Sleep duration and chronic kidney disease: The Korean Genome and Epidemiology Study (KoGES)-Kangwha study

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Background/Aims: Sleep duration affects health in various ways. The objective of this study was to investigate the associations of sleep duration with chronic kidney disease (CKD) in a Korean adult population.

Methods: This cross-sectional analysis was conducted for total of 1,360 participants who completed baseline health examinations for the Korean Genome and Epidemiology Study-Kangwha study in 2010 to 2011. Sleep habits were measured by an interviewer-assisted questionnaire. Sleep duration was calculated based on the number of hours per day participants had slept over the past 1 year. CKD was defined as either proteinuria or estimated glomerular filtration rate (eGFR) < 60 mL/min/1.73 m². Multiple logistic regression models were applied to examine associations between sleep duration and CKD.

Results: Women with very long sleep duration (≥ 9 hours/day) were at significantly increased odds for having high serum creatinine (odds ratio [OR], 2.936; 95% confidence interval [CI], 1.176 to 7.326), low eGFR (OR, 3.320; 95% CI, 1.372 to 8.034), and CKD (OR, 3.112; 95% CI, 1.315 to 7.363), compared those with a typical sleep duration (7 to < 8 hours/day), after adjusting for sociodemographic status, socioeconomic status, health behaviors, comorbidities, and sleep quality. Among women, for every 1 hour increase in sleep duration per day, there was a 24.6% increase in the presence of CKD (OR, 1.246; 95% CI, 1.019 to 1.523). However, among men, sleep duration was not significantly associated with CKD.

Conclusions: Very long sleep duration was independently associated with a higher prevalence of CKD among Korean women. Gender may influence this association.

Keywords: Sleep duration; Sleep quantity; Renal insufficiency, chronic; Kidney function; General population

INTRODUCTION

Epidemiologic studies suggest that sleep duration may adversely affect one's health in a number of ways. Interestingly, both short and long sleep durations have been shown to be associated with increased risks of all-cause

mortality, cardiovascular disease, and other chronic diseases [1-3]. Meanwhile, sleeping habits in the general population reflect a complexity of interactions related to the presence of comorbid medical conditions and physical, psychological, social, and lifestyle factors.

Chronic kidney disease (CKD) has emerged as a public health problem worldwide, with reports of increasing prevalence and adverse complications [4-7]. Moreover, CKD has been recognized as a predictor of end-stage kidney disease and cardiometabolic disease [4]. Nevertheless, adverse outcomes of CKD can be prevented through early detection, education, treatment, and intervention to modify harmful lifestyle factors [8,9]. In particular, changing one's sleep duration may be effective in preventing CKD. Although cross-sectional and prospective epidemiologic studies have suggested that sleep quality is a significant risk factor for CKD [10,11], little is known of the association between sleep quantity and CKD [8,12,13]. While a few studies have suggested that sleep duration can influence kidney function, distinct associations remain unclear. Therefore, we aimed to investigate the relationships between sleep duration and CKD in a Korean adult population.

METHODS

Study population
Data for the present study were derived from the Korean Genome and Epidemiology Study (KoGES)-Kangwha study, an ongoing rural community-based prospective cohort. During the baseline survey period from 2006 to 2011, the KoGES-Kangwha study enrolled 4,899 community dwellers from Kangwha Island, Incheon, South Korea. Current cross-sectional analysis was conducted for a total of 1,360 participants who completed the questionnaire concerning sleep (544 men and 816 women aged 36 to 88 years) in 2010 to 2011. All participants provided written informed consent, and the Institutional Review Board of Severance Hospital, Yonsei University College of Medicine, approved the study protocol.

Measurements
Trained interviewers obtained information on the participants' demographic characteristics, socioeconomic status (household income, marital status, and working status), previously known diseases, medication use, and health behaviors (sleep, cigarette smoking, alcohol intake, and physical activity) using standardized questionnaires. Depressive symptoms were assessed using the Beck Depression Inventory (BDI), and depression was determined on the basis of BDI score of ≥ 16 or a self-reported physician's diagnosis [14]. Smoking status, alcohol consumption, and physical activity were categorized as either current or non-current.

Sleep habits were measured by an interviewer-assisted questionnaire. Participants were asked to report the number of hours per day they had slept over the past 1 year, including naps, whether they had trouble falling asleep, whether they had trouble getting back to sleep after they had awaken, snoring behaviors, and the presence of sleep apnea. In the present study, average sleep durations were defined as the total time in bed per day (calculated from bedtime, rise time, and naps). Participants were divided into five groups based upon their reported sleep duration: < 6 hours/day, "very short sleepers"; 6 to < 7 hours/day, "short sleepers"; 7 to < 8 hours/day, "usual sleepers (reference group)"; 8 to < 9 hours/day, "long sleepers"; and ≥ 9 hours/day, "very long sleepers."

All participants completed health examinations, including anthropometric measurements, blood pressure measurements, blood laboratory tests, bone mineral density measurements, and electrocardiography. Body weight was measured to the nearest 0.1 kg on a digital scale (GL-6000-20, CAS Korea, Seoul, Korea), and standing height was measured to the nearest 0.1 cm on a stadiometer (SECA 225, SECA, Hamburg, Germany). Body mass index (BMI) was calculated as body weight (kg) divided by standing height (m^2). Resting blood pressures were measured twice at a 5-minute interval using an automatic sphygmomanometer (Dinamap 1846 SX/P, GE Healthcare, Waukesha, WI, USA). Additional measurements were performed, if the first and second measurements differed by ≥ 10 mmHg for either systolic or diastolic blood pressure, and the average of the last two measurements was used for analysis.

Fasting blood samples were collected from the antecubital vein after at least an 8-hour fast. Blood samples were sent to an independent research laboratory center for analysis. Serum creatinine concentrations and blood urea nitrogen concentrations were measured by the col-

Choi H, et al. Sleep duration and CKD

KJIM

orimetric methods, and serum concentrations of cholesterol were measured by enzymatic methods with an automatic analyzer (ADVIA 1650, Siemens, Tarrytown, NY, USA in 2010; ADVIA 1800, Siemens in 2011). Diabetes mellitus was determined on the basis of fasting glucose concentration (≥ 126 mg/dL) or a self-reported physician's diagnosis [15]. Hypercholesterolemia was defined (according to the Korean Society of Lipidology and Atherosclerosis criteria) as a total cholesterol concentration ≥ 230 mg/dL [16], taking a lipid-lowering drug, or a self-reported physician's diagnosis.

Kidney function was estimated by serum creatinine concentration, presence of proteinuria, and estimated glomerular filtration rate (eGFR). Serum creatinine concentration cutoffs were sex specific, corresponding to the study design, with cutoffs of > 1.3 mg/dL for men and > 1.0 mg/dL for women. The intra-assay coefficients of variation were 1.7% at 1.8 mg/dL and 1.3% at 8.4 mg/dL. The total coefficients of variation were 3.8% at 1.8 mg/dL and 3.7% at 8.4 mg/dL. Proteinuria was diagnosed as 1+ or more by semiquantitative dipstick test. An eGFR was calculated using the modification of diet in renal disease study equation [17] as follows: $186 \times (\text{creatinine}/88.4)^{-1.154} \times (\text{age})^{-0.203} \times (0.742 \text{ if female})$. The diagnosis of CKD was defined as either kidney damage or an eGFR of < 60 mL/min/1.73 m^2, according to criteria set by the National Kidney Foundation Kidney Disease Outcomes Quality Initiative [18].

