disorders [1,12]. Appropriate modification of the diet and adherence to regular meal times is an effective and inexpensive solution in the fight against sleep problems and obesity, which can bring many benefits [11].

Health implications of sleep-obesity interaction

The relationship between sleep and obesity is bidirectional, as sleep deprivation promotes weight gain, while obesity can worsen sleep quality [9]. In recent years, this interaction has become a subject of research, especially in the context of the increasing incidence of type 2 diabetes and hypertension. Scientific evidence indicates that sleep disorders, such as short sleep duration, sleep fragmentation, insomnia, and obstructive sleep apnea, have a significant impact on metabolism and cardiovascular complications [5,8,9,13,14,15]. Insufficient sleep disrupts hormonal balance by reducing leptin levels and increasing ghrelin levels, which leads to increased appetite and a preference for high-calorie foods [5,8,9,13]. People who sleep less often lead a sedentary lifestyle, are less likely to engage in physical activity, and are more prone to a positive energy balance, which promotes weight gain. As a result, short sleep contributes to the development of obesity, which in turn worsens the quality of sleep, creating a vicious circle [8,9]. Studies indicate that sleep duration has a stronger effect on the risk of obesity in women, which may result from hormonal differences and socioeconomic factors. In turn, men

are more susceptible than women to the development of type 2 diabetes due to short sleep duration [9].

Sleep disorders significantly affect glucose regulation, as they activate the hypothalamic-pituitary-adrenal axis, increasing the secretion of cortisol and catecholamines, which impairs glucose tolerance and reduces tissue sensitivity to insulin [14]. In people with obesity, especially visceral obesity, chronic low-grade inflammation, increased levels of TNF-α, IL-6 and free fatty acids are observed, which additionally deepens insulin resistance. The result of these mechanisms is a significantly higher risk of developing type 2 diabetes in people with sleep disorders [14].

Sleep disorders may contribute to the development of hypertension. Sleep deprivation leads to oxidative stress, which impairs endothelial function and causes chronic inflammation. As a result, the bioavailability of nitric oxide (NO) decreases, which impairs the regulation of vascular tone and promotes the progression of hypertension [15].

In the context of health, promoting proper sleep hygiene and early detection and treatment of sleep disorders should be an integral part of the prevention and treatment strategy for obesity and its complications. Incorporating sleep quality assessment into routine check-ups can help identify high-risk individuals and prevent the development of cardiovascular and metabolic diseases [5,8,9,13].

Obstructive sleep apnea as a risk factor for obesity

Obstructive sleep apnea (OSA) is a condition where the airflow is reduced or completely blocked during sleep, which results in intermittent lack of oxygen and disturbed sleep patterns [8]. This is a global health concern, characterized by intermittent upper airway blockage during sleep, impacting approximately 936 million adults, with obesity as the predominant risk factor [16,17,18]. A substantial amount of research suggests that this condition may be connected to impaired glucose regulation [8].

Intermittent obstructions in the throat during sleep lead to prolonged exposure to hypoxia, hypercapnia, oxidative stress, and systemic inflammation. [16,19]. As a result, OSA has been independently linked to a significant increase in the risk of hypertension, diabetes, dyslipidemia, life-threatening cardiovascular diseases, and overall mortality [16,20].

It is well-known that type 2 diabetes (T2DM) contributes to obesity. According to Qie R. et al's analysis, individuals with OSA had a 40% higher risk of developing type 2 diabetes compared

to those without OSA. The researchers observed a linear correlation between OSA and T2DM risk, with the risk increasing by 8% for each 5-event increase in the AHI score (measurement used to assess the severity of sleep apnea). The study also found that OSA is linked to T2DM in both genders, but the connection was more pronounced in men. However, OSA might be underdiagnosed in women due to less typical symptoms like fatigue or mood disturbances, rather than observed apneas or loud snoring [21].

