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ORIGINAL RESEARCH

Association Between Nocturnal Sleep Duration and Obesity Indicators Among People with Type 2 Diabetes: A Cross-Sectional Study in Ningbo, China

Miao Xu[1,*], Kaushik Chattopadhyay[2,*], Xingjun Qian[3], Jialin Li[1], Xueyu Li[1], Jing Sun[4], Li Li[1]

[1]Department of Endocrinology and Metabolism, Ningbo First Hospital, Ningbo, People's Republic of China; [2]Division of Epidemiology and Public Health, School of Medicine, University of Nottingham, Nottingham, UK; [3]Health Management Center, Ningbo First Hospital, Ningbo, People's Republic of China; [4]School of Medicine and Dentistry, Griffith University, Gold Coast, Queensland, Australia

*These authors contributed equally to this work

Correspondence: Li Li, Department of Endocrinology and Metabolism, Ningbo First Hospital, Ningbo, People's Republic of China, Tel +8613757426626, Email lilyningbo@163.com

Aim: The study aimed to investigate the association between the nocturnal sleep duration and five obesity indicators, namely, visceral fat area (VFA), subcutaneous fat area (SFA), bodyweight, body mass index (BMI) and waist circumference (WC), among people with type 2 diabetes mellitus (T2DM) in Ningbo, China.

Methods: A cross-sectional study was conducted using the National Metabolic Management Centre (MMC) - Ningbo First Hospital data from 1st March 2018 to 28th February 2021. Adults with T2DM were included in the study. Simple and multiple (adjusted for sociodemographic and lifestyle factors and health conditions) linear regression analyses were performed to identify the associations.

Results: In terms of VFA, SFA, bodyweight, BMI and WC, the eligibility criteria were satisfied by 2771, 2771, 2863, 2863 and 2862 patients, respectively. In the unadjusted model, the shorter nocturnal sleep duration was associated with higher VFA, SFA, bodyweight, BMI and WC. In other words, an hour increase in the nocturnal sleep duration was associated with a decrease of 2.07 cm^2 in VFA (regression coefficient = −2.07; 95% CI = −3.25 to −0.88), 2.67 cm^2 in SFA (−2.67; −4.55 to −0.78); 0.82 kg in bodyweight (−0.82; −1.2 to −0.43), 0.2 kg/m^2 in BMI (−0.2; −0.31 to −0.09) and 0.46 cm in WC (−0.46; −0.76 to −0.16). In the adjusted models, the shorter nocturnal sleep duration was still found to be associated with higher VFA, SFA, bodyweight, BMI and WC (except SFA and WC in models where we further adjusted for health conditions).

Conclusion: The nocturnal sleep duration among people with T2DM in Ningbo, China is negatively associated with visceral and general obesity indicators (VFA, bodyweight and BMI). Thus, there is a need for appropriate interventions to address the issue of sleep deprivation.

Keywords: type 2 diabetes mellitus, nocturnal sleep, obesity, China

Introduction

Type 2 diabetes mellitus (T2DM) is closely associated with obesity.[1] A number of indicators are used for different types of obesity. The visceral fat area (VFA) is used for abdominal visceral fat mass and the subcutaneous fat area (SFA) for abdominal subcutaneous fat mass.[2] Waist circumference (WC) is a central obesity indicator, but visceral fat mass and subcutaneous fat mass are not distinguishable from it.[2] Central obesity, especially visceral obesity, increases blood glucose levels[3] and the risk of diabetic micro- and macro-vascular complications.[4–6] Chinese people with T2DM tend to have more visceral fat accumulation compared to Caucasians.[7]

In China, sleep deprivation is prevalent, and a meta-analysis of 47 studies reported the pooled prevalence of sleep disturbances among older adults as 36%.[8] Another study found that 23% of people with T2DM in China sleep for less than six hours compared to only 12% of healthy people.[9] Shortage of sleep causes an increase in ghrelin and a decrease in leptin, which are essential for sensing hunger and satiety.[10] The shortage activates the hypothalamic-pituitary-adrenal

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(HPA) axis[11] and increases the concentration of cortisol.[12] Because glucocorticoid plays a role in fat accumulation in the abdominal region, so, the shortage of sleep may be associated with abnormal fat accumulation.

Globally, limited studies have been conducted on this topic, especially among people with T2DM, and the findings were inconsistent.[13–21] To the best of our knowledge, no such study has been conducted among people with T2DM in China. Thus, the study aimed to investigate the association between the nocturnal sleep duration and five obesity indicators among these patients. The findings could support the need for appropriate actions to address this issue.

