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ORIGINAL ARTICLE

Association between Self-Reported Sleep Duration and Diabetes Mellitus: Data from a 7-Year Aggregated Analysis

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Background: This study investigates the association between sleep duration and diabetes mellitus (DM) in a large representative population-based survey in South Korea.

Methods: The fourth (2007–2009), fifth (2010–2012), and sixth (2013) Korea National Health and Nutrition Examination Survey data sets were used. A total of 37,989 individuals were selected for the study. Chi-square tests and multivariate logistic regression analyses were used to analyze whether general characteristics, health status, and health risk behaviors were associated with DM.

Results: After adjusting for confounders, the odds of DM in short sleepers (≤5 hr/day) and long sleepers (≥9 hr/day) were 1.033-times higher (95% confidence interval [CI], 0.913–1.169) and 1.334-times higher (95% CI, 1.140–1.562), respectively, compared with individuals who slept 7 hr/day. Subgroup analysis according to gender showed a U-shaped association for both genders, although it appeared stronger in men.

Conclusion: This study identified a U-shaped association between sleep duration and the risk for DM. Additional studies should help clarify the important information in this study.

Keywords: Diabetes mellitus; Sleep

INTRODUCTION

Sleep is a biobehavioral phenomenon that is regulated by circadian, homeostatic, and neurohormonal processes [1]. Recently, sleep duration has been recognized as a behavioral factor adversely affecting public health [1-3].

Chronic sleep disturbances and poor sleep quality are very common [4] and have become increasingly prevalent in the modern society, affecting millions of people. The average sleep time has decreased to 7 hours per night, and more than one out of three adults sleep less than 7 hours per night [5]. The sleep duration for Koreans was 469 minutes, which was the shortest duration among the 18 Organization for Economic Cooperation and Development countries [6].

Too little and too much sleep are adversely associated with health outcomes such as mortality [2], coronary heart disease [1,7], stroke [1], respiratory disorders [8], and health-related quality of life [9]. Sleep disturbances including poor sleep quality and sleep loss not only increase morbidity and mortality [5,10], but also increase the risk of developing diabetes mellitus (DM) [7,11-14].

Recent meta-analyses have identified a U-shaped association between sleep duration and the risk for DM. Both short and long sleep durations have been linked with an increased risk for DM [15,16]; however, other studies have not found a uniform relationship [17,18]. Many experimental studies have shown that both short and long sleep duration are associated with decreased glucose tolerance and reduced insulin sensitivity [19,20], and ultimately DM. These data have provided scientific evidence for epidemiological surveys that have shown that the risk for DM is increased by chronic, short sleep duration and poor sleep quality. However, most of these studies were undertaken in Western countries [21], and little is known about the Korean population.

According to the International Diabetes Federation, the estimated number of diabetic patients worldwide was 382 million in

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2013 and will rise to 592 million by 2035 [22]. Given the significant economic burden associated with diabetes, an investigation into lifestyle factors that can be modified to lower the risk for diabetes is crucial. There is a definite need to investigate the association between sleep duration and DM in both genders [23]. Therefore, the objective of this cross-sectional study was to identify significant differences in the association between sleep duration and DM in men and women within a large representative population-based survey in Korea.

METHODS

1. Study sample

The fourth (2007–2009), fifth (2010–2012), and sixth (2013) Korea National Health and Nutrition Examination Survey (KNHANES) data sets were used to investigate the relationship between sleep duration and DM. KNHANES began assessing the health and nutritional status of Korean civilians in 1998. Conducted by the Korea Ministry of Health and Welfare, the survey is made up of three parts: a health interview survey, a health examination survey, and a nutrition survey.

The survey was approved by the Institutional Review Board of the Korea Centers for Disease Control and Prevention (2007-02 ON-04-P, 2010-02CON-21-C, 2013-07CON-03-4C). This study adhered to the tenets of the Declaration of Helsinki. The survey target population is that people who live in nursing homes, the military, foreign and imprisoned people were excluded and included South Korean individuals older than 1 year of age. The KNHANES data was released periodically between 1998 and 2005, and annually since 2007. The fourth, fifth, and sixth KNHANES used stratified, multistage probability sampling units that were based on the geographic area, sex, and age. This information was obtained from the household registries of the 2005 National Census Registry.

