Association between Sleep duration and Incidence of type 2 Diabetes in China

Hongzhou Liu

3rd Medical Center of Chinese PLA General Hospital

Anping Wang

The First Medical Center, Chinese PLA General Hospital

Junping Wen

Fujian Provincial Hospital, Key Laboratory of Endocrinology, Fujian Medical University

Yimin Mu

The first Medical Center, Chinese PLA General Hospital

Jingtao Dou

The First Medical Center, Chinese PLA General Hospital

Weijun Gu

The First Medical Center, Chinese PLA General Hospital

Li Zang

The First Medical Center, Chinese PLA General Hospital

Saichun Zhang

The First Medical Center, Chinese PLA General Hospital

Zhaohui Lyu (✉ metabolism301@126.com)

Chinese PLA General Hospital <https://orcid.org/0000-0002-3912-329X>

Gang Chen

Fujian Provincial Hospital, Key Laboratory of Endocrinology, Fujian Medical University

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Abstract

Objective: We assess the relationship between night sleep duration and the incidence of type 2 diabetes in China.

Methods: We used logistic regression models to estimate odds ratios (ORs) and 95% confidence intervals (CIs) for the incidence of type 2 diabetes among 11,539 participants at baseline from the REACTION cohort.

Results: Compared to people who sleep for 7-8 h/night, people with a longer sleep duration (≥ 9 hours/night) had a greater risk of type 2 diabetes (hazard ratio [OR] 1.27; 95% confidence interval [CI] 1.01–1.61), while shorter sleep (< 6 h/night) had no significant difference. When the dataset was stratified based on selected covariates, the association between type 2 diabetes and long sleep duration became more evident among individuals < 65 years of age, male, body mass index < 24 or with hypertension or hyperlipidemia, no interaction effects were observed. Furthermore, compared to people persistently sleeping 7–9 h/night, those who persistently slept ≥ 9 h/night had a higher risk of type 2 diabetes. The optimal sleep duration was 6.3-7.5 h/night.

Conclusion: Short or Long sleep duration were associated with a high risk of type 2 diabetes. Persistently long sleep duration increased the risk. The optimal sleep duration was 6.3-7.5 hours/night.

Introduction

Type 2 diabetes is a critical public health challenge worldwide. Patients with type 2 diabetes are at increased risk for premature mortality and hospitalization due to complications[1]. Given the global burden of type 2 diabetes, understanding the impacts of modifiable risk factors is of great importance.

Sleep is essential to the health of patients with type 2 diabetes[2]. Although humans spend about a third of their time sleeping, they may not understand the importance of it. Adequate high-quality sleep is vital to maintain the normal physiological state of the body[3]. Insufficient sleep is a health problem[4], and long sleep duration is associated with increased body mass index (BMI)[5], impaired glucose tolerance[6], and increased probability of developing type 2 diabetes[7, 8]. Although lifestyle changes, such as increasing physical activity and weight loss, are of great importance to the management of this disease, understanding the link between type 2 diabetes and sleep duration may help to reduce its incidence.

Short sleepers[9] and long sleepers[10] show increased incidence of type 2 diabetes. In addition, a study in Japan found a J-shaped relationship between sleep time and HbA_{1c} level[11]. Therefore, this retrospective cohort study assessed the associations between both nighttime and daytime napping and risk for type 2 diabetes. We used data from the REACTION study cohort, which covered a 4-year period. To the best of our knowledge, no such study has yet explored this relationship in Chinese people with a risk for type 2 diabetes.

Methods

Study subjects

We used data from the REACTION cohort study, which investigated the association between type 2 diabetes and pre-type 2 diabetes and the risk of cancer in the Chinese population[12]. All subjects live in Laoshan, Jingding, and Gucheng communities of Beijing (China) or in Ningde and Wuyishan, Fujian Province (China). They were invited to complete baseline questionnaires and medical examinations in 2011. During the first follow-up survey in 2015, the same community were investigated, and the study had a total size of 13,311 participants.

In all, 1,556 subjects were diagnosed as type 2 diabetes in 2011 and 216 subjects lacked self-reported sleep duration or reported sleep durations of < 4 h/night or > 12 h/night. These subjects were excluded. The remaining 11,539 subjects (4,043 men, 7,496 women) were enrolled in the present study.

