Jordan Journal of Nursing Research,
DOI: https://doi.org/10.14525/JJNR.2026.38

Jordan Journal of Nursing Research

https://jjnr.just.edu.jo/jjnr

A Systematic Review of the Association between Sleep Quality and Glycemic and Other Metabolic Indicators in Individuals with Type 2 Diabetes

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ARTICLE INFO

Article History:
Received: November 12, 2025
Accepted: April 26, 2026

ABSTRACT

Background: There is an association between sleep quality and glycemic control outcomes, particularly glycated hemoglobin (HbA1c), fasting plasma glucose, and related metabolic markers in adults with type 2 diabetes mellitus. ***Purpose***: This review aims to examine the mentioned association and includes studies conducted in accordance with current methodological and diagnostic standards. ***Methods*****:** Research published between 2010 and 2025 and indexed in international databases was screened according to predefined inclusion criteria, which required studies to involve adults with type 2 diabetes and to assess the relationship between sleep quality and glycemic outcomes. Sleep quality was evaluated through parameters, such as sleep duration, continuity, sleep onset latency, and subjective sleep satisfaction. Eligible studies were compared based on glycemic control indicators, particularly HbA1c (Hemoglobin A1c), which is recognized as a primary metabolic outcome influenced by sleep quality. ***Results*****:** A total of 24 studies meeting the criteria were included after screening seven databases. The findings indicate that insufficient and poor-quality sleep is generally associated with elevated HbA1c levels, impaired glucose tolerance, increased insulin resistance, and adverse lipid profiles. Furthermore, some studies have reported that sleep disorders may negatively affect the course of diabetes by contributing to increased inflammatory markers. ***Conclusion*****:** The findings suggest that sleep quality is an important lifestyle factor to consider in the management of type 2 diabetes. ***Implications for Nursing***: The results underscore the importance of healthcare professionals integrating sleep assessments and interventions into clinical practice for individuals with diabetes.

Keywords: Adults, Metabolic variables, Sleep quality, Systematic review, Type 2 diabetes.

What does this paper add?

1. This review provides an up-to-date synthesis of studies (2010–2025) examining the association between sleep quality and glycemic control, specifically in individuals with type 2 diabetes, using contemporary diagnostic criteria and methodologies.
2. It highlights consistent evidence linking poor sleep quality with higher HbA1c levels, increased insulin resistance, and unfavorable metabolic profiles, reinforcing sleep as a modifiable risk factor in diabetes management.
3. This review underscores the clinical importance of incorporating sleep assessment into routine diabetes care and supports the need for targeted sleep interventions to improve metabolic outcomes.

Introduction

The prevalence of type 2 diabetes mellitus (T2DM) is steadily increasing worldwide, representing a major global public health challenge (Republic of Türkiye Ministry of Health, 2020). In Turkey, the prevalence of diabetes was reported as 7.2% in the Turkish Diabetes Epidemiology Study (TURDEP-I), conducted in 1997–1998 and published in 2002 (Satman et al., 2002). In the subsequent TURDEP-II study conducted in 2010, this rate increased to 13.7%, indicating a marked rise in diabetes prevalence over time (Satman et al., 2002). Factors contributing to the increase in diabetes include longer life expectancy, lifestyle changes due to urbanization, physical inactivity, and dietary habits (Turkish Endocrinology and Metabolism Society, 2014; Yousef, 2025). Moreover, inadequate sleep has also been identified as a risk factor for diabetes. A clinical review reported that insufficient sleep duration has been associated with an increased risk of developing type 2 diabetes and obesity (Knutson et al., 2007).

Sleep is defined as an active physiological state involving sustained unresponsiveness to the external environment and dynamic changes in neurological, metabolic, and cardiorespiratory functions (Lim & Foldvary-Schaefer, 2010). Although it varies by individual and age, the ideal sleep duration for adults is on average 7–8 hours (Hernandez et al., 2012). Quality sleep is recommended to be timely, of sufficient duration, and uninterrupted (Kline et al., 2013; Buysse et al., 1989). However, due to current living conditions or physiological and psychological problems, sleep disorders have become a widespread concern (Ohayon, 2002; Bonnet & Arand, 1995). Sleep disorders are characterized by disruptions in sleep patterns and refer to issues related to the quality, timing, and quantity of sleep. They include difficulties in falling asleep and maintaining sleep, falling asleep at inappropriate times, sleeping too much or too little, and exhibiting abnormal behaviors during sleep (American Academy of Sleep Medicine, 2007). Over the past 50 years, daily sleep duration has decreased by 1.5 to 2 hours among adults and adolescents, and approximately one-third of Americans aged 30-64 years are reported to sleep less than six hours a day (National Center for Health Statistics, 2005). Similar results have drawn attention in Turkey. According to the "National Sleep Epidemiology Study in the Adult Population," which mapped Turkey's sleep profile, 13% of people reported having difficulty falling asleep, 30% slept more than eight hours, and 11% slept less than six hours (Demir, 2010).

During sleep, changes occur in hormone levels that regulate body metabolism. Some experimental studies suggest that glucose tolerance and insulin sensitivity exhibit circadian variation across sleep–wake cycles (Van Cauter et al., 1997; Van Cauter et al., 1991). Glucose utilization is highest during wakefulness, lowest during Non-Rapid Eye Movement (NREM) sleep, and moderate during Rapid Eye Movement (REM) sleep; glucose tolerance is also lower throughout the night (Van Cauter et al., 2008). Growth hormone rises at the onset of sleep and reaches its peak level during slow-wave sleep (SWS). Cortisol levels significantly increase in the second half of sleep, predominantly during REM sleep (Van Cauter et al., 2008; Van Cauter et al., 2007). Thyroid-stimulating hormone (TSH) secretion increases during nighttime sleep (Spiegel et al., 1999). Leptin follows a circadian rhythm that peaks in the early phases of the sleep period (Knutson et al., 2007), while circulating ghrelin concentrations also exhibit a peak at their maximum level during the night (Yıldız et al., 2004).

Sleep restriction, sleep fragmentation, and sleep-disordered breathing have been associated with changes in neurohormonal functioning—such as increased sympathetic activity (Stamatakis & Punjabi, 2010; Somer et al., 1995), elevated cortisol levels (Spiegel et al., 1999), suppression of growth hormone (Van Cauter et al., 2008; Van Cauter et al., 2007) and TSH secretion Spiegel et al., 1999; Kessel et al., 2010), and reduced leptin secretion (Spiegel et al., 2004). These neurohormonal alterations have been proposed to be associated with obesity, insulin resistance, and impaired glucose metabolism in observational and experimental studies (Lucassen et al., 2012; Knutson & Van Cauter, 2008) (Figure 1). Persistent hyperglycemia is linked to microvascular and macrovascular complications of diabetes. Psychological comorbidities, such as depression may coexist with sleep disturbances and metabolic dysregulation, suggesting a bidirectional relationship between sleep and T2DM (Taub & Redeker, 2008).

