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Relation of sleep quality and sleep duration to type 2 diabetes: a population-based cross-sectional survey

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ABSTRACT

Objectives: To investigate the association between self-reported sleep duration, sleep quality and the prevalence of diabetes in a contemporary sample of Chinese adults.

Design: Cross-sectional survey.

Setting: Community-based investigation in Xuzhou, China.

Participants: 16 893 Chinese men and women aged 18–75 who fulfilled the inclusion and exclusion criteria were enrolled.

Primary and secondary outcome measures: Self-reported quality and duration of sleep were obtained by questionnaire, and type 2 diabetes was assessed by fasting blood glucose. Sleep quality was categorised as good, common or poor. Sleep duration was measured by average hours of sleep per night, with categories of ≤6 h, 6–8 h and ≥8 h. A logistic regression model was used to evaluate the association between sleep duration or sleep quality and diabetes.

Results: Both poor quality of sleep and short sleep duration (≤6 h) were associated with increased prevalence of diabetes, with higher rates in relatively healthy Chinese people. Compared with the group with good quality of sleep and 6–8 h sleep duration, diabetes was the most prevalent in individuals with poor sleep quality and ≤6 h sleep duration (OR 1.41, 95% CI 1.07 to 1.85) and in those with poor sleep quality who slept ≥8 h (OR 1.39, 95% CI 0.85 to 2.26), even after adjustment for a large number of further possible factors.

Conclusions: The results suggest that sleep of poor quality and short duration is associated with diabetes.

ARTICLE SUMMARY

Article focus

- To describe the status of type 2 diabetes in people in Xuzhou, China, and its association with sleep duration and sleep quality.

Key messages

- Type 2 diabetes was related to sleep duration and quality.
- People with short sleep duration and poor sleep quality had a higher risk of type 2 diabetes.

Strengths and limitations of this study

- A strength of the study is the large sample.
- Limitations include the cross-sectional design, sleep time and sleep quality were self-reported.

INTRODUCTION

The prevalence of type 2 diabetes continues to increase and affects an estimated 92.4 million people in China.[1] It has become a major public health problem in the country. Ageing, being female, obesity and an unhealthy lifestyle are generally considered to be risk factors for diabetes, but an increasing number of studies have shown that diabetes is associated with sleep quantity and quality. A prospective study including 6599 initially healthy, non-diabetic men with a mean±SD age of 44.5±4.0 years suggested that sleep disturbances were associated with diabetes prevalence in middle-aged men after a 14.8-year follow-up.[2] The Sleep Heart Health Study with a sample size of 1486 subjects showed that sleep duration of 6 h or less or 9 h or more was associated with an increased prevalence of diabetes and glucose intolerance, compared with sleep duration of 7–8 h per night, after adjustment for confounders.[3] Mallon *et al*[4] demonstrated that difficulty maintaining sleep and short sleep duration (≤5 h) were associated with an increased incidence of diabetes in men. The Massachusetts Male Ageing Study recruited more than 1100 men, and those reporting shorter and longer sleep duration were two and three times, respectively, as likely to develop diabetes over the period of follow-up.[5] Hayashino *et al* confirmed that medium and high frequencies of difficulty initiating sleep were associated with a higher incidence of diabetes in relatively healthy Asian workers, even after adjustment for a large number of further possible factors.[6]

Experimental studies have shown that sleep deprivation and disturbed sleep tend to decrease glucose tolerance and compromise insulin sensitivity,[7 8] which suggests that habitual short sleep duration may lead to insulin resistance by increasing sympathetic nervous system activity, raising evening cortical levels and decreasing cerebral glucose utilisation. The increased burden on the pancreas from insulin resistance can compromise beta cell function and lead to type 2 diabetes over time.[9–11]

However, these studies were carried out in Europe, the USA and Japan.[4–9 12] They therefore do not represent populations across the globe, particularly those from the Indian subcontinent (where type 2 diabetes is highly prevalent) or Africa.[13] It is also not clear whether the results are applicable to the Chinese population. There is increasing evidence that the epidemiology of type 2 diabetes varies with ethnicity.[14]

In the present study, we examined the relation of self-reported habitual sleep time, sleep quality and diabetes in a large community-based sample in China.