Standard protocol approvals, registrations, and patient consents

All participants provided written informed consent and all protocols were approved by the Ethical Committee of Chinese PLA General Hospital and Fujian Provincial Hospital.

Questionnaire

Nighttime and midday sleep time and sleep quality data were obtained through a self-administrated questionnaire[12]. Sleep duration was calculated from bedtime to waking time, and was categorized into 5 groups: < 6 , 6 to < 7 , 7 to < 8 , 8 to < 9 , or ≥ 9 h. Midday napping was divided into groups of no napping (0 min), 1–29, 30–59, 60–89, and ≥ 90 minutes. Sleep quality was divided into three groups: good, fair, and poor, with frequent use of hypnotics included in the fair group.

Assessment of covariates

Data such as age, sex, smoking status and drinking status were collected during the baseline investigation by trained doctors using a detailed questionnaire. Smoking and alcohol consumption were classified into three levels: current, occasional, and never. Subjects who smoke at least 1 cigarette per day for more than half a year were defined as current smokers[13]. Subjects who drink at least 1 time per week for more than half a year were defined as current drinkers[14]. The first level was regarded as positive responses.

Statistical analysis

We performed all analyses with Stata statistical software, ver. 14.2 (Stata Corp, College Station, TX, USA). Data were compared using analysis of variance (ANOVA) for continuous variables and χ^2 analysis for categorical variables. Continuous variables are expressed as mean $\pm$ standard deviation (SD), and categorical variables aer expressed as number and proportion.

Binary logistic regression was constructed to assess the ORs and 95% confidence intervals (CIs) of sleep duration and type 2 diabetes using sleep duration of 7 to 8 h/night as the reference groups, as previous studies have suggested that sleeping for 7-8 h [15, 16] is optimal. Potential covariates included in the multivariate-adjusted model were age, gender, body mass index, smoking and drinking status, hypertension and hyperlipidemia. Considering that type 2 diabetes risk might follow nonlinear trends, we used restricted cubic spline model with 3 knots at 25th, 50th and 75th percentiles of sleep duration and 7 h/night as the reference group[8, 17]. Subjects were divided into several groups by age (<65,≥65 years), sex (male, female), BMI (<24, ≥24 kg/m²)[18], hypertension (yes, no), and hyperlipidemia (yes, no). In addition, potential interactions were tested using interaction terms of these covariates with sleep duration.

We evaluated the association between changes in sleep duration and incidence of type 2 diabetes. This association was examined using crude and multivariate-adjusted models, with subjects persistently sleeping 7–9 h/night in both surveys as the reference group.

We further evaluated the joint effects of sleep duration and midday napping and that of sleep duration and sleep quality on the risk of developing diabetes, using moderate sleep duration (7–8 h/night) with midday napping (1–29 min), and moderate sleep duration (7–8 h/night) with good sleep quality as the reference groups.

Results

Among 11,539 subjects, 13.11% (1,513)reported sleeping ≥ 9 h/night and 5.18% ≥ 598 reported midday napping > 90 minutes. Compared to subjects reporting 7–8 h/night of sleep, those reporting sleep duration ≥ 9 h/night were more likely to be female, current smokers, and current drinkers. Meanwhile, compared to subjects with 1–29 minutes of midday napping, those reporting midday napping ≥ 90 minutes were more likely to be male, hypertension and hyperlipidemia, current smokers, current drinkers ($p < 0.05$). In addition, compared to the reference groups, participants reporting ≥ 9 hours/night of sleep were less likely to have hypertension and hyperlipidemia (Table 1).

Table 1
General characteristics of the study participants according to sleep duration and midday napping(n = 9750)

