Sleep Medicine 33 (2017) 119–124

Contents lists available at ScienceDirect

Sleep Medicine

journal homepage: www.elsevier.com/locate/sleep

Original Article

Age- and gender-specific associations of napping duration with type 2 diabetes mellitus in a Chinese rural population: the RuralDiab study

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ARTICLE INFO

Article history:
Received 14 July 2016
Received in revised form
22 September 2016
Accepted 30 September 2016
Available online 29 October 2016

Keywords:
Napping duration
Type 2 diabetes mellitus
Rural population

ABSTRACT

Background: The consistency and strength of the relationship between napping duration and type 2 diabetes mellitus (T2DM) remained uncertain, especially in the rural population. The purpose of this study was to explore the relationship between napping duration and T2DM in a Chinese rural population.
Methods: A total of 12663 participants (4365 males and 8298 females) were derived from the RuralDiab study in China. Napping duration was obtained through a standardized questionnaire, and was divided into five categories: no napping (reference), 1~, 31~, 61~, and ≥91 min. Fasting blood glucose was measured. Logistic regression was used to estimate odds ratios (*ORs*) and 95% confidence intervals (*CIs*). A meta-analysis including seven studies was conducted to validate the result of the RuralDiab study.
Results: The crude and age-standardized prevalence of T2DM were 10.31% and 8.14%, respectively. Compared with no napping, the adjusted *OR* (95%*CI*) for napping duration ≥91 min was 1.23 (1.05−1.45). A similar relationship was found only in females aged 45−54 years, but not in males and other age group females. In addition, napping duration was associated with T2DM in a positive dose-dependent manner among females aged 45−54 years (*P* for trend <0.05). The meta-analysis demonstrated this association, and the pooled *OR* (95%*CI*) for the longest napping duration compared with no napping was 1.28 (1.22−1.35).
Conclusion: Longer napping duration is associated with higher risk of T2DM in the Chinese rural population, and this association varies across gender and age. Further multi-center prospective researches are needed to confirm the relationship and reveal underlying mechanisms.

1. Introduction

Type 2 diabetes mellitus (T2DM) has become one of the leading causes of disease burden and mortality, worldwide, and caused 1.3 million deaths in 2010; this disease is projected to have an estimated prevalence of 4.4% in 2030 [1,2]. The estimated number of adults with diabetes worldwide was 415 million in 2015 and will be 642 million in 2040 [3]. In 2010, the prevalence of diabetes was 11.6% in the Chinese adult population, which represents up to 113.9 million individuals [4]. Thus, finding out the determinants of T2DM is urgently needed to prevent this public health problem in China. It is well known that genetic and environmental factors (including diet and exercise) contribute to the prevalence of T2DM, while other behavioral factors might also be involved in the development of T2DM.

Daytime napping is a well-accepted habit in China especially in rural areas, and has been considered a healthy life style behavior for thousands years. Napping may help eliminate fatigue and improve

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http://dx.doi.org/10.1016/j.sleep.2016.09.004
1389-9457/

mood. It particularly benefits the task performance, such as logical reasoning, response time, and symbol recognition [5]. One study showed that a daytime nap for less than 30 min could promote wakefulness and enhance performance and learning capacity, while long naps may be associated with higher morbidity and mortality of some diseases [6]. Other studies demonstrated that daytime napping was associated with an increased prevalence of metabolic syndrome, hypertension, and non-alcoholic fatty liver disease and might increase the risk of all-cause and cardiovascular disease (CVD) mortality [7–11].

Few prospective [12,13] and cross-sectional [14–17] studies concerning the association between napping duration and T2DM have been published. However, the definition of napping duration between studies was different and no population-based study focused on rural population. More important, the study exploring the relationship between napping duration and T2DM by combining epidemiological research and meta-analysis has not yet been reported. Therefore, we conducted an analysis in the Rural Diabetes, Obesity and Life style (RuralDiab) study combined with a meta-analysis to further explore the relationship between nap duration and T2DM.

