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Age-specific patterns of obesity and sleep quality in newly diagnosed type 2 diabetes mellitus: A cross-sectional, multicenter, observational study

Abstract

Background: Obesity and poor sleep quality are common comorbidities in type 2 diabetes mellitus (T2DM) and may vary across age groups. However, age-specific patterns and the factors associated with these conditions in newly diagnosed T2DM remain insufficiently characterized. Understanding these patterns may support more individualized assessment and early intervention at the time of diagnosis.

Aim: Obesity and poor sleep quality are common yet under-recognized comorbidities in type 2 diabetes mellitus (T2DM). This study aimed to evaluate age-specific patterns of obesity and sleep quality among newly diagnosed T2DM patients and to examine the relationship between these variables across different age groups.

Methods: This multicentric, cross-sectional study enrolled adults aged 18–80 years with newly diagnosed T2DM from 17 centers across India (October 2023–April 2024). Participants were categorized into three age groups (18–40, 41–50, and >50 years). Anthropometric measurements, glycemic indices, lifestyle factors, and Epworth Sleepiness Scale (ESS) scores were recorded. Obesity was defined as BMI ≥27.6 kg/m² (Asian criteria) and poor sleep as ESS ≥10. Associations were analyzed using ANOVA, chi-square tests, Pearson correlation, and multiple imputation by chained equations (MICE)-based mixed-effects logistic regression.

Results: Among 591 participants, obesity was most prevalent in the youngest group (56.8%), whereas poor sleep was highest in the oldest group (20.4%). BMI showed a significant positive correlation with ESS scores ($p<0.001$). Poor sleep was independently associated with self-employment (AOR 2.70), grade 2 hypertension (AOR 5.80), and frequent alcohol use (AOR 4.18). Male sex (AOR 0.40) and not being in paid employment (AOR 0.52) were associated with lower odds of obesity, while grade 1 hypertension, smoking, and family history of diabetes were associated with higher obesity risk. Age was not independently associated with either outcome after adjustment.

Conclusion: Obesity is more common in younger adults, whereas poor sleep is more frequent in older adults with newly diagnosed T2DM. However, metabolic, occupational, and behavioral factors are more strongly associated with obesity and poor sleep than age alone, supporting early individualized assessment of weight status, sleep quality, cardiovascular risk, and modifiable lifestyle factors at the time of diagnosis.

Keywords: type 2 diabetes mellitus, obesity, sleep quality, epworth sleepiness scale, age-specific patterns, hypertension, lifestyle factors, India

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Introduction

The latest data from the 2025 IDF Diabetes Atlas highlights the escalating impact of diabetes on individuals, families, and nations. Around 11% of adults aged 20–79 years, equivalent to 1 in 9 individuals, are living with diabetes, with more than 40% unaware of their condition. Projections indicate that by 2050, approximately 1 in 8 adults (around 853 million individuals) will have diabetes, marking a 46% increase. More than 90% of diabetes cases are type 2, primarily influenced by a combination of socioeconomic, demographic, environmental, and genetic factors. Key drivers of this increase include urbanization, an aging population, reduced physical activity, and increasing rates of overweight and obesity.[1]

Emerging evidence highlights the important role of sleep in metabolic health. Both sleep duration and quality appear to significantly influence metabolic outcomes, including obesity, insulin resistance, and metabolic syndrome.[2–4] Experimental evidence has also demonstrated that prolonged sleep restriction and circadian disruption can adversely affect glucose metabolism and insulin sensitivity.[3] Sleep quality is closely associated with obesity, and this relationship may reflect a complex metabolic phenotype involving adiposity, altered lipid metabolism, and other cardiometabolic risk factors.[4,5] In patients with T2DM, obesity is frequently associated with sleep-disordered breathing, particularly obstructive sleep apnea, which can further impair sleep quality.[5] Poor sleep quality has also been associated with diabetic complications and adverse metabolic parameters in individuals with T2DM.[6] Short sleep duration and reduced sleep efficiency have been linked to higher BMI and central obesity, suggesting a bidirectional relationship between sleep disturbances and adiposity.[7]

The interplay between obesity, sleep quality, and metabolic dysfunction may vary across age groups. Identifying age-specific patterns may therefore provide clinically relevant information for early risk assessment and individualized intervention. The present

study aimed to investigate age-specific patterns of obesity and sleep quality in patients with newly diagnosed T2DM and to explore the relationship between these factors across different age groups. Understanding these patterns may help in developing personalized screening and intervention strategies based on patient age.

Methods

Study design and participants

This multicentric, cross-sectional observational study was conducted at 17 sites across India over a period of six months, from October 2023 to April 2024. The study sites comprised a mix of private clinics, standalone diabetes care centers, and hospital-based outpatient departments, representing both primary and secondary levels of healthcare. While the majority of centers were located in the Mumbai Metropolitan Region (including Mumbai, Navi Mumbai, Thane, Virar, and Mira Road), additional participating sites were based in Indore (Madhya Pradesh), Patiala (Punjab), and Lucknow (Uttar Pradesh), ensuring a broader geographic representation.

Inclusion criteria were based on the American Diabetes Association (ADA) diagnostic guidelines for T2DM, defined as HbA1c ≥6.5% or fasting plasma glucose ≥126 mg/dL.[8] Participants were required to be 18–80 years of age and have complete baseline data available. Exclusion criteria included individuals below 18 years of age; those diagnosed with other forms of diabetes such as type 1 diabetes, maturity-onset diabetes of the young (MODY), or gestational diabetes mellitus (GDM); and those with preexisting major medical illnesses such as cardiac disease, chronic kidney or liver disease, cerebrovascular accidents, or psychiatric disorders, including individuals on medications for these conditions. Also excluded were patients with preexisting respiratory diseases such as asthma or chronic obstructive pulmonary disease (COPD), and immune-mediated conditions like rheumatoid arthritis or connective tissue disorders, especially those treated with steroids or biologics. Individuals with a history of cancer or those who had undergone chemotherapy were also excluded, along with those diagnosed with sleep disorders prior to T2DM diagnosis, those on medications affecting weight or sleep, and pregnant women. Eligible participants were stratified into three age groups (18–40, 41–50, and above 50 years) to explore age-related trends in obesity and sleep quality.