Variables	Sleep duration, h/night					Midday napping, min					
	< 6 (n = 549)	6 to < 7 (n = 1649)	7 to < 8 (n = 4162)	8 to < 9 (n = 3666)	≥ 9 (n = 1513)	F/χ^2	P^*	0 (n = 6678)	0 to < 30 (n = 3104)	30 to < 60 (n = 402)	60 to < 90 (n = 757)
Age, y	62.03 $\pm$ 9.14	61.10 $\pm$ 9.37	61.14 $\pm$ 9.17	61.07 $\pm$ 9.58	60.25 $\pm$ 10.22	4.31	< 0.01	61.18 $\pm$ 8.57	65.29 $\pm$ 8.46	52.57 $\pm$ 9.34	52.85 $\pm$ 9.45
Male/female	203/346	615/1034	1484/2678	1225/2441	516/997	10.12	0.04	2020/4658	1286/1818	155/247	323/434
BMI,kg/m ²	25.39 $\pm$ 3.35	25.40 $\pm$ 3.29	25.24 $\pm$ 3.34	25.23 $\pm$ 3.31	25.08 $\pm$ 3.41	2.11	0.08	25.35 $\pm$ 3.37	25.62 $\pm$ 3.30	24.00 $\pm$ 2.96	25.12 $\pm$ 3.01
Smoking	109	284	673	536	255	13.86	< 0.01	1017	559	49	121
Drinking	79	246	494	397	187	20.77	< 0.01	654	432	64	143
Good Sleep quality	197	312	512	403	209	286.25	< 0.01	5678	2755	316	647
Comorbidities											
Hypertension	142	443	1056	928	372	2.42	0.66	1612	970	73	150
Hyperlipidemia	86	186	537	432	185	9.59	0.05	787	515	23	55
Abbreviation: BMI = body mass index.											
Data mean (SD) are presented for continuous variables.											
* p Values were derived from ANOVA for continuous variables and χ^2 tests for categorical variables											

During the follow-up investigation, we documented 694 type 2 diabetes. Compared to people who slept for 7–8 h/night, the ORs (95% CIs) of type 2 diabetes were 1.21 (0.85–1.72) for < 6 hours/night, 0.91 (0.70–1.17) for 6–7 hours/night, 1.03 (0.85–1.24) for 8–9 hours/night, and 1.27 (1.01–1.61) for ≥ 9

hours/night($p = 0.04$), respectively. After adjusting for age (continuous), sex, body mass index (continuous), smoking status (yes or no), drinking status (yes or no), hypertension (yes or no), hyperlipidemia (yes or no), similar associations were observed for those obtaining ≥ 9 h/night of sleep ($p = 0.02$) (Table 2). Compared to participants napping for 1–29 minutes, the ORs (95% CIs) of type 2 diabetes were 1.30 (0.53–3.20) for those reporting no midday napping, 1.04 (0.38–2.83) for 30–59 minutes, 1.02 (0.39–2.65) for 60–89 minutes, and 1.27 (0.48–3.31) for midday napping ≥ 90 minutes. In addition, no significant association was observed between these groups after adjusting for age, sex, body mass index, smoking status, drinking status, type 2 diabetes mellitus, hyperlipidemia. Restricted cubic spline regression analysis showed a J-shaped curve and confirmed that people who slept ≥ 9 h/night had a high risk of type 2 diabetes (Fig. 1). The optimal nighttime sleep duration was 7.2–7.5 h, and it was 6.3–7.5 h after adjusting for all variables. When stratified by selected covariates, the association between type 2 diabetes and long sleep duration became more evident in individuals who were < 65 years of age, male, body mass index < 24 or with hypertension or hyperlipidemia, no interaction effects was observed (Fig. 2).

Table 2
Association of sleep duration and midday napping with type 2 diabetes

Model 1: crude				Model 2: adjusted OR (95% CI)*	
variable	cases/total	OR(95% CI)	P	OR(95% CI)	P
Sleep duration, hours/night					
< 6	38/549	1.21(0.85–1.72)	0.29	1.15(0.80–1.64)	0.45
6 to < 7	87/1649	0.91(0.70–1.17)	0.44	0.90(0.70–1.16)	0.43
7 to < 8	241/4162	1		1	
8 to < 9	218/3666	1.03(0.85–1.24)	0.77	1.04(0.86–1.26)	0.68
≥ 9	110/1513	1.27(1.01–1.61)	0.04	1.32(1.05–1.68)	0.02
Midday napping, minutes					
0	596/9678	1.30(0.53–3.20)	0.57	1.10(0.44–2.74)	0.84
1–29	5/104	1		1	
30–59	20/402	1.04(0.38–2.83)	0.94	1.39(0.50–3.82)	0.53
60–89	37/757	1.02(0.39–2.65)	0.97	1.30(0.49–3.42)	0.60
≥ 90	36/598	1.27(0.48–3.31)	0.63	1.53(0.58–4.02)	0.39
Abbreviations: CI = confidence interval; OR = odds ratio.					
*Adjusted for age (continuous), sex, body mass index (continuous), smoking status (current, former, or never), drinking status (current, former, or never), hypertension (yes or no), and hyperlipidemia (yes or no).					