2. Participants and methods

2.1. Study participants

The participants were screened from the RuralDiab study which included 16607 participants from Luoyang and Xuchang City of Henan province in China. Of these participants, only those aged between 35 and 74 years (15100 participants) were included in this part of study. Due to the potential influence of health burden on napping, those with diagnosed stroke, coronary heart disease or cancer (2396 subjects) were excluded. In addition, the participants who had varying work shifts that affected their sleep and napping patterns (and consequently, T2DM risk) were excluded (n = 8). The subjects with missing information regarding nap duration (n = 14) and diagnosis of T2DM (n = 19) were also excluded. Finally, a total of 12663 eligible participants were selected for the analysis in this study.

The protocol of this study was in accordance with the guidelines of the Helsinki Declaration, and was approved by the ethic committee of the Zhengzhou University Medical Ethics Committee. Informed consent was obtained from all respondents.

2.2. Assessment of potential covariates

A structured questionnaire survey was conducted by well-trained staff through face-to-face interviews in order to collect information on demographic characteristics (age, gender, educational level, socioeconomic status and marital status), life style (smoking, alcohol drinking and physical activity), history of disease and medication, and family history of disease (defined as parents or siblings of the respondents had a history of disease). Age was classified into four categories: 35–44, 45–54, 55–64, and 65–74 years. Education level was divided into elementary school or below, junior high school and high school or above. Socioeconomic status was assessed according to average monthly individual income (<500, 500~, and ≥1000 RMB). Marital status was divided into married/cohabitating and unmarried/divorced/widowed. Smoking was defined as at least one cigarette per day for sequential or cumulative six months. Alcohol use was defined as at least consuming alcohol 12 times per year. Physical activity was grouped into low, moderate and high level based on International Physical Activity Questionnaire (IPAQ) [18]. Night sleep duration was divided into four groups (<7, 7~, 8~, and ≥9 h) based on the quartile cut points.

Body weight and height were measured twice with the metric scale and the vertical weight scale followed a standardized protocol [19] and the readings were taken to the nearest 0.1 kg and 0.1 cm, respectively. Body mass index (BMI) was calculated based on the measured height and weight. Blood pressure (BP) was measured three times for each participant according to the American Heart Association's standardized protocol [20] with an electronic sphygmomanometer (HEM-770A Fuzzy, Omron, Japan). The average values were calculated for analysis. Venous blood samples were drawn from the participants after overnight fasting. Serum was separated by centrifugation at 3000 rpm for 10 min, 4 °C and stored at −20 °C for further tests. Fasting blood glucose was measured on the day of blood drawing using a modified hexokinase enzymatic method.

2.3. Determination of napping duration

Participants were asked to answer the question: “Did you take a nap usually over the past year?” Those who gave a positive answer were further asked to report the average duration of their nap per day. Based on the existing literature [13,14], the napping duration was categorized into five groups: no napping (reference), 1~, 31~, 61~, and ≥91 min.

2.4. Definition of T2DM

The definition of T2DM was on the basis of the American Diabetes Association (ADA) diagnostic criteria (2009) [21], participants were defined with T2DM if the fasting blood glucose ≥7.0 mmol/l or having a self-reported previous diagnosis of diabetes by a physician after excluding type 1 diabetes mellitus, gestational diabetes mellitus, and diabetes due to other causes.