METHODS

The data were part of a cross-sectional survey of 'Risk factors of diabetes mellitus among residents living in Xuzhou city' which was conducted from March to November 2008 with a sample size of 23 742 subjects (11 676 men and 12 066 women) aged 15–75 years from urban and rural areas of Xuzhou City selected by multistage stratified random sampling.[15] In our study, we excluded subjects who were aged <18 years, pregnant, on antihypertensive medication, or suffering from any cardiovascular disease, stroke, neuropathy, psychosis, depression, chronic obstructive pulmonary disease, obstructive sleep apnoea syndrome, prediagnosed diabetes, ache and any other diseases. Those who had missing information on sleep duration or sleep quality were also excluded. Face-to-face interviews were carried out by trained physicians and public health workers using a standardised questionnaire to collect socio-demography, lifestyle and health-related information. Altogether, 16 893 adults (7702 men and 9191 women) with complete data were included in our analysis. Of these, 954 had type 2 diabetes mellitus.

The study protocol was approved by Xuzhou Center for Disease Control and Prevention. All participants provided written informed consent.

Key measurements

A subject was defined as having diabetes if the diagnosis had been made by a doctor or if the subject was receiving antidiabetes therapy (insulin and/or tablets) or if two fasting blood samples showed glucose concentrations according to the current WHO definition of diabetes.[16]

Self-reported sleep quality during the previous year was recorded in three categories (good, common or poor). Subjects were asked to rate difficulties with initiating and maintaining sleep on a five-point scale (1, no problems, average <1 day per month; 2, minor problems, average 1–3 days per month; 3, moderate problems, average 4–7 days per month; 4, severe problems, average 8–15 days per month; 5, very severe problems, average ≥16 days per month). Good sleep was defined as no or minor problems, common sleep as moderate problems, and poor sleep as severe or very severe problems. Sleep quantity was measured as self-reported average total hours for a night's sleep during the previous year, and was categorised as ≤6, 6–8 and ≥8 h per night.

Age, gender, current employment status, level of education, cigarette smoking, alcohol intake, physical activity, family history of diseases including diabetes, hypertension, heart disease and cancer were assessed using a standardised questionnaire. Employment status was categorised as manual, non-manual, unemployed and retired. Education was categorised into below high school, high school and above high school level. Lifestyle variables included cigarette smoking, alcohol drinking and physical activity level. Cigarette smoking was defined as having smoked at least 100 cigarettes in their lifetime. Information was obtained on the amount and type of alcohol that was consumed during the previous year, and alcohol drinking was defined as the consumption of at least 30 g alcohol per week for 1 year or more. Regular leisure-time physical activity was defined as participating in moderate or vigorous activity for no less than 30 min per day at least 3 days a week. Body mass index (BMI) was calculated by dividing the weight in kilograms by height in metres squared. BMI was categorised as under weight (≤18.5 kg/m^2), normal weight (18.5–24.0 kg/m^2) and overweight/obese (≥24.0 kg/m^2).[17]

Statistical analysis

We evaluated the distribution of sleep quality and duration in the total population and how it varied by incident of diabetes. Multiple logistic regression analysis was used to assess associations between the three-level sleep difficulty complaints and subjective sleep duration with diabetes by adjustment of age, sex, education categories, smoking, employment status, alcohol consumption, BMI categories and regular exercise. The interaction between sleep quality and duration was analysed by a −2 log likelihood ratio test in logistic regression models. The last logistic regression models included nine dummy variables to represent all nine possible combinations of sleep quality and duration, with good sleep and 6–8 h sleep duration as reference. The minimum statistical significance level for all analyses was $p<0.05$. Statistical analysis was performed on a Lenovo computer using the statistical analysis program SPSS V.11.5.