Statistical analysis

The distribution of continuous variables was described as means with standard deviations and compared using one-way analysis of variance. Categorical variables were reported as observed numbers and percentages, and compared using the chi-square test. A general linear model using contrast coefficients was used for linear trend analysis of continuous variables, and Cochran-Armitage test and Mantel-Haenszel test were used for categorical variables. Multiple linear regression models were used to assess the independent association between sleep duration and CKD. Sex, age, BMI, systolic blood pressure, smoking status, alcohol consumption, physical activity, diabetes mellitus, hypercholesterolemia, depression, history of cardiovascular disease, history of cancer, menopausal status, socioeconomic status (household income, marital status,

and working status), and sleep quality (sleep difficulty, sleep awakeness, snoring, and sleep apnea) were considered as covariates in the model. In addition, multiple logistic regression models were used to estimate odds ratios (OR) with 95% confidence intervals (CI) for CKD criteria. We performed statistical analyses on the total population, as well as men and women separately, because we found significant sex differences in kidney function. We plotted serum creatinine concentration and eGFR versus average sleep duration expressed on a continuous scale using cubic spline models. In a sensitivity analysis, we calculated age-specific sex-stratified ORs for CKD across the average sleep duration. An additional multiple logistic regression analysis was conducted excluding participants with hypertension (n = 516), diabetes mellitus (n = 165), and a history of cardiovascular disease (n = 103). All statistical analyses were performed using SAS software version 9.2 (SAS, Cary, NC, USA), and statistical significance was defined as a two-sided p value of less than 0.05.

RESULTS

The baseline characteristics of all participants are presented in Table 1. Of 1,360 participants, there were 130 very short sleepers (< 6 hours/day, 9.6%), 301 short sleepers (6 to < 7 hours/day, 22.1%), 458 usual sleepers (7 to < 8 hours/day, 33.7%), 319 long sleepers (8 to < 9 hours/day, 23.5%), and 152 very long sleepers (≥ 9 hours/day, 11.2%). Among men, the percentages of participants who slept < 6 and ≥ 9 hours were 8.6% and 12.1%, respectively. Among women, the corresponding percentages were 10.2% and 10.5%, respectively. The number of participants with a very short sleep duration was greater for women than for men, and the number of participants with a very long sleep duration was smaller for women than for men. The mean sleep duration was 431.4 minutes/day for men and 430.6 minutes/day for women. The mean serum creatinine concentration was 1.1 mg/dL for men and 0.9 mg/dL for women, and was thus significantly higher among men. The prevalence of high serum creatinine concentration was 7.4% among both men and women. The mean eGFR was 76.0 mL/min/1.73 m^2 for men and 73.7 mL/min/1.73 m^2 for women, and was thus significantly higher among

Table 1. Baseline characteristics of the study population (n = 1,360)

Variable	Total (n = 1,360)	Men (n = 544)	Women (n=816)	p value
Age, yr	60.0 ± 10.3	61.5 ± 10.2	59.0 ± 10.2	< 0.001
Body mass index, kg/m²	24.5 ± 3.1	24.3 ± 3.0	24.7 ± 3.2	0.033
SBP, mmHg	118.2 ± 17.3	118.9 ± 16.2	117.7 ± 18.0	0.208
DBP, mmHg	71.4 ± 10.4	74.1 ± 10.0	69.6 ± 10.3	< 0.001
Sleep duration, min	430.9 ± 76.2	431.4 ± 76.2	430.6 ± 76.3	0.861
< 6 hours/day	130 (9.6)	47 (8.6)	83 (10.2)	
6 to < 7 hours/day	301 (22.1)	127 (23.3)	174 (21.3)	
7 to < 8 hours/day	458 (33.7)	185 (34.0)	273 (33.5)	
8 to < 9 hours/day	319 (23.5)	119 (21.9)	200 (24.5)	
≥ 9 hours/day	152 (11.2)	66 (12.1)	86 (10.5)	
Sleep quality				
Sleep difficulty (at least 1/week)	413 (30.4)	108 (19.9)	305 (37.4)	< 0.001
Sleep awake (at least 1/week)	506 (37.2)	159 (29.2)	347 (42.5)	< 0.001
Snoring	672 (49.4)	282 (51.8)	390 (47.8)	0.160
Sleep apnea	117 (8.6)	76 (14.0)	41 (5.0)	< 0.001
Depression	176 (12.9)	56 (10.3)	120 (14.7)	0.022
Diabetes mellitus	165 (12.1)	84 (15.4)	81 (9.9)	0.003
Hypertension	516 (37.9)	212 (39.0)	304 (37.3)	0.561
Hypercholesterolemia	327 (24.0)	94 (17.3)	233 (28.6)	< 0.001
History of cardiovascular disease	103 (7.6)	59 (10.8)	44 (5.4)	< 0.001
History of cancer	53 (3.9)	14 (2.6)	39 (4.8)	0.055
Current drinker	519 (38.2)	324 (59.6)	195 (23.9)	< 0.001
Current smoker	154 (11.3)	136 (25.0)	18 (2.2)	< 0.001
Regular exercise	503 (37.0)	214 (39.3)	289 (35.4)	0.159
Low household income (> 1 million won)	580 (42.6)	197 (36.2)	383 (46.9)	< 0.001
Single, divorced, or separated	200 (14.7)	29 (5.3)	171 (21.0)	< 0.001
Unemployed or housewives	446 (32.8)	119 (21.9)	327 (40.1)	< 0.001
Fasting glucose, mg/dL	98.4 ± 20.8	101.8 ± 24.4	96.1 ± 17.6	< 0.001
Total cholesterol, mg/dL	191.9 ± 33.9	184.2 ± 32.2	197.1 ± 34.1	< 0.001
HDL-C, mg/dL	46.3 ± 11.6	43.7 ± 10.8	48.1 ± 11.8	< 0.001
Triglycerides, mg/dL	148.2 ± 89.5	156.1 ± 101.2	143.0 ± 80.4	0.008
hs-CRP, mg/L	1.7 ± 5.3	1.9 ± 7.0	1.5 ± 3.7	0.196
Blood urea nitrogen, mg/dL	16.2 ± 4.8	17.0 ± 4.9	15.7 ± 4.6	< 0.001
Creatinine, mg/dL	0.9 ± 0.2	1.1 ± 0.2	0.9 ± 0.1	< 0.001
eGFR, mL/min/1.73 m²	74.6 ± 11.5	76.0 ± 12.4	73.7 ± 10.7	< 0.001
Proteinuria (≥ 1+)	15 (1.1)	8 (1.5)	7 (0.9)	0.430
High creatinine (> 1.3 men, > 1.0 women)	100 (7.4)	40 (7.4)	60 (7.4)	0.084
Low eGFR (< 60 mL/min/1.73 m²)	115 (8.5)	46 (8.5)	69 (8.5)	0.079
CKD	125 (9.2)	52 (9.6)	73 (8.9)	0.774

Values are presented as mean ± SD or number (%).

SBP, systolic blood pressure; DBP, diastolic blood pressure; HDL-C, high density lipoprotein cholesterol; hs-CRP, high-sensitivity C-reactive protein; eGFR, estimated glomerular filtration rate; CKD, chronic kidney disease.

Choi H, et al. Sleep duration and CKD

KJIM

men. The prevalence of low eGFR was 8.5% among both men and women. The overall prevalence of CKD was 9.6% among men and 8.9% among women; the difference was not statistically significant. The prevalences of CKD according to stage are presented in Supplementary Table 1.

