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Day napping and short night sleeping are associated with higher risk of diabetes in older adults

Qun Xu, MD PhD, Yiqing Song, MD ScD, Albert Hollenbeck, PhD, Aaron Blair, PhD, Arthur Schatzkin, MD PhD, Honglei Chen, MD, PhD

Epidemiology Branch, National Institute for Environmental Health Sciences, Research Triangle Park, North Carolina (Q Xu and H Chen); Division of Preventive Medicine, Brigham & Women's Hospital, Harvard Medical School, Boston, MA (Y Song); Nutritional Epidemiology Branch and Occupational and Environmental Epidemiology Branch, National Cancer Institute, Rockville, MD (A Blair, A Schatzkin); AARP, Washington DC (A Hollenbeck).

Running title: Napping, sleeping and risk of diabetes

Correspondence and Reprints:
Honglei Chen, MD, PhD
Email chenh2@niehs.nih.gov

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Objective- To examine whether day napping or short night sleeping is associated with higher risk of diabetes.

Research design and methods- A prospective study of hours of daytime napping and night sleeping assessed in 1996-1997 in relation to diabetes diagnosed between 2000 and 2006 (n = 10,143) among 174,542 participants of the NIH-AARP Diet and Health Study. Odds ratios (OR) and 95% confidence intervals (CI) were derived from multivariate logistic regression models.

Results- Longer day napping was associated with higher risk of diabetes. After adjusting for potential confounders, compared with individuals who did not nap, the OR was 1.23 (95%CI: 1.18-1.29) for those reporting < 1 hour and 1.55 (95%CI: 1.45-1.66) for ≥ 1 hour of napping (*P* for trend < 0.0001). For night sleeping, with 7-8 hours as the referent, the OR was 1.46 (95%CI: 1.31-1.63) for < 5 hours, 1.11 (1.06-1.16) for 5-6 hours, and 1.11 (0.99-1.24) for ≥ 9 hours. In both analyses, additional adjustment for BMI only modestly attenuated the associations. Further analysis showed a statistically significant interaction between hours of napping and sleeping on diabetes (*P* for interaction < 0.0001). Among participants with no napping, only short night sleeping was associated with higher occurrence of diabetes, whereas among those with ≥ 1 hour of napping, both long and short sleeping was associated with higher risk.

Conclusions- Day napping and short night sleeping are associated with higher risk of diabetes. The association between sleep duration and diabetes may be modified by napping habit.

It is recommended that adults have 7-8 hours of quality sleep per night; however, national data show that short sleeping has become increasingly prevalent across all adult age and gender groups over the past decades (1). Short sleep may have deleterious health consequences, including higher risk of diabetes that was recently reported in a few prospective cohorts (2-5). It is hypothesized that obesity may in part explain this observation on short sleep duration and diabetes (6).

Day napping is common among older adults (7, 8), however the health consequences of napping are poorly understood. Recent cross-sectional analyses reported that day napping was more common among diabetic patients than those without diabetes (8, 9). These cross-sectional analyses provide little information on the direction and nature of this finding. Although it is plausible that napping is secondary to clinical diabetes, it is not unreasonable to hypothesize that napping itself may be associated with a higher risk of diabetes. A further complication is that day napping and night sleeping may not be independent of each another and may jointly affect diabetes. However, to the best of our knowledge, this possibility has not been evaluated.

We therefore used data from the National Institute of Health-AARP (formerly known as the American Association of Retired Persons) Diet and Health cohort to prospectively evaluate the individual and joint effect of hours of day napping or night sleeping on the risk of incident diabetes.

