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Relationship between daytime napping with the occurrence and development of diabetes: a systematic review and meta-analysis

Mengdie Liu, Minhui Liu, Shuo Wang, Yumei Sun, Fang Zhou, Hongyu Sun

ABSTRACT

Objective To determine the relationship of napping with incident diabetes risk and glycaemic control in people with diabetes.

Design Systematic review and meta-analysis.

Data sources MEDLINE (PubMed), EMBASE, Web of Science and the Cochrane Library were searched for studies published from database inception to 9 May 2023.

Eligibility criteria Observational studies reporting the relationship of napping with diabetes or glycaemic control in patients with diabetes in adult populations were included.

Data extraction and synthesis Two reviewers independently screened the literature, extracted data and assessed the quality of the included studies. The results were reported as ORs and 95% CIs, which were pooled by using fixed and random effects models, and subgroup analyses were performed. The Grading of Recommendations Assessment, Development and Evaluation method was used to assess the quality of the evidence.

Results Forty studies were included in our review. Habitual napping was associated with an increased diabetes risk (OR 1.20, 95% CI 1.14 to 1.27) and poor glycaemic control in patients with diabetes (OR 2.05, 95% CI 1.55 to 2.73). Nap durations less than 30 min were unrelated to diabetes (OR 1.05, 95% CI 0.97 to 1.14). Nap durations of 30–60 min were associated with diabetes risk (OR 1.09, 95% CI 1.02 to 1.17), but there were differences in the subgroup analysis results. Nap durations of more than 60 min significantly increased the risk of diabetes (OR 1.31, 95% CI 1.20 to 1.44).

Conclusions Napping is associated with increased diabetes risk and poor glycaemic control, and future research will need to confirm whether there are sex and regional differences. Nap durations of more than 60 min significantly increases the risk of diabetes, and the relationship between nap duration and glycaemic control in patients with diabetes needs to be further explored in the future.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ This study presents an unprecedented systematic evaluation of the association between napping and glycaemic control in people with diabetes and provides updated insights into the relationship between napping and diabetes risk.

⇒ This study was conducted with data from many participants across three different continents, and subgroup analyses were performed based on important confounding factors.

⇒ Due to a lack of corresponding data, stratified analyses for some additional confounding factors could not be carried out.

⇒ The number of studies included in some analyses was relatively small, so conclusions need to be drawn cautiously.

INTRODUCTION

Diabetes mellitus is one of the most common chronic diseases globally, with the prevalence increasing annually. Poor glycaemic control in people with diabetes may result in various acute and chronic complications, further aggravating disease progression. The glycaemic control status can be reflected by glycosylated haemoglobin and blood glucose levels in different states (eg, such as fasting blood glucose levels). Identifying the risk factors for the development of diabetes is important for effective early prevention and intervention.

Napping is defined as sleep of short duration, typically during daylight hours. It has been considered a healthy lifestyle practice, but this view has been increasingly challenged in recent years. Some studies have reported that napping may increase the risk of diabetes. However, some studies have found no connection between napping and diabetes. Nap duration may play an important role in these associations, as the durations of long and short naps vary widely across studies. Additionally, factors such as region, sex and age of participants vary among studies, which may be important.
factors contributing to the differences in the relationship of napping with diabetes. There is also controversy about the relationship of napping with glycaemic control. Gozalsh et al. concluded that napping is related to better glycaemic control, while the results of the study conducted by Bawadi et al. indicated that napping may be an independent risk factor for poor glycaemic control in people with diabetes. There are also different opinions on the relationship between specific nap durations and glycaemic control.

Existing meta-analyses of the relationship between nap duration and diabetes did not use nap duration groups, such as defined by bins of <30, 30–60 or >60 min. A meta-analysis of the relationship between different nap duration groups and diabetes and further stratified analysis of confounding factors in each group can enable a more accurate analysis of the association between nap duration and diabetes. In addition, to our knowledge, no meta-analysis has been conducted that considers the relationship between napping and glycaemic control in people with diabetes.