Table 3 shows the relationship between change in sleep time with type 2 diabetes. Compared to participants who reported between 7–9 h of sleep in both surveys, those who reported sleeping ≥ 9 hours in both surveys showed ORs of 1.51 (95% CI 1.05–2.17) and 1.54 (95% CI 1.07–2.24), indicating higher risk of diabetes. In addition, after adjusting for all variables, the OR was 1.54 (95% CI 1.07–2.24).

Table 3
Association of change in sleep duration between surveys with type 2 diabetes

Variable		Model 1: crude			*Model 2: adjusted OR (95% CI)	
Sleep duration, hours/night in 2011	Sleep duration, hours/night in 2015	cases/total	OR(95% CI)	P	OR(95% CI)	P
7–9	7–9	164/2713	1		1	
≤ 7	7–9	74/1184	1.04(0.78–1.38)	0.81	0.98(0.74–1.31)	0.91
≥ 9	7–9	47/702	1.12(0.80–1.56)	0.52	1.13(0.80–1.58)	0.50
≤ 7	≤ 7	183/3282	0.92(0.74–1.14)	0.44	0.86(0.69–1.07)	0.19
7–9	≤ 7	125/2239	0.92(0.72–1.67)	0.49	0.88(0.69–1.12)	0.29
≥ 9	≤ 7	24/370	1.08(0.69–1.68)	0.74	1.03(0.66–1.61)	0.90
≤ 7	≥ 9	8/158	0.83(0.40–1.72)	0.61	0.83(0.40–1.72)	0.61
7–9	≥ 9	30/450	1.11(0.74–1.66)	0.61	1.11(0.74–1.67)	0.62
≥ 9	≥ 9	39/441	1.51(1.05–2.17)	0.03	1.54(1.07–2.24)	0.02
Abbreviations: CI = confidence interval; OR = odds ratio.						
*adjusted for age (continuous), sex, body mass index (continuous), smoking status (current, former, or never), drinking status (current, former, or never), hypertension (yes or no) and hyperlipidemia (yes or no).						

We further explored the combined effect of sleep duration and midday napping and that of sleep duration and sleep quality on the risks of type 2 diabetes. Compared to those who reported moderate lengths of nighttime (7–8 h/night) and midday sleep (1–29 minutes), participants with long sleep duration at night (≥ 9 hours/night) and midday (>90 minutes) had a higher risk of diabetes (OR 2.28, 95% CI 0.83–6.26) (Table 4). Subjects with ≥ 9 hours/night of sleep and good sleep quality (OR 1.31, 95% CI 1.02–1.69) had a high risk of diabetes than those who reported moderate nighttime sleep duration (7–8 h/night) and good sleep quality. After adjustments, the OR was 1.37(95% CI 1.06–1.77) (Table 5).

Table 4
Joint effects of sleep duration and midday napping on incidence of diabetes

Variable		Model 1: crude			*Model 2: adjusted OR (95% CI)	
Sleep duration, hours/night in 2011	Midday napping min/day	cases/total	OR(95% CI)	P	OR(95% CI)	P
7<8	0	216/3553	1.16(0.58–2.30)	0.68	0.81(0.40–1.61)	0.54
7<8	1–29	9/170	1		1	
7<8	30–89	13/341	0.71(0.30–1.69)	0.44	0.75(0.31–1.79)	0.51
7<8	≥ 90	3/98	0.57(0.15–2.14)	0.40	0.57(0.15–2.16)	0.37
< 7	0	96/1760	1.03(0.51–2.08)	0.93	0.70(0.34–1.42)	0.32
< 7	1–29	7/112	1.19(0.43–3.30)	0.73	1.21(0.43–3.37)	0.72
< 7	30–89	15/244	1.17(0.50–2.74)	0.72	1.12(0.48–2.65)	0.79
< 7	≥ 90	7/82	1.67(0.60–4.65)	0.33	1.54(0.55–4.36)	0.41
8<9	0	191/3164	1.15(0.58–2.28)	0.69	0.81(0.40–1.63)	0.55
8<9	1–29	2/126	0.29(0.06–1.36)	0.12	0.33(0.07–1.55)	0.16
8<9	30–89	19/300	1.21(0.54–2.741)	0.65	1.26(0.55–2.86)	0.59
8<9	≥ 90	6/76	1.53(0.53–4.47)	0.43	1.53(0.52–4.51)	0.44
≥ 9	0	93/1201	1.50(0.74–3.04)	0.26	1.06(0.52–2.17)	0.87
≥ 9	1–29	4/64	1.19(0.35–4.02)	0.78	1.15(0.34–3.92)	0.83
≥ 9	30–89	5/179	0.51(0.17–1.57)	0.24	0.56(0.18–1.71)	0.31
≥ 9	≥ 90	8/69	2.35(0.87–6.36)	0.09	2.28(0.83–6.26)	0.11
Abbreviations: CI = confidence interval; OR = odds ratio.						
*adjusted for age (continuous), sex, body mass index (continuous), smoking status (current, former, or never), drinking status (current, former, or never), hypertension (yes or no) and hyperlipidemia (yes or no).						

