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# Age-Dependent Association Between Sleep Duration and Hypertension in the Adult Korean Population

Jihye Kim[1] and Inho Jo[2]

**BACKGROUND**
In Western countries, sleep deprivation has been reported to elevate blood pressure. Here, we examined whether this association is true also for an Asian population.

**METHODS**
The study sample comprised 5,393 Korean adults aged 19–99 years who had participated in the 2005 Korean National Health and Nutrition Examination Survey. Hypertension was defined as a systolic blood pressure (SBP) ≥140 mm Hg or a diastolic blood pressure (DBP) ≥90 mm Hg, or regular use of antihypertensive medication.

**RESULTS**
Among the participants, 1,345 subjects (24.9%) displayed hypertension. The median sleep duration was 7 h/day. In the young and middle-aged adults aged <65 years, the unadjusted odds ratio (OR) for hypertension was 1.5-fold greater in those with a sleep duration of ≤5 h (OR 1.52; 95% confidence interval (CI) 1.19, 1.94) as compared to those who slept 7 h. This trend did not significantly change after adjustments for putative risk factors for hypertension such as gender, obesity, smoking status, alcohol consumption, physical activity, depressive symptom, diabetes mellitus, and stroke (OR 1.31; 95% CI 1.01, 1.71). However, in the older adults aged ≥65 years, no association was found between sleep duration and the risk of hypertension. Long sleep duration (≥8 h) was not associated with hypertension in either the younger or older adults in this study.

**CONCLUSION**
Short sleep duration (≤5 h) is independently associated with hypertension in young and middle-aged Korean adults.

***Keywords:*** *age-dependent; blood pressure; cross-sectional; hypertension; Korean adults; sleep duration*

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Epidemiological studies indicate that both short and long durations of sleep are associated with increased risks of adverse health outcomes, such as cardiovascular disease, type 2 diabetes mellitus, obesity, and total mortality.[1–9]

Sleep deprivation has been reported to increase blood pressure and sympathetic nervous system activity in both normotensive and hypertensive subjects.[10–14] Many published studies have found short sleep duration to be strongly associated with hypertension,[15–19] although one study showed that longer sleep may also be related to the risk of hypertension.[18] Previous studies have emphasized that the impact of sleep on chronic diseases, including hypertension, may be different depending on the age.[20,21] For example, Van den Berg *et al.* reported that sleep duration was not associated with hypertension in the elderly.[22] Nonetheless, the association between sleep duration and hypertension in the elderly remains to be defined. All previous studies were conducted among Western populations although some studies were adjusted for ethnicity. Because cultural differences may play an important role in sleep habits or the association between sleep duration and health outcomes,[19] ethnic groups other than Western populations should be assessed before this relationship can be generalized.

In this study, we examined the association between sleep duration and hypertension after adjusting for several putative risk factors using the 2005 Korean National Health and Nutrition Examination Survey. A few studies reported the relationship between sleep duration and blood pressure using Asian population. Eguchi *et al.* examined the relationship between sleep duration and blood pressure in Japanese hypertensive patients, but not in the Japanese general population.[10] An earlier study that explored the relationship between sleep duration and components of the metabolic syndrome reported an association between short and long sleep duration and blood pressure, but this study did not control for depressive symptoms, diabetes, or stroke.[23]

## METHODS

*Study population.* The study was based on the third Korean National Health and Nutrition Examination Survey (KNHANES III), a cross-sectional and nationally representative survey carried out by the Korea Centers for Disease Control and Prevention from April to June 2005.[24] The survey used a stratified multistage probability sampling design. KNHANES III consisted of health interview, health behavior,

[1]Department of Food and Nutrition, Daegu University, Gyeongbuk, South Korea; [2]Department of Molecular Medicine, Ewha Womans University Medical School, Seoul, South Korea. Correspondence: Jihye Kim (kjhye76@daegu.ac.kr) or Inho Jo (inhojo@ewha.ac.kr)

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and nutrition surveys, as well as a health examination study. Of the 7,403 Koreans (aged 1–99 years) who participated in the health examination study and health behavior survey, 5,400 adults (≥19 years) were selected for this study. Seven were further excluded because of insufficient information on blood pressure or sleep duration. A total of 5,393 Korean adults were ultimately eligible for the analysis. Informed written consent for participation was obtained from each individual. The study was approved by the Korea Centers for Disease Control and Prevention institutional review board.