Therefore, we conducted a systematic review and meta-analysis of the relationship between nap duration and different nap duration groups with diabetes risk and glycaemic control in patients with diabetes, to provide nap-based evidence to support the guidance of clinical diabetes management.

METHODS

This systematic review and meta-analysis was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines.

Literature search strategy

We searched MEDLINE (PubMed), EMBASE, Web of Science and the Cochrane Library for studies published from database inception to 9 May 2023, without language restriction. The search terms included “nap,” “diabetes mellitus,” “glycaemic control” and “fasting plasma glucose.” The reference lists of relevant systematic reviews were manually screened for additional eligible studies. The full search strategy is illustrated in online supplemental table S1.

Eligibility criteria

Studies were considered eligible if they (1) involved human participants aged 18 years or older; (2) assessed the relationship between napping (sleep of short duration during daylight hours, could be yes/no or specific length of nap or nap frequency) and the occurrence of diabetes (diabetes diagnosed by a corresponding qualified physician or self-reported) or glycaemic control (expressed by glycosylated haemoglobin or blood glucose levels in different states of people with diabetes) and (3) were observational (cohort, cross-sectional and case-control studies). Studies were excluded if they (1) only assessed the association between excessive daytime sleepiness (measured with a recognised scale, eg, the Epworth Sleepiness Scale) and diabetes or glycaemic control and (2) were grey literature (dissertations, conference abstracts, letters, etc). If more than one study published the same data, we included the study with the largest sample size and/or the longest follow-up duration.

Study selection and data extraction

After screening titles and/or abstracts independently, two authors independently reviewed the full texts according to the inclusion and exclusion criteria. Disagreements were resolved by consensus or by the decision of a third author.

Two authors independently extracted data from the included studies, which included publication year, first author, country of the study, demographic characteristics of the participants, nap durations and their binning groups, specified types of and diagnostic methods for diabetes, glycaemic control status, outcomes (relevant conclusions given in the original texts) and control of confounding factors.

Methodological quality assessment

Two authors independently evaluated the quality of cohort studies and cross-sectional studies using the Newcastle-Ottawa scale and the Joanna Briggs Institute Critical Appraisal Tools, respectively. The Newcastle-Ottawa scale for cohort studies included items of three categories: selection, comparability and outcome. A study could be rated from zero to nine stars. The Joanna Briggs Institute Critical Appraisal Tools for Analytical Cross-sectional Studies contains eight items assessing sample selection criteria, subject description, measurement of exposure and subject condition, confounding factor identification, control of confounding factors, outcome assessment and statistical analysis. A study was awarded one point if the result of an appraisal criterion was ‘yes’ and ‘no-points’ if the result was ‘no’ or ‘unclear’.

Data synthesis and analysis

Stata V.16.0 was used to conduct statistical analyses. We analysed the relationship of napping with diabetes and glycaemic control. Napping status determination included yes/no and groups of specific nap duration (<30, 30–60 and >60 min), and glycaemic control status was represented by glycosylated haemoglobin or blood glucose levels. For studies in which the outcome was diabetes or glycaemic control assessed as a dichotomous variable, we extracted the ORs and 95% CIs after adjusting for confounders, whereas for studies that did not report ORs and 95% CIs, raw data were extracted to calculate the ORs and 95% CIs, indicating the association between napping and diabetes or glycaemic control. For studies reporting HR values or relative risk (RR) values, the HR/RR value was extracted as the OR value when the incidence of diabetes was less than 10%; if the incidence of diabetes was higher than 10%, the HR/RR value was used as the OR value, and then the study was removed for sensitivity analysis. For studies in which the outcome
was glycaemic control expressed as a continuous variable, \( \beta \) (with SE) of blood glucose or glycosylated haemoglobin values were extracted to estimate the OR and 95% CI.\(^{19}\) If there were only subgroup data analysed based on a specific characteristic in one study but no overall data, we combined these subgroup data according to the guidelines of the Cochrane Handbook.\(^{18}\)

We pooled the ORs and 95% CIs of each study. In addition, we conducted narrative analyses for studies that were unable to be meta-analysed due to the lack of valid data. Narrative analysis refers to the systematic summary of key aspects of each study’s methodology and results followed by identifying and grouping common themes based on outcomes.\(^{20}\) Subgroup analyses were based on study type, region, sex, type of diabetes and classification criteria for glycaemic control. Regions referred to the continents where the countries in which the studies were conducted were located.