Table 5
Joint effects of sleep duration and sleep quality on the incidence of type 2 diabetes

Variable		Model 1: crude			*Model 2: adjusted OR (95% CI)*	
Sleep duration, hours/night in 2011	Sleep quality	cases/total	OR(95% CI)	P	OR(95% CI)	P
7<8	1	204/3650	1		1	
7<8	2	37/512	1.32(0.92–1.89)	0.14	1.39(0.96–2.01)	0.08
≤ 7	1	94/1689	0.99(0.77–1.28)	0.97	0.98(0.76–1.26)	0.86
≤ 7	2	31/509	1.10(0.74–1.62)	0.65	1.12(0.75–1.66)	0.58
8<9	1	197/3263	1.09(0.89–1.33)	0.43	1.10(0.90–1.35)	0.35
8<9	2	21/403	0.93(0.59–1.47)	0.75	0.97(0.61–1.54)	0.89
≥ 9	1	94/1304	1.31(1.02–1.69)	0.04	1.37(1.06–1.77)	0.02
≥ 9	2	16/209	1.40(0.83–2.38)	0.21	1.46(0.85–2.50)	0.17

Discussion

In this large retrospective cohort study, we found that subjects who slept more than 9 h per night had a high risk of type 2 diabetes. Moreover, optimal sleep duration at night was 6.3–7.5 h after adjusting for age, sex, body mass index, smoking status, drinking status, hypertension and hyperlipidemia. To avoid an influence of region on our results, we selected people in both the northern and southern regions of China. To the best of our knowledge, this is the first

retrospective study to report that persistently sleeping ≥ 9 h/night is related to higher type 2 diabetes risk compared to persistently sleeping for a moderate duration (7–9 h/night) in the Chinese population.

Many studies have assessed the association between sleep duration and the incidence of type 2 diabetes[8, 19] or blood glucose level[9]. In these studies, participants have usually divided participants into several groups according sleep duration. Therefore, such studies can only draw the conclusions that one group of people has the lowest incidence of type 2 diabetes, for example, people who sleep 7–8 hours at night [9]. A meta-analysis suggested that for short duration of sleep (5–6 h/night), the RR was 1.28, while that for long duration of sleep (8–9 h/night) was 1.48[19]. In the present study, we limited the optimal sleep duration into a narrow range according to the restricted cubic spline model.

The elevated risk for type 2 diabetes and long sleep duration appeared to be more pronounced in individuals who were < 65 years old, male, BMI < 24, and/or with hypertension or hyperlipidemia, no interaction noted. However, we did not find significant differences between each subgroup based on the P-values of interaction terms. The reason for the lack of interactions may be that we observed individuals for a short period of time and type 2 diabetes is a chronic disease with a relatively low incidence. As a result, we observed fewer cases.

Afternoon napping is a common habit in many countries, including in China. The relationship of midday napping and the risk of type 2 diabetes has also been investigated in several previous cross sectional[20–22] and cohort studies[23, 24]. These studies have suggested that the incidence of type 2 diabetes or elevated blood glucose levels are higher in individuals with longer sleep duration. However, midday napping can influence the quantity and quality of nocturnal sleep[25]. Therefore, we considered the effects of midday napping on the incidence of type 2 diabetes alongside that of nocturnal sleep. To the best of our knowledge, this is the first study to examine the impact of midday napping in combination with nocturnal sleep on the incidence of type 2 diabetes in the Chinese population. The OR for the incidence of type 2 diabetes was 2.35 or 2.28 in people who slept more than 9 h at night and more than 90 min at noon. Only eight people in this group developed new type 2 diabetes within the follow-up period of 4 years, and therefore the difference was not significant. Observing the relationships between the incidence of type 2 diabetes and both sleep duration and midday napping demands a large number of subjects. Previous research has suggested that type 2 diabetes patients prefer longer midday naps because they are more fatigued[26]. We excluded individuals with diabetes at the start of our study, and therefore we can conclude that longer midday napping lead to type 2 diabetes.

