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ORIGINAL RESEARCH

Sleep Quality and Its Determinants Among Type 2 Diabetes Patients with Comorbid Metabolic Syndrome

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Purpose: The prevalence of poor sleep quality in patients with diabetes was higher than the general population. This study aimed to explore risk factors for not only poor sleep quality, but also long sleep latency, short sleep duration and low sleep efficiency, in type 2 diabetes patients (T2DM) with comorbid metabolic syndrome (MS).

Patients and Methods: A total of 281 patients aged 18–75 years were enrolled from Ningbo First Hospital during October 2021 to March 2022. Sleep quality was evaluated by the Pittsburgh Sleep Quality Index (PSQI). Sleep latency, sleep duration and sleep efficiency were obtained by a response to the questionnaire. Descriptive, independent two-sample *t*-test, Chi-square test and multiple logistic regression were conducted using SPSS Version 28.

Results: The prevalence of poor sleep quality in T2DM with comorbid MS patients was 59.10%. The factors significantly associated with poor sleep quality were depression symptoms (OR = 3.10, 95% CI: 1.38 to 6.96, P = 0.006), poor quality of life (OR = 2.49, 95% CI: 1.24 to 4.99, P = 0.010), and age (OR = 1.07, 95% CI: 1.04 to 1.10, P < 0.001). The factor significantly associated with long sleep latency was depression symptoms (OR = 2.19, 95% CI: 1.15 to 4.16, P = 0.017). The factors significantly related to short sleep duration were depression symptoms (OR = 2.56, 95% CI: 1.31 to 5.00, P = 0.006) and age (OR = 1.05, 95% CI: 1.02 to 1.08, P = 0.002). The factor significantly related to short sleep efficiency was age (OR = 1.03, 95% CI: 1.01 to 1.06, P = 0.019).

Conclusion: This study found that depression symptoms, together with poor quality of life, and increasing age were associated with poor sleep quality. Symptoms of depression were related to long sleep latency and short sleep duration. The increasing age was associated with short sleep duration and low sleep efficiency.

Keywords: type 2 diabetes, sleep quality, sleep latency, sleep duration, sleep efficiency, influence factor

Introduction

Diabetes Mellitus (DM) is a group of endocrine and metabolic diseases mainly characterized by hyperglycemia, of which more than 90% is type 2 diabetes (T2DM).[1] The global DM prevalence was 9.3% in 2019 and is estimated to be 10.9% by 2045,[2] while the DM incidence ranged from 10.9% in 2013 to 12.4% in 2018 in China.[3] DM has high mortality and disability rates, bringing a huge burden to individuals and families,[4] and the number of deaths caused by DM was approximately 4 million worldwide in 2017.[2] Metabolic syndrome (MS) is a pathological condition in which the body's metabolism of proteins, fats, carbohydrates are disturbed.[5] Patients with T2DM are more likely to have hypertension, dyslipidemia, and obesity, resulting in a large proportion of patients with diabetes meeting the MS diagnostic criteria.[6] In addition, the risk of cardiovascular events in DM patients with comorbid MS might be significantly increased.[6]

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Sleep is an important physiological process for regulating and maintaining body health, which is regulated by the central nervous system.[7] Good sleep can help restore physical strength, boost metabolism, and delay cognitive decline.[8] According to the National Sleep Foundation report,[9] good sleep quality includes the following characteristics: longer effective sleep time (sleep efficiency ≥85%), falling asleep in less than 30 minutes, waking up less than once a night, and taking less than 20 minutes to fall back asleep after waking up at night.

Sleep disturbance is manifested as difficulty in falling asleep, light sleep, early awakening, and short sleep duration.[10] Previous studies have shown that the prevalence of poor sleep in DM patients was 37–50%,[11] which was higher than the general population.[12] Long-term sleep deprivation or poor sleep quality is often associated with abnormal glucose tolerance and insulin resistance, resulting in faster DM progression.[13,14] Anothaisintawee et al[13] found that short sleep duration (<5h) and poor sleep quality were associated with developing T2DM. Barikani et al[15] found that poor sleep quality was related to higher levels of fasting blood sugar, body mass index and total cholesterol. On the other hand, poor glycemic control in DM patients may also be related to the development of short sleep duration or poor sleep quality, creating a vicious cycle.[16]

Evidence shows that there may be various factors related to sleep quality in DM patients, including but not limited to the following four domains: lifestyle-related variables, disease-related variables, emotion-related variables, and sociodemographic economic variables. Birhanu et al[17] found that drinking alcohol (OR = 2.45) and smoking cigarettes (OR = 6.26) were risk factors for poor sleep quality in DM patients. In contrast, doing exercise to the point of sweating (OR = 0.48) was estimated to reduce the risk of poor sleep quality.[18] For the disease-related variables, longer DM duration (R = 3.16), higher glycated hemoglobin (HbA_{1c}) levels (OR = 2.42) and comorbidity (OR = 1.80) were found to be the main risk factors for poor sleep quality.[17,19] Regarding emotion-related variables, depression symptoms (OR = 13.94) and anxiety symptoms (OR = 5.78) were associated with poor sleep quality.[19,20] As for sociodemographic economic variables, Shamshirgaran et al[20] found that sleep quality for middle-aged T2DM patients was more likely to be poor when compared to younger age groups (OR = 2.03). Other research[18] results showed that female T2DM patients (OR = 3.45) were prone to have poor sleep quality.

