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The role of sleep quality in the pathogenesis and management of Type 2 diabetes

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Abstract. With a growing prevalence of both Type 2 diabetes and sleep disturbances in the population, emerging evidence suggests a potential link between sleep quality and diabetes. This review explores the role of sleep quality in Type 2 diabetes, including its association with glycemic control and the potential of sleep interventions in management. The review clarifies underlying mechanisms connecting sleep disturbances to diabetes, encompassing cortisol, melatonin, ghrelin, and leptin dysregulation. Sleep quality affects emotional well-being, contributing to stress-related insulin resistance. Exploring the intricate connection between sleep quality and glycemic control uncovers intricate patterns involving HbA1c levels and intriguing gender disparities. However, the obstacle of patient adherence underscores the necessity for nuanced strategies, including personalized approaches. The implications for diabetes management and public health resonate through adaptable care during challenging circumstances, evidence-based population health strategies, and proactive prevention efforts. Adaptable care methods, rooted in telehealth and individualized support, ensure uninterrupted diabetes management. Early intervention and prevention programs can forestall prediabetes progression, necessitating proactive public health initiatives. This review showcases the links between sleep quality and Type 2 diabetes, revealing a landscape where sleep interventions hold potential, but also emphasizing the need for holistic, patient-centered approaches in diabetes management.

Keywords: Sleep quality, Type 2 Diabetes, glycemic control, sleep interventions, public health.

1. Introduction

Type 2 diabetes is a chronic metabolic disorder characterized by high blood glucose levels resulting from the body's inability to properly use or produce insulin [1]. Insulin is a hormone that helps regulate the uptake of glucose (sugar) into cells to provide energy for various bodily functions. In Type 2 diabetes, the body becomes resistant to insulin or does not produce enough of it, leading to elevated blood sugar levels, a condition known as hyperglycemia [1]. Type 2 diabetes is a global health challenge with increasing prevalence [2]. The International Diabetes Federation (IDF) estimates that in 2021, around 537 million adults between the ages of 20 and 79 were living with diabetes, with approximately 90-95% having Type 2 diabetes [3]. The IDF predicts that by 2045, the number of adults with diabetes will increase to 642 million [3]. In 2019 alone, diabetes was responsible for around 4.2 million deaths worldwide [3].

Sleep disturbances refer to disruptions in the regular sleep patterns, which can impact overall health and well-being. These disturbances can manifest in various forms, including difficulty falling asleep (insomnia), frequent awakenings during the night, waking up too early and being unable to fall back asleep, or experiencing non-restorative sleep [4]. Additionally, sleep disturbances, such as insomnia and sleep apnea, impact around 10-30% of adults globally [5]. This growing prevalence of both conditions has sparked interest in exploring potential connections between sleep quality and diabetes.

By examining research relating to Type 2 diabetes and sleep quality, this review paper sets out to explore three main areas : the association between sleep quality and glycemic control in individuals with Type 2 diabetes, an investigation into the impact of sleep disturbances, and the potential implications of integrating sleep interventions, such as implementing sleep hygiene practices or employing treatments for sleep disorders, within the framework of diabetes management. By analyzing and synthesizing existing research, this review explores the relationship between sleep quality and Type 2 diabetes while offering a glimpse into sleep-related interventions for Type 2 diabetes.

It's important to note that there have been scientific studies exploring the links between sleep quality and Type 2 diabetes, investigating areas like the connection between sleep disturbances and blood sugar control, the mechanisms linking sleep issues with diabetes, and the potential of sleep interventions for managing diabetes. However, there's a lack of comprehensive literature review papers on this topic. This underscores the significance of our current review, which aims to bridge this gap by bringing together existing research findings to offer a more complete understanding of how sleep quality is intertwined with Type 2 diabetes.