*Definition of hypertension.* Blood pressure was measured with a Baumanometer mercury sphygmomanometer (WA Baum, Copiague, NY) after the subjects had rested for 5 min in sitting position. Systolic (SBP) and diastolic blood pressures (DBP) were measured at phase I and V Korotkoff sound,[25] respectively. Three readings of SBP and DBP were recorded, and the average of the last two readings was used for data analysis. Hypertension was defined as SBP ≥140 or DBP ≥90 mm Hg, or regular use of antihypertensive medication.

*Sleep duration.* Sleep duration was defined as the response to the question: "How many hours of sleep do you usually get in a day on average?" The responses were categorized into five groups: ≤5, 6, 7, 8, and ≥9 h.

*Covariates.* Age was classified into two groups: <65 years for young and middle-aged adults and ≥65 years for older adults as the effect of sleep on hypertension decreases with age.[17,22] Subjects aged ≥65 years were considered elderly.[26] Height and body weight were measured while the subjects were wearing light clothes without shoes. Body mass index (BMI) was calculated from the measured height and weight of the participants. BMI group was categorized between underweight, normal weight, overweight, and obese. The cutoff point for obesity (BMI ≥25 kg/m$^2$) was defined by the International Obesity Task Force for Asian Adults in the Asian and Pacific regions.[27] Detailed data on personal characteristics were collected, including smoking habits, physical activity, alcohol consumption, depressive symptoms, and chronic disease. Smoking status was classified as three groups: nonsmoker, former-smoker (for at least 1 year), or current smoker.[24] Physical activity was examined as regular exercise during one's spare time and was classified into three groups: none, low (1–2 times/week), and high activity (≥3 times/week). Alcohol consumption was assessed by questions on drinking behavior during the month before the interview, and the participants were categorized into three groups: nondrinker, light or moderate drinker (1–30 g alcohol/day), and heavy drinker (≥30 g alcohol/day).[24] Depressive symptoms were assessed by an "yes" or "no" answers to the questionnaire "Have you felt sadness or despair affecting daily life for more than 2 weeks over the past year?" Chronic disease such as stroke was assessed by the question "Have you ever had a stroke in the past 3 months or last year or more?" Diabetes mellitus was defined as fasting plasma glucose (FPG) ≥126 mg/dl or the use of hypoglycemic agents or insulin therapy. Blood samples for measuring fasting plasma glucose were collected after an overnight fast and biochemical analysis was carried out within 2 h of blood sampling. Fasting plasma glucose was measured by enzymatic methods with an ADVIA 1650 autoanalyzer (Bayer, Pittsburgh, PA).

*Statistical analyses.* The data are expressed as numbers and percentages (categorical) or the mean ± s.d. (continuous). Differences between normal subjects and those with hypertension were evaluated using Student's *t*-test (two-tailed) or the $\chi^2$-test as appropriate. Differences among the five groups of sleep duration were determined using the generalized linear model (Duncan's test of multiple comparisons). Multivariable-adjusted logistic regression analysis was conducted to examine the odds ratio (OR) and 95% confidence interval (CI) for hypertension for categories of sleep duration. Model 1 incorporated sociodemographic variables such as gender and obesity. Model 2 incorporated sociodemographic variables plus behavioral variables such as smoking status, alcohol consumption, physical activity, and disease variables such as depressive symptoms, diabetes mellitus, and stroke. In this study, we tested for the multiplicative interaction between age and sleep duration and found that age served as an effect modifier between average daily sleep duration and the prevalence of hypertension ($P$ = 0.04). Thus, we stratified the sample by two age groups as described (<65 and ≥65 years) and performed multiple logistic analyses with each group. Although the KNHANES III included weights to account for the complex sampling design and to allow approximations of the Korean population, we conducted nonweighted analyses using SAS software because use of sample weights has not been come to an agreement for better analyses so far. All statistical analyses were performed with SAS software version 8.2 (SAS Institute, Cary, NC). Statistical significance was defined as $P < 0.05$.