Materials and Methods

Study Design, Site, Population, Data Source and Period

A cross-sectional study was conducted using the National Metabolic Management Centre (MMC) - Ningbo First Hospital data from 1st March 2018 to 28th February 2021. MMC is a multi-hospital-based programme running across mainland China to provide standardised management for metabolic diseases and led by Ruijin Hospital, Shanghai.[22] During these three years, a total of 3170 patients with metabolic disorders were registered and managed at this MMC. The study inclusion criteria were patients aged 18 to 75 years, visiting this MMC for the first time and diagnosed with T2DM based on the World Health Organization (WHO) criteria (1999).[23] We excluded those with other metabolic diseases and without data on the nocturnal sleep duration (n=40) or either of the included obesity indicators (VFA n=92, SFA n=92 and WC n=1).

Data Collection and Study Variables

A standardised questionnaire developed and piloted by MMC was used for this purpose, and the physiological, anthropometric and biochemical parameters were measured/analysed by the trained nurse/laboratory staff using the MMC standardised protocol.[22] In this study, the following variables were used: (a) self-reported sociodemographic factors, namely, age (years), sex, education (≤9 or >9 years) and family income (0–100,000 RMB/year, 101,000–300,000 RMB/year or >300,000 RMB/year); (b) self-reported lifestyle factors, namely, fruits and vegetable intake (<200 gm/day, ≥200–399 gm/day, ≥400–599 gm/day or ≥600 gm/day), physical activity (low, medium or high; using the Chinese version of the International Physical Activity Questionnaire-short (IPAQ),[24] smoking and alcohol drinking (no or yes); (c) health conditions, namely, HbA1c (%; using the high-performance liquid chromatographic (HPLC) method (D-10 Hemoglobin Analyzer, Bio-Rad, USA)), duration of T2DM (years), hypertension (no or yes; defined as systolic blood pressure ≥140 mmHg and/or diastolic blood pressure ≥90 mmHg on the day of visit using an automated blood pressure monitor (HBP-1100U, Omron, Japan) in a seated position, self-reported history of hypertension or use of antihypertensive medicines) and hyperlipidaemia (no or yes; defined as total cholesterol ≥4.5 mmol/L or triglycerides ≥1.7 mmol/L determined by enzymatic assays (AU5400, Beckman Coulter, USA) or self-reported history of hyperlipidaemia); (d) self-reported nocturnal sleep duration (hours); and (e) five obesity indicators: VFA and SFA (cm^2; calculated at the umbilical level using a dual BIA (DUALSCAN HDS-2000, Omron, Japan); bodyweight (kg) and body mass index (BMI; kg/m^2) (bodyweight and height were measured with light clothes and without shoes in standing position using a calibrated automatic digital weight and height scale (HNH-318, Omron, Japan); weight was measured to the nearest 0.1 kg, height was measured to the nearest 0.5 cm and BMI was calculated as weight in kg divided by height in m^2); and WC (cm; measured to the nearest 0.5 cm using a 150 cm medical tape at midpoint between lower rib and iliac crest).

Ethics

Ethics approval was obtained from the Research Ethics Committee of Ruijin Hospital (2017 No. 42) and Ningbo First Hospital (2019-R057). Written informed consent was obtained from all the patients. The study complied with the Declaration of Helsinki.

Statistics Analyses

Continuous data were presented as mean±SD if normally distributed or median (IQR) if skewed, and categorical data were presented as numbers (percentages). To identify any association between the nocturnal sleep duration and five

obesity indicators, the following models were created: in model 1, simple linear regression analyses were performed; in model 2, multiple linear regression analyses were performed and adjusted for sociodemographic (age, sex, education and family income) factors; in model 3, multiple linear regression analyses were performed and adjusted for sociodemographic and lifestyle (fruits and vegetable intake, physical activity, smoking and alcohol drinking) factors; and in model 4, multiple linear regression analyses were performed and adjusted for sociodemographic and lifestyle factors and health conditions (HbA1c, duration of T2DM, hypertension and hyperlipidaemia). Missing data (unknown) were included in models 2, 3 and 4. Regression coefficients (β) and 95% confidence intervals (CIs) were reported. A p-value ≤0.05 was considered statistically significant. IBM SPSS statistics version 20.0 for Windows was used for data analyses.