2. Sleep Quality and Type 2 Diabetes: An Overview

Sleep quality includes factors such as how easily one falls asleep, the duration of sleep, and how often sleep is disrupted during the night [6]. To measure sleep quality, two main approaches are commonly used: objective measures and subjective measures. Objective measures involve a sleep study called polysomnography, which records various physiological parameters during sleep, such as brain waves and muscle activity, to provide detailed insights into sleep patterns [7][8]. On the other hand, subjective measures rely on sleep questionnaires where individuals self-report their sleep patterns and perceived sleep quality [9]. Both objective and subjective measures contribute to understanding an individual's sleep quality and can be helpful in assessing sleep-related issues and their impacts.

Sleep disturbances are increasingly common among individuals with Type 2 diabetes [10]. Research indicates that a significant proportion of people with diabetes experience sleep disorders, such as insomnia and sleep apnea, due to unstable blood sugar levels and other diabetes-related symptoms [11][12]. The connection between sleep quality and diabetes pathogenesis (sequence of events or mechanisms that lead to the development/progression of a disease) is supported by several potential mechanisms. One key factor is the involvement of inflammatory processes and oxidative stress caused by sleep disturbances. Poor sleep can cause chronic low grade inflammation and metabolic issues, contributing to diabetes development and complications [13]. Additionally, disruptions in circadian rhythms and hormonal regulation can occur, further impacting glucose metabolism and insulin signaling [14].

3. Mechanisms Underlying the Sleep-Diabetes Link

Now that we've established the basics of sleep quality, it's time to delve into the intricate mechanisms connecting it to diabetes. The relationship between sleep and diabetes reveals a complicated relationship between biological, behavioral, and psychosocial factors. One crucial biological aspect involves cortisol and melatonin in regulating glucose. Cortisol, released by the adrenal glands in response to stress, maintains blood glucose levels [15]. Disrupted sleep patterns lead to irregular cortisol levels, impairing glucose metabolism and increasing insulin resistance [16]. In contrast, melatonin, produced by the pineal gland during the night, enhances insulin sensitivity. Sleep disruption further reduces melatonin, heightening the risk of insulin resistance and diabetes [17]. Ghrelin, known as the "hunger hormone," increases with inadequate sleep, leading to intensified feelings of hunger and strong desires for high-

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calorie foods [18]. On the other hand, insufficient sleep decreases leptin, a hormone that signals fullness, impeding the ability to control food intake and potentially fostering overeating and weight gain [19]. These hormonal shifts could potentially contribute to the development of obesity and type 2 diabetes.

Moreover, sleep disturbances impact emotional well-being, serving as a psychosocial bridge to diabetes. Chronic sleep issues elevate stress levels and trigger emotional disruptions such as anxiety and depression [20]. Stress-induced hyperactivity of the sympathetic nervous system and the hypothalamic-pituitary-adrenal axis can lead to insulin resistance and glucose dysregulation [21]. The sympathetic nervous system is responsible for the body's "fight or flight" response, while the HPA axis is involved in regulating stress and other bodily functions [22]. When these systems are hyperactive due to stress, they can influence the body's ability to properly respond to insulin, which is necessary for regulating blood sugar levels [21]. This phenomenon is known as insulin resistance, where the body's cells become less responsive to insulin's effects [21]. Additionally, the disruption caused by stress can lead to imbalances in glucose regulation, contributing to irregular blood sugar levels, a condition referred to as glucose dysregulation [21]. Poor emotional well-being might also lead to unhealthy coping methods like emotional eating and sedentary behaviors, heightening the diabetes risk [23]. Recognizing and addressing these different factors offer avenues for diabetes prevention and management, emphasizing the importance of cultivating healthy sleep habits for overall well-being.