The target populations consisted of 24,871 individuals (2007–2009), 25,534 individuals (2010–2012), and 8,018 individuals (2013). The average response rates for the survey were 78.4% (2007–2009), 80.8% (2010–2012), and 79.3% (2013). Data from 14,305 individuals between 1 and 18 years of age were excluded, and data from 44,118 individuals older than 19 years of age were included. Additional exclusions included 5,841 individuals with incomplete information about age, occupation, income, or marriage, and 288 individuals with incomplete information about smoking, drinking, exercise, sleep duration, DM, hypertension, and dyslipidemia. A total of 37,989 individuals were selected for this analysis.

2. Variables

1) Independent variables

Sleep duration referred to the self-reported data from the question, "How many hours do you usually sleep?" Responses were assigned to one of five subcategories: ≤5 hours, 6 hours, 7 hours, 8 hours, and ≥9 hours. The International Classification of Sleep Disorders 2nd edition definitions of sleep (i.e., ≤5 hours is 'short sleep' and ≥9 hours is 'long sleep') were used [24].

2) Dependent variables

Participants were labeled diabetic if they answered "yes" to the question, "Are you currently suffering from diabetes?" Response to the questions was categorized as either 'yes' or 'no' based on the previous study [25].

3. Socio-demographic factors

Age, gender, household income, marital status, occupation, and residency region were included as socio-demographic factors in the analysis. All of the covariate variables were categorical. Household income was calculated by dividing the household monthly income by the square root of the household size. Participants were ranked from lowest to highest household incomes and grouped into four income quartiles. The predefined categories used in the raw KNHANES data were maintained for categorizing household income. The residency regions were categorized as urban (administrative divisions of a city: Seoul, Daejeon, Daegu, Busan, Incheon, Kwangju, or Ulsan), and rural (not classified as administrative of a city). Occupational status was divided into three categories: white collar (administrative, engineering, scientific, teaching and related occupations, sales and related occupations, and service occupations), blue collar (farming, forestry, fishing and hunting occupations, craft and repair, operators, fabricators, and laborers), and unemployed (housewives and students).

4. Health behavior factors

Questions about alcohol use, smoking status, and the number of days of moderate exercise per week were assessed by the health interview survey and were included as covariates in the analyses. In response to the question "Are you current smoker?", smoking status was subcategorized as either current smoker, former smoker and never smoked. In response to the question "how many time do you usually drink alcohol?", frequency of alcohol use was subcategorized as either never drink, 1 times or less per month, 2–4 times per week and 4 times or more per week. In response to the question "How many time do you usually take moderate exercise per week?", number of days of moderate exercise per week was subcategorized as either never, 1–3, 4–6, and every day.

5. Health status factors

Body mass index (BMI), hypertension, and dyslipidemia were included in the model. BMI was categorized into four groups: thin (<18.5 kg/m^2), moderate (18.5 kg/m^2 to 23.9 kg/m^2), overweight (24.0 kg/m^2 to 26.9 kg/m^2), and obese (>27.0 kg/m^2) [26,27]. Hypertension was identified when participants answered "yes" to the question,