## RESULTS

Among the 5,393 subjects (2,276 men, 3,117 women), 1,345 (24.9%) of them had hypertension (**Table 1**). Of 1,345 hypertensive subjects, 364 (27%) are currently using antihypertensive medication. The subjects with hypertension were older ($P < 0.0001$), and were more likely to have a high BMI and a higher prevalence of obesity ($P < 0.0001$). The number of former smokers was higher in the subjects with hypertension than in the normal subjects, although a greater number of current smokers were found in the normal subjects. Depressive symptoms were more prevalent in the subjects with hypertension than in the normotensive subjects ($P = 0.0005$). Diabetes mellitus or stroke was also more prevalent in the subjects with hypertension than in the normotensive subjects ($P < 0.0001$). Finally, sleep duration was significantly shorter in the subjects with hypertension compared to the subjects with normal blood pressure ($P = 0.0003$).

The median sleep duration was 7 h/day, which was used as a reference for sleep duration in this study. A sleep duration of ≤6 h/day was reported by 39.8% of the subjects, including 13.9% sleeping ≤5 h/day. A sleep duration of ≥8 h was reported

**Table 1 | Characteristics of subjects according to the presence of hypertension**

| | Normal (*N* = 4,048) | Hypertension (*N* = 1,345) | *P* value |
|---|---|---|---|
| Age, %, years | | | |
| <65 | 90.07 | 64.61 | <0.0001 |
| ≥65 | 9.93 | 35.39 | |
| BMI, mean ± s.d., kg/m$^2$ | 23.28 ± 3.16 | 25.01 ± 3.24 | <0.0001 |
| Obesity, % | 26.34 | 50.37 | <0.0001 |
| Smoking status, % | | | |
| Never | 22.36 | 23.05 | <0.0001 |
| Former | 15.61 | 23.72 | |
| Current | 62.03 | 53.23 | |
| Alcohol consumption, %, g/day | | | |
| None | 70.5 | 72.34 | 0.0004 |
| 0–30 | 10.45 | 6.84 | |
| ≥30 | 19.05 | 20.82 | |
| Regular physical activity, %, times/week | | | |
| None | 52.3 | 54.28 | <0.0001 |
| 1–2 | 14.16 | 8.77 | |
| ≥3 | 33.55 | 36.95 | |
| Depressive symptom, % | 14.53 | 18.51 | 0.0005 |
| Diabetes mellitus, % | 4.56 | 16.81 | <0.0001 |
| Stroke (ever) | 0.77 | 5.06 | <0.0001 |
| Blood pressure, mean ± s.d., mm Hg | | | |
| SBP | 112.27 ± 11.59 | 139.92 ± 17.74 | <0.0001 |
| DBP | 73.82 ± 8.20 | 87.52 ± 11.10 | <0.0001 |
| Sleep duration, mean ± s.d., h/day | 6.88 ± 1.32 | 6.71 ± 1.47 | 0.0003 |

BMI, body mass index; DBP, diastolic blood pressure; SBP, systolic blood pressure.

by 30.8% of the subjects, including 7.3% sleeping ≥9 h a day (Table 2). Both short and long sleep durations (≤5 or ≥9 h) were associated with older age, female sex, no physical activity, depressive symptoms, diabetes mellitus, stroke, higher SBP and DBP, and hypertension.

We finally examined the ORs and 95% CIs of prevalent hypertension across the five categories of sleep duration using 7 h of sleep as a reference (Table 3). Among the young and middle-aged adults aged <65 years, the unadjusted OR of prevalent hypertension was 1.5-fold greater in those with a sleep duration of ≤5 h (OR 1.52; 95% CI 1.19, 1.94) compared to those with a sleep duration of 7 h. This trend persisted after adjustment for putative risk factors for hypertension such as gender, obesity, smoking status, alcohol consumption, physical activity, depressive symptoms, diabetes mellitus, and stroke (OR 1.31; 95% CI 1.01, 1.71). However, in the older adults aged ≥65 years, no significant association was found between sleep duration and the risk of hypertension (OR 1.15; 95% CI 0.75, 1.77). A sleep duration of ≥8 h was not associated with hypertension in either the young or older adults in this study.