RESULTS

Table 1 presents characteristics of the study population. Over half of the subjects were women. The mean±SD age was 45.1±14.4 years, and 19% of the subjects were

Table 1 Baseline characteristics of the study population (N=16 893)

Reported variable	All	Diabetes		Sleep quality			Sleep duration		
		No	Yes	Good	Common	Poor	≤6 h	6–8 h	≥8 h
n	16 893	15 939	954	4791	10 835	1267	3269	10 441	3183
Age (years), mean±SD	45.1± 14.4	44.9± 14.7	48.6± 13.2	42.9± 15.7	46.3± 16.5	49.9± 12.3	48.7± 15.9	44.1± 16.7	41.8± 14.6
Sex (% male)	45.6	45.7	43.4	44.8	48.9	48.1	44.2	48.9	48.9
Occupation									
Manual	13 140	12 466	674	3974	8218	948	2352	8757	2031
Non-manual	1025	982	43	221	724	80	245	468	312
Unemployed	1066	1019	47	157	783	126	217	342	507
Retired	1662	1482	190	439	1110	113	455	876	331
Education									
Below high school	7164	6650	514	2157	4566	441	1386	4427	1351
High school	8617	8215	402	2555	5430	632	1663	5325	1629
Above high school	1112	1074	38	259	659	194	220	689	203
Smoker	3165	2970	195	986	1926	253	594	1957	614
Alcohol use	3081	2896	185	910	1935	236	477	1986	618
Regular exercise	5240	4965	275	1743	3212	305	974	3532	734
Family history of diabetes	912	899	13	271	595	46	166	587	159
BMI, mean±SD	23.4± 4.7	23.1± 5.8	25.7± 4.4	23.1± 4.6	23.6± 4.9	22.5± 6.1	24.4± 4.2	23.5± 4.5	23.7± 5.4
Obesity (%) (BMI ≥28)	1033	838	194	292	640	101	286	425	322
Hypertension	2671	1469	1202	531	737	206	498	1640	533
Diabetes	954	/	/	228	578	148	234	528	192
Sleep duration									
≤6 h	3269	3009	234	356	2043	870	N/A	N/A	N/A
6–8 h	10 441	9847	528	2638	7485	318	N/A	N/A	N/A
≥8 h	3183	2977	192	1797	1307	79	N/A	N/A	N/A
Sleep quality									
Good	4791	4563	228	N/A	N/A	N/A	356	2638	1797
Common	10 835	10 257	578	N/A	N/A	N/A	2043	7485	1307
Poor	1267	1119	148	N/A	N/A	N/A	870	318	79

Values are numbers of subjects unless otherwisse indicated.

≥60 years of age. Most (83.9%) of the subjects were employed. Only 6.6% had received a high school education or above. With regard to lifestyle factors, 18.7% were current smokers, 18.2% were alcohol drinkers, and 69% reported no regular exercise. Furthermore, 33.4% were obese. Overall, 28.4% of the subjects reported good sleep quality, and 7.5% reported poor sleep quality in the preceding year; 19.4% of adults slept for 6 or fewer hours, and 18.8% reported 8 or more hours sleep. The prevalence of diabetes in the population was 5.6% (5.9% in women and 5.4% in men), and was 4.8%, 5.3% and 11.7% in subjects with good, common and poor sleep quality, respectively. It was higher in those with poor sleep quality than in those with good sleep quality (11.7% vs 4.8%, $\chi^2 = 82.48$, $p<0.01$) and common sleep quality (11.7% vs 5.3%, $\chi^2 = 81.02$, $p<0.01$). No significant difference was found between the good sleep and common sleep groups (4.8% vs 5.3%, $\chi^2=2025$, $p>0.05$). With regard to sleep quantity, the prevalence of diabetes was 7.2%, 5.1% and 6.0% in subjects who slept for 6 or fewer hours, 6–8 h and 8 and more hours, respectively. It was significantly lower among subjects in the 6–8 h group than those in the group receiving 6 or fewer hours ($\chi^2 = 20.94$, $p<0.01$) and those receiving 8 or more hours ($\chi^2 = 4.63$, $p<0.05$). No significant difference was found between subjects sleeping for 6 or fewer hours and those sleeping for 8 or more hours ($\chi^2 = 3.32$, $p>0.05$).