Furthermore, the connection between sleep quality and metabolic processes extends to neural responses in the context of food desire and preferences. Sleep deprivation resulted in reduced activity in key brain regions: the anterior cingulate cortex (ACC) showed a decrease with a t-value of 3.87 ($p=0.0008$), indicating a compromised ability to evaluate food rewards; the lateral orbitofrontal cortex (LOFC) had reduced activity with a t-value of 2.08 ($p=0.0491$), suggesting impaired reward processing and impulse control; and the anterior insula cortex had decreased activity with a t-value of 2.63 ($p=0.0154$), indicating potential disruptions in recognizing bodily states related to food desire [24]. In contrast, the amygdala exhibited heightened reactivity, showing an increase in activity with a t-value of 3.08 ($p=0.0055$), which could signify elevated emotional significance of food [24]. These neural changes corresponded with behavioral shifts: a significant rise in preference for high-calorie foods, indicated by a t-value of 2.21 ($p=0.04$), while the preference for low-calorie foods remained unchanged with a t-value of 1.15 ($p=0.26$) [24]. The findings underscore that sleep deprivation disrupts neural circuits related to food reward processing, influencing subsequent food choices towards more energy-dense options, even when not driven solely by hunger. By uncovering how sleep disturbances influence hormones and emotional well-being, we create a clear rationale for exploring their potential impact on glycemic control.

4. Impact of Sleep Quality on Glycemic Control

With a solid understanding of the mechanisms, real-world implications can be investigated. The impact of sleep quality on glycemic control in individuals with diabetes has been investigated through various research studies. In a cross-sectional study by Mehrdad et al., adult diabetes patients reporting more sleep disturbances exhibited higher HbA1c levels, implying a potential connection between poor sleep and suboptimal long-term blood glucose management [25]. HbA1c, also known as glycated hemoglobin, a critical marker in diabetes care, reflects higher blood glucose levels, as glucose binds to hemoglobin over approximately 120 days [26]. A separate study in Makkah City reinforced this idea, showing a link between sleep disorders and diabetes. hile a positive correlation was observed between the duration of diabetes and PSQI scores, indicating a potential impact of prolonged hyperglycemia on sleep quality, the correlation between HbA1c levels and PSQI scores was not statistically significant ($p > 0.05$), suggesting that the relationship might not be strongly supported by the data [1]. This suggests that while sleep quality may influence glycemic control, its effects might not be universally consistent, highlighting the complexity of this relationship. Further research is needed to fully grasp its mechanisms and variations among individuals with diabetes.

In contrast, an exploration involving participants from Xuzhou City, China, delved into subjective sleep quality's interaction with glycemic control indicators. Initially, subjective sleep quality did not reveal significant associations with HbA1c levels across all participants. However, after accounting for

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variables, an intriguing gender discrepancy surfaced: an association manifested in women but not men. Furthermore, shifts in sleep quality correlated more prominently with glycemic changes in men, particularly among younger individuals. These insights illuminate a potential link between subjective sleep disruptions and glycemic control, albeit with intriguing gender and age differentials [27]. The combination of these studies suggests that while sleep disturbances might indeed influence glycemic control, an understanding tailored to individual differences would be the most important in designing effective interventions.

5. Role of Sleep Interventions in Diabetes Management

Exploring the role of sleep interventions in diabetes management, studies have particularly focused on the link between sleep apnea and type 2 diabetes. In a study by Isao Muraki, Hiroo Wada, and Takeshi Tanigawa, a significant connection emerged. Sleep apnea was associated with worsened glycemic control, reflected in higher HbA1c levels, increased insulin resistance, and elevated fasting blood glucose levels [28]. This underscores how sleep disruptions can negatively impact diabetes outcomes [28]. Importantly, the study emphasized the potential of continuous positive airway pressure (CPAP) therapy in diabetes management. Patients adhering to CPAP treatment exhibited substantial improvements in HbA1c levels and insulin resistance, showcasing the tangible benefits of addressing sleep apnea through CPAP in ameliorating metabolic disturbances associated with diabetes [28]. Similarly, Susheel P. Patil, Indu A. Ayappa, and their team evaluated the effectiveness of CPAP therapy for obstructive sleep apnea [29]. Utilizing GRADE (Grading of Recommendations Assessment, Development, and Evaluation) methodology, their analysis highlighted the considerable impact of CPAP in managing sleep apnea. The study focused on key metrics, including the apnea-hypopnea index (AHI) & Epworth Sleepiness Scale (ESS) to assess the impact of CPAP therapy. In the analysis, CPAP intervention led to a substantial reduction in AHI by -19.63 events per hour, indicating a significant improvement in sleep apnea severity [29]. The ESS score underwent a mean reduction of -3.18 points, indicating reduced sleepiness after CPAP therapy [29]. Lower ESS scores suggest improved daytime wakefulness and reduced propensity for falling asleep in various situations. Their comprehensive assessment employed GRADE methodology, emphasizing the significance of CPAP in managing sleep apnea, which is known to affect diabetes outcomes.