Treatment was initiated according to ADA guidelines, with patients managed through lifestyle modifications, pharmacotherapy, or a combination of both, depending on their HbA1c status and associated comorbidities.

Data collected included anthropometric parameters (BMI), glycemic indices (HbA1c, fasting and postprandial blood glucose), Epworth Sleepiness Scale (ESS) scores for assessment of sleep quality, and self-reported physical activity levels. Obesity was defined as a BMI of 27.6 kg/m² or higher, in accordance with criteria adapted for Asian populations.

Anthropometric measurements, blood pressure and laboratory investigations

Height was measured using a calibrated Seca 213 Portable Stadiometer (seca GmbH & Co. KG, Germany), with participants standing upright without shoes. Weight was measured using a calibrated OMRON weighing scale (OMRON Healthcare, India). BMI was calculated as weight in kilograms divided by height in metres squared (kg/m²). Waist circumference was measured using a non-stretchable measuring tape at the midpoint between the lowest rib and the iliac crest, with the participant standing upright and at the end of normal expiration.

Blood pressure was measured using a calibrated oscillometric automated digital upper-arm BP monitor (OMRON Healthcare, India), with the participant seated and rested for at least 5 minutes before measurement. The appropriate cuff size was selected according to the participant's arm circumference. Blood pressure was measured with the arm supported at heart level, and the procedure was performed according to standardised measurement practices.

Laboratory investigations were performed at Dr Lal PathLabs, India. The laboratory is accredited by the National Accreditation Board for Testing and Calibration Laboratories (NABL) under ISO 15189 standards, including its National Reference Laboratory in New Delhi (Certificate No. MC-2113). Blood samples were collected using standard phlebotomy procedures and processed according to the laboratory's validated standard operating procedures.

The study protocol was reviewed and approved by the Institutional Ethics Committee (No: MED/DrSP/2023/DECODE-T2D), and all participants provided written informed consent.

Statistical analysis

Data were analyzed using IBM SPSS Statistics version 30.0.0.0 and R version 4.6.0. Multiple imputation, mixed-effects logistic regression and model diagnostics were performed in R using the mice, lme4, car, pROC, DHARMa and performance packages. Continuous variables were expressed as mean ± standard deviation and categorical variables as frequencies and percentages. Comparisons across the three age groups were performed using one-way analysis of variance (ANOVA) for continuous variables and chi-square tests for categorical variables, with post hoc analyses conducted when ANOVA results were significant. Pearson correlation analysis was used to evaluate the relationship between BMI and ESS scores. The association was further visualized using a scatter plot with a regression line.

Two binary outcomes were analyzed using mixed-effects logistic regression models, a form of generalized linear mixed model (GLMM) with a logistic link: poor sleep, defined as ESS ≥10, and obesity, defined as BMI ≥27.6 kg/m². The ESS total score was calculated by summing the eight ESS items, each scored from 0 to 3. Participants with ESS <10 were coded as 0 and participants with ESS ≥10 were coded as 1. Obesity was coded as 0 for non-obese and 1 for obese.

Missing data were handled using multiple imputation by chained equations (MICE). For the poor sleep analysis, participants with complete ESS data and participants with partially missing ESS items were included, while participants missing all eight ESS items were excluded from the ESS regression analysis because the ESS module was not completed and the outcome could not be reliably derived. Missing ESS items were imputed at item level using classification and regression tree imputation, and the ESS total score and ESS ≥10 outcome were derived within each imputed dataset. For the obesity analysis, the obesity outcome was not imputed. Four implausible BMI values were corrected using verified corrected BMI values from the source data. Since all corrected BMI values were below the obesity cutoff, these participants were classified as non-obese and retained in the obesity analysis. Missing predictor values were imputed using classification and regression tree imputation. Twenty imputed datasets were generated for each primary model.

A formal a priori sample-size calculation was not performed. The achieved sample comprised 591 participants enrolled across 17 centers during the predefined study period from October 2023 to

April 2024. Model stability for the subsequent multivariable analyses was assessed based on the number of outcome events relative to the number of estimated predictor parameters.

Model-building strategy was determined separately for each outcome based on clinical relevance and the number of outcome events relative to the number of model parameters. For the poor sleep model, the final model was restricted to self-employment, grade 2 hypertension and frequent alcohol use to improve model stability. Across the imputed datasets, there were 74–81 poor sleep events, giving an approximate events-per-variable ratio of 24.7–27.0. For the obesity model, all prespecified clinically relevant predictors were entered together because the number of obesity events was sufficient relative to the number of model parameters. The obesity model included 281 events and approximately 16 fixed-effect parameters, giving an approximate events-per-variable ratio of 17.6. Study center was included as a random intercept in both models to account for the multicentric study design.

Adjusted odds ratios, 95% confidence intervals and p values were reported. Estimates from the imputed datasets were pooled using Rubin's rules. Complete-case mixed-effects logistic regression analyses were performed as sensitivity analyses. Bonferroni correction was applied to exploratory univariate comparisons to reduce the risk of false positive findings, with a corrected significance threshold of P <0.003 based on 17 comparisons. Additional Bonferroni correction was not applied to the final multivariable regression models because these models included clinically relevant and pre-selected predictors and were interpreted as adjusted association models. For multivariable models, two-sided P values <0.05 were considered statistically significant.

Model diagnostics included variance inflation factors or adjusted generalized variance inflation factors, ROC-AUC, Brier score, calibration plots, DHARMa simulated residual diagnostics, center-level variance, intraclass correlation coefficient and Nakagawa marginal R^2. Marginal R^2 was used to describe the explanatory power of the fixed effects in the mixed-effects logistic regression models. Conditional R^2 was assessed but was not reported as a numerical value when the center-level random-intercept variance was zero or near-zero.