The general characteristics of the male and female participants are presented according to sleep duration category in Tables 2 and 3. In both men and women, mean age was highest among very long sleepers. In men, individuals with a very long sleep duration were more likely to be short, weigh less, and comprise a higher frequency of unemployed men. Among men, we noted no significant associations between sleep duration and serum creatinine concentration, eGFR, and CKD prevalence. In women, individuals with a very long duration were more likely to have a lower BMI, a higher frequency of menopause, and the lowest household income. Moreover, among women, we observed significantly different distributions for serum creatinine levels, eGFR, and CKD prevalence according to sleep duration. Nevertheless, in both men and women, very long sleepers showed the highest prevalences of CKD.

Table 4 showed the result of the multiple linear regression analysis of the associations between sleep duration and CKD. Adjusted ORs for kidney functions and its components were estimated in separate models with average sleep duration assessed as a continuous variable in one and a categorical variable in the other. Among women, the longest sleep duration was significantly associated with high serum creatinine concentrations, low eGFR, and presence of CKD in the unadjusted model. After additional adjustment for sociodemographic status, socioeconomic status, health behaviors, comorbidities, and sleep quality, the associations remained significant. Women who slept ≥ 9 hours/day showed significantly increased odds for having high serum creatinine concentrations (OR, 2.936; 95% CI, 1.176 to 7.326), low eGFR (OR, 3.320; 95% CI, 1.372 to 8.034), and CKD (OR, 3.112; 95% CI, 1.315 to 7.363), compared to the reference group (sleep duration of 7 to < 8 hours/day). Among women, for every 1 hour increase in sleep duration per day, there was a 24.6% increase in the presence of CKD after adjusting for covariates. As a further visual cue, cubic splines were used to display the relationship between average sleep duration and kidney function (Supplementary Fig. 1).

Women who slept more than 8 hours per day exhibited higher serum creatinine concentration and lower eGFR than the reference group. As shown in Fig. 1, the ORs (95% CI) for high serum creatinine concentration, low eGFR, and presence of CKD was the highest among female very long sleepers. Among men, there were no significant associations between sleep duration and high serum creatinine concentration, low eGFR, and presence of CKD.

In the sensitivity analysis (Supplementary Tables 2 and 3), we found that sleeping more than 8 hours was significantly associated with CKD (OR, 2.699; 95% CI, 1.065 to 6.841) in women of older age (60 years or older) when stratified according to the median age. Among younger women (less than 60 years), there were no significant associations between sleep duration and kidney function; however, increases in average sleep duration tended to increase the risk for CKD. Additionally, we repeated the logistic regression analysis after excluding participants with hypertension, diabetes mellitus, and a history of cardiovascular disease (Supplementary Table 4), and the association trend was quite consistent.

DISCUSSION

We investigated the associations between sleep duration and CKD in a Korean adult population. Herein, sleeping more than 9 hours was significantly associated with CKD in women; however, sleep duration was not significantly associated with CKD in men.

In recent decades, the average sleep duration in most individuals has reduced, and many studies have investigated shorter sleep durations and their effects on health. In particular, the average sleep duration of Koreans was 7 hours and 49 minutes per day, which was the lowest among 18 OECD (Organisation for Economic Co-operation and Development) member countries [19]. Notwithstanding, epidemiological evidence of associations between sleep duration and CKD is insufficient. Previous studies reported that sleeping less than 5 hours was associated with proteinuria in the Japanese population [8,20] and higher risk of CKD among the shift workers [13]. More recently, an increasing number of studies have linked prolonged sleep duration with poor health effects [21,22]. However, studies have yet to iden-

Table 2. Characteristics of the study participants according to sleep duration in men (n = 544)

Variable	Sleep duration					*p* value	*p* for trend
	< 6 (n = 47)	6 to < 7 (n = 127)	7 to < 8 (n = 185)	8 to < 9 (n = 119)	≥ 9 (n = 66)		
Age, yr	59.4 ± 10.6	59.5 ± 10.4	61.4 ± 9.8	62.3 ± 9.2	65.6 ± 11.2	0.001	< 0.001
Body mass index, kg/m²	24.2 ± 3.5	24.3 ± 3.0	24.6 ± 2.9	24.1 ± 3.1	23.9 ± 2.7	0.424	0.510
SBP, mmHg	117.4 ± 16.0	118.4 ± 14.9	119.1 ± 15.5	119.0 ± 17.3	120.0 ± 18.4	0.935	0.387
DBP, mmHg	73.2 ± 10.6	74.1 ± 10.6	73.7 ± 9.1	75.1 ± 9.7	73.6 ± 11.1	0.765	0.714
Sleep duration, min	290.9 ± 38.4	368.0 ± 13.6	428.1 ± 13.3	487.2 ± 13.2	561.8 ± 33.1	< 0.001	< 0.001
Sleep difficulty (at least 1/week)	17 (36.2)	29 (22.8)	31 (16.8)	13 (10.9)	18 (27.3)	0.001	0.058
Sleep awakeness (at least 1/week)	17 (36.2)	35 (27.6)	55 (29.7)	33 (27.7)	19 (28.8)	0.840	0.573
Snoring	29 (61.7)	68 (53.5)	91 (49.2)	63 (52.9)	31 (47.0)	0.528	0.209
Sleep apnea	8 (17.0)	20 (15.7)	25 (13.5)	16 (13.4)	7 (10.6)	0.848	0.265
Depression	6 (12.8)	8 (6.3)	10 (5.4)	8 (6.7)	6 (9.1)	0.451	0.755
Diabetes mellitus	6 (12.8)	14 (11.0)	27 (14.6)	26 (21.8)	11 (16.7)	0.194	0.069
Hypertension	21 (44.7)	42 (33.1)	69 (37.3)	52 (43.7)	28 (42.4)	0.384	0.339
Hypercholesterolemia	7 (14.9)	20 (15.7)	36 (19.5)	22 (18.5)	9 (13.6)	0.783	0.935
History of cardiovascular disease	4 (8.5)	7 (5.5)	25 (13.5)	16 (13.4)	7 (10.6)	0.185	0.152
History of cancer	2 (4.3)	1 (0.8)	5 (2.7)	5 (4.2)	1 (1.5)	0.447	0.769
Current drinker	26 (55.3)	78 (61.4)	117 (63.2)	65 (54.6)	38 (57.6)	0.577	0.596
Current smoker	11 (23.4)	35 (27.6)	44 (23.8)	27 (22.7)	19 (28.8)	0.827	0.965
Regular exercise	18 (38.3)	58 (45.7)	68 (36.8)	53 (44.5)	17 (25.8)	0.058	0.145
Low household income (> 1 million won)	20 (42.6)	48 (37.8)	59 (31.9)	40 (33.6)	30 (45.5)	0.264	0.929
Single, divorced, or separated	4 (8.5)	10 (7.9)	6 (3.2)	3 (2.5)	6 (9.1)	0.096	0.438
Unemployed or housewives	8 (17.0)	23 (18.1)	38 (20.5)	26 (21.8)	24 (36.4)	0.040	0.009
Fasting glucose, mg/dL	98.4 ± 28.7	100.4 ± 23.8	102.5 ± 23.5	101.7 ± 22.4	105.5 ± 28.5	0.558	0.115
Total cholesterol, mg/dL	183.9 ± 32.0	185.6 ± 31.2	184.7 ± 32.0	182.9 ± 34.0	182.3 ± 32.3	0.947	0.697
HDL-C, mg/dL	44.0 ± 10.6	43.7 ± 11.2	43.9 ± 10.7	43.9 ± 11.0	42.5 ± 10.5	0.911	0.490
Triglycerides, mg/dL	141.4 ± 80.4	163.1 ± 114.7	158.3 ± 99.6	156.4 ± 100.2	147.1 ± 94.2	0.700	0.859
hs-CRP, mg/L	1.6 ± 2.3	2.0 ± 7.7	1.5 ± 2.4	2.8 ± 12.3	1.3 ± 1.8	0.516	0.967
Blood urea nitrogen, mg/dL	17.4 ± 4.9	16.5 ± 4.6	16.9 ± 4.6	17.4 ± 5.6	17.6 ± 5.1	0.441	0.545
Creatinine, mg/dL	1.1 ± 0.1	1.1 ± 0.2	1.1 ± 0.2	1.1 ± 0.2	1.1 ± 0.2	0.919	0.415
eGFR, mL/min/1.73 m²	77.2 ± 12.4	76.8 ± 10.7	75.6 ± 11.5	76.3 ± 15.1	74.1 ± 12.6	0.598	0.172
Proteinuria (≥ 1+)	0	2 (1.6)	3 (1.6)	2 (1.7)	1 (1.5)	0.941	0.624
High creatinine (> 1.3 mg/dL)	3 (6.4)	5 (3.9)	17 (9.2)	10 (8.4)	5 (7.6)	0.501	0.324
Low eGFR (< 60 mL/min/1.73 m²)	3 (6.4)	7 (5.5)	18 (9.7)	11 (9.2)	7 (10.6)	0.634	0.197
CKD	3 (6.4)	9 (7.1)	20 (10.8)	12 (10.1)	8 (12.1)	0.677	0.192