Despite the potential benefits, incorporating sleep interventions in diabetes care presents challenges, as patient adherence to CPAP therapy could be a key obstacle, affecting the long-term effectiveness of interventions. This underscores the importance of personalized approaches and patient education, as emphasized in the sleep hygiene education and behavioral interventions discussed by Muraki et al. and the medication adherence interventions [30]. While both studies provide insights on the benefits of sleep interventions, the challenges of patient adherence and long-term effectiveness necessitate a holistic approach to diabetes care that addresses both medical and behavioral aspects.

6. Implications for Diabetes Management and Public Health

The implications for diabetes management encompass adaptable care strategies during crises, evidence-based population health approaches, and proactive public health measures for prevention. They emphasize the need for innovative care solutions, a shift towards community-focused strategies, and the importance of early intervention and prevention efforts to curb the diabetes epidemic and improve overall public health. Integrating these implications into practice can lead to more effective and comprehensive diabetes care that considers both individual needs and broader community health objectives.

Disruptions caused by the pandemic highlight the importance of innovative solutions such as telehealth and personalized guidance to ensure uninterrupted diabetes care [31]. Adaptable care methods guarantee continued support for individuals with diabetes during challenging times, maintaining the consistency of care and preventing potential health deterioration. This approach not only ensures that patients receive necessary care but also enhances healthcare system resilience in times of crisis.

Incorporating adaptable care strategies as a permanent component of diabetes management is vital. They enhance access to care, increase patient engagement, and build resilience for future crises.

Addressing health determinants at a population level fosters healthy behaviors and prevents diabetes development, extending beyond individual-focused care. Implementing population health strategies involves interventions targeting factors like socioeconomic disparities and community norms [32]. By emphasizing lifestyle changes, education, and community involvement, these approaches can yield lasting improvements in diabetes prevention and management. This shift represents a transformative approach, where healthcare systems invest in preventive measures that can have far-reaching impacts on community health. Embracing evidence-based population health strategies has the potential to reduce the overall burden of diabetes and improve the quality of life for a broader population.

By intervening early with individuals at risk, healthcare systems can prevent the progression of prediabetes to diabetes, shifting focus from treatment to prevention. Public health measures involve implementing programs focusing on lifestyle changes and community support, leading to significant reductions in diabetes incidence and associated burdens. The implications of this study emphasize the need for healthcare systems to prioritize preventive measures as part of their diabetes management strategies. The role of proactive public health efforts in preventing diabetes would have a large impact in early identification and engagement of individuals at risk through successful preventive programs.

7. Conclusion

The exploration of sleep quality's impact on Type 2 diabetes highlights its intricate connections with biological, behavioral, and psychosocial factors. Sleep disturbances, ranging from disrupted circadian rhythms to emotional stress, are entwined with diabetes development, influencing glycemic control as evidenced by potential associations with elevated HbA1c levels. The incorporation of sleep interventions into diabetes management, particularly addressing sleep apnea through therapies like continuous positive airway pressure (CPAP), shows promise. However, challenges of patient adherence underscore the need for holistic approaches encompassing education and tailored strategies. As physicians play pivotal roles as both facilitators and obstacles, education for both healthcare professionals and patients is crucial in diabetes management.

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