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Association between insomnia and type 2 diabetes mellitus in Han Chinese individuals in Shandong Province, China

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Abstract

Purpose Diabetes and sleep disorders are public health threats worldwide, but the potential association between them is still unclear.

Methods We conducted a community-based cross-sectional study including 5078 participants (2665, 52.5% male) to determine the association between insomnia and diabetes mellitus prevalence.

Results In patients with type 2 diabetes mellitus (T2DM) and nondiabetic controls, the prevalence of insomnia was 20.2% (68/377) and 12.2% (578/4741), respectively. The results showed that insomnia was associated with T2DM after adjusting for age, sex, BMI, smoking, alcohol consumption, presence of disease history (hypertension, dyslipidemia, stroke, cardiovascular diseases, cancers), and depression (odds ratio [OR] = 1.31, 95% confidence interval [CI] 1.03–1.66). After stratifying by age and sex, insomnia was significantly associated with diabetes mellitus only in the subgroup of middle-aged participants (40–59 years) (OR = 1.61, 95% CI 1.16–2.23) and males (OR = 1.48, 95% CI 1.08–2.03) after controlling for the above covariates.

Conclusions This study suggests that insomnia is independently and significantly associated with diabetes mellitus in the northern Chinese population, especially in the 40–59-year-old age group and in males.

Keywords Insomnia · Sleep duration · Diabetes mellitus · Athens insomnia scale · Cross-sectional study

Introduction

With the rapid increase in the prevalence of diabetes mellitus around the world, vascular injuries caused by diabetes have been shown to account for a majority of the social and economic burden in both developing and developed countries [1]. Insomnia has become increasingly more prevalent in many countries, which has resulted in serious public health problems worldwide [2].

Accumulating evidence has suggested that sleep deficiency is linked to an increased risk of diabetes mellitus [3]. Some observational studies revealed that either a short or long sleep duration is associated with future diabetes mellitus incidence [4–6]. Studies have found that short sleep duration and poor sleep quality increase the risk of diabetes [7–10]. In contrast, some scholars have reported that there is no association between severe sleep disorders and clinically identified diabetes mellitus [11–13]. However, most of these previous studies have focused on investigating the relationship between sleep duration and diabetes mellitus [3, 8] and lacked an appropriate assessment of sleep quality.

Despite efforts made by researchers to investigate the relation between sleep quality and diabetes [9, 14], the results linking sleep quality and diabetes mellitus have been controversial because the studies have usually categorized sleep quality as "poor" or "good" sleep instead of comprehensively evaluating the sleep disorder or insomnia using a validated insomnia criterion.

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It remains unclear whether insomnia is associated with a higher prevalence of diabetes in the Chinese adult population. In this cross-sectional study, we evaluated the relationship between insomnia and diabetes mellitus based on a quantitative validated insomnia scaling system in a community in northern China.

Materials and methods

Study design and participants

This community-based cross-sectional study was conducted from January to April of 2016 in the Kuiwen community, located in Weifang, Shandong Province, of northeastern China. Participants 18 years and older who provided written informed consent were included in this study. After excluding individuals with missing information related to diabetes mellitus or sleep disorders (284 participants, 5.3%), a total of 5078 subjects (94.7%) were finally eligible for investigation. Physical examinations and questionnaires were conducted by trained medical professionals from Weifang Maternity and Child Health Hospital, Weifang Hospital of Traditional Chinese Medicine, and Anqiu People's Hospital. The study was approved by the Ethics Committee of Weifang Maternity and Child Health Hospital. All experiments in this study were performed in accordance with the guidelines of the Declaration of Helsinki, and all participants provided written informed consent.

Diagnosis of type 2 diabetes mellitus

The participants who met one or a combination of the following criteria were diagnosed as having T2DM: (1) self-reported history of diabetes mellitus diagnosed by a qualified clinical physician; (2) current use of hypoglycemic agents including insulin; and (3) fasting blood glucose level ≥ 7.0 mmol/L according to the diagnostic criteria of the American Diabetes Association [15].

Assessment of insomnia

Sleep quality was assessed by using the Athens Insomnia Scale (AIS) system, which is a validated screening tool for insomnia in different ethnic populations [16, 17]. The AIS consists of eight items, with each item scored from 0 to 3 by the degree of severity of the sleep disorders. The total score ranges from 0 to 24, and scores ≥ 6 are considered to indicate insomnia [17], based on the balance between sensitivity (93%) and specificity (85%) [17]. The AIS has been translated into many languages and has been used in different populations worldwide, including the Chinese population, with a Cronbach's α of 0.81 [16] and a good predictive value of 99% [17].