Table 1. Demographic characteristics of the study population

Characteristic	Total	Diabetes mellitus		p-value
		No	Yes	
Sleep duration				<0.0001
≤5	5,948 (15.7)	5,302 (89.1)	646 (10.9)	
6	9,905 (26.1)	9,273 (93.6)	632 (6.4)	
7	10,745 (28.3)	10,073 (93.8)	672 (6.3)	
8	8,401 (22.1)	7,807 (92.9)	594 (7.1)	
≥9	2,975 (7.8)	2,686 (90.3)	289 (9.7)	
Age (yr)				<0.0001
≤29	4,751 (12.5)	4,737 (99.7)	14 (0.3)	
30–39	7,286 (19.2)	7,236 (99.3)	50 (0.7)	
40–49	7,262 (19.1)	7,029 (96.8)	233 (3.2)	
50–59	6,937 (18.3)	6,376 (91.9)	561 (8.1)	
60–69	6,193 (16.3)	5,174 (83.6)	1,019 (16.5)	
70–79	4,549 (12.0)	3,727 (81.9)	822 (18.1)	
≥80	996 (2.6)	862 (86.6)	134 (13.5)	
Gender				<0.0001
Male	16,252 (42.8)	14,889 (91.6)	1,363 (8.4)	
Female	21,722 (57.2)	20,252 (93.2)	1,470 (6.8)	
Household income level				<0.0001
Low	7,632 (20.1)	6,578 (86.2)	1,054 (13.8)	
Lower middle	9,685 (25.5)	8,921 (92.1)	764 (7.9)	
Upper middle	10,213 (26.9)	9,678 (94.8)	535 (5.2)	
High	10,444 (27.5)	9,964 (95.4)	480 (4.6)	
Marital status				<0.0001
Married	27,595 (72.7)	25,511 (92.5)	2,084 (7.6)	
Single	5,313 (14.0)	5,264 (99.1)	49 (0.9)	
Separated, divorced	5,066 (13.3)	4,366 (86.2)	700 (13.8)	
Occupation				<0.0001
White-collar	12,631 (33.3)	12,177 (96.4)	454 (3.6)	
Blue-collar	10,338 (27.2)	9,542 (92.3)	796 (7.7)	
Unemployed	15,005 (39.5)	13,422 (89.5)	1,583 (10.6)	
Resedential region				0.001
Urban	17,028 (44.8)	15,845 (93.1)	1,183 (7.0)	
Rural	20,946 (55.2)	19,296 (92.1)	1,650 (7.9)	
Smoking status				<0.0001
Current smoker	11,100 (29.2)	10,292 (92.7)	808 (7.3)	
Former smoker	4,551 (12.0)	4,049 (89.0)	502 (11.0)	
Never smoked	22,323 (58.8)	20,800 (93.2)	1,523 (6.8)	

(Continued to the next)

Table 1. Continued

Characteristic	Total	Diabetes mellitus		p-value
		No	Yes	
Frequency of alcohol use				<0.0001
Never drink	10,950 (28.8)	9,632 (88.0)	1,318 (12.0)	
≤1 Times/mo	10,787 (28.4)	10,194 (94.5)	593 (5.5)	
2–4 Times/wk	13,505 (35.6)	12,816 (94.9)	689 (5.1)	
>4 Times/wk	2,732 (7.2)	2,499 (91.5)	233 (8.5)	
No. of days of moderate exercise per week				<0.0001
Never	23,186 (61.1)	21,232 (91.6)	1,954 (8.4)	
1–3	9,145 (24.1)	8,662 (94.7)	483 (5.3)	
4–6	3,315 (8.7)	3,113 (93.9)	202 (6.1)	
Everyday	2,328 (6.1)	2,134 (91.7)	194 (8.3)	
Body mass index (kg/m^2)				<0.0001
Thin (<18.5)	1,906 (5.0)	1,841 (96.6)	65 (3.4)	
Moderate (18.5–23.9)	19,688 (51.9)	18,558 (94.3)	1,130 (5.7)	
Overweight (24.0–26.9)	10,766 (28.4)	9,804 (91.1)	962 (8.9)	
Obese (≥27.0)	5,614 (14.8)	4,938 (88.0)	676 (12.0)	
Frequency of eating out				<0.0001
Every day	6,281 (16.5)	6,026 (95.9)	255 (4.1)	
1–6/wk	20,003 (52.7)	18,553 (92.8)	1,450 (7.3)	
1–3/mo	4,790 (12.6)	4,286 (89.5)	504 (10.5)	
Almost nothing	6,900 (18.2)	6,276 (91.0)	624 (9.0)	
Depression				<0.0001
Yes	5,324 (14.0)	4,812 (90.4)	512 (9.6)	
No	32,650 (86.0)	30,329 (92.9)	2,321 (7.1)	
Hypertension				<0.0001
No	30,289 (79.8)	29,106 (96.1)	1,183 (3.9)	
Yes	7,685 (20.2)	6,035 (78.5)	1,650 (21.5)	
Dyslipidemia				<0.0001
No	35,421 (93.3)	33,272 (93.9)	2,149 (6.1)	
Yes	2,553 (6.7)	1,869 (73.2)	684 (26.8)	
Year				<0.0001
2007	1,401 (3.7)	1,336 (95.4)	65 (4.6)	
2008	6,511 (17.2)	6,079 (93.4)	432 (6.6)	
2009	7,335 (19.3)	6,810 (92.8)	525 (7.2)	
2010	6,058 (16.0)	5,614 (92.7)	444 (7.3)	
2011	5,928 (15.6)	5,439 (91.8)	489 (8.3)	
2012	5,469 (14.4)	5,026 (91.9)	443 (8.1)	
2013	5,272 (13.9)	4,837 (91.8)	435 (8.3)	
Total	37,974 (100.0)	35,141 (92.5)	2,833 (7.5)	