The relationship between OSA and obesity is bidirectional. Carneiro-Barrera A. and colleagues conducted research on the effects of a weight loss and lifestyle intervention on the severity of obstructive sleep apnea (OSA) and associated metabolic diseases in adult men aged 18-65 with moderate to severe OSA, who had overweight or obesity and were undergoing Continuous Positive Airway Pressure (CPAP) therapy. CPAP is a device that provides a steady flow of air through a mask to help keep the airways open while sleeping. The intervention focused on weight loss and lifestyle changes resulted in improvements and even remission of OSA and comorbid conditions in adults with moderate to severe OSA, who were overweight or obese and undergoing CPAP therapy. After 8 weeks, 15% of the participants in the intervention group achieved complete OSA remission, and 45% no longer required CPAP therapy. Six months later, 29.4% of participants reached full OSA remission, and 61.8% were no longer reliant on CPAP. Additionally, the intervention group showed reductions of 7% in body weight, 19% in fat mass, and 26% in visceral fat after 6 months [16].

The relationship between sleep and the development of obesity in children and adolescents

There are many factors that contribute to obesity in young patients. One of the overlooked, modifiable factors influencing obesity is sleep disorders [22]. More and more studies indicate a link between disturbed sleep patterns in early childhood and the development of obesity [23]. Unfortunately, sleep problems are becoming more common, more and more children and adolescents sleep less and go to bed irregularly at late hours [22,23,24,25]. Studies have shown that bedtime and bedtime variability are associated with increased obesity in young people [22,23]. It has been found that teenagers who go to bed late have higher BMI values than teenagers who go to bed earlier in the day [22,23]. Other studies have shown that not only bedtime but also short sleep duration can lead to an increased risk of weight gain. Especially in children <10 years of age [24]. It has been proven that each additional hour of sleep gained in childhood corresponded to a 35% reduction in the risk of obesity at the age of 32 [23]. Establishing regular bedtimes and an appropriate number of hours of sleep in childhood can

improve metabolic functions and contribute to the development of healthier habits related to adulthood [24,26].

The scientific literature increasingly emphasizes the existence of a link between an improper diet and sleep disorders. Developing proper eating patterns from the earliest years of a child's life is crucial, because the way of eating has a significant impact on the functioning of the entire body, including the quality of sleep. Eating high-protein, high-calorie meals just before bedtime can reduce the quality of night's rest, despite its seemingly sufficient length. An improper diet leads to sleep disorders, and sleep disorders in a vicious circle contribute to an increased risk of developing obesity and can cause chronic inflammation in the body. For this reason, following the principles of healthy nutrition is an important element of the prevention of metabolic disorders, obesity in children and adolescents [23].

Untreated metabolic disorders in childhood can lead to serious multi-organ complications in the future and increase the risk of premature morbidity and mortality in adulthood. Effective prevention requires a holistic approach, involving not only specialists - such as pediatricians and dieticians - but also parents and children. Promoting a balanced diet, regular physical activity and taking care of proper sleep hygiene, which is often underestimated in the context of children's health, can be an effective, alternative strategy for reducing the occurrence of obesity and its many serious complications [23,24].

Summary

Sleep deprivation has a profound impact on the regulation of body weight and metabolic processes. Insufficient sleep leads to hormonal imbalances, including reduced leptin and increased ghrelin, which triggers overeating and weight gain. Moreover, circadian rhythm disturbances, such as those caused by shift work, contribute to insulin resistance and fat storage [1,5,8,10]. Obesity, in turn, worsens sleep quality, creating a vicious cycle that contributes to the development of metabolic disorders, including type 2 diabetes and hypertension [16,20]. In children and adolescents, poor sleep habits, including late bedtimes and inadequate sleep duration, contribute to higher body mass index (BMI) and an increased risk of obesity [22,23,24,25]. Therefore, addressing sleep disorders, promoting healthy sleep hygiene, and maintaining proper dietary habits are essential for preventing obesity and its associated health complications [23,24].

Author's contribution

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Study design – Magdalena Jaskółka, Karolina Trytek-Miś, Kinga Cogiel, Patrycja Ochman-Pasierbek,

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