2.5. Meta-analysis

Based on the guideline of the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA), a meta-analysis was conducted by combining the results of current study and those of previous studies on association between napping duration and T2DM. PubMed, Web of Science, CNKI (China National Knowledge Infrastructure), Chongqing VIP and Wanfang databases were searched for studies, and the literature search was updated on April 6, 2016, using the following search terms: (diabetes or T2DM or T2D or DM) AND (nap or napping or noon break or midday rest or siesta). References listed by each original article were also searched to identify more studies. The included studies were those examining the association of napping duration and T2DM. The exclusion criteria were: (1) conducted in particular population (eg, pregnant women), (2) literature reviews, and (3) editorials. Two investigators independently extracted the searched data, if they had disagreements, then discussed with a third investigator. Information extracted from each article included title, the name of the first author, publication date, study location, study design, sample size, gender ratio and age range of the participants, covariates adjusted in the multivariable analysis, categories of napping duration, Definition of T2DM, and *OR* (95% *CI*) for the longest napping duration category. Cochran Q was used to examine heterogeneity among the studies. A random- or fixed-effects model was used to synthesize the pooled OR in the presence ($P < 0.10$) or absence ($P > 0.10$) of heterogeneity. Potential publication bias was evaluated by Begg's and Egger's tests.

2.6. Statistical analysis

Categorical variables were expressed in percentages and compared by Mantel- Haenszel test. Continuous variables were

expressed in means (plus and minus standard deviations) and compared by analysis of variance. The age standardized prevalence of T2DM was calculated according to the sixth census data in China.

Logistic regression was used to estimate the risk of T2DM based on the odds ratios (*ORs*) and 95% confidence intervals (*CIs*). The adjustment model included age, gender, education level, average monthly individual income, marital status, smoking, alcohol drinking, physical activity, BMI, night sleep duration, and family history of diabetes. Tests for linear trend were performed computing five napping duration categories as continuous variables (0 for no napping, 1 for 1~, 2 for 31~, 3 for 61~ and 4 for ≥91 min) in the regression model. The statistical interaction between gender as well as age and napping duration were examined in multiplicative effects model. Subgroup analyses according to gender and age group were conducted to further explore this association.

The statistical analyses were performed by SPSS 21.0 and the relationship was considered to be statistically significant at two-tailed $P < 0.05$. The meta-analysis was performed using STATA, version 11.0 (STATACorp., College Station, Texas, USA).

3. Results

Among the 12663 participants (4365 males and 8298 females), the mean age was 55 years old, 65.53% of the participants were females. Overall, 1306 participants were T2DM patients, and the crude and age-standardized prevalence of T2DM were 10.31% and 8.14% respectively.

Table 1 shows the demographic and clinical characteristics of the participants in relation to napping duration. Compared with participants who reported no napping, the other participants were more likely to be older, male and smokers; they also tended to have lower education level, lower average monthly individual income, longer night sleep duration, higher BMI and higher fasting glucose. We also observed a dose-response relationship between napping duration and prevalence of T2DM (P for trend <0.001).

As shown in Table 2, napping duration was associated with the risk of T2DM in a dose-dependent manner (P for trend <0.05) before and after adjustment. The *OR* (95%*CI*) of T2DM for longer nap duration (≥91 min) was 1.35 (1.15–1.58) in the univariate model when compared with the reference group and the value decreased to 1.23 (1.05–1.45) after adjustment. The table also showed that napping duration of 31~ min or 61~ min mildly increased the risk of T2DM, although this relationship was not statistically significant.

The subgroup analysis based on gender found that similar association was observed in females, but not in males. In particular, this relationship was slightly stronger among females than overall participants. The increment of each 30 min in napping duration was associated with 6% (95%*CI*: 1%–12%) increased risk of T2DM among females, while the relevant risk among overall subjects was 5% (95% *CI*: 1%–9%). However, the multiplicative interaction between gender and napping duration was not found ($P = 0.297$).

We further explored whether such association persisted in different age groups. Table 3 shows that the similar relationship was detected and slightly enhanced within the subgroup aged 45–54 years. The adjusted *OR* (95%*CI*) was 1.67 (1.21–2.31) for napping duration ≥91 min. And the females aged 45–54 years whose napping duration ≥91 min had the highest risk of T2DM with an adjusted *OR* (95%*CI*): 2.02 (1.36–3.01) compared with the referential group. No interaction was found between age and napping duration in the multiplicative effects model ($P = 0.539$).