Values are presented as number (%).

"Are you currently suffering from hypertension?" Hypertension was then categorized as either 'yes' or 'no.' Dyslipidemia was identified when participants answered "yes" to the question, "Are you currently suffering from dyslipidemia?" Dyslipidemia was then categorized as either 'yes' or 'no.' In response to the question "Have you felt sadness or despair which hindered everyday life consistently for 2 weeks or more during the last year?", depression was subcategorized as either 'yes' or 'no.' In response to the question "How many time do you usually eat out?", frequency of eating out was subcategorized as: every day, 1–6 per week, 1–3 per month and almost nothing.

6. Statistical analysis

Chi-square tests and multivariate logistic regression analyses were used to analyze whether general characteristics, health status, and health risk behaviors were associated with DM. Statistical analysis software SAS ver. 9.2 (SAS Institute Inc., Cary, NC, USA)

Table 2. Results of logistic regression between independent variables and diabetes mellitus

Variable	Diabetes mellitus
Sleep duration	
≤5	1.019 (0.900–1.153)
6	0.930 (0.825–1.048)
7	1.000
8	1.134 (1.003–1.282)
≥9	1.328 (1.134–1.556)
Age (yr)	
≤29	1.000
30–39	2.303 (1.220–4.346)
40–49	9.797 (5.351–17.935)
50–59	19.293 (10.556–35.262)
60–69	30.699 (16.756–56.243)
70–79	29.237 (15.872–53.854)
≥80	18.869 (9.975–35.692)
Gender	
Male	1.622 (1.412–1.863)
Female	1.000
Household income level	
Low	1.258 (1.101–1.439)
Lower middle	1.208 (1.060–1.376)
Upper middle	1.094 (0.955–1.252)
High	1.000
Marital status	
Married	1.000
Single	1.001 (0.706–1.419)
Separated, divorced	1.130 (1.012–1.262)
Occupation	
White-collar	1.000
Blue-collar	0.928 (0.811–1.061)
Unemployed	1.270 (1.110–1.452)
Resedential region	
Urban	1.000
Rural	1.047 (0.962–1.140)
Smoking status	
Current smoker	1.247 (1.087–1.431)
Former smoker	1.112 (0.951–1.300)
Never smoked	1.000

(Continued to the next)