Results

The study analyzed 591 patients with T2DM, categorized into three age groups: <40 years (36.2%), 41–50 years (27.7%), and >50 years (36%). Demographic analysis revealed that the <40 years group had a higher proportion of females (62.6%), whereas the >50 years group had more males (54.5%; P = 0.002). The mean weight was highest in the <40 years group (75.3 ± 13.9 kg) and lowest in the >50 years group (70.2 ± 13.9 kg; P = 0.001). The mean BMI was comparable across age groups (overall 28.7 ± 10.6; P = 0.072), with 74.6% of participants classified as overweight or obese (grades II–IV).

Glycemic control markers, including HbA1c, fasting blood sugar (FBS), and postprandial blood sugar (PPBS), showed no statistically significant differences across age groups. The overall mean HbA1c was 9.3 ± 2.3% (P = 0.728). The mean FBS was 193.4 ± 73.6 mg/dL (P = 0.946), and PPBS was 276.3 ± 104.8 mg/dL (P = 0.534), with 80.4% and 92.1% of patients having values above the diabetic range (>125 mg/dL and >140 mg/dL, respectively).

HDL cholesterol levels showed a marginal difference across age groups, with the lowest levels in the 41–50 years group (40.7 ± 7.1 mg/dL) and the highest levels in the >50 years group (45.4 ± 10.0 mg/dL; p = 0.004); however, this did not meet the Bonferroni-corrected threshold for exploratory univariate comparisons. Vegetarianism (includes eggitarian) was most common in the >50 group (43.7%), and least in the <40 group (22.4%), with a significant trend (P < 0.001). Conversely, non-vegetarian diets were more prevalent in younger individuals, especially the <40 group (75.2%) (Table 1).

Table 1 Sociodemographic and clinical characteristics of newly diagnosed T2DM patients stratified by age groups (<40, 41–50, and >50 years)

Variable	Overall (n=591)	<40 years (n=214)	41–50 years (n=164)	50+ years (n=213)	P-value
Age (years, mean ± SD)	46.7 ±12.4	34.1± 4.6	45.6± 2.9	60.2 ±7.3	<0.001*
Male (n, %)	271 (45.9%)	80 (37.4)	75 (45.7)	116 (54.5)	0.002
Female (n, %)	320 (54.1%)	134 (62.6)	89 (54.3)	97 (45.5)	
Weight (kg, mean ± SD)	73.0 ± 14.1	75.3 ± 13.9	73.6 ± 13.9	70.2 ± 13.9	0.001*
BMI (mean ± SD)	28.7 ± 10.6	29.9 ± 15.2	28.8 ± 8.4	27.5 ± 4.4	0.072*
HbA1c (% mean ± SD)	9.3 ± 2.3	9.4 ± 2.2	9.2 ± 2.3	9.4 ± 2.5	0.728*
FBS >125 mg/dL (mean ± SD)	193.4 ± 73.6	192.1 ± 66.6	194.0 ± 74.2	194.3 ± 79.8	0.946*
PPBS >140 mg/dL (mean ± SD)	276.3 ± 104.8	270.7 ± 98.2	275.7 ± 100.8	282.2 ± 113.9	0.534*
HDL cholesterol (mean ± SD)	43.3 ± 9.0	43.3 ± 9.0	40.7 ± 7.1	45.4 ± 10.0	0.004
Vegetarian (eggetarian + vegetarian) (%)	31.80%	22.40%	26.20%	43.70%	<0.001
Non-vegetarian (mixed + non-vegetarian) (%)	66.80%	75.20%	70.10%	55.90%	
Education (%)					
Uneducated / no formal schooling	5.10%	1.00%	5.40%	9.20%	<0.001
Up to primary school	3.80%	2.60%	2.70%	5.90%	
Up to middle school	9.30%	6.20%	9.50%	12.40%	
Up to high school	17.40%	13.80%	16.20%	22.20%	
Intermediate or post high school diploma	6.10%	7.70%	4.70%	5.40%	
Graduate general	31.80%	32.30%	31.80%	31.40%	
Graduate professional	13.30%	19.00%	14.20%	6.50%	
Postgraduate - general	7.00%	9.20%	8.10%	3.80%	

Citation: Patil S, Bagri SA, Shah T, et al. Age-specific patterns of obesity and sleep quality in newly diagnosed type 2 diabetes mellitus: A cross-sectional, multicenter, observational study. *J Diabetes Metab Disord Control.* 2026;13(2):106–114. DOI: 10.15406/jdmdc.2026.13.00320

Table 1 Continued.....

Post-graduate professional	5.90%	7.70%	6.80%	3.20%	
PhD or doctorate	0.40%	0.50%	0.70%	--	
Occupation (%)					
Government employee	2.80%	1.00%	4.70%	3.20%	<0.001
Housewife	30.10%	16.20%	28.90%	45.70%	
Private employee	35.00%	48.70%	40.90%	15.60%	
Self-employed	17.10%	19.30%	16.10%	15.60%	
Unemployed	0.60%	0.50%	0.70%	0.50%	
Retired	5.30%	--	0.70%	14.50%	
Others	9.60%	14.60%	8.70%	6.30%	
Blood pressure categorization (%)					
Optimal BP (135/80 mmHg)	39.00%	46.90%	34.80%	34.30%	0.047
High normal BP (130-139/85-89 mmHg)	23.60%	23.50%	26.20%	21.60%	
Grade 1 hypertension (140-159/90-99 mmHg)	27.80%	21.10%	29.30%	33.30%	
Grade 2 hypertension (>160/>100 mmHg)	9.70%	8.50%	9.80%	10.80%	
Smoking status (%)					
Yes	15.90%	23.20%	13.20%	10.70%	0.002
No	84.10%	76.80%	86.80%	89.30%	
Family history of diabetes (%)					
No	37.00%	26.90%	32.30%	50.70%	<0.001
Yes	63.00%	73.10%	67.70%	49.30%	
Hypertension (%)					
Yes	28.80%	11.20%	23.00%	50.00%	<0.001
No	71.20%	88.80%	77.00%	50.00%	
Cardiovascular disease / ischemic heart disease (%)					
Yes	2.20%	1.10%	--	4.80%	0.006
No	97.80%	98.90%	100.00%	95.20%	
Stroke (%)					
Yes	2.40%	--	0.70%	5.90%	<0.001
No	97.60%	100.00%	99.30%	94.10%	

*One-way ANOVA for continuous variables and Chi-squared test for all other categorical variables

Education levels also showed statistically significant differences ($P < 0.001$). The highest proportion of individuals with no formal schooling was in the >50 group (9.2%), while younger participants (<40 years) had higher representation in professional and postgraduate education categories. Occupation patterns revealed that younger adults were more likely to be private employees, while housewives (45.7%) and retirees (14.5%) dominated the older group ($P < 0.001$) (Table 1).