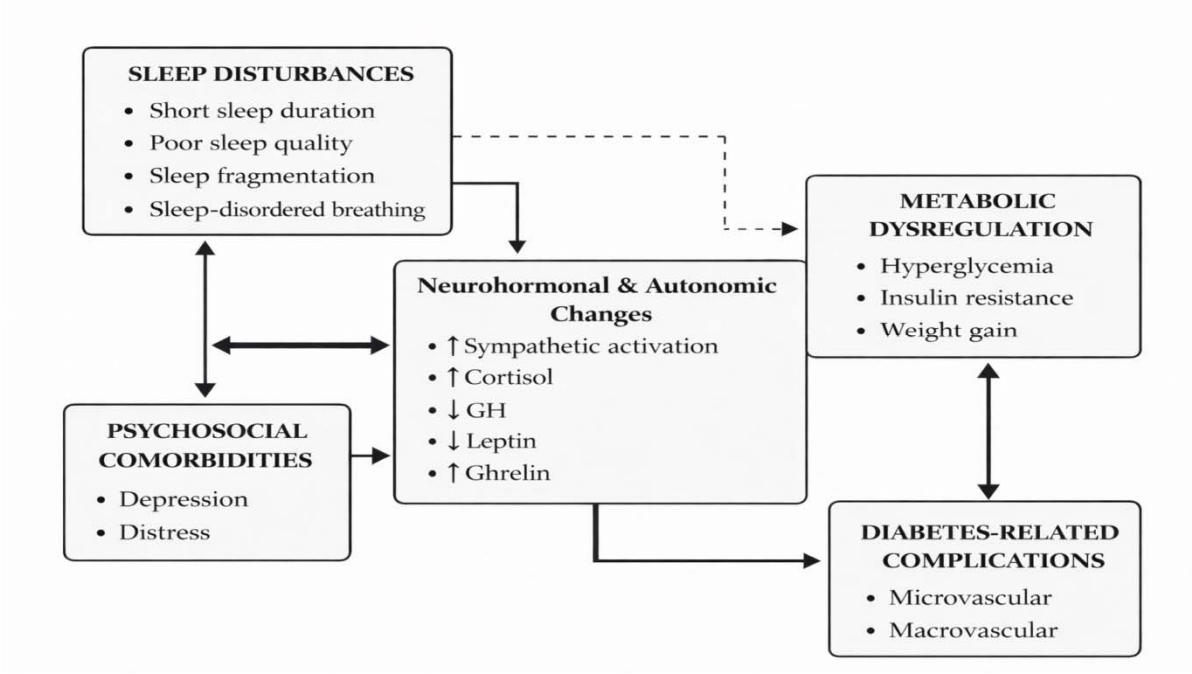

Figure 1. Conceptual model illustrating the proposed pathways linking sleep disturbances to metabolic dysregulation and diabetes-related complications in individuals with T2DM, conceptually informed by prior literature (Lucassen et al., 2012; Taub & Redeker, 2008)

Sleep-related neurohormonal mechanisms, including alterations in cortisol, melatonin, leptin, and ghrelin levels, have been widely discussed in the literature for their potential role in metabolic regulation. These mechanisms are thought to contribute to key metabolic processes, such as energy balance, insulin sensitivity, and glucose homeostasis. To provide a conceptual overview of these interrelated pathways, Figure 1 illustrates the proposed neurohormonal links between sleep disturbances and metabolic dysregulation. These neurohormonal alterations have been associated with obesity, insulin resistance, and impaired glucose metabolism in both observational and experimental studies (Lucassen et al., 2012; Knutson & Van Cauter, 2008). Solid arrows represent primary hypothesized mechanistic pathways supported by the reviewed evidence. Dashed arrows indicate potential direct associations reported in some studies, but not consistently mediated through the neurohormonal pathway. Directional arrows reflect proposed relationships and do not imply causality.

Although sleep has been proposed as a potentially relevant metabolic factor, current diabetes management guidelines (e.g., ADA, IDF) (American Diabetes Association, 2014; Turkish Endocrinology and Metabolism Society, 2014; International Diabetes Federation, 2014) place limited emphasis on structured sleep assessment, likely reflecting the heterogeneity and methodological limitations of the available evidence. Despite growing scientific interest, the magnitude, consistency, and clinical implications of the reported associations remain insufficiently clarified. Therefore, this systematic review aimed to comprehensively synthesize and critically evaluate the existing evidence regarding the associations between specific sleep parameters and metabolic outcomes in individuals with T2DM.

Methods

This systematic review was prepared according to the recommendations of the "Preferred Reporting Items for Systematic Review and Meta Analysis Protocols 2015 Statement (PRISMA-P)." Since the review was conducted by examining existing studies, ethical committee approval was not required for the study (Kalav et al., 2020).

This systematic review was prospectively registered in the International Prospective Register of Systematic Reviews (PROSPERO) under the registration number CRD420251042052. The registered protocol, titled "Evaluation of Studies Examining the Effect of Sleep Quality on Metabolic Variables in Individuals with

T2DM: A Systematic Review", outlines the objectives, eligibility criteria, and planned methodology for study selection, data extraction, and synthesis.

Search Strategy

For this systematic review, the databases searched included Google Scholar, Medline/PubMed, Cochrane Library, Scopus, CINAHL Complete, OVID, and Web of Science. The search was conducted between January 3, 2023, and March 25, 2025, using the following English keywords: “sleep and diabetes,” “diabetes and sleep disorders,” “sleep in T2DM,” “sleep quality and Diabetes Mellitus,” “the importance of sleep in diabetes,” and “the effect of sleep on diabetes and diabetes on sleep.” The number of studies identified in each database and the subsequent screening process were reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines and are illustrated in the PRISMA flow diagram (Fig. 1).

Gray literature was not included in this systematic search. The review focused exclusively on peer-reviewed studies indexed in major academic databases, and gray literature (such as dissertations, conference proceedings, institutional reports, or unpublished studies) was not searched. This decision was made to ensure the methodological consistency and quality of the included evidence.

Inclusion Criteria

This systematic review included studies published within the past 15 years that examined the association between sleep characteristics (including sleep quality and sleep disorders) and glucose metabolism in individuals with type 2 diabetes mellitus (T2DM). Only full-text, English-language primary research articles were included, while review articles were excluded.

The selection of studies was guided by the Population, Intervention/Exposure, Comparator, Outcome, and Study Design (PICOS) framework recommended by the Joanna Briggs Institute (Bağrıaçık & Bayraktar, 2022).

- **P (Population):** Adults diagnosed with type 2 diabetes mellitus (T2DM), regardless of gender, race, or socioeconomic status.
- **I (Intervention/Exposure):** Sleep-related characteristics, including sleep quality, sleep duration, sleep continuity, and the presence of sleep disorders.
- **C (Comparator):** Where applicable, studies comparing different levels or categories of sleep characteristics (e.g., good vs. poor sleep quality, adequate vs. insufficient sleep) or comparing with other relevant influencing factors.
- **O (Outcome):** Indicators of glucose metabolism and metabolic control, including HbA1c, fasting blood glucose, insulin resistance, and related metabolic parameters.
- **S (Study Design):** Randomized controlled trials, observational studies (including cross-sectional and cohort studies), and correlational research.

Exclusion Criteria

- **Study Design:** To maintain a focused scope, qualitative studies, case reports, case series, and secondary research, such as systematic reviews or meta-analyses, were excluded.
- **Outcome Measures:** Studies that did not provide primary data or specific metrics related to glucose metabolism in the context of sleep were excluded.
- **Publication Type:** Grey literature—including dissertations, conference proceedings, institutional reports, and unpublished manuscripts—was excluded to ensure methodological consistency and high evidence quality.

Note on Limitations: The decision to exclude grey literature is acknowledged as a study limitation. While it ensures a standardized level of peer review, it may increase the potential for publication bias, which is further addressed in the Discussion section.

Study Selection

The study selection process was conducted independently by two researchers. The electronic search yielded 1,452 records from Google Scholar (n = 754), Medline/PubMed (n = 126), Cochrane Library (n = 587), Scopus (n = 60), CINAHL Complete (n = 203), OVID (n = 115), and Web of Science (n = 107). After removing duplicates and screening titles and abstracts for relevance, studies that did not meet the inclusion criteria or the full texts of which were not suitable for the review were excluded. Ultimately, 24 studies were included in the systematic review (Fig. 2).