Covariates

A questionnaire administered by trained physicians using face-to-face interviews was used to collect information such as sex, age, lifestyle, disease history, and other characteristics. Tobacco use ≥ 1 cigarette per day consecutively for more than 1 year was defined as smoking. Alcohol consumption was defined as the intake of ≥ 100 ml of alcohol-containing liquids per day for more than 1 year. Body mass index (BMI) was calculated by height (accurate to 0.1 cm) and weight (accurate to 0.1 kg). A history of stroke, cardiovascular disease, and cancer was obtained based on previous history, without deep examination. Depressive status was measured using the Patient Health Questionnaire-9 (PHQ-9), with a summary score ≥ 5 defined as depression.

Hypertension was defined as a self-reported history of hypertension, current use of antihypertensive medication, systolic blood pressure ≥ 140 mmHg, or diastolic blood pressure ≥ 90 mmHg [18]. Hyperlipidemia was defined as the presence of a history of hyperlipidemia, current use of cholesterol-lowering medicine, a total cholesterol level ≥ 5.7 mmol/L or triglycerides ≥ 1.7 mmol/L [19].

After an overnight fast, blood samples were drawn from the study participants by trained phlebotomists and then saved in trisodium ethylenediaminetetraacetic acid tubes. Biochemical factors were measured using the Autoanalyzer (Hitachi 747; Hitachi, Tokyo, Japan) in the central laboratory of Weifang Material and Child Health Hospital.

Statistical analyses

Statistical tests were carried out using SPSS 13.0 (IBM-SPSS, Chicago, USA). Continuous variables are presented as the mean ± standard deviation (SD) or median with the interquartile range (IQR). Categorical variables are presented as percentages. Chi-square tests or Student's t test were used in the univariate analysis of risk factors. Binary logistic regression models were used to determine the relationship among insomnia, sleep duration, and diabetes mellitus. The odds ratios (ORs) with 95% confidence intervals were calculated after adjusting for the potential covariables. Four multiple logistic regression models were run. Two-tailed $P < 0.05$ was considered to be statistically significant.

Results

Baseline characteristics

Demographic characteristics and diabetes-related risk factors of the study participants are presented in Table 1. The data show that out of the 5078 participants, 337 (6.64%) had T2DM, and 646 (12.7%) had insomnia. The median score of

Table 1 Baseline characteristics according to the absence or presence of T2DM

Variants	Total ($n = 5078$)	T2DM ($n = 337$)	Controls ($n = 4741$)	Chi-square/t/Z	P
Age (years)	42.7 ± 13.1	55.5 ± 11.0	41.8 ± 12.78	21.84	< 0.001
Male, *n* (%)	2665 (52.5)	214 (63.5)	2451 (51.7)	17.58	< 0.001
Married, *n* (%)	4685 (92.3)	333 (98.8)	4352 (91.8)	21.70	< 0.001
Income (¥/month)				5.68	< 0.001
≤¥3000	1957 (38.5)	184 (54.6)	1773 (37.4)		
¥3001–5000	2738 (53.9)	130 (38.6)	2608 (55.0)		
≥¥5001	383 (7.5)	23 (6.8)	360 (7.6)		
Education level				12.17	< 0.001
Illiteracy/primary	183 (3.6)	31 (9.2)	152 (3.2)		
Middle school	1822 (35.9)	205 (60.8)	1617 (34.1)		
College/university	3073 (60.5)	101 (30.0)	2972 (62.7)		
Current smoking (%)	1324 (26.1)	106 (31.5)	1218 (25.7)	5.42	0.020
Current drinking (%)	146 (2.9)	13 (3.9)	133 (2.8)	1.25	0.264
Body mass index (kg/m^2)	24.54 ± 3.74	26.85 ± 3.85	24.37 ± 3.67	11.46	< 0.001
Hypertension, *n* (%)	1570 (30.9)	238 (70.6)	1332 (28.1)	266.43	< 0.001
Dyslipidemia, *n* (%)	1822 (35.9)	220 (65.3)	1602 (33.8)	135.63	< 0.001
History of stroke, *n* (%)	44 (0.9)	11 (3.3)	33 (0.7)	24.16	< 0.001
History of cardiovascular disease, *n* (%)	48 (0.9)	10 (3.0)	38 (0.8)	13.54	< 0.001
History of cancers, *n* (%)	63 (1.2)	6 (1.8)	57 (1.2)	0.86	0.502
Depression, *n* (%)	324 (6.4)	16 (4.7)	308 (6.5)	1.61	0.204
Scores of AIS	0 (0, 3)	1 (1, 4)	0 (0, 2)	2.98	0.002
Insomnia, *n* (%)	646 (12.7)	68 (20.2)	578 (12.2)	18.08	< 0.001

AIS is 1 (interquartile 1–4) and 0 (0–2) in patients with T2DM and in nondiabetic controls, respectively ($P = 0.002$). In addition, 20.2% (68/377) of diabetic patients suffered from insomnia, while only 12.2% (578/4741) of nondiabetic participants did ($P < 0.001$).

