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The Effect of Sleep Duration and Quality on Glycemic Control in Adults with Type 2 Diabetes: A Longitudinal Study

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ABSTRACT

Type 2 diabetes (T2D) is a chronic condition necessitating comprehensive management to prevent complications. Emerging evidence underscores the critical role of sleep duration and quality in influencing glycemic control. This review synthesized longitudinal studies to evaluate the interplay between sleep and glycemic outcomes in adults with T2D. Optimal sleep duration (7–9 hours per night) is linked to improved metabolic health, while both short (≤6 hours) and long (≥10 hours) sleep durations, alongside poor sleep quality, are associated with adverse glycemic outcomes, including elevated HbA1c levels and increased glucose variability. The review identified key mechanisms such as insulin resistance, inflammation, autonomic dysregulation, and behavioral factors underlying these associations. A narrative review methodology was utilized to examine current evidence and highlight trends in sleep and glycemic control. Longitudinal studies revealed a bidirectional relationship where poor sleep exacerbates hyperglycemia, while hyperglycemia disrupts sleep patterns, suggesting that addressing sleep disturbances may reciprocally benefit glycemic outcomes. Despite challenges such as measurement variability and intervention feasibility, integrating sleep-focused interventions into diabetes care holds promise. Future research should explore mechanistic pathways, assess intervention outcomes, and leverage technology for personalized care. By recognizing sleep as a modifiable factor, this review advocated for a holistic approach to enhance glycemic control and overall well-being in T2D management.

Keywords: Type 2 Diabetes (T2D), Sleep Duration, Sleep Quality, Glycemic Control, Longitudinal Studies.

INTRODUCTION

Type 2 diabetes (T2D) is a chronic metabolic disorder characterized by insulin resistance and hyperglycemia, affecting millions of individuals worldwide [1–3]. Effective management of glycemic control is crucial to prevent the long-term complications associated with T2D, including cardiovascular disease, neuropathy, and nephropathy. While traditional management strategies emphasize diet, exercise, and pharmacotherapy, emerging evidence suggests that sleep duration and quality may play a pivotal role in glycemic regulation. Sleep disturbances, common among individuals with T2D, may exacerbate glucose dysregulation through various physiological mechanisms, including altered insulin sensitivity, increased inflammation, and dysregulated appetite hormones. Sleep is essential for maintaining metabolic homeostasis, yet many adults experience insufficient or poor-quality sleep due to lifestyle factors, stress, or underlying health conditions [4, 5]. Both short and long sleep durations have been associated with adverse health outcomes, particularly in metabolic diseases. Additionally, poor sleep quality, characterized by frequent awakenings or non-restorative sleep, has been linked to increased HbA1c levels and heightened glucose variability [6, 7]. Despite these findings, the complex interplay between sleep and glycemic control in T2D remains underexplored, particularly in longitudinal contexts. This review examines the impact of sleep duration and quality on glycemic control in adults with T2D over time. It synthesizes current evidence to elucidate the bidirectional relationship between sleep and glucose metabolism while highlighting potential mediators such as inflammation and circadian misalignment. The review also identifies gaps in knowledge and proposes future research directions to

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advance our understanding of sleep as a modifiable factor in diabetes management. By emphasizing the importance of sleep in glycemic control, this review aims to broaden the scope of T2D management strategies and foster interdisciplinary approaches to improve patient outcomes.

The Relationship Between Sleep Duration And Glycemic Control

Optimal sleep duration, generally defined as 7-9 hours per night, is associated with better metabolic health outcomes [8]. Both short (≤6 hours) and long (≥10 hours) sleep durations have been linked to poor glycemic control, highlighting the importance of achieving a balanced sleep schedule [9, 10].

i. **Short Sleep Duration:** Short sleep duration has been consistently associated with elevated hemoglobin A1c (HbA1c) levels in adults with T2DM. Sleep deprivation may impair glucose metabolism by reducing insulin sensitivity and increasing cortisol levels, which promote gluconeogenesis and inhibit glucose uptake by peripheral tissues. Furthermore, insufficient sleep alters appetite-regulating hormones, such as ghrelin and leptin, leading to increased caloric intake and weight gain—both critical factors in T2DM progression.

ii. **Long Sleep Duration:** Prolonged sleep duration, while less studied, has also been linked to poor glycemic control. Excessive sleep may reflect underlying health conditions, such as depression, obstructive sleep apnea (OSA), or chronic fatigue, which contribute to metabolic dysregulation. These conditions may exacerbate insulin resistance, inflammatory responses, and glycemic variability.