While the above studies investigated the potential influential factors associated with overall sleep quality in the patients with diabetes, few studies analyzed the factors related to sleep latency, sleep duration and sleep efficiency, all of which are significant components for good sleep quality in patients with diabetes.[10] To fill the research gap, we aimed to investigate the prevalence of poor sleepers, and explore the risk factors for poor sleep quality, long sleep latency, short sleep duration and low sleep efficiency, in patients with diabetes. We hypothesized that the four sleep variables were predicted by the following variables: lifestyle-related variables, including smoking cigarettes, drinking alcohol, and physical activity levels; disease-related variables, including treatment methods, years of DM, DM complications; emotion-related variables, including depression and anxiety symptoms; clinical characteristics, including body mass index (kg/m^2), waist circumference (cm), HbA_{1c} (%), systolic blood pressure (mmHg), diastolic blood pressure (mmHg), triglycerides (mmol/L), total cholesterol (mmol/L), high-density lipoprotein cholesterol (mmol/L) and low-density lipoprotein cholesterol (mmol/L). The confounding variables were gender, age, marriage, education level and monthly income.

Materials and Methods

We analyzed the cross-sectional data from participants with type 2 diabetes. The study protocol has been approved by the Griffith University Human Research Ethics Committee (GUHREC) (GU Ref No: 2021/740) and Ningbo First Hospital Ethics Committee (NFHEC) (Approval No: 2021R073). The study was conducted in accordance with the ethical standards set out in the 1964 Declaration of Helsinki and its subsequent amendments.[21]

Study Population

T2DM patients with comorbid MS aged 18–75 years were recruited from October 2021 to March 2022 in Endocrinology Department, Ningbo First Hospital. Patients were excluded if they had advanced diabetes complications or a serious mental illness. All participants signed the informed consent form.

The diagnosis criteria for diabetes referred to the report of the WHO Diabetes Expert Committee,[22] which was as follows: typical symptoms of diabetes plus either random blood glucose ≥11.1 mmol/L; fasting blood glucose ≥7.0

mmol/L; oral glucose tolerance test 2 hours ≥11.1 mmol/L. Patients already diagnosed with diabetes were also included in the study. The diagnosis criteria for MS referred to the IDF standard:[23] central obesity, waist circumference ≥90 cm (Chinese male) or ≥80 cm (Chinese female) and those with two or more of the following characteristics, 1) triglycerides >1.70 mmol/L or have received relevant treatment; 2) high-density lipoprotein cholesterol <1.03 mmol/L (male) or <1.29 mmol/L (female), or have received relevant treatment; 3) systolic blood pressure ≥130 or diastolic blood pressure ≥85 mmHg, or have received relevant treatment; 4) fasting blood glucose ≥5.6 mmol/L or previously diagnosed with T2DM.

Measurement

Sleep-Related Variables

Sleep quality was evaluated by the Pittsburgh Sleep Quality Index (PSQI),[24] which was a self-rated scale assessing participants' sleep status over the previous month. There were 19 self-rated items, and the scale was divided into seven subscales, including subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleep medications and daytime dysfunction. Each subscale had a score between 0 and 3. The sum of the seven subscale scores gave an overall PSQI score ranging from 0 to 21, with a higher score indicating poorer sleep quality. We divided patients into poor sleepers (PSQI >5) and good sleepers (PSQ ≤ 5) based on the previous study,[24] indicating a PSQI score of >5 had high sensitivity in distinguishing between good and poor sleep quality.

Sleep latency was obtained from patients' responses to the question "During the past month, how long does it usually take for you to fall asleep each night?". Short sleep latency was defined as falling asleep in ≤30 minutes,[9] while long sleep latency was defined as falling asleep in >30 minutes.[9]

Sleep duration was obtained from patients' responses to the question "During the past month, what was the average number of hours of actual sleep you got at night?". Long sleep duration was defined as an actual sleep time of ≥6h and short sleep duration was defined as an actual sleep time of <6h.

Sleep efficiency was calculated by sleep duration divided by the total amount of time spent in bed. The total amount of time spent in bed was the time between when the patient went to bed and the time when the patient got up in the morning. High sleep efficiency was defined as sleep efficiency ≥85%[9,25] and short sleep efficiency was defined as sleep efficiency <85%.[9,25]

Emotion-Related Variables

Depression symptoms were evaluated through the Patient Health Questionnaire-9 (PHQ-9),[26] a nine-item self-report instrument to evaluate a patient's condition of depression over the preceding two weeks. Each item had a score of 0–3. The total score ranged from 0 to 27. Scores of 0–4, 5–9, 10–14, 15–19, 19–27 indicated no depression, mild depression, moderate depression, moderately severe depression, and severe depression, respectively. Patients were classified as being without depression symptoms if the score was PHQ-9 ≤4. Patients were classified as being with depression symptoms if the score was PHQ-9 ≥5.

Anxiety symptoms were evaluated by the General Anxiety Disorder 7-Item (GAD-7),[27] a seven-item self-report instrument to evaluate a patient's anxiety condition in the previous two weeks. Each item had a score of 0–3. Scores of 0–4, 5–9, 10–14, 15–21 indicated no anxiety, mild anxiety, moderate anxiety, and severe anxiety, respectively. Patients were classified as being without anxiety symptoms if the score was GAD-9 ≤4. Patients were classified as being with anxiety symptoms if the score was GAD-7 ≥5.