Results

In terms of VFA, SFA, bodyweight, BMI and WC, the eligibility criteria were satisfied by 2771, 2771, 2863, 2863 and 2862 patients, respectively. Table 1 shows the characteristics of included patients. The mean age was 51 years, and 65% were males. The mean nocturnal sleep duration was 8 hours. The mean VFA was 94.8±40.2 cm^2, SFA was 180.8±64.2 cm^2, bodyweight was 69.5±13.3 kg, BMI was 25.4±3.8 kg/m^2 and WC was 89.3±10.3 cm.

Table 2 reports the association between the nocturnal sleep duration and five obesity indicators. In model 1, the shorter nocturnal sleep duration was associated with higher VFA, SFA, bodyweight, BMI and WC. In other words, an hour increase in the nocturnal sleep duration was associated with a decrease of 2.07 cm^2 in VFA (β=−2.07; 95% CI=−3.25 to −0.88), 2.67 cm^2 in SFA (−2.67; −4.55 to −0.78); 0.82 kg in bodyweight (−0.82; −1.2 to −0.43), 0.2 kg/m^2 in BMI (−0.2; −0.31 to −0.09) and 0.46 cm in WC (−0.46; −0.76 to −0.16). In model 2, 3 and 4, the shorter nocturnal sleep duration was still found to be associated with higher VFA, SFA, bodyweight, BMI and WC (except for SFA and WC in model 4).

Discussion

In our study, the nocturnal sleep duration in people with T2DM was found to be negatively associated with visceral and general obesity indicators (VFA, bodyweight and BMI). The finding is consistent with a previous study conducted in Japan in people with T2DM[25] and other populations in different parts of the world.[14,16,26] Studies conducted in other populations have reported a U-shaped association between the nocturnal sleep duration and BMI and WC.[17,18] The reasons behind these could be the differences in population characteristics such as sociodemographic characteristics and disease conditions.[14,16,21,26–29]

Sleep deprivation is associated with metabolic conditions including diabetes, hypertension and hyperlipidaemia.[28,30–32] These metabolic conditions are also associated with SFA and WC.[33–35] These could be the reasons for the disappearance of the association between the nocturnal sleep duration and SFA and WC after adjustment for these metabolic conditions. It is possible that sleep insufficiency can lead to insulin resistance, the reduction of leptin and elevation of ghrelin and dysregulation of cortisol and growth hormone, and all these can lead to VFA accumulation but not SFA.[10,12,36] It should be noted that people with T2DM are genetically predisposed to muscle insulin resistance, and are, therefore, prone to becoming overweight or obese.[37] It is possible that increased glucose and insulin level in the body promotes fat production and storage.[38] In addition, antidiabetic drugs (eg, metformin, and GLP-1 receptor agonists) reduce hepatic glucose production in people with T2DM and leads to some weight loss and fat reduction. However, other antidiabetic drugs (eg, insulin, insulin secretagogues and thiazolidinediones) leads to weight gain and deposition of fat. Furthermore, insulin resistance caused by lipotoxicity is associated with tissue lipid deposition in various insulin target tissues eg, visceral fat deposition.[39]

In our study, the average BMI was 25 kg/m^2 which was higher than the target of <24 kg/m^2 and the average WC was 89 cm which was higher than the target of <85 cm for males and <80 cm for females, as recommended in the Chinese T2DM prevention and management guideline.[40] Similarly, the average VFA was 95 cm^2 which was higher than the recommended target of 80 cm^2 for abdominal visceral obesity among Chinese.[41] One longitudinal study conducted among Canadian adults concluded that an increase in sleep duration can decrease visceral fat accumulation.[15] Thus, there is a scope to develop, evaluate and implement appropriate interventions to address the issue of sleep deprivation. For

Table 1 Patient Characteristics (Values are Mean±SD or n (%) Unless Otherwise Indicated)