Analysis of associations between insomnia and T2DM

Results for the analysis of the associations between insomnia and diabetes mellitus are presented in Table 2. Four models were established to investigate the association by adjusting for different possible confounding factors. The data show that the crude OR was high (OR = 1.83, 95% CI 1.49–2.56) (model 1) and that in model 3, insomnia was associated with a higher risk for diabetes mellitus (OR = 1.31, 95% CI 1.03–1.66) when adjustments were made for potential confounding factors, including age, sex, BMI, smoking, alcohol consumption, and presence of disease history (hypertension, dyslipidemia, stroke, cardiovascular diseases, cancers) and current prevalence of depression.

The analysis was further stratified by age, and a significant association between insomnia and diabetes mellitus was found in only the 40–59-year-old group after adjusting for the other covariates (OR = 1.61, 95% CI 1.16–2.23). When the study participants were stratified based on sex, insomnia was significantly correlated with an increased risk of T2DM in males (OR = 1.48, 95% CI 1.08–2.03) but not in females (OR = 1.15, 95% CI 0.81–1.62).

Discussion

To our knowledge, this was one of the largest community-based cross-sectional studies performed in northern Chinese

Table 2 The odds ratios of T2DM according to insomnia in all the participant and stratified by age and gender

	Model 1	Model 2	Model 3
Overall	1.83 (1.49–2.56)	1.36 (1.09–1.70)	1.31 (1.03–1.66)
Age (years)			
18–39	1.19 (0.51–2.77)	1.28 (0.55–2.99)	1.28 (0.53–3.13)
40–59	1.64 (1.21–2.21)	1.85 (1.36–2.52)	1.61 (1.16–2.23)
≥ 60	1.02 (0.74–1.42)	1.08 (0.77–1.51)	1.11 (0.78–1.56)
Gender			
Male	2.06 (1.54–2.74)	1.53 (1.13–2.07)	1.48 (1.08–2.03)
Female	1.93 (1.41–2.63)	1.16 (0.83–1.61)	1.15 (0.81–1.62)

Model 1: unadjusted. Model 2: adjusted for age and sex. Model 3: adjusted for model 2 and further adjusted for smoking, drinking, BMI, presence of disease history (hypertension, dyslipidemia, stroke, cardiovascular diseases, cancers), and depression

adults to investigate the relationship between insomnia and diabetes mellitus using a validated insomnia scaling system. Our study demonstrates that insomnia is an independent risk factor for incident T2DM, especially among adults aged 40–59 years and males.

In the present study, the data show that 20.2% of diabetic patients suffered from insomnia, while only 12.2% of nondiabetic participants did. When age, sex, BMI, smoking, alcohol consumption, and the presence of disease history were adjusted, insomnia was associated with a higher risk for diabetes mellitus (OR = 1.31, 95% CI 1.03–1.66), indicating that the association is independent. Our findings are consistent with previous studies performed in other ethnic populations [9, 12, 20]. The Hispanic Community Health Study/Study of Latinos (HCHS/SOL) showed that both decreased quantity and quality of sleep are associated with diabetes in Hispanic/Latinos, with the association largely explained by obesity [21]. A prospective cohort study conducted in western Scotland showed that cumulative insomnia exposure was correlated with a 34% increase in T2DM incidence [22]. A cross-sectional survey from Japan showed that individuals affected with T2DM are likely to experience sleep disturbance/insomnia symptoms [23]. In a historical cohort study conducted in Taiwan, the T2DM incidence rate of patients with insomnia was significantly higher than that in patients without insomnia (34.7 vs 24.3 per 1000 person-years) [24]. There are also studies reporting different findings on the association between sleep quality and diabetes [11, 25]. An earlier cross-sectional study showed that difficulty in getting to sleep or early waking is associated with diabetes [11]. Similarly, another cross-sectional study showed that poor sleep quality or insomnia alone is not significantly associated with a higher risk of diabetes [26]. A population-based cohort study including healthy adults in Taiwan showed that insomnia symptoms do not modify the association between sleep duration and the individual components of metabolic syndrome, including impaired fasting glucose (IFG) and diabetes [25]. These inconsistent observations may be due to differences in the evaluation of some important confounding factors, such as exercise, depression, and history of hypertension and hyperlipidemia. Another possible explanation may be the use of different criteria for assessing insomnia.