Quality of Life

Quality of life was assessed by the SF-12 Quality of Life Questionnaire,[28] a 12-item health measurement scale divided into two domains and eight dimensions. All scores were converted into standard scores ranging from 0 to 100. A higher score indicated better quality of life. Patients were classified as being with good quality of life if the scores were above the mean score of the recruited patients. Patients were classified as being with poor quality of life if the scores fell below the mean.

Physical Activity Level

Physical activity levels were evaluated by the International Physical Activity Questionnaire (IPAQ-SF).[29] There were seven items assessing the physical activity frequency and duration of different intensities. Patients were classified as having high physical intensity, medium intensity level and low intensity levels based on criteria of previously published study.[30]

Clinical Characteristics, Lifestyle-Related and Disease Related Variables, and Sociodemographic Profiles

Clinical characteristics, including HbA_{1c} (%), triglycerides (mmol/L), total cholesterol (mmol/L), high-density lipoprotein cholesterol (mmol/L) and low-density lipoprotein cholesterol (mmol/L) were obtained from patients' medical records within one month of the enrollment time of the patients. Weight (kg), height (cm), waist circumference (cm), systolic blood pressure (mmHg), and diastolic blood pressure (mmHg) were measured by researchers at enrollment. Based on the previous study,[31] BMI between 18.5 kg/m^2 to 23.9 kg/m^2 was classified as a standard weight group, BMI between 24 kg/m^2 to 27.9 kg/m^2 was classified as an overweight group, and BMI $\geq$ 28 kg/m^2 was classified as an obese group. HbA_{1c} <7%[20] was classified as with good blood glucose control, and $HbA_{1c} \geq 7\%$[20] was classified as with poor blood glucose control.

The self-designed questionnaire was used to obtain the following variables: the lifestyle-related variables, including smoking cigarettes and drinking alcohol; disease-related variables, including treatment methods, years of DM, DM complications; sociodemographic profiles, including gender, age, marriage, education level and monthly income.

Statistical Analysis

In continuous variables, descriptive analyses were presented as mean and standard deviations. Independent Two-sample *t*-test was used to assess the differences between groups in constant demographic characteristics and clinical variables. For the categorical variables, the descriptive analysis was presented as number and percentages. A Chi-square Test was used to assess the differences in categorical variables between the groups.

Variables with statistically significant differences in Two-sample *t*-test and Chi-square Test were then incorporated step by step into the Multiple Logistic Regression Model. In the first step, the lifestyle-related variables, disease-related variables, emotion-related variables, and clinical characteristics were included in the model, followed by the inclusion of the confounding variables. The predicted variables were sleep quality, sleep latency, sleep duration and sleep efficiency. The odds ratios (OR) and 95% confidence interval (CI) were calculated to investigate the potential risk factors.

IBM SPSS Statistics Version 28 was used for all analyses. The two-sided test and $P < 0.05$ were considered statistically significant.

Results

Basic Participants' Characteristics

A total of 281 patients were included in this study, with an average age of 49.91±11.85. There were more male patients (59.80%) than females (40.20%) and 255 patients (90.70%) were married with a spouse, while only 10 patients reported being divorced or widowed. The educational level of most patients was junior high school or below (41.30%). The monthly income distribution was relatively average. Most patients did not smoke cigarettes (75.40%) or drink alcohol (65.50%). Most patients had diabetes for less than five years (66.50%) and did not have DM complications (76.50%). Most patients reported they did not have depression symptoms (66.90%) or anxiety symptoms (79.70%). The mean score for PSQI was 6.63±3.28. 76.90% of patients reported their sleep latency was less than 30 minutes, and 82.90% patients said their sleep duration was more than 6 hours, while 59.40% of patients reported their sleep efficiency was less than 85% (Table 1).

Distribution of Participants' General Characteristics Based on Sleep Quality

We divided the patients into two groups, one with good sleep quality and the other with poor sleep quality, based on the PSQI scores. Results (Table 1) showed that patients with good sleep quality were mostly younger than patients with poor sleep quality (45.49±11.63 vs 52.98±11.03, T=−5.48, $P < 0.001$), while the proportion of patients with college and higher

Table 1 Distribution of Participants' General Characteristics According to Sleep Quality