Sleep Quality and Glycemic Control

Sleep quality encompasses various dimensions, including sleep latency, continuity, and perceived restfulness [11, 12]. Poor sleep quality, as characterized by frequent awakenings, difficulty falling asleep, or non-restorative sleep, has profound implications for glycemic control [13].

i. **Impact of Sleep Fragmentation:** Fragmented sleep disrupts the natural progression of sleep stages, particularly slow-wave sleep (SWS), which is critical for glucose metabolism. SWS deficits impair insulin sensitivity and disrupt nocturnal glucose regulation, leading to morning hyperglycemia. Additionally, frequent awakenings may activate the hypothalamic-pituitary-adrenal (HPA) axis, increasing stress hormone levels and worsening glycemic control.

ii. **Role of Perceived Sleep Quality:** Subjective perceptions of sleep quality also influence diabetes outcomes. Adults with T2DM who report poor sleep quality often exhibit higher HbA1c levels, increased glycemic variability, and greater difficulty adhering to diabetes self-management routines. Perceived sleep insufficiency may stem from chronic stress, depression, or anxiety, all of which adversely affect glycemic control.

Mechanisms Linking Sleep and Glycemic Control

Several physiological and behavioral mechanisms underlie the association between sleep and glycemic control in adults with T2DM:

i. **Insulin Resistance:** Both short and fragmented sleep impair insulin sensitivity by altering the activity of insulin-signaling pathways [14]. Sleep deprivation reduces insulin-stimulated glucose uptake in skeletal muscles and adipose tissue, contributing to hyperglycemia.

ii. **Inflammation:** Poor sleep quality increases levels of pro-inflammatory cytokines, such as interleukin-6 (IL-6) and tumor necrosis factor-alpha (TNF-α). Chronic inflammation exacerbates insulin resistance and beta-cell dysfunction, hindering glycemic regulation.

iii. **Autonomic Dysregulation:** Sleep disturbances disrupt autonomic nervous system balance, leading to increased sympathetic activity and reduced parasympathetic tone. This dysregulation elevates blood glucose levels through heightened gluconeogenesis and glycogenolysis.

iv. **Hormonal Alterations:** Sleep deprivation affects the secretion of appetite-regulating hormones, leading to increased hunger and caloric intake [15]. Elevated ghrelin levels and reduced leptin levels promote weight gain, further aggravating insulin resistance and hyperglycemia.

v. **Behavioral Factors:** Poor sleep patterns can adversely affect diabetes self-management by reducing motivation, impairing decision-making, and increasing susceptibility to unhealthy behaviors such as overeating or physical inactivity. These factors collectively hinder glycemic control.

Findings From Longitudinal Studies

Longitudinal studies provide valuable insights into the dynamic relationship between sleep and glycemic control in adults with T2DM:

i. **Sleep Duration Trajectories:** Studies tracking sleep duration over time reveal that consistent short or long sleep durations are associated with progressive worsening of glycemic control [16]. Conversely,

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interventions that promote sleep extension in individuals with chronic sleep deprivation have demonstrated improvements in HbA1c levels and fasting glucose.

ii. **Sleep Quality Trends:** Long-term assessments of sleep quality indicate that persistent sleep fragmentation and low perceived sleep quality are predictive of higher glycemic variability and increased risk of diabetes complications. Improvements in sleep quality over time are correlated with better glycemic outcomes and enhanced quality of life.

iii. **Bidirectional Relationship:** Evidence suggests a bidirectional relationship between sleep and glycemic control [17]. Poor sleep exacerbates hyperglycemia, while hyperglycemia disrupts sleep patterns through mechanisms such as nocturia, restless leg syndrome, and OSA. Addressing one factor may, therefore, have reciprocal benefits for the other.