Blood pressure classification showed an age-related pattern, with optimal blood pressure being more common in the younger group (<40 years: 46.9%) than in older individuals (>50 years: 34.3%). The prevalence of grade 1 and grade 2 hypertension increased with age ($P = 0.047$); however, this association did not meet the Bonferroni-corrected significance threshold. Smoking was more prevalent in the younger age group (23.2%) and declined steadily with age ($P = 0.002$). A positive family history of diabetes was more common among younger individuals (73.1% in the <40 years group) than in the >50 years group (49.3%), demonstrating a significant inverse relationship with age ($P <0.001$). Hypertension was present in 50% of participants in the >50 years group compared with 11.2% in the <40 years group ($P <0.001$). Cardiovascular disease/ischemic heart disease showed a nominal increase with age ($P = 0.006$), whereas stroke was significantly more prevalent among older adults ($P <0.001$) (Table 1).

Comparison of age-specific patterns revealed that the prevalence of obesity was highest in the youngest group (18–40 years) at 56.8%, followed by 51.1% in >50 years and 50.6% in the 41–50 years group. Poor sleep quality, assessed using the ESS, was reported most frequently in the oldest group (>50 years) at 20.4%, compared to 16.7% and 11.9% in the 18–40 and 41–50-year groups, respectively. Mean HbA1c levels were comparable across all age groups, ranging from 9.2% to 9.4%, indicating similar levels of glycemic dysregulation at diagnosis.

Regular physical activity was least common among participants aged 41–50 years (20.3%), followed by the youngest group (<40 years; 22.4%), and was most common among those aged >50 years (29.4%). However, the differences across age groups were not statistically significant ($P = 0.186$; Supplementary Table 1 and Figure 1).

The correlation analysis using scatter plot with a regression line demonstrated a statistically significant positive correlation between BMI and ESS scores ($P <0.001$), indicating that individuals with higher BMI tend to report greater daytime sleepiness. Additionally, a significant positive association was observed between obesity and poor sleep quality across all age groups ($P < 0.001$) (Figure 1). Patients with BMI ≥27.6 kg/m² were more likely to have ESS scores ≥10, suggesting clinically relevant sleep disturbances. This trend remained consistent across age categories (Figure 2).

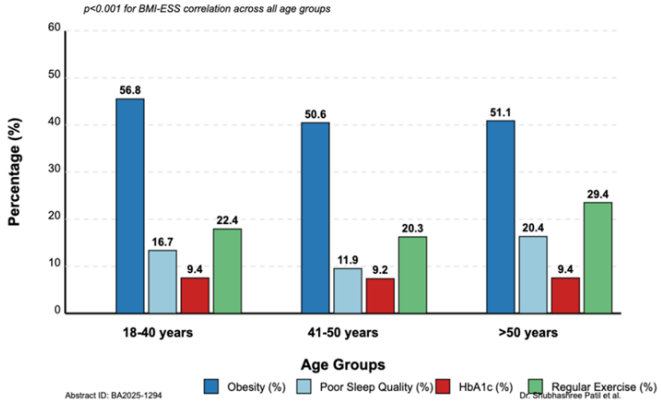

Figure 1 Age-specific patterns of obesity, poor sleep quality, regular exercise and HbA1c in patients with newly diagnosed T2DM.

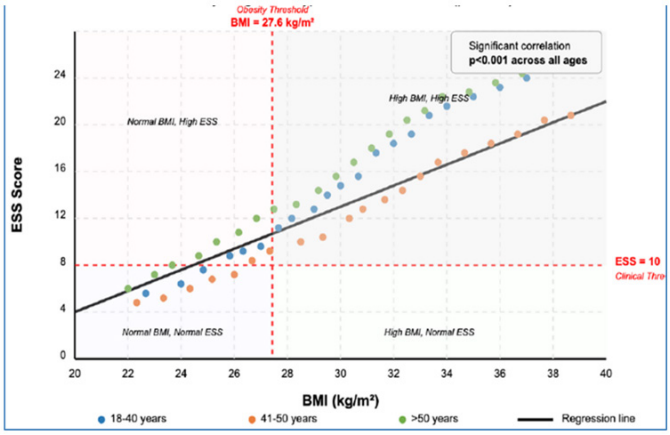

Figure 2 Correlation between BMI and ESS in newly diagnosed T2DM.

The study also evaluated several sociodemographic and clinical factors that influence obesity and sleep quality across age groups. Higher education levels (graduate/professional or postgraduate) and employment in the private sector were significantly more common in the <40 group, while the 50+ group was predominantly composed of housewives and retired individuals (P < 0.001). Younger patients had a higher prevalence of optimal blood pressure than those aged >50 years (46.9% vs. 34.3%; P = 0.047); however, this association did not meet the Bonferroni-corrected significance threshold. Smoking was more prevalent in the younger age group than in the >50 years group (23.2% vs. 10.7%; P = 0.002) (Table 1).