Values are presented as mean ± SD or number (%).

SBP, systolic blood pressure; DBP, diastolic blood pressure; HDL-C, high density lipoprotein cholesterol; hs-CRP, high-sensitivity C-reactive protein; eGFR, estimated glomerular filtration rate; CKD, chronic kidney disease.

tify whether these same relationships exists in people who sleep longer.

In the present study of 1360 Koreans, the overall prev-

alence of CKD was 9.2% (9.6% for men and 8.9% in women), similar to other results. According to data from the National Health and Nutrition Examination Surveys

Table 3. Characteristics of the study participants according to sleep duration in women (n = 816)

Variable	Sleep duration					p value	p for trend
	< 6 (n = 83)	6 to < 7 (n = 174)	7 to < 8 (n = 273)	8 to < 9 (n = 200)	≥ 9 (n = 86)		
Age, yr	59.8 ± 10.0	57.7 ± 10.6	57.2 ± 9.8	60.1 ± 9.6	63.6 ± 10.5	< 0.001	0.004
Body mass index, kg/m²	25.1 ± 3.2	25.0 ± 3.3	24.4 ± 3.2	24.8 ± 3.1	24.1 ± 3.2	0.085	0.030
SBP, mmHg	117.6 ± 19.9	117.4 ± 17.7	116.2 ± 17.6	119.4 ± 17.2	119.5 ± 19.7	0.339	0.385
DBP, mmHg	69.4 ± 11.4	69.3 ± 10.3	69.2 ± 10.3	70.2 ± 10.0	70.3 ± 10.1	0.795	0.501
Sleep duration, min	297.3 ± 40.9	368.4 ± 13.6	428.0 ± 13.5	484.8 ± 11.1	567.6 ± 42.0	< 0.001	< 0.001
Sleep difficulty (at least 1/week)	45 (54.2)	70 (40.2)	92 (33.7)	66 (33.0)	32 (37.2)	0.008	0.007
Sleep awakeness (at least 1/week)	49 (59.0)	76 (43.7)	103 (37.7)	74 (37.0)	45 (52.3)	0.001	0.140
Snoring	43 (51.8)	93 (53.4)	124 (45.4)	91 (45.5)	39 (45.3)	0.405	0.118
Sleep apnea	2 (2.4)	10 (5.7)	11 (4.0)	13 (6.5)	5 (5.8)	0.563	0.296
Depression	14 (16.9)	22 (12.6)	26 (9.5)	28 (14.0)	12 (14.0)	0.375	0.852
Diabetes mellitus	9 (10.8)	20 (11.5)	25 (9.2)	16 (8.0)	11 (12.8)	0.671	0.743
Hypertension	39 (47.0)	73 (42.0)	84 (30.8)	70 (35.0)	38 (44.2)	0.017	0.280
Hypercholesterolemia	25 (30.1)	56 (32.2)	72 (26.4)	61 (30.5)	19 (22.1)	0.407	0.270
History of cardiovascular disease	2 (2.4)	8 (4.6)	14 (5.1)	14 (7.0)	6 (7.0)	0.535	0.093
History of cancer	2 (2.4)	9 (5.2)	15 (5.5)	9 (4.5)	4 (4.7)	0.839	0.721
Menopause	67 (80.7)	127 (73.0)	201 (73.6)	168 (84.0)	76 (88.4)	0.004	0.011
Current drinker	20 (24.1)	39 (22.4)	72 (26.4)	45 (22.5)	19 (22.1)	0.826	0.792
Current smoker	0	2 (1.1)	11 (4.0)	5 (2.5)	0	0.061	0.630
Regular exercise	32 (38.6)	70 (40.2)	97 (35.5)	64 (32.0)	26 (30.2)	0.386	0.058
Low household income (> 1 million won)	41 (49.4)	73 (42.0)	114 (41.8)	103 (51.5)	52 (60.5)	0.012	0.022
Single, divorced, or separated	20 (24.1)	33 (19.0)	47 (17.2)	43 (21.5)	28 (32.6)	0.037	0.143
Unemployed or housewives	33 (39.8)	75 (43.1)	108 (39.6)	71 (35.5)	40 (46.5)	0.416	0.859
Fasting glucose, mg/dL	100.1 ± 27.0	96.2 ± 20.0	95.6 ± 15.7	94.3 ± 12.2	97.3 ± 16.4	0.134	0.217
Total cholesterol, mg/dL	205.0 ± 31.2	196.4 ± 37.1	193.7 ± 30.6	200.8 ± 35.2	193.5 ± 37.0	0.033	0.064
HDL-C, mg/dL	49.7 ± 13.2	48.3 ± 10.7	48.3 ± 11.8	47.4 ± 11.3	47.2 ± 13.5	0.571	0.131
Triglycerides, mg/dL	137.0 ± 61.1	139.9 ± 92.4	142.5 ± 81.6	147.6 ± 77.6	145.4 ± 74.8	0.835	0.390
hs-CRP, mg/L	1.4 ± 2.7	1.4 ± 2.7	1.4 ± 2.9	1.5 ± 2.7	2.3 ± 8.0	0.332	0.101
Blood urea nitrogen, mg/dL	15.7 ± 4.5	16.0 ± 4.9	15.3 ± 4.1	15.6 ± 4.6	16.4 ± 5.4	0.300	0.416
Creatinine, mg/dL	0.9 ± 0.1	0.9 ± 0.1	0.8 ± 0.1	0.9 ± 0.1	0.9 ± 0.2	0.006	0.023
eGFR, mL/min/1.73 m²	73.6 ± 10.1	73.8 ± 11.3	75.3 ± 10.2	72.7 ± 9.2	70.5 ± 13.8	0.003	0.039
Proteinuria (≥ 1+)	0	1 (0.6)	2 (0.7)	3 (1.5)	1 (1.2)	0.732	0.208
High creatinine (> 1.0 mg/dL)	2 (2.4)	15 (8.6)	12 (4.4)	17 (8.5)	14 (16.3)	0.002	0.005
Low eGFR (< 60 mL/min/1.73 m²)	5 (6.0)	15 (8.6)	13 (4.8)	19 (9.5)	17 (19.8)	0.001	0.005
CKD	5 (6.0)	15 (8.6)	14 (5.1)	22 (11.0)	17 (19.8)	0.001	0.002

Values are presented as mean ± SD or number (%).
SBP, systolic blood pressure; DBP, diastolic blood pressure; HDL-C, high density lipoprotein cholesterol; hs-CRP, high-sensitivity C-reactive protein; eGFR, estimated glomerular filtration rate; CKD, chronic kidney disease.