RESEARCH DESIGN AND METHODS

Study Participants. The NIH-AARP Diet and Health cohort was established in 1995-1996 by the National Cancer Institute to investigate roles of diet and lifestyle in cancer etiology (10). Cohort participants included 566,402 AARP members ages 50 to 71 in 1995-1996 from six states and two metropolitan areas of the US. All study participants completed a comprehensive dietary survey, included a 124-item food frequency questionnaire and a short survey on demographics, medications, and lifestyle (10). Six months later in 1996-1997, 334,908 participants of the original cohort further answered a second questionnaire (the risk factor survey) to provide more details on their health behaviors, including hours of daytime napping and nighttime sleeping. A follow-up questionnaire was mailed out to surviving participants of the original cohort in 2004-2006 to update exposures and to ascertain the occurrences of major chronic diseases, including diabetes. A total of 318,261 participants responded to the follow-up survey. The base population of the current analysis therefore included 220,934 participants who participated in both the risk factor survey in 1996-1997 and the follow up survey in 2004-2006. We excluded 481 participants with missing values on hours of day napping and night sleeping and 22,041 participants with missing values on diabetes diagnosis. As the sleeping habits were assessed in 1996-1997, to reduce the possibility that diabetes itself might have affected sleeping habits, we further excluded 23,870 participants who reported a diabetes diagnosis before 2000. The final analytic sample included 164,399 participants without diabetes and 10,143 diabetic cases diagnosed after 2000.

Exposure Assessment. At the risk factor survey in 1996-1997, participants were asked the number of hours spent on day napping and night sleeping during a typical 24-hour period over the past 12 months. Five choices were allowed for the day napping question: none, < 1 hour, 1-2 hours, 3-4 hours, or ≥ 5 hours. For night sleeping, the answer included four categories: < 5 hours, 5-6 hours, 7-8 hours, and ≥ 9 hours. The risk factor questionnaire also asked participants to recall how often they participated in light physical activities (such as bowling, slow walking or slow dancing etc.) or moderate to vigorous activities (such as tennis, biking, swimming etc.) in the past 10 years with six possible answers: none, rarely, weekly but <1 hour per week, 1-3 hours, 4-7 hours, and >7 hours per week. Finally, the risk factor questionnaire asked participants whether their blood relatives of immediate family (father, mother, brother, or sister) had been diagnosed with diabetes.

The amount of coffee or alcohol consumption and total calorie intake were derived from the dietary survey in 1995-1996. In addition, the survey collected basic demographics and lifestyle such as date of birth, gender, race, education level, marital status, and smoking habit. Further, participants were asked to self-evaluate their health status as excellent, very good, good, fair, or poor. Finally, participants also reported weight in pounds (0.45 kilograms) and height in inches (2.54 cm). Body mass index was calculated as weight in kilograms divided by height in squared meters (kg/m^2).

Ascertainment of Diabetes. As part of the 1995-1996 dietary survey, participants were asked whether they had ever been told by a doctor that they had diabetes. A similar question was also asked on the follow-up questionnaire in 2004-2006 with categorical choices of the year of first diagnosis: before 1985, 1985-1994, 1995-1999 and 2000 to present. These questions did not differentiate type 2 from type 1 diabetes. However, in adults, approximately 90% to 95% of all diagnosed diabetes are type 2 diabetes (11). As the current study included only older adults and incident cases diagnosed after 2000, we believe that most of the cases in the current analysis should have type 2 diabetes.

Statistical Analysis. Multivariate odd ratios (OR) and 95% confidence intervals (CI) were derived from logistic regression models. In the napping analysis, participants reporting no napping were used as the reference group and those with ≥ 1 hours of napping were grouped together as only 0.2% of the participants reported more than 2 hours of napping. For the sleeping analysis, we used the 7-8 hours of sleep as the referent as it was reported by most participants (60.1%) and is considered optimal sleep length for adults. Potential confounders included age in 5-year groups at the risk factor survey, gender, race (Whites vs. non-Whites), education level (less than 8 years, 8-11 years, 12 years or completed high school, post-high school or some college, college and post graduate), marital status (married or living as married, widowed, divorced, separated or never married), smoking status (never smokers; past smokers years since last smoking: ≥ 35, 30-34, 20-29, 10-19, 1-9; current smokers (cigarettes/day):1-10, 11-20, > 20), coffee consumption (cups/day: 0, < 1, 1, 2-3, > 3), alcohol consumption (drinks/day: 0, < 1, 1-1.9, 2-2.9, ≥ 3), general health status (excellent, very good, good, fair or poor), family history of diabetes (yes vs. no) and total energy intake (quintiles). As obesity and lack of physical activity may be in the pathway between napping and sleeping habits and diabetes, we first fitted the regression models without these variables and then added them individually or simultaneously. In the napping analysis, statistical significance for a linear trend was tested by assigning a value to each category of the napping variable (0 for no napping, 0.5 for < 1 hour and 1.5 for ≥ 1 hour) and including it as a continuous variable in the regression model. No such tests were conducted for sleeping analysis as its relation to diabetes was not linear.