Table 2. Continued

Variable	Diabetes mellitus
Frequency of alcohol use	
Never drink	1.595 (1.351–1.883)
≤1 Times/mo	1.185 (0.995–1.412)
2–4 Times/wk	1.128 (0.956–1.332)
>4 Times/wk	1.000
No. of days of moderate exercise per week	
Never	1.000
1–3	0.870 (0.778–0.974)
4–6	0.993 (0.845–1.167)
Everyday	0.936 (0.793–1.106)
Body mass index (kg/m^2)	
Thin (<18.5)	0.805 (0.616–1.053)
Moderate (18.5–23.9)	1.000
Overweight (24.0–26.9)	1.181 (1.073–1.301)
Obese (≥27.0)	1.671 (1.495–1.868)
Frequency of eating out	
Every day	0.992 (0.837–1.177)
1–6/wk	0.902 (0.805–1.012)
1–3/mo	0.876 (0.766–1.002)
Almost nothing	1.000
Depression	
Yes	1.129 (1.010–1.261)
No	1.000
Hypertension	
No	1.000
Yes	2.436 (2.224–2.668)
Dyslipidemia	
No	1.000
Yes	2.487 (2.230–2.773)
Year	
2007	1.000
2008	1.013 (0.763–1.345)
2009	1.038 (0.784–1.375)
2010	1.031 (0.772–1.378)
2011	1.078 (0.808–1.438)
2012	1.010 (0.755–1.351)
2013	1.113 (0.832–1.488)

Values are presented as odds ratio (95% confidence interval).

was used for the data analysis.

RESULTS

1. Prevalence of short sleep and long sleep

In this study, there were 16,252 males (42.8%) and 21,722 females (57.2%). The prevalence of short sleep (≤5 hours) was 15.7%, and the prevalence of long sleep (≥9 hours) was 7.8% (Table 1). DM was present in 8.4% of males and 6.8% of females. The prevalence of DM in people with short sleep duration (≤5 hours) was 10.9%, and the prevalence of DM in people with long sleep duration (≥9 hours) was 9.7% (Table 1).

2. Association between sleep duration and diabetes mellitus

Table 2 adjusted for age, gender, household income, marital sta-

Table 3. Results of logistic regression between independent variables and diabetes mellitus by gender

Variable	Diabetes mellitus	
	Male	Female
Sleep duration		
≤5	1.046 (0.865–1.266)	0.990 (0.839–1.169)
6	0.924 (0.780–1.094)	0.948 (0.799–1.124)
7	1.000	1.000
8	1.184 (1.000–1.401)	1.096 (0.915–1.314)
≥9	1.346 (1.074–1.686)	1.316 (1.053–1.644)
Age (yr)		
≤29	1.000	1.000
30–39	2.615 (1.081–6.328)	2.037 (0.810–5.120)
40–49	11.203 (4.801–26.144)	8.600 (3.609–20.490)
50–59	25.585 (10.965–59.701)	13.806 (5.828–32.704)
60–69	36.062 (15.379–84.562)	24.752 (10.432–58.728)
70–79	27.406 (11.558–64.986)	28.547 (11.971–68.072)
≥80	13.896 (5.493–35.151)	20.626 (8.437–50.424)
Household income level		
Low	1.128 (0.930–1.369)	1.497 (1.232–1.819)
Lower middle	0.955 (0.796–1.146)	1.608 (1.324–1.953)
Upper middle	1.032 (0.863–1.234)	1.204 (0.975–1.486)
High	1.000	1.000
Marital status		
Married	1.000	1.000
Single	0.962 (0.618–1.499)	0.924 (0.513–1.665)
Separated, divorced	1.125 (0.899–1.408)	1.014 (0.886–1.159)
Occupation		
White-collar	1.000	1.000
Blue-collar	0.889 (0.749–1.056)	1.049 (0.839–1.312)
Unemployed	1.322 (1.089–1.604)	1.380 (1.124–1.694)
Resedential region		
Urban	1.000	1.000
Rural	1.133 (1.002–1.281)	0.962 (0.854–1.083)
Smoking status		
Current smoker	1.155 (0.967–1.380)	1.256 (0.999–1.579)
Former smoker	0.980 (0.808–1.189)	1.430 (1.020–2.005)
Never smoked	1.000	1.000
Frequency of alcohol use		
Never drink	1.424 (1.176–1.724)	2.772 (1.589–4.835)
≤1 Times/mo	1.217 (0.990–1.497)	1.979 (1.127–3.476)
2–4 Times/wk	1.064 (0.891–1.270)	1.885 (1.060–3.353)
>4 Times/wk	1.000	1.000
No. of days of moderate exercise per week		
Never	1.000	1.000
1–3	0.879 (0.754–1.025)	0.843 (0.713–0.997)
4–6	0.963 (0.770–1.203)	1.044 (0.825–1.322)
Everyday	0.998 (0.784–1.271)	0.885 (0.703–1.115)
Body mass index (kg/m^2)		
Thin (<18.5)	0.611 (0.410–0.910)	1.067 (0.740–1.538)
Moderate (18.5–23.9)	1.000	1.000
Overweight (24.0–26.9)	1.093 (0.954–1.252)	1.239 (1.079–1.423)
Obese (≥27.0)	1.369 (1.150–1.630)	1.903 (1.641–2.207)
Frequency of eating out		
Every day	0.867 (0.702–1.070)	1.324 (0.975–1.798)
1–6/wk	0.904 (0.767–1.065)	0.928 (0.788–1.092)
1–3/mo	1.004 (0.818–1.232)	0.819 (0.683–0.982)
Almost nothing	1.000	1.000
Depression		
Yes	1.219 (1.015–1.465)	1.084 (0.942–1.248)
No	1.000	1.000
Hypertension		
No	1.000	1.000
Yes	2.344 (2.058–2.670)	2.475 (2.174–2.818)
Dyslipidemia		
No	1.000	1.000
Yes	2.620 (2.208–3.107)	2.449 (2.121–2.827)
Year		
2007	1.000	1.000
2008	0.750 (0.533–1.056)	1.870 (1.072–3.262)
2009	0.767 (0.548–1.072)	1.944 (1.116–3.386)
2010	0.888 (0.627–1.258)	1.709 (0.971–3.008)
2011	0.892 (0.630–1.264)	1.839 (1.048–3.228)
2012	0.839 (0.590–1.194)	1.737 (0.988–3.053)
2013	0.881 (0.619–1.255)	1.975 (1.124–3.469)