Previous studies have showed that the prevalence of poor sleep quality was significantly higher among people with diabetes than those without it[27]. In our study, only 16 participants reporting ≥ 9 h/night sleep and poor sleep quality developed diabetes during the follow-up period. As a result, the difference in the incidences of diabetes are not statistically significant between this group and the reference group. A larger sample size is needed to investigate the effects of sleep quality.

Numerous possible mechanisms could explain the relationship between long sleep duration and midday napping and the incidence of type 2 diabetes. Research revealed that leptin and ghrelin are of great importance to the incidence of type 2 diabetes[28]. Short sleep can reduce leptin and elevate ghrelin in the blood, leading to increases in hunger and appetite, accompanied by a decrease in glucose tolerance[29]. In addition, short sleep may contribute to the secretion of adiponectin and insulin. Adiponectin, which is secreted by adipocytes, is associated with insulin sensitivity[30, 31]. Sleep restriction can increase sympathetic nervous system activity, leading to decreased insulin sensitivity[32, 33]. However, the mechanisms through which long sleep duration leads to increased risk for type 2 diabetes are not fully understood. Long sleep duration may reflect a more sedentary life style and, similar to short sleepers, long sleepers may engage in more snacking[34].

The study also had several limitations. First, the sleep duration at night and midday is defined as the time from going to bed to waking in the questionnaire survey, which is slightly different from the actual time to sleep. However, it was impossible to obtain objective measures of sleep duration and napping in large prospective population studies, and the self-administrated survey is the most commonly used method of evaluating sleep duration and napping in large population-based studies. Second, previous studies have suggested that poor sleep quality is associated with higher blood glucose levels in patients with type 2 diabetes[35]. However, some subgroups contained few cases of type 2 diabetes, causing their differences to be nonsignificant. A larger sample size is needed in future studies on this subject.

Conclusions

We found a J-shaped relationship between sleep duration and the incidence of type 2 diabetes, with the lowest risk for type 2 diabetes in individuals sleeping 6.3–7.5 h after adjusting for covariates. Sleep duration that is too long or too short increase the risk of type 2 diabetes. Further studies are needed to reveal the mechanism driving the relationship between sleep time and the incidence of diabetes.

Declarations

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Duality of Interest

No potential conflicts of interest relevant to this article were reported

Authors' contributions

ZH L and GC designed the experiment. HZ L, AP W and JP W performed the experiment—analyzed data and wrote the manuscript. YM M, JT D, WJ G—SC Z and LZ edited the manuscript.

