

BMJ Open Association of napping and night-time sleep with impaired glucose regulation, insulin resistance and glycated haemoglobin in Chinese middle-aged adults with no diabetes: a cross-sectional study

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ABSTRACT

Objective: To assess associations between napping and night-time sleep duration with impaired glucose regulation, insulin resistance (IR) and glycated haemoglobin (HbA1c).

Design: Cross-sectional study.

Setting: Fujian Province, China, from June 2011 to January 2012.

Participants: This study enrolled 9028 participants aged 40–65 years. Data of 7568 participants with no diabetes were included for analysis. Type 2 diabetes was defined applying WHO criteria.

Outcome measures: Participants' daytime napping and night-time sleep duration data were collected using a standardised self-reported Chinese-language questionnaire about sleep frequency and quality. Anthropometric and laboratory parameters were also measured. IR was defined as a HOMA-IR index value >2.50. ORs and 95% CIs were derived from multivariate logistic regression models.

Results: Participants (mean age 51.1±7.0 years) included 3060 males and 4508 females with average night-time sleep of 7.9 h. A higher proportion of males napped than females. After adjustment for potential confounders, ORs for HbA1c >6.0% were 1.28 and 1.26 for those napping ≤1 h and >1 h (p=0.002 and p=0.018), respectively. Statistically significant differences in IR between nappers and non-nappers were only marginal clinically. Odds for HbA1c >6.0% were significantly lower in participants with longer night-time sleep durations than in the reference group (>8 h vs 6–8 h). Odds for IR were significantly lower in participants whose night-time sleep hours deviated from the reference group (<6 h, >8 h vs 6–8 h).

Conclusions: Chinese middle-aged adults with no diabetes who napped had higher HbA1c and IR; those with shorter night-time sleep durations had increased HbA1c. Night-time sleep hours that are either <6 or >8

Strengths and limitations of this study

- This study showed that middle-aged Chinese adults with out diabetes who reported napping and shorter night-time sleep had higher HbA1c. Daytime napping was also associated with higher odds of insulin resistance. Night-time sleep hours that deviate from the reference 6 to 8 h show association with lower odds for insulin resistance.
- The strength of the results is the simultaneous assessment of the pathophysiological pathways of hyperglycaemia and insulin resistance together with glycaemic level.
- The major strengths of the current study include the large sample size and the wide range of demographic, socioeconomic and health-related data collected in the analysis to account for potential confounders.
- Limitations: because of its cross-sectional design, the direction of causality could not be determined from our analysis. Second, because self-reported questionnaires were used to obtain data on night-time sleep duration and napping, the study lacks an objective sleep measurement.

tend to be associated with lower odds for IR. Further studies are necessary to determine the underlying clinical significance and mechanisms behind these associations.

INTRODUCTION

Sleep loss is a common condition in today's society. Sleep duration per night is reported to have declined by 1.5–2 h in different

populations over the last few decades, but data from the same study do not support that all adults need more sleep.¹ Additionally, several experimental and epidemiological studies have shown that shortened or altered sleep may adversely affect glucose homeostasis, including decreased glucose tolerance and increased insulin resistance (IR).^{2–4}

Daytime napping is also common in many parts of the world, particularly in China, where napping is a well-accepted behaviour in all age groups as part of a regular routine and healthy lifestyle.^{5–6} However, little is understood about the effects of napping on health, especially on glucose metabolism, including IR, impaired glucose regulation (IGR) and glycated haemoglobin (HbA1c).

Diabetes remains a critical public health challenge, especially with the related increased risk of cardiovascular-related mortality. The prevalence of diabetes in China has increased remarkably from 2.5% in 1994 to 9.7% in 2010, making China one of the countries with the largest diabetes burden worldwide.⁷ IGR, IR and HbA1c are associated with increased risk of cardiovascular diseases and diabetes.^{8–10}

Therefore, the purpose of the present cross-sectional analysis was to assess the associations between daytime napping and night-time sleep duration with IGR, IR and HbA1c in middle-aged Chinese adults with no diabetes.

METHODS

Study population

We conducted this cross-sectional study from June 2011 to January 2012 in Fujian Province, China. Study participants were selected from the cohort of the REACTION study (Risk evaluation of cancers in Chinese diabetic individuals: a longitudinal study), which investigated the association between diabetes and cancer in 259 657 Chinese adults aged 40 years and older in 25 communities across mainland China from 2011 to 2012.¹¹ For the present study, a total of 9028 participants aged 40–65 years completed a standardised questionnaire and blood samples were collected. The data of 7568 participants who met the inclusion criteria (ie, absence of diabetes) were retained for further analysis. The remaining 1460 patients with a diagnosis of diabetes or incomplete data were excluded, including 1247 patients with diabetes, 31 patients with missing data of napping and night-time sleep and 182 patients without laboratory and anthropometric data. All investigators received special training (eg, acquiring a basic understanding of the questionnaire and being trained to take measurements for blood pressure, body height, weight and waist circumference) before the investigation. The study received approval from the Endocrinology Branch of the Chinese Medical Association, and all participants gave written informed consent.