Poor sleep quality was associated with a significantly higher prevalence of diabetes (OR 1.76, 95% CI 1.14 to 2.71) independent of possible confounders. A sleep duration of ≤6 h increased the risk of diabetes (OR 1.25, 95% CI 1.03 to 1.51, $p<0.01$) compared with the group that slept 6–8 h. No significant association was found between sleep duration of ≥8 h and diabetes (OR 0.87, 95% CI 0.77 to 1.11) (table 2).

Subjects with poor sleep quality and sleep duration of ≤6 h were more likely to have diabetes than those with good quality sleep who slept for 6–8 h (OR 1.41, 95% CI 1.07 to 1.85). The joint association of poor sleep and sleep duration of ≥8 h was a non-significant increase in the association with diabetes (OR 1.39, 95% CI 0.85 to 2.26). For subjects with common or good sleep, no interaction with sleep duration was found (table 3).

Table 2 Multivariate adjusted OR (95% CI) of diabetes and sleep quality or sleep duration

Sleep	Model 1 OR (95% CI)	Model 2 OR (95% CI)	Model 3 OR (95% CI)
Difficulty			
Good	1	1	1
Common	1.26 (0.98 to 1.62)	1.21 (0.95 to 1.59)	1.19 (0.94 to 1.50)
Poor	2.12 (1.46 to 3.08)	1.81 (1.21 to 2.70)	1.76 (1.14 to 2.71)
Duration			
6–8 h	1	1	
≥8 h	1.06 (0.90 to 1.25)	1.01 (0.88 to 1.15)	0.87 (0.71 to 1.11)
≤6 h	1.43 (1.15 to 1.77)	1.31 (1.09 to 1.71)	1.25 (1.03 to 1.51)

Model 1, adjusted for age, sex, education, occupation and BMI. Model 2, adjusted for age, sex, education, occupation, BMI, family history of diabetes, smoking status, alcohol consumption and hypertension. The interaction between sleep quality and sleep duration was not statistically significant. Thus these two variables were entered into the model separately, except for model 3, in which the results were adjusted for each other.

DISCUSSION

We found that poor sleep quality and short sleep duration were associated with an increased prevalence of diabetes in the Chinese population, independently of potential confounders such as age, obesity, family history of diabetes, alcohol consumption, smoking, physical activity and other diseases. Previous epidemiological studies on the relationship between sleep duration or sleep quality and diabetes have shown inconsistent results. A representative cross-sectional study including 372 144 participants found that insufficient rest or sleep resulted in a slightly increased incidence of diabetes.[12] In that study, the investigators controlled for age, sex, race/ethnicity, smoking, BMI and other comorbid conditions, but did not control for hypertension, any cardiovascular disease or any other diseases that could increase the risk of diabetes or sleeping difficulty.[17] A prospective Japanese study showed that persistent (>4 years) complaints of medium and high frequency of difficulty initiating sleep were associated with an increased incidence of diabetes. However, two potential confounders of sleep, disordered breathing and depression, were not controlled for in this study.[6] In our study, after controlling for these risk factors for diabetes and sleeping difficulty, we found that poor sleep quality was associated with a significant risk of diabetes. When we introduced the criterion of short sleep duration into the definition of poor sleep quality, we noticed a strong and significant effect on the association of poor sleep quality with diabetes. Subjects with poor sleep quality who slept for ≤6 h had an association with diabetes that was 125% higher than for subjects who slept for 6–8 h with good sleep quality. In contrast, those who had poor sleep quality and slept for ≥8 h did not show a reduced incidence of diabetes compared with the control group. Subjects with common sleep quality who slept for ≤6 h or ≥8 h had a slightly higher incidence of diabetes compared with the control group. Interestingly, we did not find that sleep duration of ≤6 h or ≥8 h increased rates of diabetes. Thus sleep quality, not sleep duration, seemed to be the important factor. The joint association of poor sleep and short sleep duration with diabetes found in our study is consistent with a previous report.[18]