A positive family history of diabetes was more common among participants aged 18–40 years than among those aged >50 years (73.1% vs. 49.3%; P <0.001). Hypertension was more prevalent in older adults (50.0% in the >50 years group vs. 11.2% in the 18–40 years group; P <0.001). Cardiovascular disease/ischemic heart disease showed a nominal increase with age (4.8% vs. 1.1%; P = 0.006), whereas stroke was significantly more prevalent among older adults (5.9% in the >50 years group; P <0.001). The 41–50-year age group had the lowest mean HDL cholesterol level (40.7 mg/dL), compared with the >50 years group (45.4 mg/dL; P = 0.004); however, this difference did not meet the Bonferroni-corrected significance threshold (Table 1).

Individuals aged 50 years and above had the highest mean waist circumference (95.8 cm vs. 93.2 cm in those under 40 years), although the difference was not statistically significant (P = 0.495). Younger participants (<40 years) reported more frequent alcohol use (8.5% vs. 3.3% in the 50+ group; P = 0.367), whereas regular physical activity was more common among older adults (29.4% vs. 22.4%; P = 0.186) (Supplementary Table 2). Cost was a common barrier to choosing allopathy across all age groups (11.3% overall), with slightly greater concern among those aged 50 and above (12.1% vs. 10.1%; P = 0.801). Younger individuals were more likely to prefer lifestyle changes before initiating medication (0.5% vs. 0% in the 41–50 age group; P = 0.681) (Supplementary Table 3). Older adults (>50 years) more often perceived allopathy as effective (40.8% vs. 28.7% in those under 40 years; P = 0.023), but this did not meet the Bonferroni-corrected threshold. Family and social influence affected treatment choices across age groups but was more pronounced among younger participants (44.0% vs. 36.2%; p = 0.238). While a majority of participants (98.1%) rejected traditional therapies, refusal was highest among those aged >50 years (100% vs. 96.3–97.7% in younger groups; p = 0.458), possibly due to prior experiences or stronger trust in allopathy.

For the poor sleep analysis, 531 participants were included in the primary model, comprising 471 participants with complete ESS data and 60 participants with partially missing ESS items that were handled using item-level MICE. Sixty participants with all eight ESS items missing were excluded from the ESS regression analysis because the ESS module was not completed and the outcome could not be reliably derived. For the obesity analysis, the primary model included 551 participants with observed or corrected obesity outcome data; four implausible BMI values were corrected using verified source data and retained as non-obese.

The primary mixed-effects logistic regression analysis with multiple imputation (MICE + GLMM) identified three factors associated with higher odds of poor sleep (ESS ≥10). Self-employment was associated with increased odds of poor sleep (AOR 2.70, 95% CI 1.48–4.92; P = 0.001), as was grade 2 hypertension (AOR 5.80, 95% CI 2.93–11.48; P <0.001) and frequent alcohol use (AOR 4.18, 95% CI 1.68–10.41; P = 0.002). Grade 2 hypertension demonstrated the strongest association with poor sleep. Summary estimates are presented in Table 2, and full model estimates are presented in Supplementary Table 4.

Table 2 Significant adjusted associations from the primary mixed-effects logistic regression models

Outcome	Predictor	AOR	95% CI	p value
Poor sleep (ESS ≥10)	Self-employed vs others	2.7	1.48–4.92	0.001
	Grade 2 hypertension vs others	5.8	2.93–11.48	<0.001
	Frequent alcohol use vs never/occasional alcohol use	4.18	1.68–10.41	0.002
Obesity	Male vs female	0.4	0.24–0.67	<0.001
	Not currently in paid employment vs employed for wages	0.52	0.28–0.95	0.032
	Grade 1 hypertension vs optimal blood pressure	1.58	1.01–2.47	0.047
	Smoker vs non-smoker	1.96	1.13–3.39	0.016
	Family history of diabetes vs no family history	1.6	1.09–2.34	0.016

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For obesity, male sex was associated with lower odds of obesity (AOR 0.40, 95% CI 0.24–0.67; P <0.001), and not currently being in paid employment was also associated with lower odds of obesity (AOR 0.52, 95% CI 0.28–0.95; P = 0.032). In contrast, grade 1 hypertension (AOR 1.58, 95% CI 1.01–2.47; P = 0.047), smoking (AOR 1.96, 95% CI 1.13–3.39; p = 0.016) and family history of diabetes (AOR 1.60, 95% CI 1.09–2.34; P = 0.016) were associated with higher odds of obesity. Complete multivariable model results are provided in Supplementary Table 5.

Sensitivity analyses using complete-case mixed-effects logistic regression models yielded generally similar findings (Supplementary Table 6). Self-employment and grade 2 hypertension remained significantly associated with poor sleep, whereas the association between frequent alcohol use and poor sleep was attenuated and did not reach statistical significance. For obesity, male sex and not being in paid employment remained significantly associated with lower odds of obesity in both the primary and complete-case analyses.

Model performance and diagnostic measures are summarized in Supplementary Table 7. The primary poor sleep and obesity models demonstrated modest discrimination, with ROC-AUC values of 0.692 and 0.658, respectively. The corresponding Brier scores were 0.114 and 0.232, respectively. Multicollinearity diagnostics indicated minimal collinearity, with a VIF range of 1.01–1.03 for the poor sleep model and a maximum adjusted GVIF of 1.49 for the obesity model. The center-level variance and intraclass correlation coefficients were close to zero, indicating minimal between-center variability after adjustment. The marginal R^2 values were 0.128 for the poor sleep model and 0.091 for the obesity model, indicating modest explanatory power. Corresponding marginal R^2 values in the complete-case analyses were 0.082 and 0.084, respectively. Diagnostic plots, including ROC curves, calibration plots and DHARMa residual analyses, are presented in Supplementary Figures 1 and 2.

Only statistically significant predictors from the primary MICE + GLMM models are shown. Full multivariable model results, complete-case sensitivity analyses and diagnostic summaries are provided in the supplementary material. AOR, adjusted odds ratio; CI, confidence interval; ESS, Epworth Sleepiness Scale; MICE, multiple imputation by chained equations; GLMM, generalized linear mixed model. Poor sleep was defined as ESS ≥10. Obesity was defined as BMI ≥27.6 kg/m^2. Study center was included as a random intercept.