Data collection

Data, including demographics, medical history and lifestyle factors from all 7568 participants were recorded. Height and weight, waist and hip circumference and

blood pressure for each participant were determined by a single physician. Waist circumference was measured at the level of the umbilicus and hip circumference at the widest part of the buttocks according to standardised WHO criteria and the recommendations of expert consultation.¹² Altogether four physicians conducted all examinations, each participating for 2 months at a time over the data collection period. Body mass index (BMI) was calculated as weight (kg) divided by the square of height (m). The waist-to-hip ratio (WHR) was calculated as the ratio of waist-to-hip circumference. Blood pressure was measured three times using an automatic sphygmomanometer after the participants had been resting for 5 min in a sitting position before each measurement; the mean of the three readings was used for analysis. After at least an 8-h overnight fast, venous blood samples were drawn at 0 and 2 h during a 75 g oral glucose tolerance test. Blood glucose, including fasting blood glucose (FBG) and 2 h plasma glucose (PG), was measured using the glucose oxidase method. Fasting serum insulin (FINS), triglycerides (TG), total cholesterol (TC), high-density lipoprotein cholesterol (HDL-C) and low-density lipoprotein cholesterol (LDL-C) levels were determined using chemiluminescence methods. HbA1c was measured by high-performance liquid chromatography.

Participants were asked to self-report the average hours and minutes of daytime napping and night-time sleep per day. Napping habits were categorised as no napping, ≤ 1 h and >1 h napping per day. Night-time sleep duration was divided into three categories: <6 h, 6–8 h and ≥ 8 h. Participants' snoring habits were also recorded during the interview.

Definitions and diagnostic criteria

Type 2 diabetes was defined according to WHO criteria¹³ as fasting plasma glucose ≥ 7.0 mmol/L and/or 2 h postprandial glucose ≥ 11.1 mmol/L, or as having been diagnosed with type 2 diabetes. IGR was defined as $6.1 \leq$ fasting plasma glucose < 7 mmol/L and/or $7.8 \leq$ 2 h postprandial glucose < 11.1 mmol/L. HOMA-IR was calculated as fasting insulin (mU/L)* fasting plasma glucose (mmol/L)/22.5,¹⁴ and IR was defined as HOMA-IR values > 2.50 .¹⁵ HbA1c was the preferred test for monitoring glucose control, and HbA1c $> 6.0\%$, based on WHO guidelines for HbA1c¹³ and as previously described in the literature,¹⁰ was applied as an independent predictor of subsequent cardiovascular disease in middle-aged adults with no diabetes.

A diagnosis of hypertension was based on the Seventh Joint National Commission recommendation of systolic blood pressure ≥ 140 mm Hg and/or diastolic blood pressure ≥ 90 mm Hg or having been diagnosed with hypertension or use of antihypertension treatment. Dyslipidaemia was defined as having one or more of the following: TC > 6.2 mmol/L, TG > 2.3 mmol/L, LDL-C > 4.1 mmol/L, HDL-C < 0.91 mmol/L or TC/HDL-C > 5 .¹⁶ Obesity was defined as BMI ≥ 30 kg/m² and overweight was defined as $25 \leq$ BMI < 30 kg/m².

Statistical analysis

Clinical data were presented as mean \pm SD for normally distributed data, as median with IQR for skew distributed data and as number with percentage for categorical data. Since only 0.1% of participants reported ≥ 2 h of napping, we combined participants reporting >1 h and <1 h napping for analysis, and participants reporting no nap were used as the reference group. One-way analysis of variance, χ^2 test or non-parametric test were used to compare differences between categories of napping (eg, no nap, ≤ 1 h and >1 h) or night-time sleep (eg, <6 h, 6–8 h, >8 h). The Bonferroni correction was applied for the comparisons of pair-wise groups. Binary logistic regression analysis was constructed to assess the ORs of HbA1c $>6.0\%$, IGR and IR associated with napping and night-time sleep. The first regression model was unadjusted. The second models included napping time and night-time sleep (adjusting for one another). The third models were further adjusted for age and gender. To prevent the effect of latent confounders, another 11 variables were selected by the forward conditional method before entering into the fourth model (FBG, hypertension, family history of diabetes (FHD), dyslipidaemia, smoking status, alcohol status, frequency of snoring, level of physical activity, education levels, BMI and WHR). All data analyses were conducted with SPSS V.17.0 statistical software package (SPSS, Chicago, Illinois, USA). All *p* values <0.05 (two-sided) indicated statistical significance.