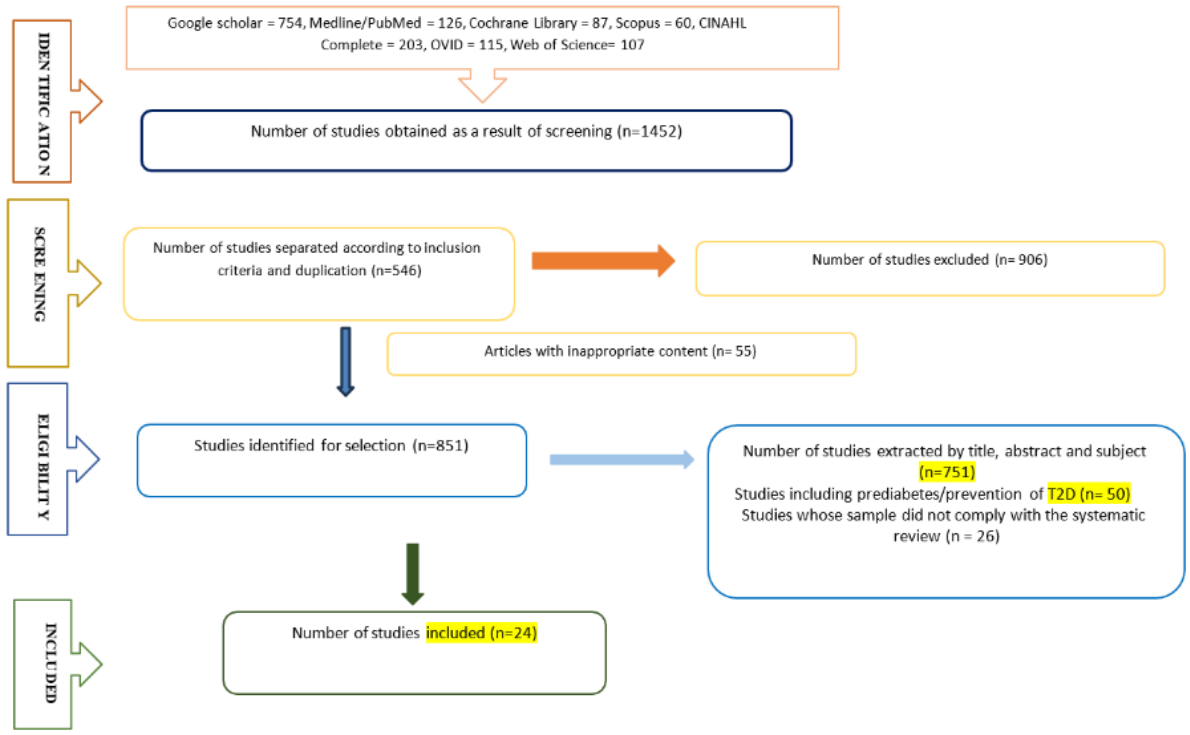

Figure 2. PRISMA flowchart of the studies included in the systematic review

Results

The electronic search using the identified keywords and their synonyms yielded 1,452 records from Google Scholar (754), PubMed/Medline (126), CINAHL Complete (203), Scopus (60), Web of Science (107), Cochrane Library (87), and Ovid (115). After removing duplicates, titles and abstracts were screened for relevance, resulting in 546 records. These were assessed according to the inclusion and exclusion criteria, and 24 studies were finally included in the review (Fig. 2).

Data extraction and analysis were conducted independently by two reviewers using a standardized data extraction form to minimize bias. Discrepancies were resolved through discussion or consultation with a third reviewer. The methodological quality of each study was evaluated using appropriate quality appraisal tools before synthesis. The findings from the 24 included studies were analyzed through structured content analysis and summarized under the following categories: research characteristics (author–year–country, sample size), study aim, study design, instruments used, metabolic variables, sleep measures, and key outcomes (Table 1).

Study Characteristics

It was determined that the studies included in the systematic review were conducted between 2010 and 2025. When analyzed according to the countries or regions where the studies were conducted, significant variability was observed.

Study Topics and Purpose

To facilitate a structured synthesis of the diverse data, the topics of the included studies were systematically categorized into five main groups based on a thematic analysis of their primary research objectives and outcome measures. This categorization was employed to manage the heterogeneity among the studies and to provide a clearer clinical framework for discussing the multi-faceted relationship between T2DM and sleep parameters.

Accordingly, the studies were distributed across the following thematic domains:

- Sleep Quality: Seven studies (29.16%) primarily evaluated subjective or objective sleep quality [Luyster & Dunbar-Jacob, 2011; Jin et al., 2012; Nakanishi-Minami et al., 2012; Tsai et al., 2012; Song et al., 2013; Kajbaf et al., 2014; Zhang et al., 2025).

- Sleep Duration: Eight studies (33.33%) examined the impact of sleep length on metabolic health (St-Onge et al., 2012; Buyukaydin et al., 2012; Tare et al., 2014; Ohkuma et al., 2014; Wang et al., 2015; Tajiri et al., 2018; Cros et al., 2019; Radcliffe et al., 2021).
- General Sleep Disorders: Three studies (12.5%) investigated various sleep-related disturbances (Hood et al., 2014; Tanno et al., 2014; Costa et al., 2014).
- Diabetes-Related Complications: One study (4.16%) focused on the specific effect of diabetic neuropathic pain on sleep (Sadosky et al., 2014).
- Sleep Apnea: Five studies (20.83%) addressed the prevalence and clinical impact of obstructive sleep apnea in individuals with diabetes (Kosseifi et al., 2010; Lai et al., 2013; Obaseki et al., 2014; Grimaldi et al., 2014; Abdissa, 2020).

Sample Size

The sample sizes of the included studies varied substantially, ranging from 10 participants (Abdissa, 2020) to 45,602 participants (Lai et al., 2013). This variation was largely attributable to differences in research design; for example, small-scale clinical or observational studies typically involved limited samples, whereas large epidemiological or database-based studies used extensive population-level data. Such variation in sample size may influence the strength and generalizability of the findings, with larger samples providing stronger statistical power and smaller samples offering more detailed, but less generalizable, insights.

Study Design and Instruments

Clear criteria regarding study design were applied during the selection process; therefore, only studies with identifiable and scientifically valid research designs were included. Eligible studies were required to examine the relationship between type 2 diabetes mellitus (T2DM) and sleep. Among the 24 included studies, two (8.33%) employed a longitudinal design (Tanno et al., 2014; Tajiri et al., 2018), five (20.83%) were cross-sectional studies (Tare et al., 2014; Obaseki et al., 2014; Abdissa, 2020; Zhang et al., 2025), five (20.83%) followed a cohort design (Kosseifi et al., 2010; Sadosky et al., 2014; Lai et al., 2013; Kajbaf et al., 2014; Grimaldi et al., 2014), eight (33.33%) were descriptive studies (Luyster & Dumbar, 2011; Jin et al., 2012; Nakanishi-Minami et al., 2012; Tsai et al., 2012; St-Onge et al., 2012; Song et al., 2013; Hood et al., 2014; Costa et al., 2014), and four (16.66%) were experimental or quasi-experimental studies (Wang et al., 2015; Tajiri et al., 2018; Cros et al., 2019; Radcliffe et al., 2021).

The instruments used for data collection varied across studies and were selected based on the specific objectives and sleep-related variables examined. Commonly used tools included standardized sleep and metabolic assessment scales, which are detailed in Table 1.

Metabolic Variables Used in the Studies

Among the included studies, metabolic outcomes related to glycemic control were examined in six studies (25%) (Jin etal., 2012; St-Onge et al., 2012; Buyukaydin et al., 2012; Song et al., 2013; Lai et al., 2013; Grimaldi et al., 2014). These studies assessed several key metabolic indicators: fasting glucose (four studies), HbA1c (six studies), cholesterol profiles (two studies), and kidney function (one study). Detailed distributions of metabolic variables across studies are presented in Table 1.