Discussion

The study highlights distinct age-related patterns among newly diagnosed patients with T2DM. Young adults aged 18–40 years demonstrated the highest prevalence of obesity and higher BMI, while individuals aged 41–50 years showed intermediate obesity prevalence and lower physical activity levels. Older adults aged >50 years showed higher ESS-defined poor sleep, despite a lower mean BMI. A positive association was observed between BMI and ESS scores, suggesting that higher BMI may be linked to increased daytime sleepiness. However, the adjusted models indicated that age alone was not the main explanatory factor. Instead, the observed differences in obesity and ESS-defined poor sleep appeared to be influenced by modifiable metabolic, occupational and behavioral factors, including hypertension, employment status, alcohol use, smoking and family history of diabetes.

Sleep disturbances and altered metabolic parameters are increasingly recognized as significant factors in the progression and management of T2DM. Recent literature highlights a strong interrelationship between sleep quality, sleep duration, obesity, and glycemic control among patients with T2DM, often compounded by age-related changes. Arora et al.,[9] conducted a cross-sectional study involving 146 newly diagnosed T2DM patients, using a 7-day sleep diary, a sleep questionnaire, and the Homeostatic Model Assessment of Insulin Resistance (HOMA2-IR) standardized technique to assess sleep quality and metabolic health. They demonstrated that sleep quality, particularly the frequency of night awakenings, was directly associated with higher BMI and indirectly linked to increased insulin resistance. In contrast, sleep duration did not show a significant association with either BMI or insulin resistance, suggesting that poor sleep quality may contribute to metabolic dysfunction, with BMI potentially influencing the relationship between sleep disturbances and insulin resistance.[9] Similarly, the Fukuoka Diabetes Registry-based study by Ohkuma et al. included 4,870 patients with T2DM and used self-reported sleep duration data to analyze associations with glycemic control and BMI. This large-scale observational study noted a U-shaped association where both short and long sleep durations correlated with poorer glycemic control and higher BMI. The study also revealed a significant interaction between sleep duration and either age or insulin use in relation to HbA1c levels.[10]

Foster et al.,[11] conducted a cross-sectional study involving 306 obese patients with T2DM, using overnight polysomnography to diagnose obstructive sleep apnea (OSA). The researchers reported a significantly high prevalence of undiagnosed OSA, linking obesity and sleep-disordered breathing with impaired glucose metabolism.[11] Similarly, Sokwalla et al.,[12] conducted a comparative cross-sectional study with 223 ambulant individuals with T2DM in Kenya, using the Berlin Questionnaire to assess OSA risk and Pittsburgh Sleep Quality Index (PSQI) to evaluate sleep quality. The study findings also noted increased risk of OSA and reduced sleep quality, further supporting the metabolic-sleep interaction.[12]

Rosique-Esteban et al.,[13] in the PREDIMED-Plus trial, analyzed data from 1,986 community-dwelling older adults with overweight/obesity and T2DM, using accelerometry-derived sleep parameters. Their cross-sectional analysis confirmed associations between sleep characteristics and both obesity and T2DM, indicating a significant relationship between sleep duration and variability with the risk of T2DM.[13] Their findings add robust support to the evidence that sleep interventions may serve as potential targets for metabolic improvements.

In the current cohort of young adults (18–40 years), the highest burden of obesity was noted, along with moderate sleep disturbances. This group also showed a higher prevalence of smoking, elevated BMI, and strong family history of diabetes. These findings highlight the need for early, targeted interventions focusing on weight management, smoking cessation, and psychological support. Clinicians should proactively assess occupational and lifestyle factors that may contribute to unhealthy weight gain and poor sleep quality in this age group. In line with this finding, a cross-sectional study by Yoshikawa et al., involving 380 patients with T2DM, found that those aged <50 years had the highest PSQI scores (4.99±2.40) and BMI (25.5±4.8 kg/m^2), both of which declined significantly with age ($P<0.05$ and $P<0.01$, respectively). Higher BMI was modestly but significantly correlated with poorer sleep quality ($P<0.05$). Younger patients also reported shorter sleep duration, greater daytime sleepiness, and a preference for evening chronotypes.[14]

Among middle-aged adults (41–50 years), obesity levels were intermediate, and sleep disturbances were the lowest. However, this group had the least physical activity and lowest HDL, indicating a potentially neglected window for preventive cardiometabolic

interventions. The study findings highlight the need for monitoring sustaining physical activity, addressing work-life balance, and evaluating metabolic and cardiovascular risk profiles during routine check-ups. A Sweden-based, long-term follow-up study revealed that sleep disturbances, such as difficulties in falling asleep and regular use of hypnotics, were associated with an increased risk of developing T2DM in middle-aged men (n=6,599; mean follow-up: 14.8 +/- 2.4 years). Elevated resting heart rate at baseline was also found to be a risk factor for diabetes.[15]

In the older age group (>50 years), sleep disturbances were more pronounced despite relatively better exercise habits. This group also exhibited higher rates of hypertension, cardiovascular disease, and stroke, underscoring the need for comprehensive cardiovascular risk assessment and proactive preventive strategies. Clinical management should include screening for sleep disorders like sleep apnea and insomnia, evaluating age-related physiological changes affecting sleep, and reviewing medications for potential impacts on sleep quality due to polypharmacy. A retrospective observational cohort study, using data from the US Collaborative Network within the TriNetX database (n >1 million), found that individuals with newly diagnosed T2DM had a higher 5-year risk of developing sleep disorders compared to those without diabetes. While the absolute risk was greater in middle-aged and older adults, the relative risk increase was consistently more pronounced in younger adults.[16] Zhang et al. conducted a cross-sectional analysis using self-reported data collected from 2,646 elderly T2DM patients in China. They found that, in older adults with T2DM, physical exercise was strongly associated with lower cognitive impairment ($P < 0.001$). The findings corroborate the positive impact of physical exercise in improving sleep and reducing depression, thereby reducing cognitive decline in older patients with T2DM.[17]