Few studies have examined the relationship between insomnia and risks for diabetes among different age groups. In the present study, we stratified the participants into the young, middle-age, and old groups, and found that subjects in the middle-aged group and old groups had a much higher OR than the young group (1.11 (95% CI 0.78–1.56), 1.61 (1.16–2.33) and 1.28 (0.53–3.13) in old, middle-aged, and young group, respectively). This might be associated with the fact that sleep duration usually decreases with age and that young people can tolerate a short sleep time, which might impact the development of diabetes. A study performed in Taiwan reported that patients aged < 40 years with non-apnea sleep disorders have a higher risk for developing diabetes mellitus [20]. However, this study was retrospective, and potential related confounders, including lifestyle, alcohol use, smoking, and body weight, were absent. Nilsson and coworkers found a significant association between sleep disturbances and the development of diabetes over a 15-year span in middle-aged men [27]. In another longitudinal study of middle-aged women, researchers observed no significant association between sleep disorders and diabetes [28]. Such discrepancies might be partly explained by the fact that these studies included only one sex, and therefore, the study cohorts could not represent a general population. Obstructive sleep apnea (OSA) is a chronic treatable sleep disorder and a frequent comorbidity in patients with type 2 diabetes and insomnia [29, 30], whereas OSA is significantly associated with incident type 2 diabetes [31]. Considering that OSA is associated with male sex and older age [32], it can be inferred that comorbidity might, in part, explain the sex and age discrepancy in the association between type 2 diabetes and insomnia.

Few studies have been carried out to evaluate the joint effects of insomnia and sleep duration on prevalent diabetes. A cross-sectional study including 1741 men and women randomly selected from Central Pennsylvania showed that chronic insomnia, but not poor sleep, was associated with a high risk for diabetes and that insomnia with short sleep duration was associated with increased odds of diabetes [26]. The HCHS/SOL findings showed that participants with short sleep duration and insomnia (odds ratio [OR] 1.46; 95% confidence interval [CI] 1.02, 2.11), average sleepers with insomnia (1.28; 95% CI 1.02, 1.61), and those with a long sleep duration without insomnia (1.33; 95% CI 1.07, 1.65) had elevated odds of diabetes compared to those with average sleep and no insomnia [21]. A systematic review and meta-analysis including 36 studies (1,061,555 participants) showed that pooled RRs of ≤ 5, 6, and ≥ 9 h/day of sleep duration were, respectively, 1.48 (95% CI 1.25, 1.76), 1.18 (1.10, 1.26), and 1.36 (1.12, 1.65), while poor sleep quality was associated with diabetes, with a pooled RR of 1.40 (1.21, 1.63) [33]. Sleep duration was not considered in the present study, which is a main limitation; however, considering the findings in previous studies in other ethnicities [21, 26, 33], it can be inferred that insomnia might be an independent risk factor for prevalent diabetes in the northern Chinese population. Therefore, sleep disturbances, including both sleep quality and sleep duration, should be considered in clinical guidelines for type 2 diabetes screening.

There are other limitations that should be addressed. First, this is a cross-sectional study, which limits our ability to interpret the cause-effect relationship for the associations we have observed between insomnia and diabetes. As the study showed that either insomnia is a risk factor for T2DM or diabetes is a risk factor for insomnia [22, 24], the divergent

causal association might be addressed in future mechanistic studies. Second, selection bias in the community may have also led to the lower age of subjects with diabetes than that of nondiabetic subjects. We focused on the association between insomnia and diabetes, and we also adjusted for these confounding factors in the analysis; thus, the magnitude but not the direction of the association may have changed. Finally, although in the present study we adjusted for some confounding factors (age, sex, smoking, drinking, BMI, presence of disease history (hypertension, dyslipidemia, stroke, cardiovascular diseases, cancers), and depression), there were some potential factors (such as prediabetes, polycystic ovary syndrome, sleep duration, family history associated with diagnosis of DM, obstructive sleep apnea, and use of hypnosis) that may have had an effect on the association between insomnia and diabetes mellitus and need be investigated in a future study.

In conclusion, we showed that insomnia might be an independent risk factor for diabetes mellitus in males and middle-aged adults in northern China. These results suggest that insomnia, as assessed by an insomnia questionnaire, is an independent risk factor for diabetes mellitus. The association between insomnia and diabetes is not only statistically significant but may also be clinically relevant, suggesting that insomnia might be an independent risk factor for diabetes mellitus.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of Weifang Maternity and Child Health Hospital and with the 1964 Declaration of Helsinki and its later amendments or with comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

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