RESULTS

Of the 7568 participants (mean age: 51.1 \pm 7.0 years), 3060 males and 4508 females were included in the analysis; the percentage of females was greater than that of males in all three groups and males were only marginally older in the napping group compared to the other two groups. Participants' average night-time sleep was 7.9 h; 46.5% did not nap while 36.6% and 16.9% napped ≤ 1 h and >1 h, respectively. Table 1 shows baseline characteristics by napping categories. When compared with the no napping group or less napping (>1 h) group, those who napped over 1 h were more likely to have lower FBG, higher 2 h PG, lower HDL-C, higher WHR and higher snoring frequency; they also were more likely to be smokers and alcohol users, although only minor differences were found. Compared with the no napping group, the two groups who napped 1 and >1 h were found to have significant differences, including lower SBP, higher FINS, higher TG, higher HbA1c and higher HOMA-IR, but these statistically significant differences were still marginal clinically. In addition, fewer participants with night-time sleep over 8 h were observed in the two groups that reported 1 and >1 h of napping compared to the no napping group (27.1% and 27.9% vs 45.5%; table 1).

Demographic and clinical characteristics were also assessed by group based on night-time sleep duration

(table 2). Participants who reported sleeping <6 h per night were more likely to nap than those reporting ≥ 8 h of night-time sleep, who were less likely to nap. Significant differences were found in SBP, FBG, FINS, HDL-C, WHR and HbA1c between those with night-time sleep durations of more than 8 h compared to those with night-time sleep durations of less than 6 h or from 6 to 8 h, however, some differences may not be considered clinically meaningful in terms of participants' health and/or sleep status (table 2).

As shown in table 3, participants who reported napping had a higher risk of HbA1c $>6.0\%$, IGR and IR. Compared with the no napping group, the crude OR of HbA1c $>6.0\%$ for those with napping time >1 h was 1.24 (*p*=0.018). After adjusting for other variables (eg, night-time sleep, age, gender, FBG, hypertension, dyslipidaemia, smoking status, alcohol status, education levels, BMI and WHR), the adjusted ORs of HbA1c $>6.0\%$ for those with napping times ≤ 1 h and >1 h were 1.28 (*p*=0.002) and 1.26 (*p*=0.018), respectively. Similar associations were observed between IR and napping, the adjusted ORs of IR for those with napping times ≤ 1 h and >1 h were 1.55 (*p* <0.001) and 1.69 (*p* <0.001), respectively. No associations were observed between IGR and napping (table 3).

In terms of night-time sleep, participants with longer night-time sleep durations (>8 h) were less likely to have HbA1c $>6.0\%$ and IR compared to those with 6–8 h night-time sleep (table 4). Compared with the reference group (individuals with 6–8 h sleep per night), the crude OR for HbA1c $>6.0\%$ was 1.47 (*p* <0.001) among participants with night-time sleep <6 h. In contrast, the crude OR was 0.70 (*p* <0.001) for participants with night-time sleep of ≥ 8 h. The association between longer night-time sleep duration and HbA1c $>6.0\%$ remained significant after adjusting for other variables (OR=0.69 and 0.57 with *p* <0.001). Compared with the reference group, the crude ORs for IGR did not reach statistical significance, but the adjusted ORs showed that participants with shorter night-time sleep (<6 h) were less likely to have IGR, where OR=0.77 (*p*=0.042) when adjusted for age, gender and napping, and OR=0.74 (*p*=0.020) when further adjusted for other variables selected by the forward conditional method (hypertension, FHD, dyslipidaemia, smoking status, alcohol status, snoring, education level, BMI and WHR). The crude OR showed that participants with <6 h night sleep were less likely to have IR (OR=0.69, *p*=0.048). The ORs of such associations remained statistically significant after adjustments for daytime napping, age and gender, but the OR (0.70, *p*=0.096) did not remain statistically significant after further adjustments for other variables selected by the forward conditional method (ie, FBG, hypertension, dyslipidaemia, alcohol status, BMI and WHR). However, a significant association between longer night-time sleep (>8 h) and IR was observed in the final model; the adjusted OR of 0.84 (*p*=0.049) showed that participants with night-time sleep >8 h were less likely to have IR (table 4).

Table 1 Characteristics of the study participants according to daytime napping categories