References

1. Group IDFDA: **Update of mortality attributable to diabetes for the IDF Diabetes Atlas: Estimates for the year 2013.** *Diabetes Res Clin Pract* 2015, **109**(3):461-465.
2. Alnaji A, Law GR, Scott EM: **The role of sleep duration in diabetes and glucose control.** *Proc Nutr Soc* 2016, **75**(4):512-520.
3. Gallicchio L, Kalesan B: **Sleep duration and mortality: a systematic review and meta-analysis.** *J Sleep Res* 2009, **18**(2):148-158.
4. Prevention. CfDcA, Epidemic ISlaPH: 2014. Available at: <http://www.accqsleeplabs.com/wp-content/uploads/2014/10/CDC-report.pdf>.
5. Patel SR, Malhotra A, White DP, Gottlieb DJ, Hu FB: **Association between reduced sleep and weight gain in women.** *Am J Epidemiol* 2006, **164**(10):947-954.
6. Spiegel K, Leproult R, Van Cauter E: **Impact of sleep debt on metabolic and endocrine function.** *Lancet* 1999, **354**(9188):1435-1439.
7. Cespedes EM, Dudley KA, Sotres-Alvarez D, Zee PC, Daviglus ML, Shah NA, Talavera GA, Gallo LC, Mattei J, Qi Q *et al.*: **Joint associations of insomnia and sleep duration with prevalent diabetes: The Hispanic Community Health Study/Study of Latinos (HCHS/SOL).** *J Diabetes* 2016, **8**(3):387-397.
8. Yaggi HK, Araujo AB, McKinlay JB: **Sleep duration as a risk factor for the development of type 2 diabetes.** *Diabetes Care* 2006, **29**(3):657-661.
9. Kim C-R, Song Y-M, Shin J-Y, Gim W: **Association between Sleep Duration and Impaired Fasting Glucose in Korean Adults: Results from the Korean National Health and Nutrition Examination Survey 2011-2012.** *Korean J Fam Med* 2016, **37**(1):51-56.
10. Cappuccio FP, D'Elia L, Strazzullo P, Miller MA: **Quantity and quality of sleep and incidence of type 2 diabetes: a systematic review and meta-analysis.** *Diabetes care* 2010, **33**(2):414-420.
11. Ohkuma T, Fujii H, Iwase M, Kikuchi Y, Ogata S, Idewaki Y, Ide H, Doi Y, Hirakawa Y, Nakamura U *et al.*: **Impact of sleep duration on obesity and the glycemic level in patients with type 2 diabetes: the Fukuoka Diabetes Registry.** *Diabetes Care* 2013, **36**(3):611-617.
12. Ning G: **Risk Evaluation of cAncers in Chinese diabeTic Individuals: a lONGitudinal (REACTION) study.** *J Diabetes* 2012, **4**(2):172-173.
13. Yang G, Fan L, Tan J, Qi G, Zhang Y, Samet JM, Taylor CE, Becker K, Xu J: **Smoking in China: findings of the 1996 National Prevalence Survey.** *Jama* 1999, **282**(13):1247-1253.
14. Yuan JM, Ross RK, Gao YT, Henderson BE, Yu MC: **Follow up study of moderate alcohol intake and mortality among middle aged men in Shanghai, China.** *Bmj* 1997, **314**(7073):18-23.
15. Kwok CS, Kontopantelis E, Kuligowski G, Gray M, Muhyaldein A, Gale CP, Peat GM, Cleator J, Chew-Graham C, Loke YK *et al.*: **Self-Reported Sleep Duration and Quality and Cardiovascular Disease and Mortality: A Dose-Response Meta-Analysis.** *J Am Heart Assoc* 2018, **7**(15):e008552.
16. Yamada T, Hara K, Shojima N, Yamauchi T, Kadowaki T: **Daytime Napping and the Risk of Cardiovascular Disease and All-Cause Mortality: A Prospective Study and Dose-Response Meta-Analysis.** *Sleep* 2015, **38**(12):1945-1953.
17. Desquilbet L, Mariotti F: **Dose-response analyses using restricted cubic spline functions in public health research.** *Stat Med* 2010, **29**(9):1037-1057.
18. Ren Q, Su C, Wang H, Wang Z, Du W, Zhang B: **Change in Body Mass Index and Its Impact on Incidence of Hypertension in 18-65-Year-Old Chinese Adults.** *Int J Environ Res Public Health* 2016, **13**(3).
19. Cappuccio FP, D'Elia L, Strazzullo P, Miller MA: **Quantity and quality of sleep and incidence of type 2 diabetes: a systematic review and meta-analysis.** *Diabetes Care* 2010, **33**(2):414-420.
20. Fang W, Li Z, Wu L, Cao Z, Liang Y, Yang H, Wang Y, Wu T: **Longer habitual afternoon napping is associated with a higher risk for impaired fasting plasma glucose and diabetes mellitus in older adults: results from the Dongfeng-Tongji cohort of retired workers.** *Sleep Med* 2013, **14**(10):950-954.
21. Lam KB, Jiang CQ, Thomas GN, Arora T, Zhang WS, Taheri S, Adab P, Lam TH, Cheng KK: **Napping is associated with increased risk of type 2 diabetes: the Guangzhou Biobank Cohort Study.** *Sleep* 2010, **33**(3):402-407.
22. Zhou J, Kessler AS, Su D: **Association between Daytime Napping and Chronic Diseases in China.** *Am J Health Behav* 2016, **40**(2):182-193.
23. Hublin C, Lehtovirta M, Partinen M, Koskenvuo M, Kaprio J: **Napping and the risk of type 2 diabetes: a population-based prospective study.** *Sleep Med* 2016, **17**:144-148.
24. Xu Q, Song Y, Hollenbeck A, Blair A, Schatzkin A, Chen H: **Day napping and short night sleeping are associated with higher risk of diabetes in older adults.** *Diabetes Care* 2010, **33**(1):78-83.
25. Yoon IY, Kripke DF, Elliott JA, Youngstedt SD, Rex KM, Hauger RL: **Age-related changes of circadian rhythms and sleep-wake cycles.** *J Am Geriatr Soc* 2003, **51**(8):1085-1091.
26. Singh R, Kluding PM: **Fatigue and related factors in people with type 2 diabetes.** *Diabetes Educ* 2013, **39**(3):320-326.