We used the \( I^2 \) statistic to measure heterogeneity, and values of <25%, 26%–50% and >50% denoted low, moderate and high degrees of heterogeneity, respectively.\(^{21}\) When \( I^2 > 50\% \), the random-effects model was used for analysis; otherwise, the fixed-effects model was used.\(^{18}\) We performed sensitivity analyses by excluding one study at a time to observe changes in outcomes. Publication bias was assessed using funnel plots and Egger’s test.

**Evaluation of certainty of evidence**

The quality of evidence was assessed independently by two authors using the Grading of Recommendations Assessment, Development and Evaluation method. The assessment is based on the consideration of the risk of bias, inconsistency, indirectness, imprecision, publication bias, large effects, plausible confounding and dose-response gradients, and the quality of evidence is classified as high, moderate, low or very low.\(^{22}\)

**Patient and public involvement**

No patients were involved in the study.

**RESULTS**

The search identified 1593 non-duplicated potentially eligible studies. After a detailed review of titles and abstracts, a total of 109 full-text articles were reviewed. Ultimately, 69 articles were excluded due to not meeting eligibility criteria (figure 1), and a total of 40 articles were included.\(^{3-9} 11-14 23-53\) Of the 40 included studies, 22 were cross-sectional studies, and 18 were cohort studies.

**Study characteristics**

Our systematic review included a total of 1528216 participants aged 19 years or older, of which 648255 participants (42.4%) were men. Of the 40 studies included in this systematic review and meta-analysis, 32 were about napping and diabetes,\(^{5-9} 23-30 32 33 35-44 46-51 53\) and the other 8 were about napping and glycaemic control.\(^{11-14} 31 34 45 52\) In all the eight studies on napping and glycaemic control, glycosylated haemoglobin was used as an indicator of glycaemic control, and there were no other glycaemic control indicators, such as fasting plasma glucose. The study regions included Asia (China, Japan, Arabia, Iran), North America (the USA, Mexico) and Europe (the UK, Germany, Spain, Finland, Greece). Further details of the study characteristics are summarised in online supplemental table S2.

**Methodological quality**

The scores for the cross-sectional studies were between 5 and 8 points, and the scores for the cohort studies were between 6 and 9 stars. In the cross-sectional studies, the exposure scores were all low, mainly because the information on napping and specific nap duration was basically obtained in the form of questionnaires or interviews, which were relatively subjective. Information on follow-up rates and the number of participants lost to follow-up was lacking in reports of several cohort studies (n=6, 33.3%). Overall, the quality of the included studies was comparatively high. Details of the quality assessment are summarised in online supplemental table S3.

**Association between napping and diabetes**

Data from 4 of the 32 studies on the relationship between napping and diabetes could not be pooled because they could not be extracted efficiently. Therefore, we performed narrative analyses of these four studies. Papan dreou et al.\(^{33}\) compared the prevalence of type 2 diabetes mellitus (T2DM) associated with three categories of napping durations (30–60, 60–90 and ≥90 min), using participants who napped for 5–30 min as the control, and found that participants who napped for more than...
90 min had a higher prevalence of T2DM. Hublin et al. found that daily or near daily napping was related to the future risk of T2DM, but the results became insignificant after adjusting for body mass index. McWhorter et al. investigated the relationship between napping frequency and T2DM using napping less than three times a week as a control and found that frequent napping (≥3 times/week) was associated with a higher risk of T2DM. Zhou et al. conducted a survey of 435,342 adults aged 40–69 years and found that higher nap frequency was associated with an increased T2DM risk. Data from the remaining 28 studies could be pooled, and the results were as follows.