	VFA n=2771	**SFA n=2771**	**Bodyweight n=2863**	**BMI n=2863**	**WC n=2862**
	94.8±40.2 cm^2	180.8±64.2 cm^2	69.5±13.3 kg	25.4±3.8 kg/m^2	89.3±10.3 cm
Age (years)	51.1±11.6	51.1±11.6	51.1±11.7	51.1±11.7	51.1±11.7
Sex					
Male	1788 (64.5)	1788 (64.5)	1846 (64.5)	1846 (64.5)	1845 (64.5)
Female	983 (35.5)	983 (35.5)	1017 (35.5)	1017 (35.5)	1017 (35.5)
Education (years)					
≤9	1401 (50.6)	1401 (50.6)	1449 (50.6)	1449 (50.6)	1448 (50.6)
>9	1355 (48.9)	1355 (48.9)	1397 (48.8)	1397 (48.8)	1397 (48.8)
Unknown	15 (0.5)	15 (0.5)	17 (0.6)	17 (0.6)	17 (0.6)
Family income (1000 RMB/year)					
0–100	977 (35.3)	977 (35.3)	1019 (35.6)	1019 (35.6)	1018 (35.6)
101–300	1251 (45.1)	1251 (45.1)	1281 (44.7)	1281 (44.7)	1281 (44.5)
>300	425 (15.3)	425 (15.3)	433 (15.1)	433 (15.1)	433 (15.1)
Unknown	118 (4.3)	118 (4.3)	130 (4.5)	130 (4.5)	130 (4.5)
Fruits intake (gm/day)					
<200	1736 (62.6)	1736 (62.6)	1790 (62.5)	1790 (62.5)	1789 (62.5)
≥200–399	898 (32.4)	898 (32.4)	925 (32.3)	925 (32.3)	925 (32.3)
≥400–599	109 (3.9)	109 (3.9)	113 (3.9)	113 (3.9)	113 (3.9)
≥600	26 (0.9)	26 (0.9)	27 (0.9)	27 (0.9)	27 (0.9)
Unknown	2 (0.1)	2 (0.1)	8 (0.3)	8 (0.3)	8 (0.3)
Vegetable intake (gm/day)					
<200	662 (23.9)	662 (23.9)	679 (23.7)	679 (23.7)	679 (23.7)
≥200–399	1311 (47.3)	1311 (47.3)	1358 (47.4)	1358 (47.4)	1357 (47.4)
≥400–599	664 (24.0)	664 (24.0)	683 (23.9)	683 (23.9)	683 (23.9)
≥600	132 (4.8)	132 (4.8)	135 (4.7)	135 (4.7)	135 (4.7)
Unknown	2 (0.1)	2 (0.1)	8 (0.3)	8 (0.3)	8 (0.3)
Physical activity					
Low	1223 (44.1)	1223 (44.1)	1256 (43.9)	1256 (43.9)	1256 (43.9)
Medium	1333 (48.1)	1333 (48.1)	1385 (48.4)	1385 (48.4)	1384 (48.4)
High	188 (6.8)	188 (6.8)	194 (6.8)	194 (6.8)	194 (6.8)
Unknown	27 (1.0)	27 (1.0)	28 (1.0)	28 (1.0)	28 (1.0)
Smoking					
No	1833 (66.1)	1833 (66.1)	1895 (66.2)	1895 (66.2)	1895 (66.2)
Yes	876 (31.6)	876 (31.6)	903 (31.5)	903 (31.5)	902 (31.5)
Unknown	62 (2.2)	62 (2.2)	65 (2.3)	65 (2.3)	65 (2.3)

(*Continued*)

Table 1 (Continued).

	VFA n=2771	SFA n=2771	Bodyweight n=2863	BMI n=2863	WC n=2862
Alcohol drinking					
No	1504 (54.3)	1504 (54.3)	1563 (54.6)	1563 (54.6)	1563 (54.6)
Yes	1204 (43.5)	1204 (43.5)	1234 (43.1)	1234 (43.1)	1233 (43.1)
Unknown	63 (2.3)	63 (2.3)	66 (2.3)	66 (2.3)	66 (2.3)
HbA1c (%)*	7.8 (6.6, 9.6)	7.8 (6.6, 9.6)	7.8 (6.6, 9.6)	7.8 (6.6, 9.6)	7.8 (6.6, 9.6)
Unknown	86 (3.1)	86 (3.1)	88 (3.1)	88 (3.1)	88 (3.1)
Duration of T2DM (years)*	5.7 (2.0, 10.5)	5.7 (2.0, 10.5)	5.8 (2.0, 10.6)	5.8 (2.0, 10.6)	5.8 (2.0, 10.6)
Unknown	335 (12.1)	335 (12.1)	348 (12.2)	348 (12.2)	348 (12.2)
Hypertension					
No	1198 (43.2)	1198 (43.2)	1237 (43.2)	1237 (43.2)	1237 (43.2)
Yes	1568 (56.6)	1568 (56.6)	1621 (56.6)	1621 (56.6)	1620 (56.6)
Unknown	5 (0.2)	5 (0.2)	5 (0.2)	5 (0.2)	5 (0.2)
Hyperlipidaemia					
No	492 (17.8)	492 (17.8)	507 (17.7)	507 (17.7)	507 (17.7)
Yes	2140 (77.2)	2140 (77.2)	2210 (77.2)	2210 (77.2)	2209 (77.2)
Unknown	139 (5.0)	139 (5.0)	146 (5.1)	146 (5.1)	146 (5.1)
Nocturnal sleep duration (hours)	7.8±1.3	7.8±1.3	7.8±1.3	7.8±1.3	7.8±1.3