## DISCUSSION

We found an age-dependent association between sleep duration and the risk of hypertension using the 2005 Korean National Health and Nutrition Examination Survey. Specifically, a short duration of sleep was independently associated with hypertension among young and middle-aged Korean adults aged <65 years, but not in older individuals aged ≥65 years. The risk of hypertension was 1.3-fold greater with sleep durations of ≤5 h compared to a sleep duration of 7 h after adjustment for putative risk factors such as gender, obesity, smoking status, alcohol consumption, physical activity, depressive symptoms, diabetes mellitus, and stroke.

Our findings agree with the results of previous studies. In a cross-sectional analysis, the Whitehall II study showed that a short duration of sleep (≤5 h/night) among British women aged 35–55 years was significantly associated with hypertension after adjustments for age, employment, alcohol intake, smoking, physical activity, BMI, Short Form 36 (SF-36) physical and mental health scores, depression, hypnotics use, and cardiovascular disease drugs (OR 1.72; 95% CI 1.07, 2.75).[15] Stang *et al.*[28] reported that the age-adjusted prevalence ratio increased by 20% in Dutch women (age 45–74 years) with short sleep durations (≤5 h/night) compared to women who slept 7 h (OR 1.24; 95% CI 1.04, 1.46). The Western New York Health Study[19] showed that the risk for hypertension was 1.7-fold higher in American women (age 35–64 years) with short sleep durations (<6 h) than in women with normal durations of sleep (6–8 h) when adjusted for marital status, socioeconomic status, BMI, waist circumference, smoking habits, alcohol consumption, physical activity, SF-36 physical and mental health scores, depressive symptoms, and diabetes. So far there has only been one longitudinal analysis from NHANES I, which showed that a short duration of sleep (≤5 h/night) was associated with a 60% higher risk of hypertension among middle-aged American adults aged 32–59 years when adjusted for age, gender, education, daytime sleepiness, depression, physical activity, alcohol consumption, salt consumption, smoking, pulse rate, ethnicity, overweight/obesity, and diabetes.[17]

In this study, we failed to find any significant association between short sleep duration and hypertension in the older subjects aged ≥65 years. Consistent with our finding, previous studies have shown age-dependent associations. An NHANES I study reported that no association between short sleep duration and hypertension incidence was found in older subjects between the ages of 60 and 86 years.[17] Several factors may explain the differences in relationship between younger and older subjects. First, sleep-disordered breathing, which may cause additional sleep loss,[21] is strongly associated with hypertension[29–31] and this association seems to be age dependent. Another possibility is that older people might compensate for a short sleep duration at night by daytime napping. In general, short sleep duration at night is known to be associated with a higher risk of hypertension. However, in our study, we did not separately examine sleep duration at night and daytime napping with our questionnaire, and thus, these associations cannot be directly compared. Furthermore, a survival bias