Results: Relationship and Outcomes between T2DM and Sleep

Across the included studies, sleep-related parameters were most commonly examined in relation to glycemic control, sleep quality, sleep disorders, and obstructive sleep apnea in individuals with T2DM. Overall, the findings suggested that poor sleep quality, abnormal sleep duration, and sleep-disordered breathing were frequently associated with less favorable metabolic and clinical outcomes (Luyster & Dumbar-Jacob, 2011; Jin et al., 2012; Nakanishi-Minami et al., 2012; Tsai et al., 2012; St-Onge et al., 2012; Song et al., 2013; Sadosky et al., 2014; Lai et al., 2013; Tare et al., 2014; Ohkuma et al., 2014; Hood et al., 2014; Tanno et al., 2014; Costa et al., 2014; Grimaldi et al., 2014; Wang et al., 2015; Tajiri et al., 2018; Cros et al., 2019; Andissa, 2020; Radcliffe et al., 2021; Zhang et al., 2025). In particular, several studies reported associations between poorer sleep quality and unfavorable glycemic indicators, such as higher HbA1c or fasting glucose levels (Nakanishi-Minami et al., 2012; Tsai et al., 2012; Song et al., 2013; Song et al., Grimaldi et al., 2014), while others highlighted associations involving obstructive sleep apnea, neuropathic pain, and broader diabetes-related complications (Kosseifi et al., 2010; Buyukaydin et al., 2012; Sadosky et al., 2014; Lai et al., 2013; Abdissa,

2020). However, because the reviewed studies differed substantially in design, sample characteristics, measurement methods, and reported outcomes, the findings should be interpreted with caution. Detailed study-level characteristics, reported outcomes, and the corresponding level of association are presented in Table 1.

Table 1. Overview of reviewed studies on sleep quality and metabolic parameters in individuals with T2DM

Author(s), Year, and Location	Study Topic	Aim of the Study	Sample Size	Study Design	Instruments/ Measurement Tools Used	Metabolic Variables	Level of Association between Sleep Quality and Diabetes	Results
Kosseifi et al., 2010 USA	The association between obstructive sleep apnea syndrome and microvascular complications in well-controlled diabetic patients.	We investigated the association between sleep apnea and microvascular diabetic complications in veterans with T2DM mellitus (T2DMM).	98 patients with glycated hemoglobin (HbA1c) levels below 6.5%	Retrospective study	Apnea–Hypopnea Index (AHI)	---	The study reported that higher AHI values were associated with increased odds of diabetic microvascular complications, including retinopathy. Lower oxygen saturation levels were generally associated with greater microalbuminuria and poorer glycemic control. Overall, the evidence indicates that sleep apnea is related to microvascular impairment even among individuals with well-controlled type 2 diabetes mellitus.	Obstructive sleep apnea was found to be associated with microvascular complications in individuals with well-controlled type 2 diabetes, the study observed an association between obstructive sleep apnea and microvascular complications in individuals with well-controlled T2DM.
Luyster and Dunbar-Jacop, 2011 USA	Sleep quality and quality of life in adults with T2DM	The aim of this study is to examine the relationship between sleep quality and health-related as well as diabetes-specific quality of life in adults with T2DM	300 individuals with T2DM	Survey Study	* PSQI * Medical Outcomes Study 36- Item Short Form Health Survey (SF- 36) * Diabetes Quality of Life Measure * Beck Depression Inventory-II * Health-Related Quality of Life	---	After adjusting for commonly controlled covariates, the studies consistently demonstrated that poorer sleep quality was an independent predictor of reduced overall health-related quality of life. Moreover, individuals with poorer sleep quality tended to report lower diabetes-specific quality of life scores, indicating that sleep disturbances adversely affect both general well-being and diabetes-related daily functioning.	The study reported that poorer sleep quality was associated with lower health-related and diabetes-specific quality of life. among individuals with T2DM and is consistently associated with negative impacts on their overall quality of life.
Jin et al., 2012 China	The relationship between sleep quality and glucose level, diabetic complications in elderly T2DM mellitus	To investigate the relationship between sleep quality, glucose levels, and diabetic complications in elderly patients with T2DM mellitus.	130 hospitalized patients with T2DM.	Survey study	*PSQI	* Fasting Plasma Glucose (FPG) [(10.7 ± 2.2) mmol/L vs (9.8 ± 1.9) mmol/L, T = 2.410] * HbA1c [(8.6 ± 2.2)% vs (7.8 ± 2.1)%, T = 2.068] * High-Sensitive Crp (Hs- Crp) [(5.27 ± 2.34) mg/L vs (4.44 ± 1.76) mg/L, T = 2.179]	Multiple correlation analyses indicated that several clinical and psychosocial factors were associated with sleep quality, including fasting plasma glucose (FPG), HbA1c levels, duration of diabetes, presence of diabetic complications, depressive symptoms, quality of life, and insulin use (all $p < 0.05$). In the multivariable logistic regression model, both FPG ($\beta = 1.29$, $p < 0.05$) and Pittsburgh Sleep Quality Index (PSQI) scores ($\beta = 1.07$, $p < 0.05$) showed significant associations with HbA1c. Furthermore, increases in PSQI scores were accompanied by significant changes in FPG, HbA1c, diabetic complications, and quality of life (all $p < 0.05$), the study reported significant associations between PSQI scores and FPG and HbA1c levels.	In elderly individuals with T2DM, sleep quality is closely linked to the presence and progression of diabetes-related complications. This population commonly experiences reduced sleep quality, which may impair glucose regulation and contribute to the development or worsening of complications. Furthermore, disrupted sleep negatively affects overall well-being, leading to a poorer quality of life.

Nakanishi-Minami et al., 2012 Japan	Sleep-wake cycle irregularities in type 2 diabetics	The aim was to compare bedtime, wake-up time, and estimated sleep duration between individuals with T2DM mellitus (T2DMM) and those without T2DMM.	106 outpatients	Survey Study	A self-report questionnaire designed to collect personal data on sleep habits	Fasting glucose, glycoalbumin, and HbA1c levels were significantly higher in the diabetic group, while HDL cholesterol levels were significantly lower compared to the control group ($p < 0.05$ for all).	Patients with T2DMM tended to follow a delayed sleep schedule, going to bed and waking up later than individuals without T2DMM on both weekdays and weekends. They also reported daytime sleepiness more frequently, indicating a greater burden of sleep-wake disturbances in this group.	Sleep–wake cycle disturbances are frequently reported in individuals with T2DM and The study reported delayed sleep timing and higher daytime sleepiness among individuals with T2DM. Compared with individuals without diabetes, those with T2DM tend to exhibit a higher prevalence of irregular sleep patterns, reduced sleep quality, and alterations in circadian timing, all of which may negatively influence glycemic control and other metabolic outcomes.
Tsai et al., 2012 Taiwan	Impact of subjective sleep quality on glycemic control in T2DM mellitus	The aim of this study was to investigate the relationship between sleep quality and glycemic control and its effect on T2DM patients in an Asian population.	46 People with T2DM	Survey Study	PSQI	---	The study reported that poorer sleep quality and reduced sleep efficiency were both significantly associated with higher HbA1c levels. After adjustment for potential confounders, lower sleep efficiency substantially increased the likelihood of inadequate glycemic control (adjusted OR: 6.83, 95% CI: 2.04–22.8). Similarly, participants categorized as having poor overall sleep quality demonstrated a markedly higher risk of poor glycemic control (adjusted OR: 6.94, $p < 0.05$).	Recent studies examining the association between glycemic control and sleep quality indicate that better sleep quality is linked to improved metabolic outcomes in individuals with T2DM. The study reported that poor sleep quality and lower sleep efficiency were associated with higher HbA1c levels
St-Onge et al., 2012 USA	Associations of sleep disturbance and duration with metabolic risk factors in obese persons with T2DM: Data from the Sleep AHEAD Study	To investigate the relationship between sleep disturbances and metabolic risk factors in obese patients with T2DM.	A total of 5,145 overweight or obese adults with T2DM.	Cross-sectional study	Apnea–Hypopnea Index (AHI)	* Hemoglobin A1c, 7.22% (±0.06) * Fasting plasma glucose, 153.6 mg/dL (±2.6) * Total cholesterol, 192.4 mg/dL (±2.2) * LDL-cholesterol, 114.6 mg/dL (±1.8) * HDL-cholesterol, 45.4 mg/dL (±0.7) * Triglycerides, 163.6 mg/dL (±5.5)	Among the 60 associations examined, only one reached statistical significance: higher fasting glucose levels were modestly related to lower sleep efficiency. In contrast, none of the sleep parameters showed meaningful associations with hemoglobin A1c or any components of the lipid profile.	The study reported modest associations between sleep efficiency and fasting glucose, with no significant associations observed for HbA1c or lipid parameters. Overall, these results offer limited and inconsistent evidence supporting a meaningful contribution of sleep disturbances to metabolic dysregulation in adults with obesity and T2DM.
Buyukaydin et al., 2012 Turkey	The effect of sleep apnea syndrome on the development of diabetic nephropathy in patients with T2DM	To evaluate the incidence of obstructive sleep apnea syndrome (OSAS) in T2DM patients with and without nephropathy.	52 diabetic patients	Prospective study	---	* Glycosylated hemoglobin (HbA1c), %: 7.87 ± 1.27 * Fasting glucose, mg/dL: 165 ± 60.13 * Plasma urea, mg/dL: 25 ± 6.52 * Serum creatinine, mg/dL: 0.82 ± 0.16 * Urinary albumin excretion, mg/day: 19.6 ± 31.9 * Serum triglycerides, mg/dL: 156 ± 73.10 Total cholesterol, mg/dL: 192 ±	In the study, approximately two-thirds of patients who met the criteria for OSAS experienced sleep disturbances. Most of these cases were classified as mild, with fewer patients showing moderate or severe disturbances. The analysis also indicated a positive association between triglyceride levels and respiratory indices, suggesting that worsening respiratory parameters were related to higher triglyceride concentrations.	Obstructive sleep apnea syndrome (OSAS) is frequently observed in individuals with type 2 diabetes mellitus (T2DM) and has been shown to adversely influence glycemic regulation. Given its strong association with obesity and metabolic dysregulation, The study reported a high prevalence of OSAS among individuals with T2DM and observed associations between respiratory indices and triglyceride levels.