Table 3 Multivariate adjusted OR (95% CI) of diabetes associated with sleep quality and sleep duration

Sleep quality	Sleep duration	Adjusted OR	95% CI Lower	95% CI Upper
Good	6–8 h	1		
	≥8 h	1.01	0.84	1.24
	≤6 h	0.99	0.61	1.59
Common	6–8 h	0.99	0.69	1.37
	≥8 h	1.03	0.89	1.23
	≤6 h	1.15	0.70	1.43
Poor	6–8 h	1.02	0.71	1.46
	≥8 h	1.39	0.85	2.26
	≤6 h	1.41	1.07	1.85

The interaction between sleep quality and sleep duration is not significant, p=0.07. Adjusted for age, sex, education, employment, BMI, family history of diabetes, smoking status, alcohol consumption and physical activity.

Previous studies found that self-reported short sleep duration is associated with diabetes.[3 5 6 18] Some studies have reported that long sleep duration is also associated with diabetes.[12 13 15] Our findings were not consistent with these reports. This may be due to no exact data on sleep time being collected in our study. Furthermore, short sleep duration may be related to factors such as an underlying sleep apnoea or sleep disordered breathing,[19] depressive symptoms[20] and endocrine disorders,[21] which may increase risk of diabetes.

Several potential limitations to our study deserve mention. First, as it is a cross-sectional design, we cannot determine a causal relationship between sleep quality, sleep time and diabetes. Second, information on sleep quality and sleep duration was self-reported. Therefore we cannot compare our results directly with those from other studies that used objective sleep duration or polysomnographic measures of sleep disturbance. Thus misclassification and bias in our results is a possibility. Third, we were not able to control for some important and well-known risk factors—for example, snoring, which is known to be associated with diabetes.[22] Fourth, we did

not look at diet, which has been found to be causally related to type 2 diabetes and may also have influenced sleep patterns.[23 24] Fifth, participants were limited to the 18–75-year-old age group, and therefore the study does not represent the whole population.

In summary, in this large sample of Chinese adults, poor sleep quality and short sleep duration were found to be positively associated with a higher prevalence of diabetes in relatively healthy subjects. However, it seems that no measures are currently required to target sleep specifically to decrease the prevalence of diabetes in China. Further prospective studies are needed to examine the association.

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Competing interests None.

Patient consent Obtained.