Table 4. Association between sleep duration and chronic kidney disease criteria

Sleep duration	Total no.	No. (%)	Unadjusted OR (95% CI)	Adjusted OR (95% CI)[a]
High creatinine				
Men				
Continuous, hr/day[b]	544	52 (9.6)	1.114 (0.864–1.436)	1.099 (0.832–1.452)
Categorical, hr/day				
< 6	47	3 (6.4)	0.674 (0.189–2.403)	0.608 (0.146–2.534)
6 to < 7	127	5 (3.9)	0.405 (0.145–1.128)	0.265 (0.079–0.893)
7 to < 8	185	17 (9.2)	1.000	1.000
8 to < 9	119	10 (8.4)	0.907 (0.400–2.053)	1.011 (0.404–2.534)
≥ 9	66	5 (7.6)	0.810 (0.287–2.290)	0.541 (0.164–1.780)
Women				
Continuous, hr/day[b]	816	73 (8.9)	1.324 (1.078–1.625)	1.258 (1.012–1.564)
Categorical, hr/day				
< 6	83	2 (2.4)	0.537 (0.118–2.449)	0.476 (0.097–2.341)
6 to < 7	174	15 (8.6)	2.052 (0.937–4.495)	1.767 (0.743–4.202)
7 to < 8	273	12 (4.4)	1.000	1.000
8 to < 9	200	17 (8.5)	2.020 (0.942–4.332)	1.703 (0.730–3.972)
≥ 9	86	14 (16.3)	4.229 (1.874–9.545)	2.936 (1.176–7.326)
Low eGFR				
Men				
Continuous, hr/day[b]	544	52 (9.6)	1.190 (0.938–1.511)	1.145 (0.878–1.494)
Categorical, hr/day				
< 6	47	3 (6.4)	0.633 (0.178–2.245)	0.514 (0.115–2.296)
6 to < 7	127	7 (5.5)	0.541 (0.219–1.336)	0.493 (0.177–1.369)
7 to < 8	185	18 (9.7)	1.000	1.000
8 to < 9	119	11 (9.2)	0.945 (0.430–2.078)	1.131 (0.460–2.782)
≥ 9	66	7 (10.6)	1.101 (0.438–2.768)	0.709 (0.236–2.132)
Women				
Continuous, hr/day[b]	816	73 (8.9)	1.301 (1.073–1.579)	1.222 (0.994–1.503)
Categorical, hr/day				
< 6	83	5 (6.0)	1.282 (0.443–3.708)	1.161 (0.362–3.719)
6 to < 7	174	15 (8.6)	1.887 (0.875–4.069)	1.641 (0.688–3.916)
7 to < 8	273	13 (4.8)	1.000	1.000
8 to < 9	200	19 (9.5)	2.099 (1.011–4.359)	1.692 (0.743–3.849)
≥ 9	86	17 (19.8)	4.928 (2.283–10.636)	3.320 (1.372–8.034)
Chronic kidney disease				
Men				
Continuous, hr/day[b]	544	52 (9.6)	1.182 (0.943–1.482)	1.091 (0.845–1.410)
Categorical, hr/day				
< 6	47	3 (6.4)	0.563 (0.160–1.980)	0.453 (0.102–2.009)
6 to < 7	127	9 (7.1)	0.629 (0.277–1.431)	0.603 (0.235–1.545)
7 to < 8	185	20 (10.8)	1.000	1.000
8 to < 9	119	12 (10.1)	0.925 (0.434–1.970)	1.041 (0.435–2.489)

Choi H, et al. Sleep duration and CKD

KJIM

Table 4. continued

Sleep duration	Total no.	No. (%)	Unadjusted OR (95% CI)	Adjusted OR (95% CI)[a]
≥ 9	66	8 (12.1)	1.138 (0.475–2.724)	0.591 (0.199–1.760)
Women				
Continuous, hr/day[b]	816	73 (8.9)	1.319 (1.092–1.592)	1.246 (1.019–1.523)
Categorical, hr/day				
< 6	83	5 (6.0)	1.186 (0.414–3.396)	1.076 (0.341–3.393)
6 to < 7	174	15 (8.6)	1.745 (0.821–3.712)	1.475 (0.635–3.428)
7 to < 8	273	14 (5.1)	1.000	1.000
8 to < 9	200	22 (11.0)	2.287 (1.139–4.589)	1.929 (0.885–4.204)
≥ 9	86	17 (19.8)	4.558 (2.141–9.703)	3.112 (1.315–7.363)

OR, odds ratio; CI, confidence interval; eGFR, estimated glomerular filtration rate.
[a]Adjusted model: adjusted for sex, age, body mass index, systolic blood pressure, smoking, alcohol, exercise, diabetes mellitus, hypercholesterolemia, depression, history of cancer, menopause, socioeconomic status (household income, marital status, and working status), and sleep quality (sleep difficulty, sleep awakeness, snoring, and sleep apnea).
[b]Continuous model: association analysis on total sleep duration as a continuous variable.

(NHANES) in the United States, the overall prevalences of CKD were 10.0% in 1988 to 1994 and 13.1% in 1999 to 2004 [4]. The overall prevalences of CKD in Asian adult populations are 12.9% in Japan [5] and 10.8% in China [6]. The overall prevalence of CKD in the Korea National Health and Nutrition Examination Survey (KNHANES) I to IV ranges from 3.9% to 7.9% in men and 6.3% to 12.0% in women, respectively [7].

Although plausible biological mechanisms for the relationship between short sleep duration and CKD have been proposed, it is less clear as to how long sleep duration is associated with CKD prevalence. The temporal associations between sleep duration and CKD are likely to be bi-directional; nevertheless, as long sleep duration could be either an initial symptom or a consequence of unmeasured diseases and conditions among CKD patients, any causality cannot be inferred from the present data. Previous studies have also suggested that the association of long sleep duration with CKD could be explained by residual confounding and comorbidities [3,23]. Accordingly, potential confounders could predispose individuals to both long sleep duration and poor kidney function. Thus, to reduce the effects of unmeasured confounders on our results, we adjusted for sociodemographic status, socioeconomic status, health behaviors, comorbidities, and sleep quality, which may link long sleep duration to CKD. Even after adjusting for these confounders, the association between a long sleep duration and CKD remained significant. Notwithstand-

ing, the adverse health outcomes of long sleep duration and CKD share a few commonalities, including associations with old age, diabetes, established cardiovascular disease, high blood pressure, obesity, and smoking [24]. Interestingly, sleep duration has been shown to be associated with cardiometabolic diseases by worsening kidney hemodynamics and may lead to the development of glomerulosclerosis and glomerulomegaly [24-30].