### Napping

The pooled results of 28 studies showed that napping was associated with a 20% increased risk of diabetes compared with no napping (OR 1.20, 95% CI 1.14 to 1.27, figure 2). There was high heterogeneity (I²=74.56%). In the results of the subgroup analyses based on the study type, region, sex and type of diabetes, all subgroups except the European group in the region subgroup (OR 1.06, 95% CI 0.86 to 1.31) showed that the risk of diabetes in nappers was higher than that in non-nappers (table 1).

As the included studies were all observational studies, the initial quality of the evidence was low, and the heterogeneity across studies was high, so we assessed the quality of the evidence as very low.

### Nap durations of less than 30 min

Ten studies reported the relationship between nap durations of less than 30 min and diabetes risk compared with no napping, and the pooled results revealed no association (OR 1.05, 95% CI 0.97 to 1.14). Heterogeneity was low (I²=0.00%). The subgroup analysis results of study type, continent, sex and region did not show that nap durations of less than 30 min were associated with diabetes risk (table 1).

All the included studies were observational, but the heterogeneity was low, so we assessed the quality of the evidence as low.

### Nap duration between 30 and 60 min

In comparison with non-nappers, participants taking a nap of 30–60 min had a slightly increased risk of diabetes (OR 1.09, 95% CI 1.02 to 1.17). This resulted from combining the data of five studies. The heterogeneity was low (I²=0.00%). The subgroup analyses showed that napping for 30–60 min was associated with an increased risk of diabetes only in the cohort study group (OR 1.10, 95% CI 1.01 to 1.20), the Asia regional group (OR 1.09, 95% CI 1.02 to 1.17) and the group (OR 1.10, 95% CI 1.01 to 1.20) with the outcome of the total diabetic population (table 1).

The included studies were all observational, and the heterogeneity across studies was low, so we assessed the quality of the evidence as very low.

### Nap durations of more than 60 min

The pooled results of 13 studies showed that an approximate 31% increase in the risk of diabetes relative to those who did not nap (OR 1.31, 95% CI 1.20 to 1.44). The heterogeneity was high (I²=76.61%). The subgroup analyses based on region and type of diabetes showed that the pooled results of studies in European regions (OR 1.53, 95% CI 0.80 to 2.91) and the pooled results of studies with the outcome indicator of T2DM (OR 1.25, 95% CI 0.91 to 1.73) indicated that napping for more than 60 min was not associated with diabetes risk. Additionally, among those who napped for more than 60 min, women had a 75% (OR 1.75, 95% CI 1.25 to 2.46) increased risk of diabetes, and men had a 43% (OR 1.43, 95% CI 1.19 to 1.72) increased risk (table 1).

All included studies were observational studies and had high heterogeneity, so we assessed the quality of the evidence as very low.

### Association between napping and glycaemic control in people with diabetes

Five of the eight studies on napping and glycaemic control could not be pooled because they did not provide valid data. Therefore, we performed narrative analyses of these five studies. All five studies were conducted in patients with type 2 diabetes. Gozashi et al. found that napping was associated with better glycaemic control among 118 participants with T2DM. Makino et al. examined the
combined effects of napping and night-time sleep duration on glycaemic control in 398 participants and found that napping attenuated the deleterious effects of short night-time sleep durations on glycaemic control, but the independent effect of napping on glycaemic control was not analysed. Bawadi et al. found that among people with type 2 diabetes, those who napped had significantly higher glycosylated haemoglobin levels than those who

Table 1  Results of meta-analyses of the relationship between napping and diabetes