**Table 2 | Characteristics of subjects across categories of sleep duration**

| | Sleep duration (h) | | | | | |
|---|---|---|---|---|---|---|
| | ≤5 (*N* = 752) | 6 (*N* = 1,395) | 7 (*N* = 1,587) | 8 (*N* = 1,264) | ≥9 (*N* = 395) | *P* value |
| Age, %, years | | | | | | |
| <65 | 70.35 | 85.95 | 88.59 | 85.6 | 75.7 | <0.0001 |
| ≥65 | 29.65 | 14.05 | 11.41 | 14.4 | 24.3 | |
| Gender (female), % | 62.5 | 55.48 | 57.84 | 57.28 | 58.48 | 0.04 |
| BMI, mean ± s.d., kg/m$^2$ | 23.83 ± 3.26$^a$ | 23.89 ± 3.27$^a$ | 23.73 ± 3.18$^{ab}$ | 23.48 ± 3.24$^b$ | 23.57 ± 3.63$^{ab}$ | <0.02 |
| Obesity, % | 34.54 | 35.57 | 31.14 | 29.39 | 30.69 | 0.01 |
| Smoking status, % | | | | | | |
| Never | 20.35 | 22.15 | 22.37 | 24.21 | 23.29 | 0.21 |
| Former | 15.96 | 18.57 | 18.15 | 16.22 | 20 | |
| Current | 63.7 | 59.28 | 59.48 | 59.57 | 56.71 | |
| Alcohol consumption, %, g/day | | | | | | |
| None | 72.34 | 70.61 | 70.01 | 71.91 | 70.38 | 0.33 |
| 0–30 | 7.31 | 9.61 | 10.84 | 9.49 | 8.61 | |
| ≥30 | 20.35 | 19.78 | 19.16 | 18.59 | 21.01 | |
| Regular physical activity, %, times/week | | | | | | |
| None | 56.65 | 49.75 | 51.54 | 52.61 | 61.77 | <0.0001 |
| 1–2 | 8.91 | 14.48 | 14.24 | 12.1 | 10.89 | |
| ≥3 | 34.44 | 35.77 | 34.22 | 35.28 | 27.34 | |
| Depressive symptom, % | 25.27 | 15.84 | 12.04 | 13.14 | 17.47 | <0.0001 |
| Diabetes mellitus, % | 10.19 | 7.04 | 6.39 | 7.6 | 9.56 | 0.01 |
| Stroke (ever), % | 3.19 | 1 | 1.2 | 2.14 | 3.8 | <0.0001 |
| Blood pressure, mean ± s.d., mm Hg | | | | | | |
| SBP | 123.49 ± 20.27$^a$ | 119.72 ± 18.65$^b$ | 116.95 ± 16.99$^c$ | 118.02 ± 16.30$^{bc}$ | 121.58 ± 17.83$^d$ | <0.0001 |
| DBP | 78.26 ± 10.98$^a$ | 77.54 ± 11.03$^{abc}$ | 76.60 ± 10.82$^c$ | 76.89 ± 10.47$^{bc}$ | 77.88 ± 10.19$^{ab}$ | 0.003 |
| Hypertension, % | 33.78 | 25.23 | 21.42 | 22.71 | 28.35 | <0.0001 |

BMI, body mass index; DBP, diastolic blood pressure; SBP, systolic blood pressure.
$^{a,b,c,d}$ values with unlike superscript are significantly different ($P < 0.05$).

could be another explanation for the absence of association between short sleep duration and hypertension in older subjects, because previous studies found that short sleep duration is associated with increased all-cause mortality.[32]

It is noted that these studies cannot be directly compared because they used different study conditions. First, the Korean subjects in this study were all Asians, but the subjects from other studies have mostly been Caucasians. Second, our study questionnaire examined usual sleep duration per day, which might include napping during the daytime, whereas most other studies examined sleep only at night. Third, all the studies used different categories for sleep duration. In the Western New York Health Study, sleep duration was categorized into three groups: <6, 6–8 (normal), and >8 h. And in the NHANES I study it was classified into four groups: ≤5, 6, 7–8 (normal), and ≥9 h. In our study, sleep duration was categorized into five groups, similar to those of Stang *et al.*:[28] ≤5, 6, 7 (normal), 8, and ≥9 h.