A number of mechanisms could potentially mediate the associations between long sleep duration and kidney dysfunction, encompassing both biological and socioeconomic factors. Inflammation has been shown to affect the relationship between long sleep duration and kidney dysfunction [12]. Indeed, several studies have indicated that immune dysfunction may lead to progressive kidney dysfunction through activation of the renin-angiotensin-aldosterone system, which is a well-known regulator of blood pressure and a progression factor in CKD [27,29,31-33]. In addition, lower socioeconomic status could be detrimental to CKD [23,34]. In the Nurses' Health Study II, women who had never married, lived alone, were unemployed, had low household income, and were of low societal status were more likely to sleep longer [23]. Meanwhile, lower socioeconomic status could increase the risk for CKD due to both a lack of access to health care and receipt of poorer quality of care [23]. For people with CKD, lower socioeconomic status may contribute to poor control of hypertension and diabetes mellitus due to lack of understanding of
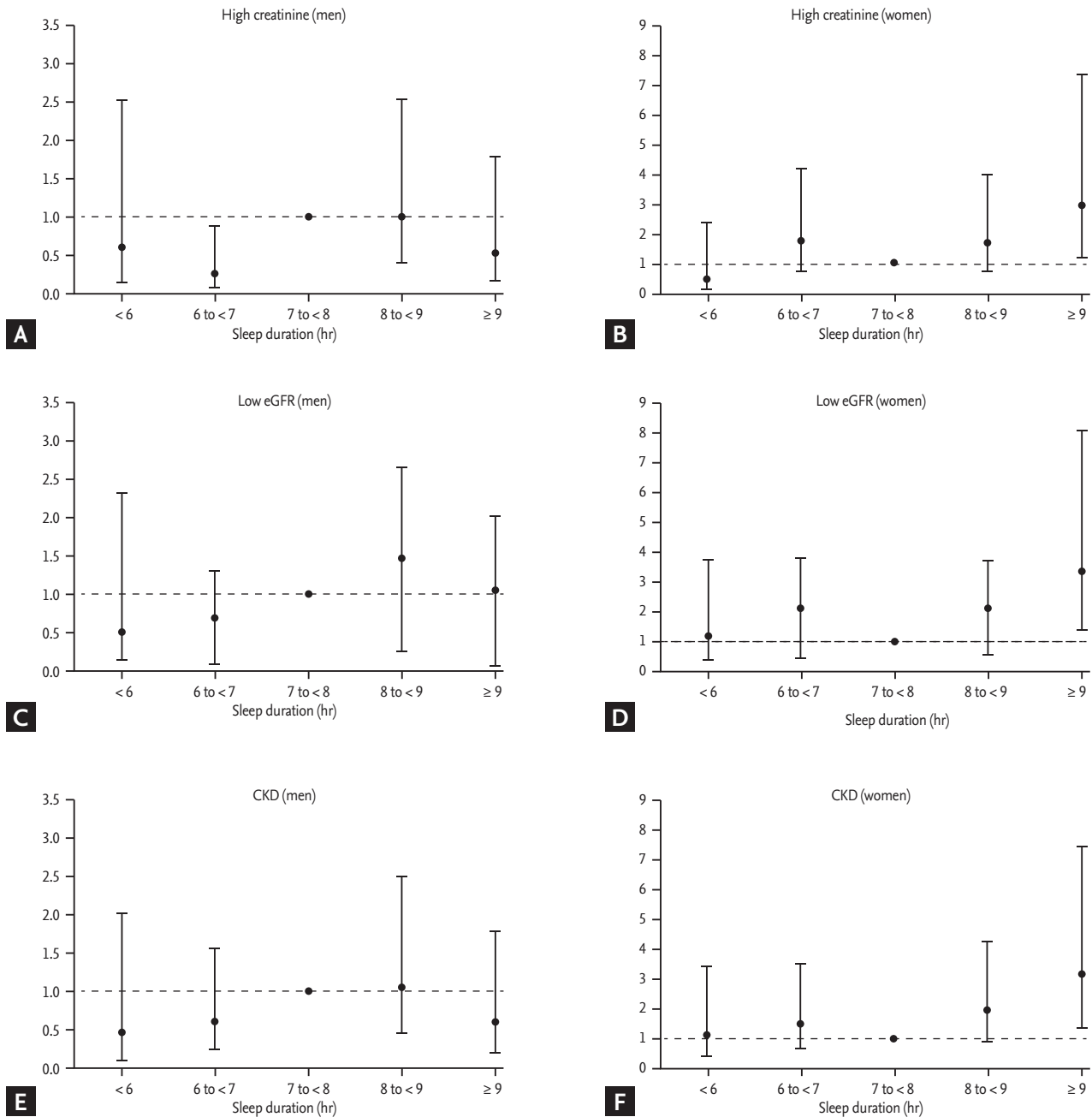
Figure 1. Association between sleep duration and chronic kidney disease (CKD). (A) Association between sleep duration and high creatinine in men. (B) Association between sleep duration and high creatinine in women. (C) Association between sleep duration and low estimated glomerular filtration rate (eGFR) in men. (D) Association between sleep duration and low eGFR in women. (E) Association between sleep duration and CKD in men. (F) Association between sleep duration and CKD in women. CKD was defined as the presence of at least one of the following factors: eGFR than 60 mL/min/1.73 m^2 or proteinuria. Adjusted model: adjusted for sex, age, body mass index, systolic blood pressure, smoking, alcohol, physical activity, diabetes mellitus, hypercholesterolemia, depression, history of cardiovascular disease, history of cancer, menopause, socioeconomic status (household income, marital status, and working status), and sleep quality (sleep difficulty, sleep awakeness, snoring, and sleep apnea).

the disease or inadequate treatment [34]. Finally, longer hours spent in bed lead to reduced physical activity and could induce a prothrombotic state [23]. Increased phys-

ical activity exerts a protective effect against CKD by reducing cardiometabolic risk factors [9,28]. In fact, an experimental study found that repeated exercise increased

Choi H, et al. Sleep duration and CKD

KJIM

GFR along with a reduction in renal mass in mice [35].

There are several limitations to this study that should be noted. As noted above, the main limitation of the present study relates to its causal relationship between the sleep duration and CKD cannot be confirmed due to the cross-sectional design of the study. Although we controlled for several potential confounders in our statistical models, residual confounding effects may have been present. Second, sleep habits were measured by a self-reported questionnaire and were not objectively confirmed. In future studies, objective measurements, including actigraphy and polysomnography to assess quality and quantity of sleep, would be needed. Third, we did not use 24-hour urinary albumin excretion, which is the gold standard test for assessing proteinuria. Instead, we measured proteinuria by a semiquantitative dipstick test, which has lower sensitivity and specificity, compared with urinary albumin test [23]. Finally, we did not exclude individuals who reported a history of chronic diseases, such as hypertension, diabetes mellitus, and cardiovascular disease, which may have influenced the results. Further longitudinal analyses are required to delineate the possible role of long sleep duration in CKD among Korean adults.

In summary, we suggest that very long sleep duration is associated with CKD in community-dwelling Korean women. Longitudinal analyses are required to clarify the roles of sleep quantity, as well as sleep quality, in maintaining and improving overall health among CKD patients. As sleep duration is a potentially modifiable risk factor, our results may help health advisors with preventing and delaying the progression of CKD.

KEY MESSAGE

1. Very long sleep duration (more than 9 hours) was significantly associated with chronic kidney disease (CKD) in community-dwelling Korean women.
2. Among women, for every one hour increase in sleep duration per day, there was a 24.6% increase in the presence of CKD.