<table>
<thead>
<tr>
<th>Group</th>
<th>Categories</th>
<th>No of studies</th>
<th>Effect size (95% CI)</th>
<th>Heterogeneity</th>
<th>Group difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nap</td>
<td>CH</td>
<td>13</td>
<td>1.14 (1.10 to 1.18)</td>
<td>(I^2=48.60%)</td>
<td>p&gt;0.05</td>
</tr>
<tr>
<td></td>
<td>CS</td>
<td>15</td>
<td>1.22 (1.13 to 1.31)</td>
<td>(I^2=75.95%)</td>
<td></td>
</tr>
<tr>
<td>Continent</td>
<td>America</td>
<td>3</td>
<td>1.30 (1.14 to 1.48)</td>
<td>(I^2=0.00%)</td>
<td>p&gt;0.05</td>
</tr>
<tr>
<td></td>
<td>Asia</td>
<td>19</td>
<td>1.21 (1.14 to 1.28)</td>
<td>(I^2=79.55%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Europe</td>
<td>6</td>
<td>1.06 (0.86 to 1.31)</td>
<td>(I^2=57.80%)</td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td>Male</td>
<td>7</td>
<td>1.14 (1.05 to 1.24)</td>
<td>(I^2=48.62%)</td>
<td>p&gt;0.05</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>9</td>
<td>1.18 (1.11 to 1.25)</td>
<td>(I^2=0.00%)</td>
<td></td>
</tr>
<tr>
<td>Diabetes type</td>
<td>T2DM</td>
<td>9</td>
<td>1.19 (1.10 to 1.29)</td>
<td>(I^2=53.06%)</td>
<td>p&gt;0.05</td>
</tr>
<tr>
<td></td>
<td>DM</td>
<td>19</td>
<td>1.21 (1.13 to 1.29)</td>
<td>(I^2=78.96%)</td>
<td></td>
</tr>
<tr>
<td>&lt;30 min</td>
<td>CH</td>
<td>5</td>
<td>1.02 (0.92 to 1.13)</td>
<td>(I^2=11.27%)</td>
<td>p&gt;0.05</td>
</tr>
<tr>
<td></td>
<td>CS</td>
<td>5</td>
<td>1.10 (0.96 to 1.25)</td>
<td>(I^2=0.00%)</td>
<td></td>
</tr>
<tr>
<td>Continent</td>
<td>America</td>
<td>1</td>
<td>1.15 (0.72 to 1.84)</td>
<td>NA</td>
<td>p&gt;0.05</td>
</tr>
<tr>
<td></td>
<td>Asia</td>
<td>8</td>
<td>1.03 (0.95 to 1.12)</td>
<td>(I^2=8.53%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Europe</td>
<td>1</td>
<td>1.20 (0.90 to 1.58)</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td>Male</td>
<td>2</td>
<td>1.02 (0.77 to 1.36)</td>
<td>(I^2=0.00%)</td>
<td>p&gt;0.05</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>3</td>
<td>0.97 (0.80 to 1.19)</td>
<td>(I^2=0.00%)</td>
<td></td>
</tr>
<tr>
<td>Diabetes type</td>
<td>T2DM</td>
<td>4</td>
<td>1.08 (0.93 to 1.24)</td>
<td>(I^2=6.83%)</td>
<td>p&gt;0.05</td>
</tr>
<tr>
<td></td>
<td>DM</td>
<td>6</td>
<td>1.03 (0.94 to 1.14)</td>
<td>(I^2=7.42%)</td>
<td></td>
</tr>
<tr>
<td>30–60 min</td>
<td>CH</td>
<td>3</td>
<td>1.10 (1.01 to 1.20)</td>
<td>(I^2=0.00%)</td>
<td>p&gt;0.05</td>
</tr>
<tr>
<td></td>
<td>CS</td>
<td>2</td>
<td>1.08 (0.95 to 1.22)</td>
<td>(I^2=0.00%)</td>
<td></td>
</tr>
<tr>
<td>Continent</td>
<td>Asia</td>
<td>4</td>
<td>1.09 (1.02 to 1.17)</td>
<td>(I^2=0.00%)</td>
<td>p&gt;0.05</td>
</tr>
<tr>
<td></td>
<td>Europe</td>
<td>1</td>
<td>1.20 (0.78 to 1.84)</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td>Male</td>
<td>2</td>
<td>0.99 (0.80 to 1.22)</td>
<td>(I^2=0.00%)</td>
<td>p&gt;0.05</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>2</td>
<td>1.11 (0.94 to 1.30)</td>
<td>(I^2=0.00%)</td>
<td></td>
</tr>
<tr>
<td>Diabetes type</td>
<td>T2DM</td>
<td>2</td>
<td>1.08 (0.95 to 1.22)</td>
<td>(I^2=0.00%)</td>
<td>p&gt;0.05</td>
</tr>
<tr>
<td></td>
<td>DM</td>
<td>3</td>
<td>1.10 (1.01 to 1.20)</td>
<td>(I^2=0.00%)</td>
<td></td>
</tr>
<tr>
<td>&gt;60 min</td>
<td>CH</td>
<td>6</td>
<td>1.28 (1.11 to 1.47)</td>
<td>(I^2=79.59%)</td>
<td>p&gt;0.05</td>
</tr>
<tr>
<td></td>
<td>CS</td>
<td>7</td>
<td>1.34 (1.18 to 1.54)</td>
<td>(I^2=69.26%)</td>
<td></td>
</tr>
<tr>
<td>Continent</td>
<td>America</td>
<td>1</td>
<td>1.36 (1.27 to 1.46)</td>
<td>NA</td>
<td>p&gt;0.05</td>
</tr>
<tr>
<td></td>
<td>Asia</td>
<td>10</td>
<td>1.30 (1.16 to 1.45)</td>
<td>(I^2=78.93%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Europe</td>
<td>2</td>
<td>1.53 (0.80 to 2.91)</td>
<td>(I^2=58.59%)</td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td>Male</td>
<td>4</td>
<td>1.43 (1.19 to 1.72)</td>
<td>(I^2=0.00%)</td>
<td>p&gt;0.05</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>5</td>
<td>1.75 (1.25 to 2.46)</td>
<td>(I^2=77.31%)</td>
<td></td>
</tr>
<tr>
<td>Diabetes type</td>
<td>T2DM</td>
<td>2</td>
<td>1.25 (0.91 to 1.73)</td>
<td>(I^2=59.24%)</td>
<td>p&gt;0.05</td>
</tr>
<tr>
<td></td>
<td>DM</td>
<td>11</td>
<td>1.33 (1.20 to 1.48)</td>
<td>(I^2=77.61%)</td>
<td></td>
</tr>
</tbody>
</table>