Six studies satisfied the criteria of the meta-analysis [12–17], and Supplementary Fig. 1 shows the detailed steps of literature search. The characteristics of the included studies are listed in Supplementary Table 1. Fig. 1 summarizes the association between napping duration and T2DM, based on the six previously published studies and the current study. Longer napping duration was significantly related to an increased risk of T2DM and the pooled *OR* for the longest napping duration vs. no napping was 1.28 (95%*CI*: 1.22–1.35), with no evidence of heterogeneity across studies ($P = 0.16$, $I^2 = 35.70\%$). The pooled *OR* was 1.35 (95%*CI*: 1.27–1.45)

Table 1
Baseline characteristics of the participants according to napping duration.

Variables	Daytime napping duration (min)					*P*
	0 (n = 4023)	1~ (n = 1054)	31~ (n = 3262)	61~ (n = 1693)	≥91 (n = 2631)	
Age (years), mean (SD)[b]	54.61 (9.41)	54.72 (9.46)	55.65 (9.71)	56.01 (9.79)	56.19 (10.06)	<0.001[b]
Gender (female), n (%)[a]	2849 (70.82)	714 (67.74)	2059 (63.12)	1035 (61.13)	1641 (62.37)	<0.001[a]
Education level, n (%)[a]						<0.001[a]
Elementary school or below	1706 (42.41)	408 (38.71)	1362 (41.75)	807 (47.67)	1280 (48.65)	
Junior high school	1757 (43.67)	428 (40.61)	1392 (42.67)	707 (41.76)	1141 (43.37)	
High school or above	558 (13.87)	217 (20.59)	508 (15.57)	178 (10.51)	210 (8.01)	
Average monthly individual income, n (%)[a]						<0.001[a]
<500 RMB	1978 (49.17)	434 (41.18)	1384 (42.43)	1098 (64.86)	1552 (58.99)	
500–1000 RMB	1141 (28.36)	342 (32.45)	972 (29.80)	351 (20.73)	595 (22.61)	
>1000 RMB	901 (22.40)	277 (26.28)	903 (27.68)	243 (14.35)	479 (18.21)	
Marital status, n (%)[a]						0.215[b]
Married/cohabitating	3680 (91.47)	956 (90.70)	2934 (89.94)	1543 (91.14)	2391 (90.88)	
Unmarried/divorced/widowed	324 (8.05)	95 (9.01)	319 (9.78)	147 (8.68)	234 (8.81)	
Smoking, n (%)[a]	587 (14.59)	132 (12.52)	549 (16.83)	315 (18.61)	512 (19.46)	<0.001[a]
Alcohol drinking, n (%)[a]	588 (14.62)	207 (19.64)	628 (19.25)	280 (16.54)	420 (16.91)	0.115[a]
Physical activity, n (%)[a]						<0.001[a]
Low	1393 (34.63)	413 (39.18)	1136 (34.83)	553 (32.66)	980 (37.25)	
Moderate	828 (20.58)	190 (18.03)	584 (17.90)	278 (16.42)	455 (17.36)	
High	1802 (44.79)	451 (42.79)	1542 (47.27)	862 (50.92)	1196 (45.58)	
BMI(kg/m^2), mean (SD)[b]	24.97 (3.45)	25.32 (3.41)	25.12 (3.39)	25.18 (3.70)	25.26 (3.57)	0.004[b]
Fasting glucose (mmol/l), mean (SD)[c]	5.37 (1.12)	5.49 (1.21)	5.43 (1.28)	5.40 (1.15)	5.43 (1.20)	0.028[b]
Insulin (IU/L), mean (SD)[b]	10.63 (5.78)	10.49 (5.28)	10.72 (5.33)	12.25 (26.91)	11.36 (9.54)	0.001[b]
Night sleep duration(h), mean (SD)[b]	7.66 (1.35)	7.72 (1.12)	7.91 (1.18)	8.17 (1.33)	8.41 (1.56)	<0.001[b]
Family history of diabetes, n (%)[a]	277 (6.89)	71 (6.74)	210 (6.44)	110 (6.50)	153 (5.85)	0.104[a]
T2DM, n (%)[a]	372 (9.25)	103 (9.77)	336 (10.29)	177 (10.45)	318 (12.08)	<0.001[a]

Abbreviations: SD, standard deviation; min, minutes; BMI, body mass index; T2DM, type 2 diabetes mellitus.
[a] Mantel-Haenszel test for categorical variables.
[b] Analysis of variance for continuous variables.
[c] Those participants with self-reported on anti-diabetic agents were excluded (n = 705).