We conducted two additional analyses to examine the robustness of our findings. First, we limited the analysis to participants who met the all of the following criteria: self-evaluated excellent or very good health, never smoked or stopped smoking > 10 years, non-obese (BMI< 30 kg/m^2), and >1 hour of moderate to vigorous physical activities per week. Presumably, this population represented a fairly healthy population at baseline and therefore association identified or confirmed in this group would be less likely attributed to poor health status or reverse causality. The second were subgroup analyses according to age (years: < 60, 60-64 and ≥ 65), gender, education level (below high school vs. high school or more), general health status ("excellent or very good", "good", and "fair or poor"), BMI (kg/m^2: 12.0-24.9, 25.0-29.9, or ≥ 30.0), smoking status (never vs. ever) and family history of diabetes (yes vs. no). When possible, detailed values of the stratifying variables were adjusted along with all other confounders to minimize the possibility of residual confounding.

Finally, we conducted a joint analysis by combining categories of daytime napping with those of night sleeping, using participants with no napping and 7-8 hours of night sleeping as the referent. We further examined the statistical interaction between these two variables by including a multiplicative interaction term in the regression model. All statistical analysis was performed by using the Statistical Analysis Systems (SAS) release 9.1 (SAS Institute, Cary, NC, USA) and the significance tests were two-tailed with $\alpha = 0.05$.

RESULTS

Table 1 shows population characteristics according to napping or sleeping duration. Compared with individuals who reported no napping, nappers were more likely to be older men, non-whites, current smokers, and to report a family history of diabetes and higher calorie intake, but they were less likely to drink coffee or alcohol and to report excellent or very good health status or 7-8 hours of night sleep. As expected, nappers had higher BMI and were less physically active. For night sleeping, participants with 7-8 hours of sleep seemed to have the demographic and lifestyle characteristics that were often associated with favorable health outcomes. Compared with this group, individuals with < 5 hours of sleeping were more likely to be women, non-whites, current smokers, and to report a higher BMI or ≥ 1 hour of day napping, a family history of diabetes, and higher calorie intake. They were however less likely to be high school graduates, married or living as married, past smokers, or to report regular drinking of coffee or alcohol, excellent or very good health status, or regular physical activities.

Duration of day napping in 1996-1997 was associated with higher risk of diabetes after 2000 in a dose-response manner (Table 2). Compared with participants who reported no napping, the multivariate OR was 1.23 (95%CI: 1.18-1.29) for those with < 1 hour of napping and 1.55 (95%CI: 1.45-1.66) for those with ≥ 1 hour of napping (*P* for trend < 0.0001). The association was essentially unchanged after further adjusting for physical activities. It was moderately attenuated after adjustment for BMI alone or simultaneously with physical activities. The OR between ≥ 1 hour vs. no napping decreased from 1.55 to 1.37 after further adjusting for BMI and to 1.36 with simultaneous adjustment of BMI and physical activities. Nevertheless, in both models, the association between napping and diabetes remained statistically significant.

The association between hours of night sleeping and diabetes appeared to be non-linear (Table 2). With participants of 7-8 hours of night sleep as the referent, the multivariate OR was 1.46 (95%CI: 1.31-1.63) for those reporting < 5 hours, 1.11 (1.06-1.16) for 5-6 hours, and 1.11 (0.99-1.24) for ≥ 9 hours of night sleep. Like the napping analysis, while the adjustment for physical activity variables made little difference, additional controlling for BMI alone or with physical activities moderately attenuated this association.

The associations between hours of day napping or night sleeping and diabetes were both confirmed among participants who were presumably healthy at the baseline risk factor survey (Table 2) and in various subgroup analyses (Online Appendix Table available at http://care.diabetesjournals.org).