CH, cohort studies; CS, cross-sectional studies; DM, diabetes mellitus; NA, not available; NA, not applicable; T2DM, type 2 diabetes mellitus.
never napped. Franke et al.13 compared the differences in glycosylated haemoglobin values between different nap duration groups in patients with T2DM and found statistically significant differences between the groups but did not find a clinically relevant tendency. Xue et al.13 investigated the relationship between nap frequency and glycated haemoglobin in patients with type 2 diabetes, and the results showed that after adjusting for confounding factors, frequent napping was associated with poorer glycaemic control compared with no napping. Data from the three remaining studies could be pooled, and the pooled results were as follows.

**Napping**

Three studies14 34 52 classified glycaemic control as a dichotomous variable (good/poor) according to the value of glycosylated haemoglobin. The pooled results of these studies showed that nappers had significantly poorer glycaemic control than non-nappers (OR 2.05, 95% CI 1.55 to 2.73, table 2). There was low heterogeneity (I²=0.00%, table 2). The subgroup analysis results for diabetes type and classification criteria for poor glycaemic control remained consistent, except for the subgroup with glycosylated haemoglobin >9.2% as the classification criterion (OR 1.08, 95% CI 0.37 to 3.15, table 2).

The included studies, all of which were observational studies, were only 3 in number and may have been imprecise; therefore, we assessed the quality of the evidence as very low.

**Sensitivity analyses**

Sensitivity analyses of the results of the relationships between napping and the risk of diabetes were conducted by removing one study at a time, and no significant effects on the pooled results were found.