Variable	Total	Good Sleep Quality (PSQI≤5)	Poor Sleep Quality (PSQI>5)	T/χ^2	P
Gender				0.65	0.422
Male	168 (59.80)	72 (42.90)	96 (57.10)		
Female	113 (40.20)	43 (38.10)	70 (61.90)		
Age	49.91±11.85	45.49±11.63	52.98±11.01	−5.48	<0.001
Marriage				3.27	0.195
Unmarried	16 (5.70)	10 (62.50)	6 (37.50)		
Married with a spouse	255 (90.70)	101 (39.60)	154 (60.40)		
Divorced or widowed	10 (3.60)	4 (40.00)	6 (60.00)		
Education				14.13	0.001
Junior high school and below	116 (41.30)	33 (28.40)	83 (71.60)		
High school or junior college	92 (32.70)	42 (45.70)	50 (54.30)		
College and above	73 (26.00)	40 (54.80)	33 (45.20)		
Monthly income (RMB)				6.20	0.045
<5000	97 (34.50)	30 (30.90)	67 (69.10)		
5000–10,000	95 (33.80)	43 (45.30)	52 (54.70)		
>10,000	89 (31.70)	42 (47.20)	47 (52.80)		
Smoke				1.80	0.180
No	212 (75.40)	82 (38.70)	130 (61.30)		
Yes	69 (24.60)	33 (47.80)	36 (52.20)		
Drink				0.01	0.938
No	184 (65.50)	75 (40.80)	109 (59.20)		
Yes	97 (34.50)	40 (41.20)	57 (58.80)		
Treatment				10.38	0.006
Oral medicine	90 (32.00)	28 (31.10)	62 (68.90)		
Oral medicine and insulin	35 (12.50)	10 (28.60)	25 (71.40)		
Oral medicine and GLP-1RA	156 (55.50)	77 (49.40)	79 (50.60)		
Years of diabetes				2.14	0.144
≤5	189 (66.50)	83 (43.90)	106 (56.10)		
>5	92 (32.40)	32 (34.80)	60 (65.20)		
Complications				8.21	0.004
No	215 (76.50)	98 (45.60)	117 (54.40)		
Yes	66 (23.50)	17 (25.80)	49 (74.20)		
Depression (Score)				13.14	<0.001
No	188 (66.90)	91 (48.40)	97 (51.60)		
Yes	93 (33.10)	24 (25.80)	69 (74.20)		
Anxiety (Score)				7.92	0.005
No	224 (79.70)	101 (45.10)	123 (54.90)		
Yes	57 (20.30)	14 (24.60)	43 (75.40)		
SF12 (Score)				13.84	<0.001
Good quality of life	179 (63.70)	88 (49.20)	91 (50.80)		
Poor quality of life	102 (36.30)	27 (26.50)	75 (73.50)		
PSQI (Score)	6.63±3.28	3.63±1.29	8.70±2.54	−21.97	<0.001
Subjective sleep quality (C1)	0.98±0.70	0.54±0.50	1.28±0.65	−10.33	<0.001
Sleep latency (C2)	0.89±1.13	0.21±0.50	1.36±1.21	−11.00	<0.001

(*Continued*)

Table 1 (Continued).

Variable	Total	Good Sleep Quality (PSQI≤5)	Poor Sleep Quality (PSQI>5)	T/χ^2	P
Sleep duration (C3)	0.97±0.70	0.63±0.52	1.21±0.70	−7.59	<0.001
Habitual sleep efficiency (C4)	1.06±1.10	0.29±0.51	1.60±1.08	−13.68	<0.001
Sleep disturbances (C5)	1.18±0.50	0.93±0.41	1.35±0.48	−7.86	<0.001
Use of sleep medication (C6)	0.07±0.40	0.00±0.00	0.13±0.52	−3.14	0.002
Daytime dysfunction (C7)	1.47±0.93	1.03±0.79	1.78±0.89	−7.33	<0.001
Sleep latency (min)				42.29	<0.001
≤30	216 (76.90)	111 (51.40)	105 (48.60)		
>30	65 (23.10)	4 (6.20)	61 (93.80)		
Sleep duration (hour)				32.35	<0.001
≥6	233 (82.90)	113 (48.50)	120 (51.50)		
<6	48 (17.10)	2 (4.20)	46 (95.80)		
Sleep efficiency (%)				89.77	<0.001
≥85	114 (40.60)	85 (74.60)	29 (25.40)		
<85	167 (59.40)	30 (18.00)	137 (82.00)		
IPAQ (Score)				2.450	0.294
Low PA intensity	141 (50.20)	61 (43.30)	80 (56.70)		
Medium PA intensity	123 (43.80)	50 (40.70)	73 (59.30)		
High PA intensity	17 (6.00)	4 (23.50)	13 (76.50)		
BMI (kg/m^2)				10.43	0.005
18.5–23.9	37 (13.20)	8 (21.60)	29 (78.40)		
24–27.9	150 (53.40)	58 (38.70)	92 (61.30)		
≥28	93 (33.10)	48 (51.60)	45 (48.40)		
WC (cm)	93.74±7.75	94.26±7.58	93.37±7.86	0.94	0.346
HbA_{1c} (%)				0.04	0.849
<7	147 (52.30)	60 (40.80)	87 (59.20)		
≥7	131 (46.60)	52 (39.70)	79 (60.30)		
SBP (mmHg)	137.56±16.82	136.24±15.95	138.46±17.38	−1.09	0.277
DBP (mmHg)	82.05±10.68	83.25±11.03	81.22±10.39	1.56	0.120
FPG (mmol/L)	8.22±3.34	8.17±2.79	8.25±3.66	−0.21	0.836
TG (mmol/L)	2.07±1.81	2.08±1.54	2.06±1.98	0.08	0.940
TC (mmol/L)	4.91±1.35	4.99±1.35	4.85±1.35	0.86	0.394
HDL-C (mmol/L)	1.18±0.25	1.18±0.26	1.17±0.24	0.47	0.642
LDL-C (mmol/L)	3.09±0.97	3.15±0.98	3.05±0.96	0.87	0.385

Note: Statistical test: Independent Two-sample *t*-test and Chi-square Test.