						31.68		
Song et al., 2013 China	Disturbed subjective sleep in Chinese females with type 2 diabetes on insulin therapy	This study aimed to determine the prevalence of poor sleep quality in Chinese patients with type 2 diabetes receiving insulin therapy and to evaluate potential risk factors that may contribute to it.	140 type 2 diabetes patients with insulin treatments were enrolled in our study.	Survey Study	PSQI	* HbA1c (%) Women: 7.79 ± 1.65 Men: 7.90 ± 1.62 Total: 7.85 ± 1.63 Fasting Plasma Glucose (FPG, mmol/L) Women: 8.66 ± 3.56 Men: 8.75 ± 3.39 Total: 8.71 ± 3.45 * Postprandial Glucose (PPG, mmol/L) Women: 13.2 ± 4.93 Men: 13.02 ± 5.12 Total: 13.14 ± 5.03	Female patients with T2DM who were using insulin reported poorer overall sleep quality compared with male patients. This difference remained statistically significant even after controlling for age, BMI, glycemic indicators, and duration of diabetes, indicating that female sex independently increased the likelihood of experiencing poor sleep quality.	Poor sleep quality has been reported among insulin-treated Chinese women with T2DM. The study reported that female sex was independently associated with poorer sleep quality after adjustment for confounders..
Sadosky et al., 2013 USA	Burden of illness associated with painful diabetic peripheral neuropathy among adults seeking treatment in the US: results from a retrospective chart review and cross-sectional survey	To characterize the disease burden among adults with painful diabetic peripheral neuropathy (PDPN) seeking treatment in the United States.	A total of 112 individuals with painful diabetic peripheral neuropathy participated in this observational study.	An observational study, a retrospective review, and a cross-sectional survey study.	* Brief Pain Inventory – Short Form (BPI-SF) * Hospital Anxiety and Depression Scale (HADS) * Medical Outcomes Study Sleep Scale (MOS Sleep Scale) * 12-Item Short Form Health Survey (SF-12v2) * EuroQol 5 * Dimensions, 3 Levels (EQ-5D-3L)	---	The study demonstrated a clear pattern in which greater pain intensity was associated with progressively poorer outcomes across multiple domains. Participants with higher pain levels reported more sleep disturbances, reduced overall health status, greater impairment in daily activities, and increased reliance on medication, accompanied by higher healthcare costs. Health utility values declined steadily as pain intensified. Similarly, pain interference scores increased markedly with rising pain levels, and sleep quality—measured using the MOS sleep index—showed substantial deterioration as pain worsened.	Individuals with painful diabetic peripheral neuropathy (PDPN) generally experience substantial pain, which the study reported that greater pain severity was associated with increased sleep disturbance scores
Lai et al., 2013 Taiwan	Population-based cohort study on the increase in the risk for T2DM mellitus development from non-apnea sleep disorders.	To investigate the impact of non- apneic sleep disorders on increasing the risk of diabetes	Using the National Health Insurance Research Database (NHIRD) of Taiwan, the study included 45,602 patients diagnosed with non-apneic sleep disorders.	A population-based, community-based retrospective cohort study conducted from 1997 to 2010.	--	--	Individuals with non-apnea sleep disorders show a modest, but significant elevation in the risk of developing diabetes mellitus, with adjusted hazard ratios indicating approximately a 5% increase in overall risk. This association appears stronger in specific subgroups, particularly males and adults younger than 40 years, whose risk increases by about 8% and 42%, respectively. When considering sleep disorders more broadly, affected individuals demonstrate roughly an 11% higher likelihood of progressing to diabetes compared with those without sleep-related problems.	The study reported that non-apnea sleep disorders were associated with a modest increase in the risk of developing T2DM.

Tare et al., 2014 ABD	Sleep duration does not mediate or modify association of common genetic variants with T2DM	To investigate whether fasting glucose or T2DM-related genetic variants are associated with sleep duration, and whether sleep duration modifies these genetic effects.	1,474 people *(The study included European-origin participants, while data collection and analysis were conducted in the USA.)*	Cross-sectional association	Specially designed questionnaire	---	Short sleep duration showed a modest positive association with the risk of type 2 diabetes (OR≈1.32). While sleep duration did not meaningfully interact with glycemic indicators, the study reported small nominal interactions involving several genetic variants (e.g., *PPARG*, *CRY2*, *HNF1B*), though these did not reach robust statistical significance.	Both short and long sleep durations have been consistently linked to a higher risk of developing T2DM in the reviewed studies. While sleep duration itself does not appear to mediate the association between genetic risk variants and glycemic traits, evidence suggests that overall sleep patterns and habits may still play a meaningful role in influencing glycemic outcomes. The study reported a modest association between short sleep duration and increased odds of T2DM (OR≈1.32).
Ohkuma et al., 2014 Japan	U-shaped association of sleep duration with metabolic syndrome and insulin resistance in patients with T2DM: the Fukuoka Diabetes Registry	To investigate the relationship between sleep duration and metabolic syndrome as well as insulin resistance in individuals with T2DM.	A total of 4,402 Japanese patients with T2DM aged 20 years and older.	Multicenter prospective study	* Depression scale used in epidemiological studies * A self-administered questionnaire.	---	Short and long sleep durations were both associated with a higher likelihood of metabolic syndrome compared with sleeping 6.5–7.4 hours. This non-linear ("U-shaped") pattern persisted even after statistical adjustment for relevant confounding factors.	Sleep duration shows a U-shaped relationship with metabolic syndrome and insulin resistance among patients with diabetes. Both short and long sleep durations are associated with adverse metabolic profiles, the study reported a U-shaped association between sleep duration and metabolic syndrome
Hood et al., 2014 USA	Night eating in patients with T2DM. Associations with glycemic control, eating patterns, sleep, and mood	To evaluate the prevalence of night eating in T2DM patients and its associations with eating behavior, sleep, mood, and related metabolic and psychosocial factors.	194 adults with T2DM	Descriptive study	* Night Eating Questionnaire (NEQ) * PSQI * Epworth Sleepiness Scale (ESS) * Morningness-Eveningness Questionnaire (MEQ) * Center for Epidemiologic Studies Depression Scale (CES-D)	---	Higher scores on the Night Eating Questionnaire were generally associated with poorer metabolic and behavioral profiles. Specifically, individuals with elevated NEQ scores tended to have higher HbA1c values and showed patterns, such as skipping breakfast, reporting poorer sleep quality, experiencing greater daytime sleepiness, and favoring an evening chronotype. These individuals also more frequently reported shorter sleep duration, a greater sense of sleep debt, later wake times, and increased depressive symptoms.	In individuals with T2DM, night-eating tendencies the study reported associations between night-eating behaviors, poorer sleep quality, and higher HbA1c levels.
Kajbaf et al., 2014 France	The relationship between metformin therapy and sleep quantity and quality in patients with T2DM referred for potential sleep disorders	To determine the association between metformin therapy and sleep parameters among individuals with T2DM.	A retrospective observational study involving 387 patients.	Retrospective observational study	Apnea–Hypopnea Index (AHI)	---	Patients using metformin demonstrated *longer sleep duration* and *higher sleep efficiency* compared with non-users. These associations remained significant even after accounting for differences in BMI, indicating that the observed improvements in sleep parameters were not solely attributable to body weight	The study reports that individuals using metformin tend to have *longer sleep duration* and *better sleep efficiency*. However, these observations come primarily from observational data; The study reported longer sleep duration and higher sleep efficiency among metformin users.
Tanno et al., 2014 Japan	Sleep-related intermittent hypoxemia and glucose intolerance: a community-based study	To characterize the relationship between sleep-related intermittent hypoxemia and glucose metabolism assessed by oral glucose tolerance test.	1,836 individuals from the Japanese population	Cross-sectional study	Japan Arteriosclerosis Longitudinal Study Physical Activity Questionnaire (JALSPAQ)	---	Intermittent hypoxemia associated with sleep-disordered breathing was found to adversely affect glucose regulation. Individuals with an oxygen desaturation index (ODI) of 15 or higher showed a greater likelihood of elevated fasting glucose, impaired glucose tolerance, and diabetes. *Beyond these odds-ratio–based associations*, greater hypoxemia severity was also consistently associated	The study reported that individuals experiencing sleep-related intermittent hypoxemia tended to show poorer glucose regulation, including reduced glucose tolerance and increased insulin resistance, the study reported that higher ODI values were associated with elevated fasting glucose and insulin resistance.