Only one study29 that presented RR as a result had an incident rate of diabetes higher than 10%, and after performing sensitivity analyses by excluding the study, we had similar results. The details are summarised in online supplemental table S4.

**Publication bias**

The funnel plots (online supplemental figure S1) and Egger’s test (p=0.91) indicated that there was no publication bias in the pooled results.

**DISCUSSION**

Our meta-analysis provides an updated summary of research data on the relationship between napping and diabetes risk, and it was the first to summarise data on the relationship between napping and glycaemic control in people with diabetes. The main finding was that napping increased diabetes risk and poor glycaemic control; specifically, napping for more than 60 min may lead to a 31% increased risk of diabetes.

Our review showed that people who napped habitually were at a higher risk of diabetes than those who did not, which was consistent with the results of several previous meta-analyses.4 10 54 Our results did not show that nap durations of less than 30 min reduce diabetes risk, but there was evidence that appropriate napping has positive effects on learning ability, memory, work performance and energy recovery.55 56 Future studies should further investigate whether appropriate napping can reduce diabetes risk compared with not napping, offering a new perspective for disease prevention.

Our review showed that napping for 30–60 min was related to diabetes, and the subgroup analyses showed inconsistent results. Tietzel and Lack37 demonstrated that short napping had short-term benefits following nocturnal sleep restriction. However, we need to further study the optimal nap duration in the context of limited night-time sleep. Understanding the ideal nap length based on night-time sleep patterns for different individuals could benefit the health of certain groups, such as shift workers. Notably, limited studies were available for each of the subgroups, so there may be imprecision in the combined results of these subgroups. Furthermore, judging from the combined results of all five studies, the risk of diabetes was only slightly increased, and its clinical significance remains to be explored.

Napping for more than 60 min can dramatically increase the risk of diabetes, which has been confirmed in several studies, including ours. Long nap durations may reduce energy consumption and cause obesity, which has an important impact on the occurrence of diabetes.58 A long nap may also disrupt individuals’ circadian rhythm of sleep and wakefulness. Circadian rhythm disorder is a susceptible environmental risk factor of T2DM,59 60 which may lead to increased concentrations of several

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**Table 2** Results of meta-analyses of the relationship between napping and glycaemic control

<table>
<thead>
<tr>
<th>Group</th>
<th>Categories</th>
<th>No of studies</th>
<th>Effect size (95% CI)</th>
<th>Heterogeneity</th>
<th>Group difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nap</td>
<td></td>
<td>3</td>
<td>2.05 (1.55 to 2.73)</td>
<td>I²=0.00%</td>
<td></td>
</tr>
<tr>
<td>Diabetes type</td>
<td>T2DM</td>
<td>2</td>
<td>1.91 (1.04 to 3.50)</td>
<td>I²=38.11%</td>
<td>p&gt;0.05</td>
</tr>
<tr>
<td></td>
<td>T1DM</td>
<td>1</td>
<td>2.10 (1.45 to 2.74)</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>Criteria</td>
<td>≥7.0%</td>
<td>2</td>
<td>2.16 (1.61 to 2.89)</td>
<td>I²=0.00%</td>
<td>p&gt;0.05</td>
</tr>
<tr>
<td></td>
<td>&gt;9.2%</td>
<td>1</td>
<td>1.08 (0.37 to 3.15)</td>
<td>NA</td>
<td></td>
</tr>
</tbody>
</table>

NA, not applicable; T1DM, type 1 diabetes mellitus; T2DM, type 2 diabetes mellitus.
hormones, such as glucocorticoids and interleukin-6, which can cause hyperglycaemia.  

Notably, we found a trend towards a higher risk of diabetes among women than men who napped for more than 60 min, but the sex difference was not statistically significant. Nonetheless, we cannot ignore the possible sex differences in the association between long naps and diabetes risk. The differences may be because women are more susceptible to the adverse effects of negative psychology than men, which has been confirmed to be associated with diabetes.  

Some studies report that napping for more than 60 min increases the risk of diabetes only in postmenopausal women.  