Abbreviations: GLP-1RA, Glp-1 receptor agonist; SF12, Short Form 12; PSQI, Pittsburgh Sleep Quality Index; BMI, Body mass index; WC, Waist circumference; SBP, Systolic blood pressure; DBP, Diastolic blood pressure; FPG, Fasting plasma glucose; TG, Triglycerides; TC, Total cholesterol; HDL-C, High-density lipoprotein cholesterol; LDL-C, Low-density lipoprotein cholesterol; RMB, Ren Min Bi; IPAQ, International Physical Activity Questionnaire; PA, Physical activity.

education levels was larger in the good sleep quality group (54.80% vs 45.20%, χ^2=14.13, P = 0.001). In addition, the proportion of patients earning less than 5000 RMB per month was less in the good sleep quality group (30.90% vs 69.10%, χ^2=6.20, P = 0.045). Less patients had a DM complication in the good sleep quality group (25.80% vs 74.20%, χ^2=8.21, P = 0.004) and more patients in the poor sleep quality group reported symptoms of depression (74.20% vs 25.80%, χ^2=13.14, P < 0.001) or anxiety (75.40% vs 24.60%, χ^2=7.92, P = 0.005). The good sleep quality group had

a less proportion of patients with poor quality of life (26.50% vs 73.50%, χ^2=13.84, P < 0.001). Moreover, the proportion of patients had shorter sleep latency, longer sleep duration and higher sleep efficiency was larger in patients with good sleep quality.

Initially, the treatment methods, DM complications, depression symptoms, anxiety symptoms, quality of life and body mass index (BMI) were included in the logistic regression model. Results (Table 2) showed that DM complications (OR = 2.27, 95% CI: 1.15 to 4.48, P = 0.018), depression symptoms (OR = 2.14, 95% CI: 1.05 to 4.37, P = 0.037), and poor quality of life (OR = 2.05, 95% CI: 1.10 to 3.83, P = 0.025) were risk factors for poor sleep quality. BMI ≥28 kg/m^2 (OR = 0.35, 95% CI: 0.13 to 0.94, P = 0.038) was a protective factor for poor sleep quality. The R^2 of the model was 0.179, indicating a 17.90% variation of sleep quality could be explained by variations in treatment methods, DM complications, depression symptoms, anxiety symptoms, quality of life and body mass index.

Table 2 Logistic Regression Analysis for Sleep Quality

Variable	Step 1			Step 2		
	OR	95% CI	P	OR	95% CI	P
Treatment			0.188			0.494
Oral medicine	Ref			Ref		
Oral medicine and insulin	0.74	(0.28,1.92)	0.532	0.69	(0.25,1.94)	0.480
Oral medicine and GLP-1RA	0.57	(0.31,1.04)	0.069	0.68	(0.35,1.31)	0.247
Complications						
No	Ref			Ref		
Yes	2.27	(1.15,4.48)	0.018	1.28	(0.61,2.69)	0.519
Depression (Score)						
No	Ref			Ref		
Yes	2.14	(1.05,4.37)	0.037	3.10	(1.38,6.96)	0.006
Anxiety (Score)						
No	Ref			Ref		
Yes	1.03	(0.41,2.58)	0.951	1.24	(0.45,3.43)	0.679
SF12 (Score)						
Good QOL	Ref			Ref		
Poor QOL	2.05	(1.10,3.83)	0.025	2.49	(1.24,4.99)	0.010
BMI (kg/m^2)			0.115			0.387
18.5–23.9	Ref			Ref		
24–27.9	0.47	(0.19,1.16)	0.100	0.51	(0.19,1.39)	0.188
≥28	0.35	(0.13,0.94)	0.038	0.48	(0.16,1.43)	0.188
Age				1.07	(1.04,1.10)	<0.001
Education						
Junior high school and below				Ref		0.153
High school or junior college				0.58	(0.28,1.18)	0.131
College and above				0.46	(0.20,1.04)	0.063
Monthly income (RMB)						0.870
<5000				Ref		
5000–10,000				1.22	(0.59,2.52)	0.598
>10,000				1.14	(0.52,2.51)	0.736
R^2	0.179			0.305		

Note: Statistical test: Multiple Logistic Regression Model.
Abbreviations: GLP-1RA, Glp-1 receptor agonist; SF12, Short Form 12; BMI, Body mass index; RMB, Ren Min Bi.

The confounding variables, including age, education level and monthly income, were then added into the model. Results (Table 2) indicated that depression symptoms and poor quality of life were the significant risk factors for poor sleep quality. Patients with depression symptoms were 3.10 times more likely to have poor sleep quality than those without depression symptoms (OR = 3.10, 95% CI: 1.38 to 6.96, P = 0.006). Patients with poor quality of life were 2.49 times more likely to have poor sleep quality than those with good quality of life (OR = 2.49, 95% CI: 1.24 to 4.99, P = 0.010). In addition, an increasing age was also related to the poor sleep quality (OR = 1.07, 95% CI: 1.04 to 1.10, P < 0.001). The R^2 of the model was changed from 0.179 to 0.305, indicating a 12.60% variation of sleep quality could be explained by variations in confounders of age, education level and monthly income.