(Continued to the next)

Table 3. Continued

Values are presented as odds ratio (95% confidence interval).

tus, occupation, residential region, smoking status, frequency of alcohol use, number of days of moderate exercise per week, BMI, hypertension, dyslipidemia, and year of the study. After adjusting for all confounders, the risk for DM in short sleepers (≤5 hr/day) had not difference found relative to a sleep duration of 7 hours (odds ratio [OR], 1.019; 95% confidence interval [CI], 0.900 to 1.153). The risk for DM in long sleepers (≥9 hr/day) was 1.328-times higher (95% CI, 1.134 to 1.556) than participants with a sleep duration of 7 hr/day (Table 2).

Table 3 reflects subgroup analyses according to gender after adjusting for age, household income, marital status, occupation, residential region, smoking status, frequency of alcohol use, number of days of moderate exercise per week, BMI, hypertension, dyslipidemia, and year of the study. Men with long sleep were 34.6% more likely to have DM (OR, 1.346; 95% CI, 1.074 to 1.686) than men with a sleep duration of 7 hours. Women with long sleep were 31.6% more likely to have DM (OR, 1.316; 95% CI, 1.053 to 1.644) than women with a sleep duration of 7 hours. Although both genders with short sleep were more likely to have DM than participants with a sleep duration of 7 hours, these findings were not statistically significant.

DISCUSSION

In this study, the primary purpose was to investigate significant differences in the association between sleep duration and DM in men and women who participated in a large representative population-based survey using 7-year aggregated data in Korea. The main results show increase in DM risk of those with long sleep was identified, with the lowest incidence of diabetes occurring among participants who slept 7 hours per night. Subgroup analysis according to gender indicated that the relationship between longer sleep duration is of greater magnitude in men. Many prospective studies have reported that both short (≤6 hours) and long (≥8 hours) sleep durations [14,28] and poor sleep quality [14] are associated with a higher risk of developing DM. Data from China suggests short sleep duration (<6 hours per night) is an independent risk factor for DM, even after adjusting for a variety of possible confounders [29]. Our results are consistent with a large number of international reports indicating a U-shape association between sleep duration and the prevalence of DM [1,5-10].