27. Jemere T, Mossie A, Berhanu H, Yeshaw Y: **Poor sleep quality and its predictors among type 2 diabetes mellitus patients attending Jimma University Medical Center, Jimma, Ethiopia.** *BMC Res Notes* 2019, **12**(1):488.
28. Taheri S, Lin L, Austin D, Young T, Mignot E: **Short sleep duration is associated with reduced leptin, elevated ghrelin, and increased body mass index.** *PLoS Med* 2004, **1**(3):e62.
29. Reutrakul S, Van Cauter E: **Sleep influences on obesity, insulin resistance, and risk of type 2 diabetes.** *Metabolism* 2018, **84**:56-66.
30. Tsao TS, Lodish HF, Fruebis J: **ACRP30, a new hormone controlling fat and glucose metabolism.** *Eur J Pharmacol* 2002, **440**(2-3):213-221.
31. Berg AH, Combs TP, Scherer PE: **ACRP30/adiponectin: an adipokine regulating glucose and lipid metabolism.** *Trends Endocrinol Metab* 2002, **13**(2):84-89.
32. Reutrakul S, Mokhlesi B: **Obstructive Sleep Apnea and Diabetes: A State of the Art Review.** *Chest* 2017, **152**(5):1070-1086.
33. Johns MW: **A new method for measuring daytime sleepiness: the Epworth sleepiness scale.** *Sleep* 1991, **14**(6):540-545.
34. Tan X, Chapman CD, Cedernaes J, Benedict C: **Association between long sleep duration and increased risk of obesity and type 2 diabetes: A review of possible mechanisms.** *Sleep Med Rev* 2018, **40**:127-134.
35. Knutson KL, Van Cauter E, Zee P, Liu K, Lauderdale DS: **Cross-sectional associations between measures of sleep and markers of glucose metabolism among subjects with and without diabetes: the Coronary Artery Risk Development in Young Adults (CARDIA) Sleep Study.** *Diabetes Care* 2011, **34**(5):1171-1176.

Figures

Figure 1

Spline curves for associations of sleep duration with type 2 diabetes a) Non-adjusted; The reference group was 7 h/night sleep duration. p values were 0.184 for the overall association and 0.204 for the nonlinear association. b) Adjusted for age (continuous), sex, body mass index (continuous), smoking status (current, former, never), drinking status (current, former, never), hypertension (yes, no), and hyperlipidemia (yes, no). The reference group was 7 h/night sleep duration. P values were 0.062 for the overall association and 0.092 for the nonlinear association.

(a)

(b)

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Spline curves for associations of sleep duration with type 2 diabetes a) Non-adjusted; The reference group was 7 h/night sleep duration. p values were 0.184 for the overall association and 0.204 for the nonlinear association. b) Adjusted for age (continuous), sex, body mass index (continuous), smoking status (current, former, never), drinking status (current, former, never), hypertension (yes, no), and hyperlipidemia (yes, no). The reference group was 7 h/night sleep duration. P values were 0.062 for the overall association and 0.092 for the nonlinear association.

Figure 2

Sleep duration and type 2 diabetes risk, stratified by baseline characteristics a) All odds ratios were calculated using moderate sleep duration (7–8 h/night) as the reference group. Each group was adjusted for all other covariates except the one being tested. CI = confidence interval. b) All odds ratios were calculated using moderate sleep duration (7–8 h/night) as the reference group, with model 2 adjusted for age (continuous), sex, body mass index (BMI) (continuous), smoking status (current, former, never), drinking status (current, former, never), hypertension (yes, no) and hyperlipidemia (yes, no). Each group was adjusted for all other covariates except the one being tested. CI = confidence interval.

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