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REFERENCES

1. Yang W, Lu J, Weng J, *et al*; China National Diabetes and Metabolic Disorders Study Group. Prevalence of diabetes among men and women in China. *N Engl J Med* 2010;362:1090–1101.
2. Nilsson PM, Rööst M, Engström G, *et al*. Incidence of diabetes in middle-aged men is related to sleep disturbances. *Diabetes Care* 2004;27:2464–9.
3. Gottlieb DJ, Punjabi NM, Newman AB, *et al*. Association of sleep time with diabetes mellitus and impaired glucose tolerance. *Arch Intern Med* 2005;165:863–7.
4. Mallon L, Broman JE, Hetta J. High incidence of diabetes in men with sleep complaints or short sleep duration: a 12-year follow-up study of a middle-aged population. *Diabetes Care* 2005;28:2762–7.
5. Yaggi HK, Araujo AB, McKinlay JB. Sleep duration as a risk factor for the development of type 2 diabetes. *Diabetes Care* 2006;29:657–61.
6. Hayashino Y, Fukuhara S, Suzukamo Y, *et al*; HIPOP-OHP Research group. Relation between sleep quality and quantity quality of life and risk of developing diabetes in healthy workers in Japan: the High-risk and Population Strategy for Occupational Health Promotion (HIPOP-OHP)Study. *BMC Public Health* 2007;7:129.
7. Donga E, van Dijk M, van Dijk JG, *et al*. A Single night of partial sleep deprivation induces insulin resistance in multiple metabolic pathways in healthy subjects. *J Clin Endocrinol Metab* 2010;95:2963–8.
8. Buxton OM, Pavlova M, Ried EW, *et al*. Sleep restriction for 1 week reduces insulin sensitivity in healthy men. *Diabetes* 2010;59:2126–33.
9. Spiegel K, Knutson K, Leproult R, *et al*. Sleep loss: a novel risk factor for insulin resistance and type 2 diabetes. *J Appl Physiol* 2005;99:2008–19.
10. Mary LP, Mokhlesi B. Sleep and glucose intolerance/diabetes mellitus. *Sleep Med Clin* 2007;2:19–29.
11. Stamatakis KA, Punjabi NM. Effects of sleep fragmentation on glucose metabolism in normal subjects. *Chest* 2010;137:95–101.
12. Shankar A, Syamala S, Kalidindi S. Insufficient rest or sleep and its relation to cardiovascular disease, diabetes and obesity in a national, multiethnic sample. *PLoS One* 2010;5:e14189.
13. Cappuccio FP, D'Elia L, Strazzullo P, *et al*. Quantity and quality of sleep and incidence of type 2 diabetes: a systematic review and meta-analysis. *Diabetes Care* 2010;33:414–20.
14. McNeely MJ, Boyko EJ, Leonetti DL, *et al*. Comparison of a clinical model, the oral glucose tolerance test, and fasting glucose for prediction of type 2 diabetes risk in Japanese Americans. *Diabetes Care* 2003;26:758–63.
15. Chen P, Lou P, Yu J, *et al*. Risk factors of diabetes mellitus of residents living in Xuzhou city. *Chin J Health Manage* 2010;4:78–80.
16. http://www.who.int/diabetes/publications/Definition%20and%20diagnosis%20of%20diabetes_new.pdf
17. Haseli-Mashhadi N, Dadd T, Pan A, *et al*. Sleep quality in middle-aged and elderly Chinese: distribution, associated factors and associations with cardio-metabolic risk factors. *BMC Public Health* 2009;9:130.
18. Vgontzas AN, Liao D, Pejovic S, *et al*. Insomnia with objective short sleep duration is associated with type 2 diabetes: a population-based study. *Diabetes Care* 2009;32:1980–5.
19. Tasali E, Mokhlesi B, Cauter EV. "Obstructive sleep apnea and type 2 diabetes: interacting epidemics". *Chest* 2008;133:496–506.
20. Golden SH, Williams JE, Ford DE, *et al*. Depressive symptoms and the risk of type 2 diabetes: the Atherosclerosis Risk in Communities study. *Diabetes Care* 2004;27:429–35.
21. Rodondi N, Newman AB, Vittinghoff E, *et al*. Subclinical hypothyroidism and the risk of heart failure, other cardiovascular events, and death. *Arch Intern Med* 2005;165:2460–6.
22. Al-Delaimy WK, Manson JE, Willett WC, *et al*. Snoring as a risk factor for type II diabetes mellitus: a prospective study. *Am J Epidemiol* 2002;155:387–93.
23. Tonstad SM, Butler T, Yan R, *et al*. Type of vegetarian diet, body weight, and prevalence of type 2 diabetes. *Diabetes Care* 2009;32:791–6.
24. Grandner MA, Kripke DF, Naidoo N, *et al*. Langer relationships among dietary nutrients and subjective sleep, objective sleep, and napping in women. *Sleep Med* 2010;11:180–4.