Table 2
Odds ratios (95% CI) of T2DM according to napping duration.

	Daytime napping duration (min)					Each 30 min increment	*P* for trend
	0	1~	31~	61~	≥91		
Total							
Model 1	1	1.06 (0.85–1.34)	1.13 (0.96–1.32)	1.15 (0.95–1.38)	1.35 (1.15–1.58)	1.07 (1.03–1.11)	<0.001
Model 2	1	0.97 (0.77–1.23)	1.04 (0.89–1.22)	1.05 (0.85–1.26)	1.23 (1.05–1.45)	1.05 (1.01–1.09)	0.030
Male							
Model 1	1	1.22 (0.83–1.78)	1.06 (0.82–1.39)	1.04 (0.75–1.42)	1.22 (0.93–1.60)	1.04 (0.97–1.11)	0.258
Model 2	1	1.03 (0.70–1.53)	0.95 (0.72–1.25)	0.93 (0.67–1.29)	1.09 (0.82–1.45)	1.01 (0.95–1.09)	0.633
Female							
Model 1	1	0.98 (0.74–1.31)	1.15 (0.95–1.39)	1.21 (0.95–1.53)	1.41 (1.16–1.72)	1.09 (1.04–1.14)	<0.001
Model 2	1	0.91 (0.68–1.23)	1.09 (0.89–1.32)	1.11 (0.87–1.43)	1.27 (1.04–1.56)	1.06 (1.01–1.12)	0.018

Abbreviations: min, minutes.
Model 1: Univariate model.
Model 2: Multivariable model adjusted for age, gender (only in total participants), education level, average monthly individual income, marital status, smoking, alcohol drinking, physical activity, body mass index, night sleep duration, family history of diabetes.

for the subgroup of prospective studies and 1.20 (95%*CI*: 1.12–1.29) for cross-sectional studies. No publication bias was detected (egger's test: 0.97).

4. Discussion

In the present study, we observed that the participants who reported napping duration ≥91 min/day had a significantly higher prevalence of T2DM, which was consistent with the prospective study conducted by Han et al. [13].Gender-stratified analysis showed a marked association of napping duration with T2DM among females, but not among males, which was in accordance with the results of the study conducted by Sun et al. [15] Shadyab et al. [16] reported that the association of napping duration and T2DM was found among white postmenopausal women. Sun et al. [15] only found this relationship in postmenopausal women, but not in men and premenopausal women. However, we found that this association was further modified by age and gender. A napping-diabetes relationship was detected in females aged 45–54 years, but not in other age groups, which might be explained by alterations in sexual hormones. Further prospective and multi-centric researches are needed to verify these findings.

Mechanisms explaining the relationship between napping and T2DM are currently unknown, but several findings had been proposed. First, longer napping duration might disrupt the internal circadian clock leading to glucose intolerance and insulin resistance, which might explain the relationship between longer napping duration and T2DM [22,23]. Second, longer napping duration might lead to difficulty in night sleep initiation and more frequent awakenings during night. Some studies reported that short duration [24–29] and poor quality [30–32] during night sleep may increase the risk of diabetes. Third, sleep disturbance including snoring and apnea were more common among participants with longer napping durations [13]; the relationship between sleep disturbance and diabetes has been reported by some prior studies [33,34]. Meanwhile, sleep disturbance may play a role in the increased insulin resistance through increased catecholamine and cortisol level as well as increased sympathetic activity [35]. Finally, Dowd et al. found that longer napping duration was related to inflammatory illness [36], while inflammation might contribute to the emergence of some pathologic features resulting in metabolic syndrome, diabetes and more [[37]].