The present study also observed that although the elderly age group had a lower BMI, they reported higher ESS scores, indicating poor sleep quality. This apparent paradox may be attributed to several factors. With advancing age, changes in circadian rhythm can alter sleep architecture, leading to reduced deep sleep and increased nighttime awakenings, which contribute to greater daytime sleepiness regardless of BMI. Pain and discomfort associated with chronic health conditions commonly seen in older adults, including osteoarthritis and poorly controlled diabetes, as well as sleep disorders such as obstructive sleep apnea and restless legs syndrome, often impair sleep and worsen daytime fatigue. Additionally, mental health concerns such as subclinical depression or anxiety, which are frequently underdiagnosed in this age group, can contribute to sleep disturbances. Social isolation and a sedentary lifestyle may lead to lower BMI while also negatively affecting sleep quality. Nutritional deficiencies, particularly magnesium or vitamin D, may further disrupt sleep regulation. These multiple influencing factors suggest that BMI alone is not a reliable indicator of sleep quality in older individuals and highlight the importance of a comprehensive evaluation of sleep health in this population.

The current study showed that self-employment, grade 2 hypertension, and frequent alcohol use were associated with higher odds of ESS-defined poor sleep among patients with newly diagnosed T2DM, suggesting that occupational stress, cardiovascular comorbidity, and behavioral factors may contribute to daytime sleepiness early in the disease course. Impaired sleep and excessive daytime sleepiness may further exacerbate insulin resistance, blood pressure variability, and glycemic instability. For obesity, male sex and not currently being in paid employment were associated with lower odds of obesity, whereas grade 1 hypertension, smoking, and a family history of diabetes were associated with higher odds in the primary model. However, the associations of grade 1 hypertension, smoking, and family history of diabetes with obesity were not consistently significant in the complete-case sensitivity analysis and should therefore be interpreted with caution. The absence of strong age-related associations in the adjusted models suggests that the observed age-specific differences in obesity and ESS-defined poor sleep are influenced more by modifiable metabolic, occupational, and behavioral factors than by age alone. These findings support the integration of sleep assessment, stress management, obesity screening, smoking cessation, and cardiovascular risk evaluation into the early clinical assessment of patients with newly diagnosed T2DM.[18–20]

The relationship between obesity, poor sleep, and T2DM may represent a bidirectional vicious cycle. Obesity, particularly central adiposity, can contribute to sleep-disordered breathing and impaired sleep quality, whereas inadequate or fragmented sleep may promote weight gain through alterations in appetite regulation, sympathetic activity, cortisol secretion, and insulin sensitivity.[21–23] Sleep disturbance may also contribute to glycemic volatility through neuroendocrine and metabolic dysregulation, while fluctuations in glucose levels and symptoms of hyperglycemia or hypoglycemia may further disrupt sleep.[24,25] Another perspective involves depressive crosstalk, whereby poor sleep and metabolic dysfunction may adversely affect mood through inflammatory, neuroendocrine, and behavioral pathways, while depressive symptoms can contribute to reduced physical activity, unhealthy dietary behaviors, disturbed sleep, and poorer diabetes self-management.[26,27] Although depression and glycemic variability were not specifically assessed in the present study, these interconnected pathways may contribute to the persistence of metabolic and sleep-related abnormalities and warrant further investigation.

Although the ESS used in the current study and other measures such as the PSQI assess different aspects of sleep, they are complementary in capturing the multifaceted impact of sleep disturbances in patients with T2DM. While direct numerical comparisons are not appropriate due to differing assessment criteria, findings from these diverse tools still contribute meaningfully to the broader understanding of sleep–metabolic interactions.

The present study is unique in its simultaneous, age-stratified evaluation of obesity and sleep quality among newly diagnosed T2DM patients in the Indian setting. Unlike earlier studies that typically focus on older adults or do not stratify by age, this study analyzes three distinct age groups (18–40, 41–50, and >50 years), enabling identification of age-specific trends at the time of diagnosis. The use of clinically relevant cutoffs such as BMI ≥ 27.6 kg/m² (specific to Asian populations) and ESS ≥ 10, along with quadrant-based scatter plot visualizations, enhances the clarity and interpretation of the findings.

The study has several limitations. Its cross-sectional design precludes the establishment of causal relationships between obesity, ESS-defined poor sleep, and glycemic control. Sleep was assessed using the ESS, which primarily measures daytime sleepiness and does not capture other important aspects of sleep, including sleep duration, sleep latency, nighttime awakenings, or overall sleep quality assessed by instruments such as the PSQI. In addition, objective assessments, such as polysomnography, were not performed to confirm the presence of sleep disorders. Although missing data were addressed using MICE and complete-case sensitivity analyses were conducted, the possibility of residual bias due to missing data cannot be completely excluded. Several behavioral and lifestyle variables, including physical activity and other participant-reported

characteristics, were based on self-report and may therefore be subject to recall and social-desirability bias. Although the multivariable models adjusted for several prespecified demographic, metabolic, and behavioral factors, residual and unmeasured confounding cannot be excluded. Potential unmeasured confounders include obstructive sleep apnea risk, psychological stress or depressive symptoms, detailed dietary characteristics, physical activity intensity, and inflammatory factors. Although study center was included as a random intercept to account for the multicentric study design, the estimated between-center variance was negligible, and center-specific effects were not interpreted. The models demonstrated modest discrimination and explanatory power, further emphasizing the possibility of residual unexplained variability in both outcomes.

Practical recommendations from the current study findings include addressing modifiable factors such as weight management, physical inactivity, and sleep hygiene across all age groups. Younger adults may benefit from stress reduction and weight control programs, while older patients require strategies to improve sleep and manage associated hypertension. An integrated management approach is essential to address obesity and sleep disturbances together, recognizing their bidirectional relationship. Regular follow up and monitoring of BMI and sleep quality, with adjustments based on age specific clinical needs, are vital for effective management.