							with increased insulin resistance and reduced insulin sensitivity, as indicated by changes in HOMA-IR and the Matsuda index. The reported odds ratios were adjusted for relevant covariates, including age, sex, and body mass index.	
Costa et al., 2014 Portugal	Relationship between socio-demographic, clinical and psychosocial variables in patients with T2DM	To examine the relationship between sociodemographic, clinical, and physiological variables in T2DM patients and provide gender-based comparisons.	A total of 90 patients with type 2 diabetes.	Survey Study	* Hospital Anxiety and Depression * Scale (HADS), *Epworth Sleepiness Scale (ESS), *PSQI.	---	Regarding social support, findings were consistently positive for both men and women, indicating comparable levels of perceived support across genders. Sleep quality assessments showed generally poor outcomes within the sample. On average, participants scored in the range indicative of diminished sleep quality, and the majority met the criteria for poor sleep, with a notable proportion also presenting symptoms suggestive of potential sleep disorders.	Symptoms of anxiety are commonly observed in individuals with type 2 diabetes. The study reported higher anxiety scores and poorer sleep quality among women with T2DM
Obaseki et al., 2014 Nigeria	Prevalence and predictors of obstructive sleep apnea syndrome in a sample of patients with T2DM Mellitus in Nigeria	To determine the prevalence of obstructive sleep apnea (OSA) in patients with T2DM through screening surveys and to identify high-risk predictors of OSA while controlling for obesity.	A total of 117 patients with T2DM.	Cross-sectional Survey Study	Epworth Sleepiness Scale (ESS)	---	Individuals with obesity (BMI ≥30 kg/m²) and those who report habitual snoring demonstrated an increased likelihood of OSA, with both factors emerging as significant predictors. In contrast, variables, such as age, daytime sleepiness, waist-to-hip ratio, and fasting blood glucose did not show meaningful associations with OSA risk in the reviewed study.	Studies focusing on obstructive sleep apnea reported that obesity and neck circumference served as independent risk factors, significantly increasing the likelihood of OSA among individuals with diabetes. After adjusting for obesity and other relevant covariates, such as age, sex, and height, neck circumference remained an independent and prominent predictor of OSA risk.
Grimaldi et al., 2014 USA	Association of obstructive sleep apnea in rapid eye movement sleep with reduced glycemic control in T2DM: therapeutic implications	To measure the effect of obstructive sleep apnea (OSA) during REM and NREM sleep on hemoglobin A1c (HbA1c) levels in individuals with T2DM	An analytical cohort consisting of 115 participants.	Cohort Study	Polysomnography (PSG) measurement Apnea-Hypopnea Index (AHI)	HbA1c, % (mean ± SD): * Overall: 7.36 ± 1.7 * With out OSA: 6.7 ± 1.3 With OSA: 7.4 ± 1.7)	In multivariate linear regression analyses, a higher REM-specific apnea–hypopnea index (REM AHI) was independently associated with increased HbA1c levels. While REM AHI showed a significant positive association with HbA1c ($p = 0.008$), the NREM AHI did not demonstrate a meaningful relationship ($p = 0.762$). When comparing REM AHI quartiles, the adjusted mean HbA1c rose from approximately 6.3% in the lowest quartile to 7.3% in the highest quartile, indicating a significant linear trend ($p = 0.044$).	In individuals with T2DM, REM-related obstructive sleep apnea (OSA) has been associated with poorer long-term glycemic control, the study reported that higher REM AHI values were independently associated with higher HbA1c levels Evidence also indicates that the metabolic benefits of CPAP therapy are closely linked to adequate nightly usage; therefore, the commonly observed adherence level of approximately four hours per night may be insufficient to achieve meaningful improvements in glycemic outcomes.
Wang et al., 2016 USA	Short-term Moderate Sleep Restriction Increases Insulin Concentration Following Oral Glucose Tolerance Test	To determine whether moderate sleep restriction has similar effects.	Fifteen healthy non-obese individuals	Randomized Controlled Study	*PSQI *Insulin resistance and sensitivity were evaluated via HOMA-IR, Matsuda Index, and QUICKI.	---	Sleep restriction did not meaningfully alter glucose levels or OGTT AUC values. In contrast, markers of insulin regulation were adversely affected: fasting insulin and insulin AUC were modestly, but significantly elevated, accompanied by higher fasting glucagon. Consistent with these hormonal changes, all insulin-resistance indices (HOMA-IR, Matsuda, QUICKI)	In healthy young adults, short-term moderate sleep restriction was associated with a measurable decline in insulin sensitivity when compared with unrestricted sleep, indicating an adverse metabolic response to reduced sleep duration.