Conflict of interest

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

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Supplementary Table 1. Prevalence of indicators of CKD in the study population (n = 1,360)

eGFR, mL/min/1.73 m²	No. (%)[a]	Proteinuria, n (%)[b]				CKD[d]	
		Unknown[c]	Negative[c]	Trace[c]	Positive (≥ 1+)[c]	Stage	No. (%)[c]
Total	1,360 (100.0)	7 (0.5)	1,296 (95.3)	42 (3.1)	15 (1.1)	All	125 (9.2)
≥ 90	105 (7.7)	0	101 (96.2)	3 (2.9)	1 (1.0)	1	1 (0.1)
60–89	1,140 (83.8)	3 (0.3)	1,098 (96.3)	30 (2.6)	9 (0.8)	2	9 (0.7)
30–59	111 (8.2)	2 (1.8)	95 (85.6)	9 (8.1)	5 (4.5)	3	111 (8.2)
15–29	0	0	0	0	0	4	0
< 15	4 (0.3)	2 (50.0)	2 (50.0)	0	0	5	4 (0.3)
Men	544 (100.0)	2 (0.4)	504 (92.6)	30 (5.5)	8 (1.5)	All	52 (9.6)
≥ 90	61 (11.2)	0	57 (93.4)	3 (4.9)	1 (1.6)	1	1 (0.2)
60–89	437 (80.3)	1 (0.2)	409 (93.6)	22 (5.0)	5 (1.1)	2	5 (0.9)
30–59	44 (8.1)	0	37 (84.1)	5 (11.4)	2 (4.5)	3	44 (8.1)
15–29	0	0	0	0	0	4	0
< 15	2 (0.4)	1 (50.0)	1 (50.0)	0	0	5	2 (0.4)
Women	816 (100.0)	5 (0.6)	792 (97.1)	12 (1.5)	7 (0.9)	All	73 (8.9)
≥ 90	44 (5.4)	0	44 (100.0)	0	0	1	0
60–89	703 (86.2)	2 (0.3)	689 (98.0)	8 (1.1)	4 (0.6)	2	4 (0.5)
30–59	67 (8.2)	2 (3.0)	58 (86.6)	4 (6.0)	3 (4.5)	3	67 (8.2)
15–29	0	0	0	0	0	4	0
< 15	2 (0.3)	1 (50.0)	1 (50.0)	0	0	5	2 (0.2)

CKD, chronic kidney disease; eGFR, estimated glomerular filtration rate.

[a]Number of participants across each kidney function category.

[b]Defined as proteinuria 1+ or more based on a dipstick urine test.

[c]Number of participants with corresponding indicators of CKD across each kidney function category.

[d]Defined as the presence of at least one of the following factors: eGFR less than 60 mL/min/1.73 m² or proteinuria.

Supplementary Table 2. Age-specific association between sleep duration and CKD criteria in men (n = 544)

Sleep duration	Unadjusted OR (95% CI)		Adjusted OR (95% CI)[a]	
	Age < 64 (n = 295)	Age ≥ 64 (n = 249)	Age < 64 (n = 295)	Age ≥ 64 (n = 249)
High creatinine				
Continuous, hr/day[b]	0.997 (0.629–1.581)	1.075 (0.791–1.461)	1.097 (0.646–1.863)	1.074 (0.747–1.545)
Categorical, hr/day				
< 7	0.754 (0.197–2.889)	0.376 (0.115–1.227)	0.336 (0.064–1.770)	0.333 (0.079–1.407)
7 to < 8	1.000	1.000	1.000	1.000
≥ 8	0.980 (0.255–3.771)	0.713 (0.297–1.712)	0.711 (0.137–3.696)	0.724 (0.233–2.246)
Low eGFR				
Continuous, hr/day[b]	1.135 (0.689–1.871)	1.086 (0.825–1.429)	1.330 (0.757–2.336)	1.134 (0.816–1.577)
Categorical, hr/day				
< 7	0.707 (0.154–3.239)	0.576 (0.218–1.523)	0.417 (0.074–2.336)	0.540 (0.150–1.937)
7 to < 8	1.000	1.000	1.000	1.000
≥ 8	1.238 (0.300–5.104)	0.782 (0.349–1.750)	1.129 (0.233–5.465)	0.860 (0.292–2.534)
CKD				
Continuous, hr/day[b]	1.083 (0.683–1.718)	1.095 (0.842–1.424)	1.259 (0.721–2.199)	1.075 (0.787–1.469)
Categorical, hr/day				
< 7	0.754 (0.197–2.889)	0.616 (0.244–1.558)	0.514 (0.105–2.522)	0.608 (0.186–1.988)
7 to < 8	1.000	1.000	1.000	1.000
≥ 8	0.980 (0.255–3.771)	0.841 (0.388–1.823)	0.921 (0.194–4.367)	0.799 (0.289–2.211)

CKD, chronic kidney disease; OR, odds ratio; CI, confidence interval; eGFR, estimated glomerular filtration rate.

[a]Adjusted model: adjusted for sex, age, body mass index, systolic blood pressure, smoking, alcohol, exercise, diabetes mellitus, hypercholesterolemia, depression, history of cardiovascular disease, history of cancer, menopause, socioeconomic status (household income, marital status, and working status), and sleep quality (sleep difficulty, sleep awakeness, snoring, and sleep apnea).

[b]Continuous model: association analysis on total sleep duration as a continuous variable.

Choi H, et al. Sleep duration and CKD

KJIM

Supplementary Table 3. Age-specific association between sleep duration and CKD criteria in women (n = 816)

Sleep duration	Unadjusted OR (95% CI)		Adjusted OR (95% CI)[a]	
	Age < 60 (n = 423)	Age ≥ 60 (n = 393)	Age < 60 (n = 423)	Age ≥ 60 (n = 393)
High creatinine				
Continuous, hr/day[b]	1.337 (0.899-1.988)	1.258 (0.995-1.592)	1.277 (0.837-1.946)	1.224 (0.932-1.607)
Categorical, hr/day				
< 7	0.938 (0.280-3.144)	2.076 (0.752-5.734)	0.796 (0.213-2.979)	2.121 (0.627-7.179)
7 to < 8	1.000	1.000	1.000	1.000
≥ 8	1.503 (0.492-4.590)	3.182 (1.256-8.059)	1.289 (0.376-4.416)	3.174 (1.030-9.785)
Low eGFR				
Continuous, hr/day[b]	1.461 (0.955-2.235)	1.197 (0.970-1.476)	1.469 (0.885-2.441)	1.184 (0.926-1.513)
Categorical, hr/day				
< 7	1.132 (0.278-4.615)	1.866 (0.789-4.413)	1.038 (0.221-4.879)	1.741 (0.627-4.832)
7 to < 8	1.000	1.000	1.000	1.000
≥ 8	2.284 (0.653-7.985)	2.587 (1.174-5.703)	2.181 (0.528-9.004)	2.597 (1.018-6.627)
CKD				
Continuous, hr/day[b]	1.479 (1.000-2.185)	1.210 (0.982-1.491)	1.581 (0.969-2.577)	1.205 (0.945-1.537)
Categorical, hr/day				
< 7	0.900 (0.237-3.420)	1.866 (0.789-4.413)	0.852 (0.196-3.704)	1.692 (0.613-4.673)
7 to < 8	1.000	1.000	1.000	1.000
≥ 8	2.374 (0.775-7.273)	2.697 (1.227-5.929)	2.471 (0.687-8.886)	2.699 (1.065-6.841)

CKD, chronic kidney disease; OR, odds ratio; CI, confidence interval; eGFR, estimated glomerular filtration rate.

[a]Adjusted model: adjusted for sex, age, body mass index, systolic blood pressure, smoking, alcohol, exercise, diabetes mellitus, hypercholesterolemia, depression, history of cardiovascular disease, history of cancer, menopause, socioeconomic status (household income, marital status, and working status), and sleep quality (sleep difficulty, sleep awakeness, snoring, and sleep apnea).