Challenges In Studying Sleep And Glycemic Control

Despite promising findings, several challenges complicate research on sleep and glycemic control:

i. **Measurement Variability:** Assessing sleep duration and quality relies on subjective self-reports and objective measures such as polysomnography or actigraphy. Discrepancies between subjective and objective measures can complicate data interpretation.

ii. **Heterogeneity of Study Populations:** Variability in demographic, socioeconomic, and health-related characteristics among study populations limits the generalizability of findings. Co-existing conditions such as OSA, depression, or cardiovascular disease further confound the relationship between sleep and glycemic control.

iii. **Intervention Feasibility:** Implementing sleep-focused interventions in real-world settings poses logistical and financial challenges. Adherence to sleep hygiene recommendations or behavioral therapies may be limited by individual preferences and resource availability.

Clinical Implications

Understanding the impact of sleep on glycemic control has significant implications for clinical practice:

i. **Screening for Sleep Disorders:** Routine screening for sleep disorders, such as insomnia or OSA, should be integrated into diabetes care. Identifying and addressing sleep disturbances may improve glycemic outcomes and overall well-being.

ii. **Personalized Sleep Interventions:** Tailored sleep interventions, including cognitive-behavioral therapy for insomnia (CBT-I), continuous positive airway pressure (CPAP) for OSA, or sleep hygiene education, can enhance sleep quality and glycemic control [18].

iii. **Integrated Care Models:** Collaborative care models involving endocrinologists, sleep specialists, and behavioral health providers are essential to address the multifaceted relationship between sleep and diabetes.

iv. **Patient Education:** Educating patients about the importance of sleep in diabetes management empowers them to prioritize healthy sleep habits. Strategies such as maintaining a consistent sleep schedule, creating a conducive sleep environment, and avoiding stimulants before bedtime should be emphasized.

Future Directions

To further elucidate the relationship between sleep and glycemic control, future research should:

i. **Explore Mechanistic Pathways:** Advanced imaging and biomarker studies can uncover precise mechanisms linking sleep disturbances to glycemic dysregulation.

ii. **Evaluate Intervention Outcomes:** Randomized controlled trials assessing the efficacy of sleep-focused interventions on long-term glycemic control are needed to establish causality and inform clinical guidelines.

iii. **Leverage Technology:** Wearable devices and mobile health applications offer opportunities to monitor sleep patterns and glycemic trends in real-time, enabling personalized diabetes care.

iv. **Address Health Disparities:** Research should prioritize understanding the impact of social determinants of health on sleep and diabetes outcomes, ensuring equitable access to sleep-focused interventions.

CONCLUSION

The interplay between sleep duration, quality, and glycemic control in adults with type 2 diabetes (T2D) underscores the significant yet underappreciated role of sleep in diabetes management. Both insufficient and excessive sleep durations, alongside poor sleep quality, are strongly associated with adverse glycemic outcomes, including elevated HbA1c levels, increased glucose variability, and heightened risk of complications. Mechanistic insights reveal that disruptions in insulin sensitivity, inflammation, autonomic regulation, and hormonal balance underlie these associations, compounded by behavioral factors that hinder diabetes self-management. Longitudinal evidence highlights the bidirectional relationship between sleep and glycemic control, emphasizing the potential for sleep-

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focused interventions to improve glycemic outcomes. Consistent improvements in sleep duration and quality have been shown to positively influence metabolic health, while poor sleep trajectories exacerbate glycemic dysregulation and disease progression. However, challenges such as variability in measurement tools, population heterogeneity, and intervention feasibility present barriers to integrating sleep into routine diabetes care. Clinically, addressing sleep disturbances through tailored interventions, routine screening, and integrated care models offers a promising avenue to enhance diabetes outcomes. Future research should focus on elucidating precise mechanistic pathways, evaluating intervention efficacy, and leveraging technology to provide real-time monitoring and personalized care. By prioritizing sleep as a modifiable factor in T2D management, healthcare providers can improve both glycemic control and overall patient well-being, fostering a holistic approach to diabetes care.

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