There was a statistically significant interaction between hours of day napping and night sleeping on diabetes (*P* for interaction < 0.0001, Figure). Day napping was associated with higher diabetes risk in a dose-response manner within each subgroup of night sleeping duration (all *P* for trend<0.05). However, the relationship between night sleeping and diabetes depended on the hours of day napping. Among participants who reported no napping, only short sleepers had higher risk of diabetes. In contrast, among participants with ≥ 1 hour of napping, both short and long hours of night sleep was associated with higher diabetes risk. Overall, participants with no napping and 7-8 hours of night sleep had the lowest risk of diabetes, while individuals who napped ≥ 1 hour during the day but slept < 5 hours at night had the highest risk.

CONCLUSIONS

In this large prospective study, we confirmed the previously reported association between short sleeping and higher risk of incident diabetes. More importantly, we observed a higher diabetes risk among day nappers and evaluated the combined effects of day napping and night sleeping on the risk of diabetes. The napping-diabetes relationship could not be explained by short night sleep as it presented across all subgroups of sleeping duration, including 7-8 hours or even ≥ 9 hours of sleep per night. The associations between napping or sleeping duration and diabetes may in part be confounded by obesity or mediated by weight gain. However, reverse causality due to clinically evident diabetes was less likely an explanation as the analyses only included incident cases diagnosed at least 3 years after the exposure assessment; further both associations were barely changed in sensitivity analyses among apparently healthy participants at baseline.

Several prospective studies have evaluated sleep duration in relation to diabetes. In most of these studies, short sleep was associated with higher risk of diabetes as compared with 7-8 hours of sleep per night (2, 5, 6, 12). Several biological mechanisms have been proposed, including increased sympathetic nerve activity, increased orexin activity, higher levels of inflammatory markers, and alternations in hormones and neuroendocrine control of appetite, which in turn induce insulin resistance, obesity and diabetes (6). However, on the other hand, sleep duration is associated with various socio-economic factors and is affected by individual health status (13), which may in part contribute to the observed relationship (14). Compared with previous studies, the current study is substantially larger and we conducted thorough sensitivity analyses among healthy individuals and subgroup analyses. The results support an independent relationship between short sleep and risk of diabetes. Adjustment for BMI modestly attenuated, but did not eliminate, this relationship.

Most prospective studies also showed higher diabetes risk among longer sleepers; however, the interpretation of this finding appears to be more complicated (2, 5, 6, 12). This finding has been hypothesized as a result of unmeasured confounding (e.g. from poor sleep quality) or of reverse causality due to chronic inflammation with undiagnosed diabetes (2, 5). In our analysis with the first 3 years of follow-up excluded, long sleeper had marginally higher risk of diabetes and this risk elevation seems to be limited to participants who napped ≥ 1 hour per day.

Our joint analyses showed that both short and long sleep were associated with increased diabetes risk among long nappers (≥ 1 hour / day), whereas among participants who did not nap, only short sleep was associated with higher risk. This preliminary finding on a potential interaction between napping and sleeping durations on diabetes need to be confirmed in future studies.

The most important finding of this study is the monotonic relationship between hours of day napping and future risk of diabetes. To the best of our knowledge, this is the first prospective study that suggests daytime napping may be an independent risk factor for diabetes. Day napping has been linked to diabetes cross-sectionally which was interpreted by the authors as a consequence of diabetes (8, 9, 15). The current analysis was prospective with cases diagnosed at least 3 years after the exposure assessment; therefore our finding is less compatible with the possibility of reverse causation. Further, this association can not be explained by compensational napping for short night sleeping as it appeared within each subgroup of sleeping duration. Finally, this association persisted in all confounder subgroups and in the sensitivity analysis and therefore alleviated concerns about substantial influences from confounding or biases due to poor health status.

Habitual napping is prevalent among the older persons. In some cultures such as the Chinese, napping is often considered as a healthy lifestyle for older adults (16). Day napping has been investigated in the context of its potential impacts on night sleeping. Most previous studies showed that napping was not related to night sleeping duration or quality, but rather was affected by individuals' health statuses (7-9, 17). On the other hand, day napping itself may also have independent health consequences which have not yet been well investigated (18). Several studies have examined napping in relation to overall or cause-specific mortalities, but the results are inconsistent (16, 19-21). In our study, day napping was associated with higher risk of diabetes even among individuals who appeared to be healthy at baseline. This underlines the needs for further investigations into the potential health consequences of napping among older adults.