| | Napping | | | p Value |
|---------------------------|-------------------------------|--------------------------------|---------------------------------|---------|
| | No napping, n=3517 (46.5%) | 1 h napping, n=2769 (36.6%) | >1 h napping, n=1282 (16.9%) | |
| Gender* | | | | |
| Male | 1353 (38.5%) | 1117 (40.3%) | 590 (46.0%)†,‡ | <0.001 |
| Female | 2164 (61.5%) | 1652 (59.7%) | 692 (54.0%) | |
| Age (year)§ | 50.88 (6.98) | 51.04 (6.96) | 51.63 (7.03)†,‡ | 0.004 |
| SBP (mm Hg)§ | 131.92 (18.42) | 130.04 (18.25)† | 130.10 (19.35)† | <0.001 |
| DBP (mm Hg)§ | 77.17 (10.87) | 77.41 (10.78) | 76.92 (11.40) | 0.382 |
| FBG (mmol/L)§ | 5.40 (0.59) | 5.28 (0.62)† | 5.21 (0.65)†,‡ | <0.001 |
| 2 h PG (mmol/L)§ | 6.38 (1.65) | 6.58 (1.65)† | 6.74 (1.67)†,‡ | <0.001 |
| FINS (uIU/mL)¶ | 5.40 (3.70, 7.80) | 6.00 (4.30, 8.40)† | 6.20 (4.30, 8.70)† | <0.001 |
| HDL-C (mmol/L)§ | 1.42 (0.35) | 1.37 (0.34)† | 1.33 (0.35)†,‡ | <0.001 |
| LDL-C (mmol/L)§ | 2.92 (0.83) | 2.94 (0.82) | 2.95 (0.85) | 0.365 |
| TC (mmol/L)§ | 5.04 (1.06) | 5.06 (1.07) | 5.05 (1.13) | 0.681 |
| TG (mmol/L)§ | 1.48 (1.12) | 1.59 (1.14)† | 1.62 (1.14)† | <0.001 |
| WHR ² | 0.864 (0.059) | 0.866 (0.061) | 0.873 (0.077)†,‡ | <0.001 |
| BMI (kg/m ²)§ | 23.86 (3.14) | 23.88 (3.01) | 24.07 (3.18) | 0.116 |
| HbA1c (%)§ | 5.61 (0.43) | 5.65 (0.42)† | 5.67 (0.43)† | <0.001 |
| HOMA-IR¶ | 1.29 (0.87, 1.89) | 1.40 (0.98, 1.98)† | 1.40 (0.96, 2.02)† | <0.001 |
| Dyslipidaemia* | | | | |
| Normal | 2643 (75.2%) | 1950 (70.4%) | 879 (68.6%) | <0.001 |
| Abnormal | 873 (24.8%) | 818 (29.6%)† | 402 (31.4%)† | |
| Smokers* | | | | |
| No | 2671 (75.9%) | 2178 (78.7%) | 922 (71.9%) | <0.001 |
| Yes | 846 (24.1%) | 591 (21.3%) | 360 (28.1%)†,‡ | |
| Alcohol users* | | | | |
| No | 2886 (82.1%) | 2234 (80.7%) | 989 (77.1%) | 0.002 |
| Yes | 631 (17.9%) | 535 (19.3%) | 293 (22.9%)†,‡ | |
| FHD* | | | | |
| No | 3311 (94.1%) | 2540 (91.7%) | 1195 (93.2%) | 0.002 |
| Yes | 206 (5.9%) | 229 (8.3%)† | 87 (6.8%) | |
| Physical activity* | | | | |
| No | 3327 (94.6%) | 2353 (85.0%) | 1068 (83.3%) | <0.001 |
| Yes | 190 (5.4%) | 416 (15.0%)† | 214 (16.7%)† | |
| Snoring* | | | | |
| Often | 676 (19.2%) | 521 (18.8%) | 297 (23.2%)†,‡ | <0.001 |
| Seldom | 1043 (29.7%) | 1020 (36.8%) | 442 (34.5%) | |
| Never | 1798 (51.1%) | 1228 (44.3%) | 543 (42.4%) | |
| Education level* | | | | |
| Low | 1635 (46.5%) | 882 (31.9%) | 508 (39.6%) | <0.001 |
| Medium | 1656 (47.1%) | 1366 (49.3%) | 639 (49.8%) | |
| High | 226 (6.4%) | 521 (18.8%)† | 135 (10.5%)†,‡ | |
| Hypertension* | | | | |
| No | 2310 (65.7%) | 1837 (66.3%) | 865 (67.5%) | 0.508 |
| Yes | 1207 (34.3%) | 932 (33.7%) | 417 (32.5%) | |
| Obesity* | | | | |
| Normal | 2341 (66.7%) | 1831 (66.2%) | 827 (64.7%) | 0.032 |
| Overweight | 1025 (29.2%) | 854 (30.9%) | 394 (30.8%) | |
| Obesity | 143 (4.1%) | 81 (2.9%)† | 58 (4.5%)‡ | |
| Night-time Sleep* | | | | |
| <6 | 127 (3.6%) | 143 (5.2%) | 76 (5.9%) | <0.001 |
| 6–8 | 1790 (50.9%) | 1875 (67.7%) | 848 (66.1%) | |
| >8 | 1600 (45.5%) | 751 (27.1%)†,‡ | 358 (27.9%)† | |

Obesity was defined as BMI ≥ 30 kg/m².

*Data are presented by count and percentage.

†Indicates a significant difference compared to the group of no napping.

‡Indicates a significant difference compared to the group of napping 1 h.

§Data are presented by mean and SD.

¶Data are presented by median and IQR due to skew distribution.

BMI, body mass index; DBP, diastolic blood pressure; FBG, fasting blood glucose; FHD, family history of diabetes; FINS, fasting insulin; HbA1c, glycated haemoglobin; HDL-C, high-density lipoprotein cholesterol; HOMA-IR, the homoeostasis model assessment of insulin resistance; LDL-C, low-density lipoprotein cholesterol; PG, plasma glucose; SBP, systolic blood pressure; TC, total cholesterol; TG, triglycerides; WHR, waist-to-hip ratio.