							collectively indicated a reduction in insulin sensitivity following insufficient sleep.	
Tajiri et al., 2018 Japan	Effect of sleep curtailment on dietary behavior and physical activity: a randomized crossover trial	The aim was to clarify the effects of sleep restriction under free-living conditions on energy intake (EI) and physical activity.	16 healthy women aged 21–22 years.	Randomized crossover study	Evaluations: * Wristwatch-type accelerometer ** Tri-axial accelerometer *** Visual Analog Scale (VAS)	---	In healthy young adults, short-term moderate sleep restriction was associated with a measurable decline in insulin sensitivity when compared with unrestricted sleep, indicating an adverse metabolic response to reduced sleep duration.	The study suggests that shorter sleep duration is associated with several adverse behavioral and metabolic outcomes, including higher sedentary activity, increased fatigue, and elevations in cortisol and insulin. Although individuals with reduced sleep appeared to engage in more physical activity, this increase largely reflected extended wakefulness rather than meaningful improvements in activity levels. Notably, total energy intake did not differ substantially between sleep conditions.
Cros et al., 2019 Switzerland	Impact of sleep restriction on metabolic outcomes induced by overfeeding: a randomized controlled trial in healthy individuals	The aim is to evaluate whether sleep restriction exacerbates the effects of short- term overeating on intrahepatic lipid (IHL) concentrations and glucose homeostasis.	10 healthy voluntary participants	Randomized, crossover design	*PSQI *Morningness-Eveningness Questionnaire (MEQ)	---	The study found that overeating led to a substantial rise in intrahepatic lipid content and an increase in endogenous glucose production. Although sleep restriction shortened overall sleep duration, slow-wave sleep remained largely unaffected. When both conditions—overeating and sleep restriction—were combined, no additional effects on liver fat accumulation or glucose production were observed.	The study reported increased intrahepatic lipid content following overeating, with no additional effect of sleep restriction.
Abdissa, 2020 Ethiopia	Prevalence of obstructive sleep apnea risk and associated factors among patients with T2DM mellitus on follow-up at Jimma Medical Center, Southwest Ethiopia.	To assess the prevalence of OSA risk and related factors in T2DM patients.	253 patient	A hospital-based cross-sectional study.	The STOP BANG Survey	---	Among the 253 individuals with diabetes included in the study, nearly half were identified as being at elevated risk for obstructive sleep apnea based on the screening assessment.	A considerable proportion of participants demonstrated an elevated risk for obstructive sleep apnea. This risk was more pronounced among individuals with obesity (BMI ≥ 30 kg/m²), limited physical activity, larger neck circumference (> 40 cm), and the presence of hypertension. These characteristics The study reported a high prevalence of elevated OSA risk among individuals with T2DM.
Radcliffe et al., 2021 USA	Severe sleep restriction suppresses appetite independent of effects on appetite regulating hormones in healthy young men without obesity	The study aimed to assessed short-term sleep restriction effects on appetite, intake, hormones, and food choices.	18 healthy male participants	Randomized, Crossover study	* Leeds Food Preference Questionnaire (LFPQ) * Three-Factor Eating Questionnaire (TFEQ)	---	Following sleep restriction (SR), participants showed reductions in satiety, appetite control, and overall energy intake compared to periods of adequate sleep (AS). SR was also associated with a modest elevation in glucose concentrations (approximately 6%; $p \leq 0.01$). In contrast, levels of appetite-regulating hormones, including Peptide YY (PYY) and Glucagon-Like Peptide-1 (GLP-1), were lower after SR, indicating a shift toward impaired metabolic and hormonal regulation relative to adequate sleep.	The study reported reduced appetite and modest elevations in glucose following severe sleep restriction. In this context, studies consistently show that severe sleep restriction reduces appetite and overall energy intake. Interestingly, these changes occur despite having minimal effects on food preferences or appetite-regulating hormones. This pattern suggests that the suppression of appetite may operate through mechanisms other than the traditional hormonal pathways.

Zhang et al., 2025 China	Evaluating sleep's role in T2DM mellitus: evidence from NHANES	To Investigated associations between sleep factors/patterns and T2DM risk using NHANES data.	A total of 14,652 individuals aged 18 and older from NHANES (2005–2014).	Cross-sectional study	* Survey, physical exam, and lab data (NHANES) -- * SLQ items (Sleep Questionnaire) *HEI (Healthy Eating Index) * PIR (Poverty-Income Ratio) * SII (Systemic Immune-Inflammation Index) * PHQ-9 (Patient Health Questionnaire-9)	Sleep-related problems—including sleep disorders, sleep difficulties, and habitual sleep duration below seven hours—were consistently linked to a higher risk of developing type 2 diabetes. Overall, individuals with poor sleep patterns showed approximately a 50% increase in diabetes risk (OR≈1.52). These associations remained robust across different age groups and BMI categories, indicating that the relationship between inadequate sleep and T2DM risk is not confined to specific demographic or clinical subgroups.	Poor sleep patterns have consistently been associated with an increased risk of developing type 2 diabetes mellitus. This relationship the study reported that poor sleep patterns were associated with increased odds of T2DM (OR≈1.52). However, further well-designed prospective studies are required to clarify whether this association reflects a causal or bidirectional relationship and to elucidate the underlying molecular pathways linking sleep disturbances and T2DM risk.

Discussion

This systematic review highlights the effects of factors, such as sleep duration, quality, sleep disorders, and obstructive sleep apnea (OSA), on the glycemic control and other diabetes-related metabolic parameters in individuals with T2DM. These 24 studies conducted between 2010 and 2025, across different geographical regions, demonstrate an increasing interest in the sleep-diabetes relationship over time, providing significant findings about the depth of this interaction. While more recent studies have employed larger samples and more structured methodologies, variations in design and measurement approaches remain evident. Additionally, the methodological diversity and differences in sleep measurement techniques have led to some heterogeneity in the findings. This underscores the complexity of the relationship between sleep and diabetes, as well as the importance of individual differences.

The included studies showed substantial methodological diversity in terms of design, sample size, and measurement tools. As summarized in Table 1, the review included longitudinal, cross-sectional, cohort, descriptive, and experimental/quasi-experimental studies. Sleep-related variables were assessed using a range of subjective and objective instruments selected according to each study's aim. Detailed information regarding study design, instruments, metabolic variables, and the reported level of association between sleep parameters and T2DM-related outcomes is presented in Table 1.

Only a limited number of the included studies directly examined metabolic endpoints alongside sleep parameters. Most investigations focused primarily on glycemic indicators, such as HbA1c and fasting glucose, while fewer studies evaluated broader metabolic outcomes, such as lipid profiles or renal function. This variability in metabolic assessment reflects differences in study objectives and may partly explain inconsistencies observed across findings (Luyster & Dumbar-Jacob, 2011; Jin et al., 2012; Nakanishi-Minami et al., 2012; St-Onge et al., 2012; Song et al., 2013; Grimaldi et al., 2014).

The relationship between sleep duration and glycemic parameters is a frequently discussed topic in the literature. A small subset of studies suggested an association between both short and long sleep duration and unfavorable glycemic indicators, including higher HbA1c levels and markers of insulin resistance. However, given the limited number of studies and their predominantly observational designs, these findings should be interpreted cautiously and cannot establish a causal relationship (Jin et al., 2012; Sadosky et al., 2014). One study reported that shorter sleep duration was associated with higher HbA1c levels and indicators of impaired glucose regulation (Jin et al., 2012). While this finding contributes to the hypothesis of a possible U-shaped association between sleep duration and metabolic health, the evidence remains limited and cannot confirm this pattern. Furthermore, although some studies have explored potential differences across subgroups, including sex-based variations, the current evidence is insufficient to support definitive conclusions regarding gender-specific mechanisms.

In our study, the effect of sleep quality on glycemic control in individuals with diabetes emerges as one of the most important relationships. Several studies included in this review reported an association between poor sleep quality and suboptimal glycemic control, particularly elevated HbA1c levels. Sleep disturbances, such as fragmentation, frequent awakenings, and

delayed bedtimes, were described as factors accompanying poorer metabolic profiles. However, most of these findings were derived from cross-sectional analyses, limiting conclusions about directionality. The relationship between sleep quality and glycemic control may therefore be bidirectional, with metabolic dysregulation potentially impairing sleep continuity while disturbed sleep may further complicate diabetes management (Luyster & Dunbar-Jacob, 2011; Sadosky et al., 2014). In addition, one study focusing on painful diabetic neuropathy reported that increased pain severity was associated with poorer sleep quality and greater sleep disturbance (Sadosky et al., 2014). These findings suggest that sleep disruption may coexist with inadequate metabolic regulation, potentially complicating daily diabetes self-management. However, given the observational nature of these studies, the direction of this relationship remains unclear. A study conducted by Trento (2008) highlighted that effective diabetes education not only improved glycemic control, but also enhanced sleep quality, which had a positive impact on HbA1c levels (Trento et al., 2008). These findings suggest that educational interventions addressing metabolic control may also influence sleep-related outcomes.