[b]Continuous model: association analysis on total sleep duration as a continuous variable.
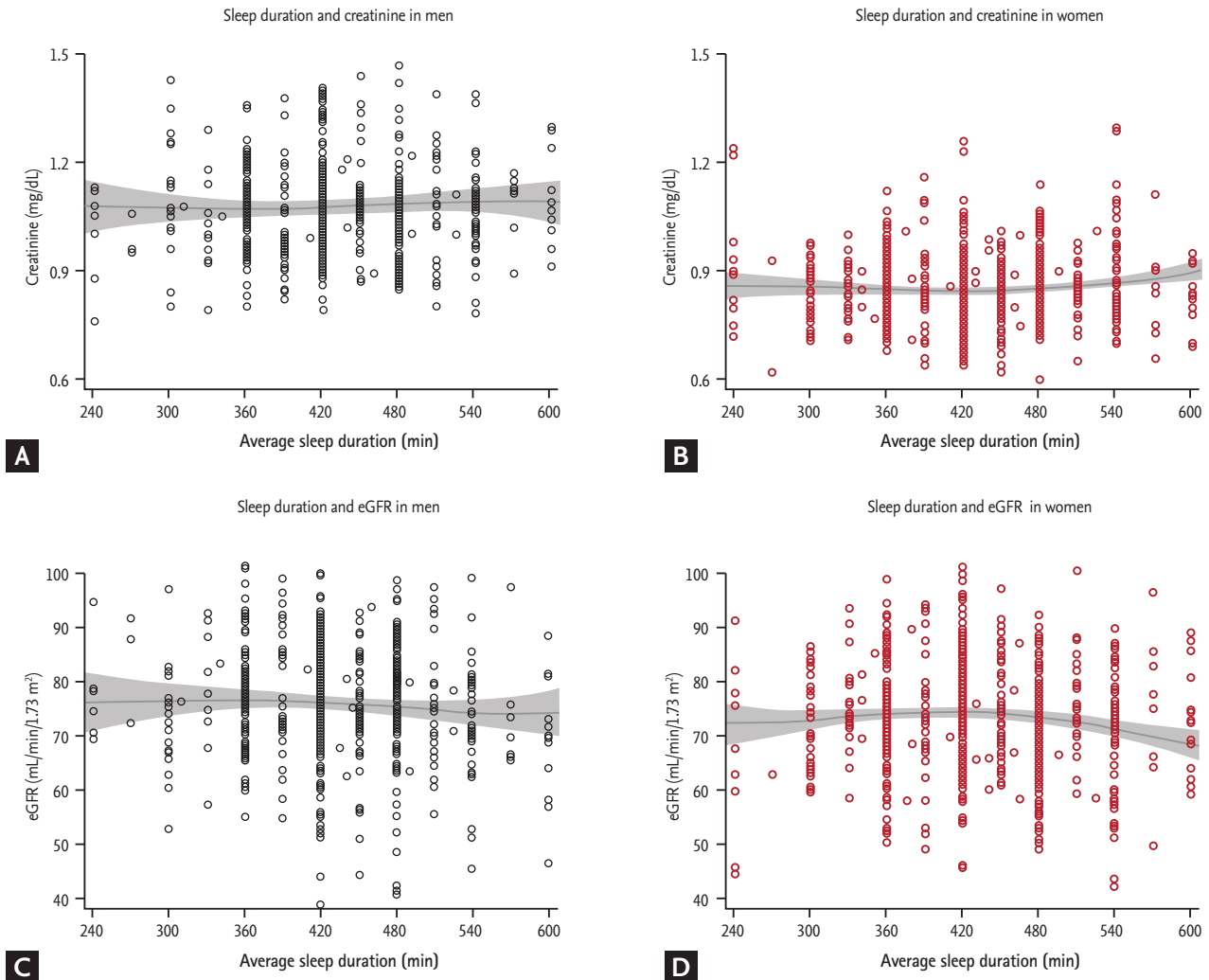
Supplementary Table 4. Association between sleep duration and CKD criteria after excluding hypertension, diabetes mellitus, and cardiovascular disease

Exclusion criteria	Total no.	No. (%)	OR, hr/day[a]	
			Unadjusted OR (95% CI)	Adjusted OR (95% CI)[b]
High creatinine				
Hypertension				
Men	332	14 (4.2)	1.186 (0.770–1.829)	1.345 (0.764–2.370)
Women	512	16 (3.1)	1.196 (0.792–1.806)	1.246 (0.697–2.228)
Diabetes mellitus				
Men	460	34 (7.4)	1.168 (0.882–1.547)	1.154 (0.837–1.591)
Women	735	46 (6.3)	1.239 (0.979–1.569)	1.127 (0.880–1.444)
Cardiovascular disease				
Men	485	31 (6.4)	0.996 (0.751–1.321)	1.012 (0.745–1.373)
Women	772	49 (6.4)	1.289 (1.029–1.614)	1.264 (1.004–1.592)
Low eGFR				
Hypertension				
Men	332	16 (4.8)	1.076 (0.716–1.618)	1.172 (0.686–2.004)
Women	512	17 (3.3)	1.249 (0.838–1.860)	1.285 (0.701–2.357)
Diabetes mellitus				
Men	460	37 (8.0)	1.178 (0.899–1.544)	1.184 (0.867–1.617)
Women	735	55 (7.5)	1.239 (0.997–1.540)	1.110 (0.883–1.397)
Cardiovascular disease				
Men	485	34 (7.0)	1.117 (0.853–1.462)	1.129 (0.845–1.508)
Women	772	57 (7.4)	1.247 (1.010–1.539)	1.213 (0.975–1.509)
Low CKD				
Hypertension				
Men	332	18 (5.4)	1.119 (0.761–1.645)	1.127 (0.705–1.800)
Women	512	18 (3.5)	1.224 (0.829–1.805)	1.267 (0.720–2.229)
Diabetes mellitus				
Men	460	39 (8.5)	1.153 (0.885–1.501)	1.136 (0.836–1.545)
Women	735	58 (7.9)	1.248 (1.009–1.543)	1.144 (0.913–1.432)
Cardiovascular disease				
Men	485	38 (7.8)	1.083 (0.838–1.399)	1.064 (0.807–1.402)
Women	772	61 (7.9)	1.269 (1.035–1.557)	1.237 (1.000–1.530)

CKD, chronic kidney disease; OR, odds ratio; CI, confidence interval; eGFR, estimated glomerular filtration rate.

[a]Continuous model: association analysis on total sleep duration as a continuous variable.

[b]Adjusted model: adjusted for sex, age, body mass index, systolic blood pressure, smoking, alcohol, exercise, diabetes mellitus, hypercholesterolemia, depression, history of cancer, menopause, socioeconomic status (household income, marital status, and working status), and sleep quality (sleep difficulty, sleep awakeness, snoring, and sleep apnea).

Supplementary Figure 1. Cubic spline functions of the association between average sleep duration and kidney function according to sex. (A) Cubic spline functions of the association between average sleep duration and creatinine in men. (B) Cubic spline functions of the association between average sleep duration and creatinine in women. (C) Cubic spline functions of the association between average sleep duration and estimated glomerular filtration rate (eGFR) in men. (D) Cubic spline functions of the association between average sleep duration and eGFR in women. The shadowed areas represent 95% confidence intervals for the fitted splines. The solid line is a restricted cubic spline. The black dots represent men and the red dots women.