Distribution of Participants' General Characteristics Based on Sleep Latency

We divided the patients into two groups, one with a short sleep latency and the other with a long sleep latency, based on the time it took to fall asleep. Results (Supplementary Table 1) showed that more male patients had a short sleep latency when compared to females (82.10% vs 17.90%, χ^2=6.54, P = 0.011). Patients with a short sleep latency were generally younger than patients with long sleep latency (49.03±12.07 vs 52.83±10.62, T=−2.29, P = 0.023), and the proportion of patients with college and higher education levels was larger in the short sleep latency group (87.70% vs 12.30%, χ^2=7.31, P = 0.026). The proportion of patients earning more than 10,000 RMB per month was also higher in the short sleep latency group (84.30% vs 15.70%, χ^2=11.96, P = 0.003). More patients did not have depression symptoms in the short sleep latency group (81.40% vs 18.60%, χ^2=6.51, P = 0.011), but the short sleep latency group had a higher proportion of patients with a BMI greater than 28 kg/m^2 (84.90% vs 15.10%, χ^2=11.80, P = 0.003). The patients in short sleep latency group had larger waist circumferences (94.38±7.71 vs 91.60±7.57, T = 2.56, P = 0.011), while patients in the short sleep latency group had lower systolic blood pressure (136.45±15.84 vs 141.22±19.41, T=−2.01, P = 0.045).

Treatment methods, depression symptoms, BMI, and systolic blood pressure (SBP) were incorporated into the logistic regression model. Results (Table 3) showed that treatment with oral and Glp-1 receptor agonist medications (OR = 0.49, 95% CI: 0.25 to 0.96, P = 0.038), BMI between 24 kg/m^2 – 27.9 kg/m^2 (OR = 0.40, 95% CI: 0.18 to 0.91, P = 0.029) and BMI ≥ 28 kg/m^2 (OR = 0.26, 95% CI: 0.10 to 0.70, P = 0.007) were protective factors for short sleep latency. Depression symptoms (OR = 2.10, 95% CI: 1.15 to 3.85, P = 0.016) were risk factors for long sleep latency. The R^2 of the model was 0.141, indicating a 14.10% variation of sleep latency could be explained by variations in treatment methods, depression symptoms, BMI and SBP.

The confounders of gender, age, education level and monthly income were then added into the model. Results (Table 3) revealed that depression symptoms were the only significant risk factor for long sleep latency. Patients with depression symptoms were 2.19 times more likely to have long sleep latency than those without depression symptoms (OR = 2.19, 95% CI: 1.15 to 4.16, P = 0.017). The R^2 of the model was transformed from 0.141 to 0.185, indicating 4.40% variation of sleep latency could be explained by variations in confounders of gender, age, education level and monthly income.

Distribution of Participants' General Characteristics Based on Sleep Duration

We divided the patients into two groups, one with long sleep duration and the other with short sleep duration. Results (Supplementary Table 2) showed that patients with long sleep duration were mostly younger than those with short sleep duration (48.85±11.51 vs 55.08±12.14, T=−3.39, P = 0.001). More patients did not have depression symptoms in the long sleep duration group (86.70% vs 13.30%, χ^2=5.74, P = 0.017), but the long sleep duration group had a higher proportion of patients with a BMI greater than 28 kg/m^2 (90.30% vs 9.70%, χ^2=6.70, P = 0.035).

Depression symptoms and BMI were included in the logistic regression model. Results (Table 4) indicated that depression symptoms (OR = 2.18, 95% CI: 1.15 to 4.16, P = 0.018) were risk factors for short sleep duration. BMI ≥28 kg/m^2 (OR = 0.27, 95% CI: 0.10 to 0.75, P = 0.012) was a protective factor for long sleep duration. The R^2 of the model was 0.073, indicating a 7.30% variation of sleep duration could be explained by variations in depression symptoms and BMI.

The confounding variable of age was subsequently added into the model. Results (Table 4) showed depression symptoms were risk factors for short sleep duration. Patients with depression symptoms were 2.56 times more likely to

Table 3 Logistic Regression Analysis for Sleep Latency

Variable	Step 1			Step 2		
	OR	95% CI	P	OR	95% CI	P
Treatment			0.107			0.114
Oral medicine	Ref			Ref		
Oral medicine and insulin	0.62	(0.25,1.53)	0.296	0.53	(0.21,1.35)	0.181
Oral medicine and GLP-1RA	0.49	(0.25,0.96)	0.038	0.50	(0.25,1.01)	0.052
Depression (Score)						
No	Ref			Ref		
Yes	2.10	(1.15,3.85)	0.016	2.19	(1.15,4.16)	0.017
BMI (kg/m^2)			0.025			0.231
18.5–23.9	Ref			Ref		
24–27.9	0.40	(0.18,0.91)	0.029	0.55	(0.23,1.32)	0.180
≥28	0.26	(0.10,0.70)	0.007	0.40	(0.14,1.15)	0.089
SBP (mmHg)						
≤130	Ref			Ref		
>130	1.89	(0.99,3.58)	0.052	1.71	(0.89,3.28)	0.110
Gender						
Male				0.77	(0.38,1.58)	0.477
Female				Ref		
Age				1.01	(0.98,1.04)	0.373
Education						0.487
Junior high school and below				Ref		
High school or junior college				1.14	(0.54,2.44)	0.726
College and above				0.65	(0.24,1.77)	0.400
Monthly income (RMB)						0.455
<5000				Ref		
5000–10,000				0.58	(0.24,1.38)	0.215
>10,000				0.65	(0.25,1.68)	0.375
R^2	0.141			0.185		

Note: Statistical test: Multiple Logistic Regression Model.
Abbreviations: GLP-1RA, Glp-1 receptor agonist; BMI, Body mass index; SBP, Systolic blood pressure; RMB, Ren Min Bi.