Conclusion

The study demonstrates age-specific patterns of obesity and ESS-defined poor sleep among patients with newly diagnosed T2DM. Although obesity is more frequent in younger adults and ESS-defined poor sleep is more frequent in older adults, age itself is not strongly associated with these outcomes in the adjusted models. Modifiable metabolic, occupational, and behavioral factors, including hypertension, alcohol use, smoking, employment status, and family history of diabetes, play a greater role in influencing obesity and daytime sleepiness. These findings highlight the importance of early, individualized interventions that incorporate weight management, sleep assessment, smoking cessation, stress management, and cardiovascular risk reduction at the time of T2DM diagnosis, irrespective of patient age.

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None.

Conflict of interest

The authors declare that there is no conflict of interest.

References

1. International Diabetes Federation. Facts & figures. *International Diabetes Federation*. 2025.
2. Arora T, Jiang CQ, Thomas GN, et al. Self-reported long total sleep duration is associated with metabolic syndrome. *Diabetes Care*. 2011;34(10):2317–2319.
3. Buxton OM, Cain SW, O'Connor SP, et al. Adverse metabolic consequences in humans of prolonged sleep restriction combined with circadian disruption. *Sci Transl Med*. 2012;4(129):129ra43.
4. Hung HC, Yang YC, Ou HY, et al. The association between self-reported sleep quality and overweight in a Chinese population. *Obesity (Silver Spring)*. 2013;21(3):486–492.
5. Hirota T, Morioka T, Yoda K, et al. Sleep quality is associated with obesity in patients with type 2 diabetes. *Diabetes*. 2018;67(suppl 1):2074.
6. Choi D, Kim BY, Jung CH, et al. Diabetic complications associated with poor sleep quality in type 2 diabetes. *Diabetes*. 2018;67(suppl 1):820.
7. Li Y, Buys N, Li L, et al. Sleep quality and its determinants among type 2 diabetes patients with comorbid metabolic syndrome. *Diabetes Metab Syndr Obes*. 2022;15:3469–3482.
8. American Diabetes Association. Diabetes diagnosis. American Diabetes Association. 2026.
9. Arora T, Chen MZ, Omar OM, et al. An investigation of the associations among sleep duration and quality, body mass index and insulin resistance in newly diagnosed type 2 diabetes mellitus patients. *Ther Adv Endocrinol Metab*. 2016;7(1):3–11.
10. Ohkuma T, Fujii H, Iwase M, et al. Impact of sleep duration on obesity and the glycemic level in patients with type 2 diabetes: the Fukuoka Diabetes Registry. *Diabetes Care*. 2013;36(3):611–617.
11. Foster GD, Sanders MH, Millman R, et al. Obstructive sleep apnea among obese patients with type 2 diabetes. *Diabetes Care*. 2009;32(6):1017–1019.
12. Sokwalla SMR, Joshi MD, Amayo EO, et al. Quality of sleep and risk for obstructive sleep apnoea in ambulant individuals with type 2 diabetes mellitus at a tertiary referral hospital in Kenya: a cross-sectional, comparative study. *BMC Endocr Disord*. 2017;17(1):7.
13. Rosique-Esteban N, Papandreou C, Romaguera D, et al. Cross-sectional associations of objectively measured sleep characteristics with obesity and type 2 diabetes in the PREDIMED-Plus trial. *Sleep*. 2018;41(12):zsy190.
14. Yoshikawa F, Kumashiro N, Shigiyama F, et al. Changes in subjective sleep quality in patients with type 2 diabetes who did not use sleep agents: a cross-sectional study according to age and clinical background. *Diabetol Int*. 2022;13(1):142–147.
15. Nilsson PM, Rööst M, Engström G, et al. Incidence of diabetes in middle-aged men is related to sleep disturbances. *Diabetes Care*. 2004;27(10):2464–2469.
16. Henson J, Ibarburu GH, Drebert Z, et al. Sleep disorders in younger and middle-older age adults with newly diagnosed type 2 diabetes mellitus: a retrospective cohort study in >1 million individuals. *Diabetes Res Clin Pract*. 2024;217:111887.
17. Zhang H, Zhang Y, Sheng S, et al. Relationship between physical exercise and cognitive impairment among older adults with type 2 diabetes: chain mediating roles of sleep quality and depression. *Psychol Res Behav Manag*. 2023;16:817–828.
18. Reutrakul S, Van Cauter E. Sleep influences on obesity, insulin resistance, and risk of type 2 diabetes. *Metabolism*. 2018;84:56–66.
19. Knutson KL, Van Cauter E, Zee P, et al. Cross-sectional associations between measures of sleep and markers of glucose metabolism among subjects with and without diabetes: the Coronary Artery Risk Development in Young Adults (CARDIA) Sleep Study. *Diabetes Care*. 2011;34(5):1171–1176.
20. Antza C, Kostopoulos G, Mostafa S, et al. The links between sleep duration, obesity and type 2 diabetes mellitus. *J Endocrinol*. 2021;252(2):125141.
21. St-Onge MP, Grandner MA, Brown D, et al. Sleep duration and quality: impact on lifestyle behaviors and cardiometabolic health: a scientific statement from the American Heart Association. *Circulation*. 2016;134(18):e367—e386.
22. Koren D, Taveras EM. Association of sleep disturbances with obesity, insulin resistance and the metabolic syndrome. *Metabolism*. 2018;84:67–75.
23. Pugliese G, Barrea L, Laudisio D, et al. Sleep apnea, obesity, and diabetes: an emerging triad. *Nutrients*. 2020;12(4):1131.
24. Reutrakul S, Van Cauter E. Sleep influences on obesity, insulin resistance, and risk of type 2 diabetes. *Metabolism*. 2018;84:56–66.

25. Khandelwal D, Dutta D, Chittawar S, et al. Sleep disorders in type 2 diabetes. *Indian J Endocrinol Metab*. 2017;21(5):758–761.

26. Roy T, Lloyd CE. Epidemiology of depression and diabetes: a systematic review. *J Affect Disord*. 2012;142(suppl):S8–S21.

27. Knol MJ, Twisk JWR, Beekman ATF, et al. Depression as a risk factor for the onset of type 2 diabetes mellitus: a meta-analysis. *Diabetologia*. 2006;49(5):837–845.

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