The major strengths of the current study include its large sample size, prospective design, detailed epidemiologic profiles, and thorough statistical analyses. Our study also has several limitations. First, in such a large cohort, we had to rely on self-reports to identify clinically diagnosed diabetes patients. Okura et al (22) found self-reported diabetes had a satisfactory agreement (kappa=0.76) with medical records, but it had a low sensitivity (66%). Further, without annual glucose tolerance screening, under-diagnosis of type 2 diabetes in our study population is also a concern. Therefore, some diabetes cases might have never been identified or reported and might thus have introduced bias if the identification of diabetes was differentially associated with napping or sleeping duration. In addition, undiagnosed preclinical diabetes cases at baseline or in early follow-up might alter their sleeping or napping habits as a result of the underlying disease. To minimize potential bias from this source, we excluded cases diagnosed in the first 3 years of follow-up and conducted sensitivity analysis among apparently healthy individuals.

Second, we did not collect data on the quality of night sleeping such as sleep fragmentations or on diseases such as obstructive sleep apnea or depression which themselves may be associated with both napping or sleep duration and risk of diabetes (6, 7, 23-25). In particular, napping is associated with obstructive sleep apnea which may in turn increase the risk of type 2 diabetes (23, 25). Although the napping-diabetes association persisted in apparently healthy population as evident in the sensitivity analysis, we could not exclude the possibility that napping may be a marker of other health conditions that increase the risk of diabetes.

Third, as in other large prospective cohorts (2, 5), information on hours of napping and sleeping was also self-reported and therefore misclassifications are likely. However, with the prospective design, exposure misclassification was likely non-differential with respect to the outcome and might thus have attenuated the true relationship. Fourth, the current analyses were limited to participants of the follow-up survey in 2004-2006 and therefore included only approximately 59% of eligible participants of the risk factor survey. Selection bias could have been introduced if napping or sleeping was associated with participation in the follow-up survey differentially by diabetes status. Finally, although we have controlled for and stratified by a variety of potential confounders, the study is observational in nature and we could not exclude the possibility of residual confounding from unmeasured or inadequately measured confounders. Adjustment for BMI modestly attenuated the associations. It is possible that a more precise measurement of adiposity may further attenuate the results. However, given the strong statistical significance, it seems unlikely that obesity entirely explains these associations.

In conclusion, this large prospective study among US older adults shows that long daytime napping ($\geq$ 1 hour) and short night sleeping (< 5 hours) are associated with higher risk of diabetes. These results may in part be explained by obesity or weight gain and we could not exclude the possibility that napping was a marker of other health conditions that increase the risk of diabetes. Further, the impact of sleeping duration on diabetes may depend on individuals' napping habits. Future prospective or mechanistic studies are needed to confirm these findings and to elucidate underlying mechanisms.

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Table 1—Population characteristic according to hours of day napping and night sleeping *

	Hours of daytime napping			Hours of night sleeping (n = 174 344)			
	None	< 1	≥ 1	< 5	5-6	7-8	≥ 9
N†	94 165	67 520	12 335	3 963	53 030	111 731	5 620
Age in years	61.6 ± 5.3	63.4 ± 5.2	63.5 ± 5.3	62.2 ± 5.4	62.1 ± 5.4	62.6 ± 5.3	63.3 ± 5.2
Men, %	51.3	63.2	64.4	47.8	55.1	58.0	55.9
Whites, %	95.3	94.7	90.3	87.6	92.0	96.1	96.6
High school or more, %	81.3	78.8	74.2	67.1	77.1	81.5	80.3
Married or couples, %	68.3	72.8	68.2	57.3	66.3	72.3	70.5
Past smokers, %	49.9	51.8	51.8	45.7	49.7	51.4	52.9
Current smokers, %	8.9	9.3	15.9	13.1	10.8	8.9	9.0
≥ 2 cups of coffee / day, %	57.6	56.8	55.4	51.7	56.8	57.7	53.0
≥ 1 drink of alcohol / day, %	26.3	23.6	21.4	18.2	21.4	26.3	34.2
Health status, %							
Excellent or very good	66.6	58.2	45.3	42.9	58.1	64.5	57.3
Good	28.3	33.9	39.3	36.9	33.8	29.8	31.5
Fair or poor	5.1	7.9	15.4	20.2	8.1	5.7	11.2
BMI, kg/m^2	26.1 ± 4.5	26.8 ± 4.7	27.6 ± 5.3	27.8 ± 5.7	26.8 ± 5.1	26.2 ± 4.5	26.5 ± 4.8
≥ 4 hours/week light activities, %	62.4	62.7	58.6	58.3	60.1	63.4	62.3
≥ 4 hours/week moderate to vigorous activities, %	53.2	52.7	45.1	48.2	51.0	53.4	48.2
Calorie intake, kcal	1770 ± 789	1872 ± 861	2022 ± 1025	1981 ± 1253	1833 ± 891	1814 ± 783	1943 ± 1005
Family history of diabetes, %	24.4	26.2	27.9	29.7	26.8	24.6	24.3
Napping, %							
0				44.5	50.3	56.3	53.9
< 1 hour				38.6	40.8	38.2	32.7
≥ 1 hour				16.9	8.8	5.6	13.4
Sleeping, %							
< 5 hours	1.9	2.3	5.4				
5-6 hours	28.3	32.0	38.0				
7-8 hours	66.6	63.0	50.5				
≥ 9 hours	3.2	2.7	6.1				