The mechanism underlying the association between short sleep duration and hypertension remains largely unclear. Sleep deprivation has been reported to increase sympathetic nervous system activity, which may cause an increase in blood pressure by increasing the synthesis of catecholamines through the activation of superior centers.[13,33,34] These studies observed increases in blood pressure on the day after a night with insufficient sleep, which was accompanied by increases in urinary excretion of norepinephrine, an indicator of increased sympathetic nervous system activity.[13,34] Other studies reported that chronic sleep deprivation might be associated with an increased blood pressure by inducing abnormal vasomotion, including endothelial vasodilation.[35,36] A prolonged sleep deprivation for 4 weeks attenuated endothelial function, which might be associated with a reduction in the intracellular magnesium level.[36] Sauvet *et al.* reported vascular dysfunction occurred before the increase in sympathetic activity and systolic blood pressure after sleep deprivation of 40 h.[35]

In this study, a long duration of sleep was significantly associated with hypertension among young and middle-aged adults after adjusting for gender and obesity. But, this relationship did not persist when analysis were further adjusted for smoking status, alcohol consumption, physical activity, depressive

**Table 3 | Odds ratios and 95% confidence intervals of hypertension among Korean adults across categories of sleep duration**

| | Sleep duration (h) | | | | |
|---|---|---|---|---|---|
| | ≤5 | 6 | 7 | 8 | ≥9 |
| Young and middle-aged adults (<65 years) | | | | | |
| *N* | 529 | 1,199 | 1,406 | 1,082 | 299 |
| Unadjusted | 1.52 (1.19, 1.94) | 1.161 (0.95, 1.42) | 1.00 (reference) | 1.054 (0.86, 1.30) | 1.349 (0.99, 1.83) |
| Adjusted | | | | | |
| Model 1[a] | 1.434 (1.11, 1.85) | 1.077 (0.88, 1.33) | 1.00 (reference) | 1.108 (0.89, 1.37) | 1.467 (1.07, 2.02) |
| Model 2[b] | 1.314 (1.01, 1.71) | 1.058 (0.86, 1.31) | 1.00 (reference) | 1.072 (0.86, 1.34) | 1.338 (0.96, 1.86) |
| Older adults (≥65 years) | | | | | |
| *N* | 223 | 196 | 181 | 182 | 96 |
| Unadjusted | 1.15 (0.78, 1.71) | 1.311 (0.87, 1.97) | 1.00 (reference) | 0.885 (0.59, 1.34) | 0.815 (0.50, 1.34) |
| Adjusted | | | | | |
| Model 1[a] | 1.183 (0.79, 1.78) | 1.355 (0.89, 2.06) | 1.00 (reference) | 0.923 (0.61, 1.41) | 0.883 (0.53, 1.47) |
| Model 2[b] | 1.153 (0.75, 1.77) | 1.419 (0.92, 2.19) | 1.00 (reference) | 0.888 (0.57, 1.38) | 0.834 (0.49, 1.42) |

Test was logistic regression.
[a]Adjusted for gender and obesity. [b]Adjusted for model 1 plus smoking status, alcohol consumption, physical activity, depressive symptoms, diabetes mellitus, and stroke.

symptoms, diabetes mellitus, and stroke. It suggests that other risk factors of hypertension such as depression or disease history might affect more than a long duration of sleep among Korean population. Many previous studies reported a similar result with our study[15,17,19] although one study showed that a long duration of sleep may be related to the risk of hypertension.[18]

Our study has several limitations. First, the information about usual sleep duration was self-reported by the participants. However, good agreement has been found in previous studies between self-reported assessments of sleep and data obtained through actigraphic monitoring.[37,38] Second, depressive symptoms, which affect sleep duration, were not diagnosed by an accurate tool, but were self-reported by the participants. Third, we were not able to control for sleep-disordered breathing that is an established risk factor for hypertension and is likely to be associated with sleep duration. Fourth, we conducted nonweighted analyses although the KNHANES III was a complex sampling design. Thus, we cannot assume the representativeness of this sample. Finally, we could not define a causal relationship between sleep duration and hypertension because our results are based on a cross-sectional design.

In conclusion, our study suggests that short sleep duration (≤5 h) is associated with higher risk of hypertension among young and middle-aged Korean adults. However, this association was not found in the elderly Korean population aged ≥65 years. Further research is needed to identify the mechanisms of the relationship between sleep duration and hypertension with better control for confounders in different ethnic or age groups using a prospective longitudinal study. If short sleep duration plays a role in the etiology of hypertension, an intervention that would increase amounts of sleep could help in the prevention and treatment of hypertension and further improve public health.

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