Table 2 Characteristics of study participants according to night-time sleep categories

| | Night-time Sleep | | | p Value |
|---------------------------|--------------------|-----------------------|----------------------|---------|
| | <6 h, n=346 (4.6%) | 6–8 h, n=4513 (59.6%) | >8 h, n=2709 (35.8%) | |
| Gender* | | | | |
| Male | 150 (43.4%) | 1756 (38.9%) | 1154 (42.6%)† | 0.005 |
| Female | 196 (56.6%) | 2757 (61.1%) | 1555 (57.4%) | |
| Age (year)‡ | 53.23 (6.46) | 50.90 (6.94)§ | 51.06 (7.08)§ | <0.001 |
| SBP (mm Hg)‡ | 129.88 (17.81) | 129.68 (18.27) | 133.13 (18.88)†,§ | <0.001 |
| DBP (mm Hg)‡ | 76.66 (10.98) | 76.89 (11.05) | 77.84 (10.71)† | 0.001 |
| FBG (mmol/L)‡ | 5.20 (0.63) | 5.28 (0.63)§ | 5.41 (0.59)†,§ | <0.001 |
| 2 h PG (mmol/L)‡ | 6.50 (1.59) | 6.54 (1.67) | 6.46 (1.66) | 0.134 |
| FINS (uIU/mL)¶ | 5.90 (4.40, 7.80) | 5.90 (4.20, 8.40) | 5.40 (3.70, 7.80)†,§ | <0.001 |
| HDL-C (mmol/L)‡ | 1.36 (0.35) | 1.37 (0.34) | 1.41 (0.35)†,§ | <0.001 |
| LDL-C (mmol/L)‡ | 2.96 (0.83) | 2.94 (0.82) | 2.92 (0.85) | 0.474 |
| TC (mmol/L)‡ | 5.11 (1.10) | 5.04 (1.07) | 5.05 (1.09) | 0.516 |
| TG (mmol/L)‡ | 1.54 (1.18) | 1.55 (1.14) | 1.54 (1.10) | 0.971 |
| WHR‡ | 0.879 (0.082) | 0.864 (0.063)§ | 0.869 (0.062)†,§ | <0.001 |
| BMI (kg/m ²)‡ | 24.18 (3.27) | 23.93 (3.11) | 23.81 (3.05) | 0.059 |
| HbA1c (%)‡ | 5.73 (0.43) | 5.65 (0.42)§ | 5.60 (0.42)†,§ | <0.001 |
| HOMA-IR¶ | 1.35 (1.00, 1.84) | 1.38 (0.95, 1.99) | 1.30 (0.87, 1.90)† | <0.001 |
| Dyslipidaemia* | | | | |
| Normal | 249 (72.0%) | 3250 (72.1%) | 1973 (72.8%) | 0.771 |
| Abnormal | 97 (28.0%) | 1260 (27.9%) | 736 (27.2%) | |
| Smokers* | | | | |
| No | 247 (71.4%) | 3521 (78.0%) | 2003 (73.9%) | <0.001 |
| Yes | 99 (28.6%) | 992 (22.0%)§ | 706 (26.1%)† | |
| Alcohol users* | | | | |
| No | 275 (79.5%) | 3644 (80.7%) | 2190 (80.8%) | 0.819 |
| Yes | 71 (20.5%) | 869 (19.3%) | 519 (19.2%) | |
| FHD* | | | | |
| No | 318 (91.9%) | 4167 (92.3%) | 2561 (94.5%) | 0.001 |
| Yes | 28 (8.1%) | 346 (7.7%) | 148 (5.5%)† | |
| Physical activity* | | | | |
| No | 294 (85.0%) | 3920 (86.9%) | 2534 (93.5%) | <0.001 |
| Yes | 52 (15.0%) | 593 (13.1%) | 175 (6.5%)†,§ | |
| Snoring* | | | | |
| Often | 77 (22.3%) | 900 (19.9%) | 517 (19.1%) | 0.003 |
| Seldom | 110 (31.8%) | 1560 (34.6%) | 835 (30.8%) | |
| Never | 159 (46.0%) | 2053 (45.5%) | 1357 (50.1%)† | |
| Education level* | | | | |
| Low | 154 (44.5%) | 1541 (34.1%) | 1330 (49.1%) | <0.001 |
| Medium | 164 (47.4%) | 2307 (51.1%) | 1190 (43.9%) | |
| High | 28 (8.1%) | 665 (14.7%)§ | 189 (7.0%)† | |
| Hypertension* | | | | |
| No | 220 (63.6%) | 3085 (68.4%) | 1707 (63.0%) | <0.001 |
| Yes | 126 (36.4%) | 1428 (31.6%) | 1002 (37.0%)† | |
| Obesity* | | | | |
| Normal | 226 (65.3%) | 2968 (65.8%) | 1805 (66.9%) | 0.840 |
| Overweight | 105 (30.3%) | 1372 (30.4%) | 796 (29.5%) | |
| Obesity | 15 (4.3%) | 170 (3.8%) | 97 (3.6%) | |
| Napping* | | | | |
| No napping | 127 (36.7%) | 1790 (39.7%) | 1600 (59.1%) | <0.001 |
| 1 h | 143 (41.3%) | 1875 (41.5%) | 751 (27.7%)†,§ | |
| >1 h | 76 (22.0%) | 848 (18.8%) | 358 (13.2%)†,§ | |

Obesity was defined as BMI ≥ 30 kg/m².