Additionally, our meta-analyses found regional differences in the relationship between napping and diabetes risk, although these differences were in significant. This may be because different countries/regions have different motivations for taking a nap. In Latin America, Mediterranean countries and China, napping is considered a healthy lifestyle that helps restore energy and improve performance during afternoon work. However, in some Western countries, napping is less common and often unplanned, likely caused by ageing, deteriorating health status or night-time insomnia. Therefore, it is necessary to describe napping in more detail when discussing its relationship with the risk of diabetes.

Most of the studies on the relationship between napping and diabetes made adjustments for night-time sleep duration. Three studies established ‘no naps and 7–8 hours of night-time sleep’ as the control group. Among them, Xu et al found that ‘naps ≥60 min and night-time sleep <5 hours’ had the highest risk of diabetes; Han et al found that the highest risk of diabetes was associated with ‘naps ≥60 min and night-time sleep ≥10 hours’ and Liu et al reported that the highest risk of diabetes was associated with ‘naps ≥90 min and night-time sleep ≥9 hours’, however, subgroup analysis by sex found that the association was only present and enhanced in women. It appears from the above studies that the combination of long nap duration and inappropriate night sleep duration may be an important risk combination, especially for naps ≥60 min. Due to the different control and grouping approaches in different studies and the limited number of studies, we were not able to analyse the combined effect of nap and night-time sleep duration on diabetes, which can be further investigated in future studies.

Our meta-analyses show that napping is pernicious to the glycaemic control of patients with diabetes. This may be related to the increase in sympathetic activity during prolonged napping, which can lead to insulin resistance and associated hyperglycaemia. Due to data limitations, we were unable to divide nap duration into different groups and to analyse their association with glycaemic control. Different types of diabetes need to be discussed separately as they differ in aetiology, clinical presentation and prognosis. The results were significant for both type 1 and type 2 diabetes in the subgroup analyses, but the subgroup with type 1 diabetes as the outcome was based on data from only one study, so the data could not be combined. The relevant conclusions need to be treated with caution due to the limited studies available, and additional studies in the future are essential to verify our conclusions.

Strengths and limitations
Our review provides the latest findings on the relationship of napping with diabetes and glycaemic control; more specific groups for nap duration were highlighted, and subgroup analyses were conducted based on important factors. Moreover, our review used data from many participants across three different continents. Nevertheless, our review has several limitations. First, the number of studies included in certain subgroup analyses was relatively small, and the results may be biased. Second, we were unable to conduct corresponding subgroup analyses for confounding factors such as nap frequency, menopausal status and other sleep conditions (except napping) due to the lack of data in the included studies. Third, we extracted the adjusted ORs from each study, and the combined results may not be accurate due to some differences in the confounders adjusted for across studies. Fourth, the meta-analyses of the relationship between napping and glycaemic control involved only a few studies, so the results may be biased.

Implications for clinical practice and research
We recommend that napping should not exceed 30 min. All levels of medical and health institutions in different countries/regions should pay attention to the effects of napping on individual physical and mental health. In the future, it will be essential to clarify the effects of sex and special life stages of women, such as pregnancy and menopause, on the relationship between nap duration and metabolic diseases, including diabetes, and their underlying mechanisms. Moreover, napping as part of sleep will be affected by other sleep status and should be given more attention in future research. More research is needed on the relationship between nap duration and glycaemic control in people with diabetes and how it is affected by other factors.

CONCLUSION
Napping for less than 30 min was not associated with diabetes risk. When the nap duration was more than 60 min, diabetes risk increased dramatically. Sex, menopausal status and region may play an important role in the relationships of different nap durations with the risk of diabetes and glycaemic control. Therefore, more research and analyses are needed in the future.

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data analysis and interpretation, and drafted the manuscript. SW and YS were involved in data analysis and interpretation, and revised the manuscript. FZ and HS were responsible for the overall supervision, interpreted the data and revised the manuscript. All authors read and approved the final manuscript. HS is responsible for the overall content as guarantor.

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