Pradhan et al. [30] explains the role of activation of inflammatory pathways for the association between sleep duration and diabetes. Short sleep duration has also been linked to glucose dysregulation through increases in hunger and appetite via downregulation of satiety and upregulation of appetite-stimulating hormones [31]. Pathways to diabetes occur via increased sympathetic activity, adiposity, elevated levels of pro-inflammatory cytokines, elevated cortisol levels, decreased carbohydrate tolerance, and insulin resistance [32]. Another potential mechanism involves melatonin, which is reduced in short sleepers. Recently published work has shown lower levels of melatonin secretion may be associated with a higher risk for DM [33]. In addition, although we did not adjust for stress level because of multicollinearity with depression, Saxena et al. [34] shows that stress leads to increased basal sympathetic activity, resulting from disturbed cortical hypothalamic axis, leading to central insulin resistance and DM as a potential mechanism.

In our study, long sleep duration was also associated with an increased risk of DM, even after controlling for all variables. One explanation for this finding is an as-of-yet unrecognized marker that could lead to both DM and an increased need for sleep (e.g., obstructive sleep apnea [OSA]). OSA causes decreased glucose tolerance and is known to fragment sleep [35]. OSA might cause an increased need for sleep, and severe apnea is associated with an increased risk for DM [36]. A longer sleep duration could directly lead to an increased risk for DM; however, plausible physiologic mechanisms for such a cause-and-effect relationship remain unknown. Although the mechanisms underlying the association between sleep duration and DM are not readily explainable, our study is consistent with recently published works.

Our study has a number of strengths and limitations. The participants in the survey are representative of the overall South Korean adult population. Because the sample size was very large, the results can be generalized to the national level. However, sample bias is always a concern. Because this was a cross-sectional study, a causal relationship could not be established between sleep duration and DM. Second, although many sleep problems exist, such as difficulty initiating or maintaining sleep (insomnia), napping, OSA and excessive daytime sleepiness, only self-reported sleep duration was utilized in this study because of lack of information. A third problem is that the respondents' reports are purely subjective. In particular, the main independent variables and dependent variable in this study were subjective health status. Future study will need to measure objective indicators. A fourth problem is that although many previous study shows type 2 DM based on

KNHANES data, the question does not specify type 1 or 2 DM because of lack of information [37-39]. However, given that most of the DM is type 2 DM, results does not change. Finally, the amount of sleep was self-reported, and participants were able to select from categories that ranged from ≤5 hours per day to ≥9 hours per day. Because this study uses a cross-sectional design, the results possibly reflect reverse causality and bidirectional relationships when assessing the association between sleep duration and DM. Therefore, longitudinal studies with validated measures of DM and sleep duration are required to replicate our findings and to clarify the causality and mechanisms that relate to sleep duration and DM and are also needed to understand the precise association between sleep duration and DM using more objective measures of sleep duration. Controlling for socioeconomic, health risk, and behavior variables, as in the current study, may partially attenuate these associations, but further research should include measures of sleep quality and obstructive sleep disorders through objective measures to understand the precise association between sleep duration and DM.

In conclusion, in this cross-sectional analysis of 7-year aggregated data, we found that the association between sleep duration and the risk for DM was U-shaped. Both short and long sleep duration were associated with a significantly elevated risk for DM, and this association appears stronger in men. Despite some of the inherent weaknesses of this study, it still provides important information about the association between sleep duration and DM among Korean adults older than 19 years of age. Future work should focus on the weaknesses (causality and self-reported data) within this study.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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AUTHORS' CONTRIBUTIONS

JH Kim and EC Park carried out the acquisition of data, performed the experiments and participated in drafted the manuscript. JH Kim and EC Park participated in the design of the study and performed the statistical analysis. JH Kim and EC Park conceived of the study, and participated in its design and coordination and helped to draft the manuscript. All authors read and approved the final manuscript.

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