*Data are presented by count and percentage.

†Indicates a significant difference compared to the group of night-time sleep 6–8 h.

‡Data are presented by mean and SD.

§Indicates a significant difference compared to the group of night-time sleep <6 h.

¶Data are presented by median and IQR due to skewed distribution.

BMI, body mass index; DBP, diastolic blood pressure; FBG, fasting blood glucose; FHD, family history of diabetes; FINS, fasting insulin; HbA1c, glycated haemoglobin; HDL-C, high-density lipoprotein cholesterol; HOMA-IR, the homoeostasis model assessment of insulin resistance; LDL-C, low-density lipoprotein cholesterol; PG, plasma glucose; SBP, systolic blood pressure; TC, total cholesterol; TG, triglycerides; WHR, Waist-to-hip ratio.

Table 3 The crude and adjusted ORs of HbA1c>6.0%, impaired glucose regulation and insulin resistance according to daytime napping

| Dependent variable | Independent variable | Crude OR (95% CI) | p Value | Adjusted OR* (95% CI) | p Value | Adjusted OR† (95% CI) | p Value | Adjusted OR‡ (95% CI) | p Value |
|--------------------|----------------------|---------------------|---------|-----------------------|---------|-----------------------|---------|-----------------------|----------|
| HbA1C>6.0% | Napping | | | | | | | | |
| | No nap | 1.0 | | 1.0 | | 1.0 | | 1.0 | |
| | ≤1 h | 1.13 (0.98 to 1.30) | 0.102 | 1.05 (0.91 to 1.22) | 0.491 | 1.05 (0.91 to 1.22) | 0.516 | 1.28 (1.09 to 1.49) | 0.002\$ |
| IGR | >1 h | 1.24 (1.04 to 1.48) | 0.018\$ | 1.16 (0.97 to 1.38) | 0.112 | 1.13 (0.94 to 1.36) | 0.186 | 1.26 (1.04 to 1.53) | 0.018\$ |
| | Napping | | | | | | | | |
| | No nap | 1.0 | | 1.0 | | 1.0 | | 1.0 | |
| Insulin resistance | ≤1 h | 1.05 (0.94 to 1.17) | 0.394 | 1.06 (0.95 to 1.19) | 0.313 | 1.06 (0.94 to 1.18) | 0.345 | 1.08 (0.96 to 1.21) | 0.214 |
| | >1 h | 1.13 (0.98 to 1.30) | 0.085 | 1.14 (0.99 to 1.32) | 0.064 | 1.12 (0.97 to 1.29) | 0.123 | 1.11 (0.95 to 1.28) | 0.181 |
| | Napping | | | | | | | | |
| | No nap | 1.0 | | 1.0 | | 1.0 | | 1.0 | |
| | ≤1 h | 1.22 (1.05 to 1.42) | 0.012\$ | 1.21 (1.04 to 1.41) | 0.016\$ | 1.22 (1.05 to 1.43) | 0.011\$ | 1.55 (1.30 to 1.85) | <0.001\$ |
| | >1 h | 1.33 (1.10 to 1.61) | 0.003\$ | 1.33 (1.10 to 1.60) | 0.004\$ | 1.37 (1.13 to 1.66) | 0.001\$ | 1.69 (1.35 to 2.12) | <0.001\$ |

HbA1c, glycated haemoglobin; IGR, impaired glucose regulation.

*Adjusted by night-time sleep.

†Further adjusted by age and gender.

‡The 11 variables were stepwise entered into the final model by forward conditional method (FBG, hypertension, FHD, dyslipidaemia, smoking status, alcohol status, frequency of snoring, physical activity, education levels, BMI and WHR); for the final model for HbA1C, the following eight variables were included FBG, hypertension, dyslipidaemia, smoking status, alcohol status, education level, BMI and WHR; for the final model for IGR, the following nine variables were included, hypertension, FDH, dyslipidaemia, smoking status, alcohol status, snoring, education level, BMI and WHR, where FBG was excluded since it is part of the definition of IGR; for the final model for IR, the following six variables were included, FBG, hypertension, dyslipidaemia and alcohol status.

\$p<0.05 indicated a significant association with the independent variable.