Table 4 Logistic Regression Analysis for Sleep Duration

Variable	Step 1			Step 2		
	OR	95% CI	P	OR	95% CI	P
Depression (Score)						
No	Ref			Ref		
Yes	2.18	(1.15,4.16)	0.018	2.56	(1.31,5.00)	0.006
BMI (kg/m^2)			0.037			0.289
18.5–23.9	Ref			Ref		
24–27.9	0.59	(0.25,1.38)	0.226	0.76	(0.32,1.83)	0.540
≥28	0.27	(0.10,0.75)	0.012	0.44	(0.15,1.28)	0.134
Age				1.05	(1.02,1.08)	0.002
R^2	0.073			0.128		

Note: Statistical test: Multiple Logistic Regression Model.
Abbreviation: BMI, Body mass index.

have short sleep duration than those without depression symptoms (OR = 2.56, 95% CI: 1.31 to 5.00, P = 0.006). Additionally, an increasing age (OR = 1.05, 95% CI: 1.02 to 1.08, P = 0.002) was associated with the short sleep duration. The R^2 of the model changed from 0.073 to 0.128, indicating 5.50% variation of sleep duration could be explained by variations in age.

Distribution of Participants' General Characteristics Based on Sleep Efficiency

We divided the patients into two groups, one with high sleep efficiency and the other with low sleep efficiency. Results (Supplementary Table 3) showed that patients with high sleep efficiency were generally younger than those with low sleep efficiency (46.50±10.96 vs 52.24±11.88, T=−4.10, P < 0.001). The proportion of patients with college and higher education levels was larger in high sleep efficiency group (50.70% vs 49.30%, χ^2=9.29, P = 0.010), and the proportion of patients earning more than 10,000 RMB per month was higher in high sleep efficiency group (50.60% vs 49.40%, χ^2=9.46, P = 0.009). The high sleep efficiency group had a higher proportion of patients with a BMI greater than 28 kg/m^2 (52.70% vs 47.30%, χ^2=10.35, P = 0.006) and the proportion of patients taking oral and Glp-1 receptor agonist medications (GLP-1RA) was lower in high sleep efficiency group (47.40% vs 52.60%, χ^2=7.39, P = 0.025).

The treatment methods and BMI were incorporated into the logistic regression model. Results (Table 5) showed that BMI ≥28 kg/m^2 (OR = 0.37, 95% CI: 0.15 to 0.92, P = 0.032) was a protective factor for high sleep efficiency. The R^2 of the model was 0.064, indicating a 6.40% variation of sleep efficiency could be explained by variations in treatment methods and BMI.

Age, education level and monthly income were then added into the model. Logistic regression results (Table 5) showed the associations between BMI and sleep efficiency was not significant anymore. Only the relation between an increasing age (OR = 1.03, 95% CI: 1.01 to 1.06, P = 0.019) and low sleep efficiency was significant. The R^2 of the model was increased from 0.064 to 0.129, indicating 6.50% variation of sleep efficiency could be explained by variations in age, education level and monthly income.

Table 5 Logistic Regression Analysis for Sleep Efficiency

Variable	Step 1			Step 2		
	OR	95% CI	P	OR	95% CI	P
Treatment			0.214			0.293
Oral medicine	Ref			Ref		
Oral medicine and insulin	0.76	(0.33,1.73)	0.508	0.65	(0.28,1.53)	0.323
Oral medicine and GLP-1RA	0.59	(0.33,1.06)	0.080	0.63	(0.34,1.15)	0.129
BMI (kg/m^2)			0.056			0.320
18.5–23.9	Ref			Ref		
24–27.9	0.62	(0.27,1.44)	0.267	0.79	(0.33,1.91)	0.606
≥28	0.37	(0.15,0.92)	0.032	0.54	(0.21,1.42)	0.212
Age				1.03	(1.01,1.06)	0.019
Education						0.685
Junior high school and below				Ref		
High school or junior college				0.75	(0.39,1.45)	0.387
College and above				0.81	(0.39,1.71)	0.583
Monthly income (RMB)						0.388
<5000				Ref		
5000–10,000				0.78	(0.39,1.54)	0.476
>10,000				0.60	(0.29,1.24)	0.171
R^2	0.064			0.129		

Note: Statistical test: Multiple Logistic Regression Model.
Abbreviations: GLP-1RA, Glp-1 receptor agonist; BMI, Body mass index; RMB, Ren Min Bi.

Discussion

The Prevalence of Poor Sleep Quality in T2DM Patients with Comorbid MS

This study found that the prevalence of poor sleep quality in T2DM with comorbid MS was 59.10% (PSQI >5). It was similar to Darraj et al's research results[32] in Jazan, Saudi Arabia, in which 55.40% of patients with diabetes reported poor sleep quality. Similarly, Luyster et al's research results[33] showed that 55.00% of T2DM patients in US were "poor sleepers" according to PSQI score classifications. However, the result of the current research was higher than the findings of research conducted in Iran (19.90%).[15] A possible reason was that the study chose a different PSQI score as the cut-off value, in which a PSQI score of 6 or greater indicated poor sleep quality. As for sleep latency, 76.90% of patients reported they fell asleep in less than 30 minutes. Similar findings (74.90%) were reported in Birhanu et al study in Ethiopia.[17] In addition, previous studies have shown that 63.30%[17] and 59.60%[18] of DM patients reported their sleep efficiency in excess of 85%, which was higher than the 40.60% found in this study. This may be due to differences in disease severity and comorbidity of the subjects. Birhanu et al's research[17] included DM outpatients and excluded patients who were seriously ill. Research conducted by Kuo[18] et al included T2DM outpatients only. In contrast, this study included both outpatients and inpatients with a diagnosis of T2DM with comorbid MS. The characteristics of a large waist circumference[34] and more medications due to comorbidities in this group of patients may be related to the low proportion of patients with a sleep efficiency more than 85%.[19]