Note: *median (IQR).

example, lifestyle change interventions such as physical activity and healthy diet could address this problem of sleep deprivation.[42]

This study has several strengths and weaknesses. Globally, the topic is a less-explored area among people with T2DM, and to the best of our knowledge, this was the first study in China. We included a wide range of obesity indicators. The routinely collected data quality was good. The five obesity indicators were measured using robust methods. However, the nocturnal sleep duration was self-reported by people with T2DM, which could have been under- or over-estimated and affected the study findings. In future studies, sleep should also be assessed objectively and Actiwatch could be used for this purpose.[18,19,43,44] Previous studies have categorised this variable using a range of cut-offs.[17,18] However, we kept it as a continuous variable because there is no consensus on how to categorise this variable into short, normal and long.[16] Missing data on adjusted variables were low in the study, and missing data were excluded listwise during multiple linear regression analyses. Since it was a cross-sectional study, the causal relationship between the nocturnal sleep duration and five obesity indicators could not be determined. We were not able to include sleep quality, daytime sleep and sleep apnoea syndrome in the present study, and these factors will be included in our future studies.

In conclusion, the nocturnal sleep duration among people with T2DM in Ningbo, China is negatively associated with visceral and general obesity indicators (VFA, bodyweight and BMI). Thus, there is a need for appropriate interventions to address the issue of sleep deprivation.

Data Sharing Statement

The dataset will be available from the corresponding author upon request unless there are legal or ethical reasons for not doing so.

Table 2 Association Between Nocturnal Sleep Duration and Five Obesity Indicators

	VFA			SFA			Bodyweight			BMI			WC		
	β Value	95% CI	*p*-value	β Value	95% CI	*p*-value	β Value	95% CI	*p*-value	β Value	95% CI	*p*-value	β Value	95% CI	*p*-value
Model 1 Unadjusted regression coefficient (95% CI; p-value)	−2.07	(−3.25, −0.88)	p=0.001	−2.67	(−4.55, −0.78)	p=0.006	−0.82	(−1.2, −0.43)	p<0.001	−0.2	(−0.31, −0.09)	p=0.001	−0.46	(−0.76, −0.16)	p=0.003
Model 2 Adjusted regression coefficient[a] (95% CI; p-value)	−1.52	(−2.68, −0.37)	p=0.01	−2.52	(−4.40, −0.65)	p=0.008	−0.50	(−0.83, −0.17)	p=0.003	−0.17	(−0.28, −0.06)	p=0.002	−0.34	(−0.63, −0.04)	p=0.025
Model 3 Adjusted regression coefficient[b] (95% CI; p-value)	−1.59	(−2.74, −0.45)	p=0.007	−2.55	(−4.41, −0.68)	p=0.007	−0.51	(−0.84, −0.18)	p=0.002	−0.17	(−0.28, −0.07)	p=0.002	−0.35	(−0.64, −0.06)	p=0.02
Model 4 Adjusted regression coefficient[c] (95% CI; p-value)	−1.25	(−2.42, −0.08)	p=0.037	−1.67	(−3.57, 0.22)	p=0.083	−0.41	(−0.74, −0.07)	p=0.017	−0.13	(−0.24, −0.02)	p=0.02	−0.25	(−0.54, 0.05)	p=0.104

Notes: [a]Adjusted for sociodemographic factors (age, sex, education and family income). [b]Adjusted for sociodemographic and lifestyle factors (age, sex, education, family income, smoking, alcohol drinking, fruits and vegetable intake, physical activity). [c]Adjusted for sociodemographic and lifestyle factors and health conditions (age, sex, education, family income, smoking, alcohol drinking, fruits and vegetable intake, physical activity, HbA1c, duration of T2DM, hypertension and hyperlipidaemia).

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Disclosure

The authors declare that they have no competing interests.

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