Additionally, research demonstrating a significant relationship between obstructive sleep apnea and T2DM (Song et al., 2013) emphasized the mutual interaction of these conditions. The diversity of sleep-related factors in individuals with diabetes points to the multifaceted elements affecting sleep quality. Associations between nighttime eating behaviors and poorer sleep quality were also reported in studies included in this review (Hood et al., 2014; Cros et al., 2019). Interestingly, only one study (Luyster & Dumbar-Jacob, 2011) reported the positive effect of oral antidiabetics on sleep quality, suggesting that the potential secondary benefits of pharmacological treatments should be further investigated.

Sleep disturbances may also influence diabetes self-management behaviors. Some studies included in this review reported that individuals experiencing sleep problems demonstrated lower levels of physical activity and reduced adherence to treatment recommendations (Lai et al., 2013; Costa et al., 2014). In addition, painful diabetic peripheral neuropathy has been associated with increased sleep impairment and functional limitations (Gore et al., 2005). These findings suggest that sleep disruption and pain-related symptoms may coexist with challenges in daily diabetes management. However, given the observational design of most studies, these relationships should be interpreted cautiously. Rather than implying a direct causal pathway, the evidence indicates that sleep quality, neuropathic pain, and self-management behaviors may interact in a complex and potentially bidirectional manner.

Obstructive sleep apnea (OSA) is one of the sleep disorders that most negatively affects glycemic control in individuals with diabetes. One study reported an association between OSA severity and elevated HbA1c levels and insulin resistance (Sadosky et al., 2013). In addition to these findings, it has also been reported that more severe forms of OSA have more pronounced negative effects on metabolic health. Two studies reported that CPAP treatment for OSA management did not provide the expected level of improvement in glycemic control (Sadosky et al., 2013; Tasali et al., 2008). This finding suggests that issues with CPAP adherence and the timing of treatment initiation may limit its effects on glycemic control. OSA management may have implications beyond sleep quality, although its metabolic impact remains uncertain. To better understand the metabolic effects of OSA, it is necessary to have more detailed knowledge of how intermittent hypoxia and sympathetic activity contribute to disrupting glycemic control. For example, the effects of systemic inflammation and oxidative stress associated with OSA on metabolic health should be key focuses of research in this area. Furthermore, inconsistencies between different diagnostic methods for OSA (e.g., polysomnography, symptom questionnaires) affect the comparability of findings. This highlights the importance of standardizing diagnostic criteria.

The association between sleep disturbances and adverse metabolic outcomes in T2DM appears biologically coherent, but the reviewed evidence suggests that these mechanisms should be interpreted as interconnected rather than isolated processes. As outlined in Figure 1 and supported by the studies summarized in Table 1, sleep restriction, fragmentation, and sleep-disordered breathing may converge on a common pathway involving neuroendocrine disruption, intermittent hypoxia, sympathetic activation, and impaired glucose regulation. In this framework, altered leptin and ghrelin signaling may influence appetite and energy balance, reduced slow-wave sleep may impair insulin sensitivity, and sleep apnea-related hypoxemia

may further aggravate oxidative stress and inflammatory activity (Spiegel et al., 2004; Tasali et al., 2008; Punjabi et al., 2009; Punjabi et al., 2004). Rather than acting independently, these pathways may jointly increase insulin resistance, worsen glycemic variability, and contribute to broader metabolic dysregulation in individuals with T2DM. At the same time, the studies included in this review also suggest that the relationship may be bidirectional, since poor glycemic control, diabetes-related symptoms, and complications, such as neuropathic pain, may themselves disrupt sleep continuity and quality. Therefore, the sleep–metabolism relationship in T2DM is more appropriately understood as a reciprocal clinical process than as a simple one-directional mechanism. However, most mechanistic evidence has been derived from experimental or non-diabetic populations, and direct extrapolation to individuals with established T2DM should therefore be made with caution.

Our findings are broadly consistent with previous systematic reviews examining sleep parameters and glycemic control in individuals with T2DM. For example, Azharuddin et al. (2020) conducted a meta-analysis of observational studies in Asian populations and reported a significant association between short sleep duration and poorer glycemic control, particularly elevated HbA1c levels. While their analysis primarily focused on sleep duration and glycemic indices, the present review expands the scope by incorporating sleep quality, sleep disorders, obstructive sleep apnea, and neuropathic pain-related sleep disturbances.

In addition, a systematic review conducted by Abate et al. (2024) reported a high prevalence of poor sleep quality among individuals with diabetes. Unlike prevalence-focused reviews, our study not only examined the occurrence of sleep disturbances, but also explored their associations with multiple metabolic parameters. Together, these findings reinforce the multifactorial nature of the sleep–diabetes relationship while highlighting the need for more standardized and longitudinal research designs.

Implications for Nursing

The findings of this review suggest that sleep should be considered an important component of nursing assessment and diabetes care in individuals with T2DM. Because poor sleep quality, abnormal sleep duration, and sleep-related breathing problems were frequently associated with less favorable glycemic and metabolic outcomes, nurses may play a key role in identifying sleep-related problems during routine follow-up and patient education. In clinical practice, incorporating basic sleep assessment into diabetes care may help nurses detect potentially modifiable factors that could affect glycemic control, self-management, and quality of life.

In addition, nurses are well positioned to provide education on sleep hygiene, daily routines, symptom monitoring, and adherence to diabetes management recommendations. Particular attention may be needed for patients who report insomnia symptoms, fragmented sleep, excessive daytime sleepiness, neuropathic pain, or possible obstructive sleep apnea. Early recognition and appropriate referral of such problems may contribute to more comprehensive and patient-centered diabetes care. Although the current evidence remains heterogeneous, the findings support the inclusion of sleep-related considerations in nursing practice, especially in the ongoing management of adults with T2DM.

Limitations

This systematic review has several limitations that should be considered when interpreting the findings. First, although study selection and data extraction were conducted by two reviewers, no formal measure of independent reviewer agreement (e.g., inter-rater agreement statistics) was reported. Therefore, the transparency and reproducibility of the selection and extraction process may be considered limited. Second, no official or standardized assessment of the quality of evidence provided by the included studies was conducted, such as a structured risk-of-bias tool or an evidence-grading framework. As a result, the overall strength of the evidence could not be evaluated according to methodological rigor. In addition, the studies included in this review used heterogeneous methods to assess sleep quality and related sleep variables, which reduced comparability across findings. Variations in sample characteristics, study settings, and healthcare contexts may also have contributed to inconsistencies in the reported results. Future systematic reviews should incorporate standardized quality appraisal methods and more explicit procedures for independent reviewer agreement in order to strengthen methodological transparency and interpretability.

Conclusion and Recommendations

The treatment of sleep disorders is crucial for improving diabetes management, and further research is needed in this area. Combining psychological treatments, sleep therapies, and lifestyle changes may enhance the positive effects on metabolic health. In this context, future studies should focus on the detailed examination of the relationships between sleep disorder management and diabetes treatment. Improving sleep quality can potentially make diabetes management more effective.

As a result, the relationship between sleep quality, sleep duration, and diabetes can both trigger metabolic disorders and contribute to the worsening of existing diabetes. This highlights the importance of not overlooking sleep disorders in diabetes treatment and suggests that improving sleep patterns could be a vital strategy for achieving better glycemic control in patients. Future research should explore the interactions between sleep, diabetes, and psychosocial factors more thoroughly, paving the way for the development of more effective treatment approaches.

Declaration

Ethics approval and consent to participate: Not applicable. This study is a systematic review based exclusively on previously published studies and did not involve recruitment of human participants, data collection from individuals, or access to identifiable personal data. Ethical considerations therefore relate to the primary studies included in the review.

Data Availability

No datasets were generated or analysed during the current study.

Conflict of Interests

The authors declare no conflict of interests.

Author Contributions

Study Design: **DT**. Data Collection: **DT, EK**. Data Analysis: **DT, EK**. Study Supervision: **EK**. Manuscript Writing: **DT, EK, EB**. Critical Revision for Important Intellectual Content: **EK**.

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