* Hours of day napping and night sleeping, age, physical activity and family history of diabetes were from risk factor survey in 1996-1997; all other covariates were collected at the dietary survey in 1995-1996. Means ± Standard deviations are presented for continuous variables and proportions are presented for categorical variables.

† The final number of participants for individual variables varies due to missing values.

Table 2—Odds ratios (OR) and 95% confidence intervals (CI) of diabetes diagnosed after 2000 according to hours of day napping or night sleeping*

	Hours of day napping †			Hours of night sleeping			
	0	< 1	≥ 1	< 5	5-6	7-8	≥ 9
No. of cases	4 465	4 463	1 172	390	3 427	5 965	348
OR (95%CI)							
Basic model	1.0	1.23 (1.18-1.29)	1.55 (1.45-1.66)	1.46 (1.31-1.63)	1.11 (1.06-1.16)	1.0	1.11 (0.99-1.24)
+ physical activities	1.0	1.23 (1.18-1.29)	1.53 (1.42-1.64)	1.47 (1.31-1.64)	1.11 (1.06-1.16)	1.0	1.09 (0.97-1.22)
+ body mass index	1.0	1.16 (1.11-1.21)	1.37 (1.28-1.47)	1.33 (1.19-1.49)	1.06 (1.01-1.11)	1.0	1.10 (0.98-1.23)
+ physical activities and body mass index	1.0	1.16 (1.11-1.21)	1.36 (1.27-1.46)	1.34 (1.20-1.50)	1.06 (1.01-1.11)	1.0	1.09 (0.97-1.22)
Sensitivity analysis‡	991	842	126	37	601	1262	64
OR (95%CI)	1.0	1.16 (1.06-1.28)	1.34 (1.10-1.63)	1.37 (0.97-1.93)	1.15 (1.04-1.27)	1.0	1.18 (0.91-1.53)

* Basic model included the following covariates: age, gender, race, education, marital status, smoking, coffee and alcohol consumption, calorie intake, family history of diabetes, and general health status.

† All *P* for trend was < 0.0001 in the day napping and diabetes analysis with the exception of sensitivity analysis (*P* for trend = 0.0002). No trend test was conducted for hours of night sleeping as the relationship was not linear.

‡ The sensitivity analysis was based on the full model and was limited to participants who met all of the following criteria: excellent or very good health status, never smokers or stopped > 10 years, non-obese (BMI<30 kg/m^2), > 1 hour of moderate to vigorous physical activities per week in the past 10 years.

Figure -- Joint analysis on day napping and night sleeping in relation to the risk of diabetes after 2000. Multivariate odds ratios (ORs) for diabetes were adjusted for age, gender, race, education, marital status, smoking status, coffee and alcohol consumptions, calorie intake, family history of diabetes, general health status, light physical activity level, moderate to vigorous physical activity level, and body mass index. The subgroup *P* for trend in the napping analyses was 0.02 for participants with < 5 hours of night sleep, 0.002 for participants with 5-6 hours of sleep, < 0.001 for participants with 7-8 hours of sleep, and 0.006 for participants with ≥ 9 hours of sleep.

Figure