The strengths of the current study include large sample size, detailed epidemiologic profiles, thorough analyses in relation to the different subgroups of gender and age, and an additional meta-analysis investigating the relationship between napping duration and T2DM which enhance the evidence of the present finding. To our best knowledge, few studies were focusing on the rural population, which accounts for a large proportion of the Chinese population and have a specific life style, including sleep habits.

Table 3
Adjusted odds ratios (95% CI) of T2DM according to napping duration by age group.

	Daytime napping duration (min)					Each 30 min increment	*P* for trend
	0	1~	31~	61~	≥91		
Total							
35~	1	0.57 (0.21–1.57)	0.68 (0.35–1.32)	0.53 (0.21–1.31)	0.87 (0.45–1.67)	0.94 (0.80–1.11)	0.460
45~	1	1.24 (0.81–1.90)	1.15 (0.83–1.59)	1.46 (0.99–2.14)	1.67 (1.21–2.31)	1.13 (1.05–1.22)	0.001
55~	1	0.96 (0.67–1.37)	1.09 (0.86–1.39)	0.99 (0.72–1.34)	1.22 (0.94–1.59)	1.04 (0.98–1.11)	0.172
65~	1	0.87 (0.52–1.45)	1.02 (0.73–1.41)	0.98 (0.66–1.46)	1.07 (0.77–1.48)	1.02 (0.94–1.10)	0.667
Male							
35~	1	0.47 (0.14–1.62)	0.41 (0.16–1.02)	0.31 (0.09–1.08)	0.45 (0.17–1.17)	0.78 (0.62–0.99)	0.056
45~	1	1.42 (0.73–2.78)	0.91 (0.53–1.57)	1.72 (0.93–3.18)	1.18 (0.67–2.09)	1.06 (0.93–1.21)	0.398
55~	1	1.07 (0.53–2.12)	1.14 (0.71–1.79)	0.76 (0.43–1.33)	1.17 (0.72–1.89)	1.01 (0.90–1.13)	0.815
65~	1	0.86 (0.34–2.17)	1.12 (0.64–1.97)	0.81 (0.42–1.59)	1.36 (0.77–2.40)	1.07 (0.93–1.22)	0.371
Female							
35~	1	0.63 (0.08–5.29)	1.36 (0.48–3.89)	0.96 (0.24–3.87)	1.88 (0.69–5.06)	1.16 (0.91–1.48)	0.244
45~	1	1.09 (0.61–1.93)	1.33 (0.90–1.97)	1.32 (0.80–2.18)	2.02 (1.36–3.01)	1.18 (1.07–1.30)	0.001
55~	1	0.92 (0.60–1.41)	1.07 (0.80–1.44)	1.08 (0.75–1.55)	1.21 (0.88–1.65)	1.05 (0.97–1.13)	0.221
65~	1	0.85 (0.45–1.60)	0.97 (0.65–1.46)	1.10 (0.67–1.81)	0.94 (0.62–1.43)	1.00 (0.90–1.10)	0.947

Abbreviations: min, minutes.
Adjusted odds ratios (95% CI) was from the multivariable model adjusted for gender (only in total participants), education level, average monthly individual income, marital status, smoking, alcohol drinking, physical activity, body mass index, night sleep duration, family history of diabetes.