Table 4 The crude and adjusted ORs of HbA1c>6.0%, impaired glucose regulation and insulin resistance according to night-time sleep

| Dependent variable | Independent variable | Crude OR (95% CI) | p Value | Adjusted OR* (95% CI) | p Value | Adjusted OR† (95% CI) | p Value |
|--|----------------------|---------------------|----------|-----------------------|----------|-----------------------|----------|
| HbA1C>6.0% | Night-time sleep | | | | | | |
| | <6 h | 1.47 (1.12 to 1.92) | 0.005\$ | 1.46 (1.12 to 1.91) | 0.006\$ | 1.27 (0.97 to 1.67) | 0.088 |
| | 6–8 h | 1.0 | | 1.0 | | 1.0 | |
| IGR | >8 h | 0.70 (0.60 to 0.80) | <0.001\$ | 0.71 (0.61 to 0.82) | <0.001\$ | 0.69 (0.60 to 0.80) | <0.001\$ |
| | Night-time sleep | | | | | | |
| | <6 h | 0.85 (0.66 to 1.10) | 0.214 | 0.85 (0.66 to 1.09) | 0.202 | 0.77 (0.60 to 0.99) | 0.042\$ |
| Insulin resistance | 6–8 h | 1.0 | | 1.0 | | 1.0 | |
| | >8 h | 1.02 (0.92 to 1.14) | 0.656 | 1.04 (0.94 to 1.16) | 0.471 | 1.04 (0.93 to 1.15) | 0.526 |
| | Night-time sleep | | | | | | |
| | <6 h | 0.69 (0.47 to 1.00) | 0.048\$ | 0.68 (0.47 to 0.99) | 0.043\$ | 0.68 (0.47 to 0.99) | 0.044\$ |
| | 6–8 h | 1.0 | | 1.0 | | 1.0 | |
| | >8 h | 0.90 (0.78 to 1.04) | 0.147 | 0.94 (0.81 to 1.09) | 0.384 | 0.95 (0.82 to 1.11) | 0.518 |
| HbA1c, glycated haemoglobin; IGR, impaired glucose regulation. | | | | | | | |

*Adjusted by daytime napping.

†Further adjusted by age and gender.

‡The 11 variables were stepwise entered into the final model by forward conditional method (FBG, hypertension, FHD, dyslipidaemia, smoking status, alcohol status, frequency of snoring, physical activity, education levels, BMI and WHR); for the final model for HbA1C, the following eight variables were included, FBG, hypertension, dyslipidaemia, smoking status, alcohol status, education level, BMI and WHR; for the final model for IGR, the following nine variables were included, hypertension, FDH, dyslipidaemia, smoking status, alcohol status, snoring, education level, BMI and WHR, where FBG was excluded since it is part of the definition of IGR; for the final model for IR, the following six variables were included, FBG, hypertension, dyslipidaemia, alcohol status, BMI and WHR.

\$p<0.05 indicated a significant association with the dependent variable.

DISCUSSION

Results of the present cross-sectional study of Chinese middle-aged adults without diabetes revealed that participants with shorter night-time sleep (<6 h) were more likely to have HbA1c >6.0% and IGR compared with these values in persons reporting 6–8 h of night-time sleep after adjusting for potential confounding factors. More importantly, we found that daytime napping (≤ 1 or >1 h) was significantly adversely associated with HbA1c >6.0% and IR.

To the best of our knowledge, the present study is the first extensive investigation of daytime napping and night-time sleep in conjunction with glucose metabolism (ie, HbA1c, IGR and IR) in middle-aged adults without diabetes. In previous epidemiologic studies regarding associations of napping with different health parameters, exceptionally few studies assessed associations with diabetes or prediabetes. A cross-sectional study, The Guangzhou Biobank Cohort Study, suggested that participants reporting frequent naps (4–6 days/week or daily) were 37% or 15% more likely to have impaired fasting glucose and 36% or 28% more likely to have diabetes after adjusting for various potential confounders.¹⁷ However, unlike our study, that previous study assessed the effect of napping in terms of napping frequency and did not evaluate other markers of glucose metabolism, including HbA1c and IR.¹⁷ In the present study, we observed altered glucose metabolism in middle-aged adult participants without diabetes who reported napping. In western countries, napping appears to be less common and may compensate for night-time sleep loss or be induced by adverse health status such as in persons with diabetes. However, in China, daytime napping is a very traditional practice common in all ages. In fact, previous studies have suggested that night-time sleep duration was not significantly associated with napping duration.^{17 18} Considering this, we excluded participants with diabetes defined by self-reports and biochemical test results. We considered that associations between daytime napping and results of HbA1c, IGR and IR were not likely due to reverse causation.

Several mechanisms other than obesity may help to explain the associations between napping and these markers of glucose metabolism. Waking from daytime napping increases sympathetic nervous system activity, which could activate the renin–angiotensin system and increase cortisol levels, thereby modulating IR and associated hyperglycaemia.^{19 20} However, the mechanism involved in these relationships may not be fully explained. Moreover, individuals, particularly those reporting >1 h daily napping, are likely to have unique lifestyle factors (eg, type of work, working hours, personalities, etc) beyond napping that may influence glucose metabolism. Further prospective or experimental studies are needed, such as studies including more categories of duration (eg, 15, 30, 60, 90 min, etc), to better explore the possible underlying mechanisms of these associations.