Depression Symptoms Contributed to Poor Sleep Quality, Long Sleep Latency and Short Sleep Duration

We found that depression symptoms were risk factors for poor sleep quality, long sleep latency and short sleep duration in T2DM patients with comorbid MS. Similarly, Chang et al[35] found that high depression scores were associated with poor sleep quality and long sleep latency in some elderly study groups in Korea. Park et al also found that[36] depression symptoms were related to shorter sleep duration in a community sample of Korean adults. Patients with depression symptoms generally had a strong tendency to over-think and feel anxious, as well as interpret information pessimistically and depressively.[37] A depressive interpretation may obstruct patients' ability to make judgments objectively and accurately regarding their sleep quality.[35] In addition, a previous study[38] showed that sleep continuity was more likely to be disrupted in patients with depression, which may account for poor sleep quality.

Poor Quality of Life Contributed to Poor Sleep Quality

This study found that patients with poor quality of life were 2.49 times more likely to have poor sleep quality compared with patients with good quality of life. Quality of life and sleep quality were interrelated,[39] and previous studies have focused on the effects of sleep quality on quality of life. Luyster et al[33] found that poor sleep quality may negatively impact health-related quality of life. Another cross-sectional study conducted in China[40] showed that poor sleep quality was a risk factor (OR = 3.67) for health-related quality of life in T2DM patients. This study analyzed these two variables from different perspective and suggested that there might be a possible correlation between them.

Increasing Age Contributed to Poor Sleep Quality, Short Sleep Duration and Low Sleep Efficiency

Furthermore, we found that increasing age was associated with poor sleep quality, short sleep duration and low sleep efficiency. Similarly, Mikołajczyk-Solińska et al[41] found that age was a significant risk factor contributing to impaired sleep quality in elderly T2DM patients. Åkerstedt et al[41] found that increased age was related to lower total sleep time and sleep efficiency. One possible reason is related to decreased melatonin secretion in the elderly.[42,43] Studies[44] have shown that the pineal gland shrinks with age and decreases production of the pineal hormone, impairing its ability to regulate sleep. In addition, the degeneration of various organs in the elderly and the increase in nocturia caused by diabetes might lead to disrupted sleep at night,[45,46] leading to impaired sleep quality.

Strengths, Limitations, and Implications

Unlike previous studies, we explored the influencing factors of sleep quality, sleep latency, sleep duration and sleep efficiency in patients with diabetes, and found common influencing factors among these four sleep variables. Results revealed that depression symptoms were a significant factor associated with poor sleep quality, long sleep latency as well as short sleep duration. Our study is the first to investigate the influencing factors of sleep variables in T2DM patients with comorbid MS. We found the proportion of patients with poor sleep quality in this group of patients was high and investigated several potential influencing factors. This study provides a scientific basis for future research on sleep quality of T2DM patients with comorbidities.

There are a few limitations we have to clarify. Firstly, this was a cross-sectional study without a large sample size. The causal relationship between depression symptoms, poor quality of life and sleep quality could not be evaluated. Cohort studies with larger sample sizes are needed to further reveal the causal relationship. Secondly, all the dependent variables, including sleep quality, sleep latency, sleep duration and sleep efficiency, were subjective outcome variables obtained through questionnaires. There might be a recall bias. Polysomnography might be used to obtain objective indicators of patients' sleep quality in future study. Then, since only 5 patients in this study reported that they slept for more than 8 hours, we could not group people who slept more than eight hours. Therefore, the studies lacked an analysis of the factors influencing the too long sleep duration. Last but not the least, like adults, children often suffer from sleep difficulties and the proportion of children with sleep difficulties ranged from 20% to 30%,[47] damaging their physical and mental health. This study only included adult participants. Future studies should also be focused on children and teenagers to find out the related factors in this group of participants and find satisfying methods to improve their sleep quality as well.

Sleep disturbance has often been reported to be related to insulin resistance and reduced glucose tolerance, contributing to the progression of diabetes and increases the risk of diabetes complications in T2DM patients. On the other hand, diabetes, especially with poor control of blood glucose level, has been reported to be associated to the development of sleep disturbance.[16] However, the mechanisms by which the interactions occur are still being elucidated. In future, the polysomnography or wearing devices can be used to obtain objective sleep indicators of diabetes patients in addition to subjective indicators obtained by the questionnaire, while randomized controlled trial study with a larger sample size can be conducted to explore the casual relationship and mechanism between these two variables.

Conclusion

The prevalence of poor sleep quality in T2DM patients with comorbid MS was 59.10%, and this study found that depression symptoms, poor quality of life and an increasing age were risk factors for poor sleep quality in this group of patients. Therefore, T2DM patients with depression symptoms or poor quality of life should be considered as an important population to be paid attention to their sleep conditions and sleep assessment are essential for them. Corresponding sleep health education and intervention measures should be implemented for patients with sleep disorders to improve their sleep quality and promote the management of diabetes.

Author Contributions

All authors made a significant contribution to the work reported, whether that in the conception, study design, acquisition of data, analysis, and interpretation, or in all these areas in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors report no conflicts of interest in this work.

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