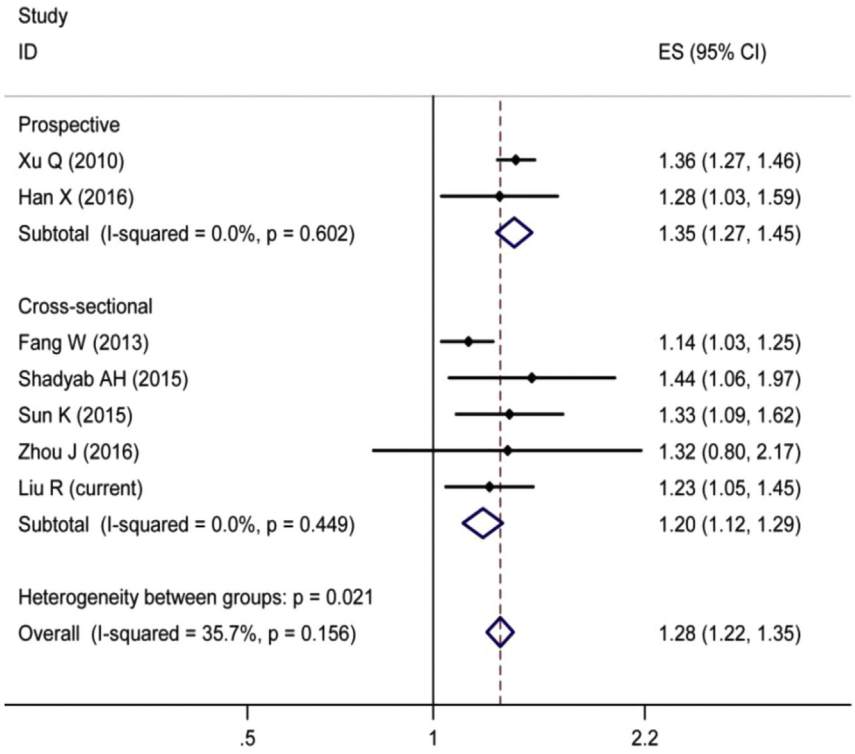

Fig. 1. Meta-analysis of napping duration for the longest vs. no napping and the risk of developing T2DM.

Several limitations should be taken into consideration. First, the information of daytime napping was self-reported, which may inevitably contribute to recall bias. Second, the oral glucose tolerance test (OGTT) was not conducted when we identified the participants with T2DM, which may underestimate the participants with T2DM. The present study was also a cross-sectional study, unlikely to avoid reverse causal inference. Therefore, future prospective and polycentric studies are needed to confirm this relationship.

In conclusion, data from this Chinese rural population suggest a dose-response relationship between napping duration and T2DM after controlling for potential confounders. Longer napping duration (≥91 min) is associated with higher risk of T2DM in Chinese rural population especially among females aged 45–54 years. Once confirmed, these findings could suggest the optimum napping duration for prevention and control of T2DM.

Funding

This work was supported by the National Key Research and Development Program "Precision Medicine Initiative" (Grant No: 2016YFC0900803), National Natural Science Foundation of China (grant numbers: 81573243, U1304821, U1204823); Henan Provincial Science Fund for Distinguished Young Scholars (grant number: 164100510021), Science and Technology Innovation Talents Support Plan of Henan Province Colleges and Universities (grant number: 14HASTIT035), High-level Personnel Special Support Project of Zhengzhou University (grant number: ZDGD13001). The funders had no role in the study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Author contributions

During the research, Chongjian Wang and Ronghai Bie designed the study. Ruihua Liu, Yuqian Li, Fang Wang, Xiaotian Liu, Hao Zhou, Panpan Wang, Jingjing Fan, Fei Xu, Kaili Yang, and Dongsheng Hu conducted the collection of the data. Ruihua Liu and Yuqian Li analyzed the data. Ruihua Liu and Yuqian Li wrote the manuscript. Panpan Wang, Jingjing Fan and Fei Xu and Dongsheng Hu provide the writing assistance. All authors read and approve this version of the article.

Acknowledgments

The authors would like to thank the participants, the coordinators, and administrators for their supports during the study. To Dr. Fatiha Karam and Dr. Ling Wang, the authors would like to express their gratitude for their critical reading of the manuscript.

Transparency document

The ICMJE Uniform Disclosure Form for Potential Conflicts of Interest associated with this article can be viewed by clicking on the following link: http://dx.doi.org/10.1016/j.sleep.2016.09.004

Conflict of interest

None.

Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.sleep.2016.09.004.

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