Results of the present analysis also found that night-time sleep duration was significantly associated with HbA1c and IGR. The lack of associations between IR and night-time sleep duration among our participants without diabetes is in agreement with a prior report in participants without diabetes in China.²¹ In another previous study, even though the participants were involved in more rigid glucose control, as in persons with diabetes, the association between napping and IR remained insignificant.²² In contrast, a recent cohort study in rural Chinese participants without diabetes also yielded significant adverse associations between self-reported short night-time sleep and IR after adjusting for adiposity and other potential confounders, but only in women, not in men.²³ Discrepancies between those results and other previous results may be attributed to different sample sizes, different grouping of night-time sleep durations or different definitions of IR by HOMA-IR. However, the previous cross-sectional study observed the same result as ours by conducting multivariable linear regression with night-time sleep and HOMA-IR as continuous variables.²² At the same time, it should be noted that although statistically significant differences were shown in certain measured parameters between nappers and non-nappers, many were not clinically significant differences. For example, the difference between a mean age of 50.9 ± 7 years in non-nappers vs 51 ± 7 years in the <1 h napping group is obviously not clinically meaningful; it indicates only a slight difference in age. Similarly, the differences in SBP were 131.9 in non-nappers vs 130.0 and 130.1 in nappers (<1 h and >1 h), which are statistically significant but were still only slightly different, not indicating a clinically significant difference. Again, although significant differences were found in FBG, FINS, HDL-C, WHR and HbA1c between groups, the actual differences would not be considered clinically meaningful in terms of participants' health and/or sleep status. Some differences, such as the HOMA-IR results between longest and shortest sleepers, were clearly significant. However, this may be a result of the way participants were grouped, that is, showing trends toward possible diabetes risk in Chinese adults who nap. Although the analysis in the present study had sufficient power due to the large sample size, the lack of clinically significant differences in conjunction with statistically significant differences between groups can only be explained as a result of confounding variables in the models and not to actual intrinsic differences between the groups. Further longitudinal study is definitely needed, including comparisons between the sleeping and napping habits of participants with and without diabetes.

Consistent with a recent study,²⁴ and especially important among results of the present study, participants with short night-time sleep duration were more likely to have IGR and higher HbA1c. However, in contrast to the present study, a Japanese study reported a U-shaped association between night-time sleep and HbA1c >6.5%.²⁵ Several underlying biological mechanisms may explain the association between night-time sleep and disordered glucose metabolism. For example, an experimental study suggested that night-time

sleep deprivation led to decreased levels of the appetite-suppressing hormone, leptin, increased levels of the appetite-stimulating hormone, ghrelin, sympathetic hyperactivity and elevated evening cortisol levels through activation of the hypothalamic-pituitary-adrenal axis,² which may inhibit pancreatic function leading to reduced glucose tolerance and IR.²⁶

The major strengths of the current study include the large sample size and the wide range of demographic, socioeconomic and health-related data that were collected in the analysis to account for potential confounders. However, this study also has limitations. First, because of its cross-sectional design, the direction of causality could not be determined from our analysis. Second, the absence of dietary data may be described as a study limitation given the associations between diet, sleep and hyperglycaemia, which is mediated through appetite-associated hormones.^{2–25} Third, as self-reported questionnaires were used to obtain data on night-time sleep duration and napping, the study lacks objective sleep measurement using polysomnography or actigraphy, which were not feasible given our large sample and misclassifications may possibly occur. Nevertheless, an earlier study comparing subjective and actigraphic measurement of sleep found good correlations between self-reported sleep duration and objective measurements.²⁷ Finally, data were not obtained on the quality of night-time sleep, including the possible presence of insomnia or obstructive sleep apnoea (OSA), which previous studies have suggested were associated with impaired glucose metabolism^{28–29} and napping.⁶ Based on a previous study defining OSA on the basis of daytime sleepiness and disordered breathing during sleep, which includes snoring,³⁰ we accounted for the frequency of self-reported or spouse-reported snoring as a marker of OSA risk, and the inclusion of snoring in the regression model did not change the associations. Nevertheless, future studies must include polysomnography data to support related findings.

In summary, results of the present cross-sectional study indicate that Chinese middle-aged adult participants without diabetes reporting daytime napping had significantly elevated HbA1c, IGR and IR, and those with shorter night-time sleep durations had higher HbA1c and impaired glucose regulation. Further experimental studies are warranted to identify the mechanism underlying these associations.

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manuscript editing. QC was involved in definition of intellectual content, literature research, data acquisition, data analysis, manuscript editing and manuscript review. WP was involved in literature research, data acquisition, data analysis, manuscript editing and manuscript review. LQ, LY, HH and LJ were involved in literature research, data acquisition, data analysis. LL, CL, TK and CZ were involved in data acquisition and data analysis. LL was involved in literature research and manuscript review. LJ and BY were involved in study design and definition of intellectual content. NG was involved in study concept, study design and is the guarantor. ZP and WJ were involved in study concept, definition of intellectual content, manuscript review and are guarantors. CG was involved in study concept, definition of intellectual content, manuscript editing, manuscript review and is the guarantor.

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