



Title	Short sleep duration increases the risk of chronic kidney disease in shift workers
Author(s)	Sasaki, Sachiko; Yoshioka, Eiji; Saijo, Yasuaki; Kita, Toshiko; Tamakoshi, Akiko; Kishi, Reiko
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1 **Abstract**

2 *Objective:* To investigate the association of sleep duration and shift work with
3 development of chronic kidney disease (CKD) in Japanese workers.

4 *Methods:* A total of 3600 participants without CKD were followed for an average of 4.4
5 years. The Cox proportional-hazards regression model was used to estimate hazard
6 ratios (HRs) and 95% confidence intervals (CIs) of the risk of CKD associated with
7 sleep duration and shift work.

8 *Results:* Sleep duration and shift work showed no significant association with the risk of
9 CKD. However, when the results were stratified by shift work status, short sleep
10 duration was associated with a significantly higher risk of CKD among shift workers
11 (HR = 3.60; 95% CI: 1.52–10.68).

12 *Conclusions:* Short sleep duration was a risk factor for early CKD but only among shift
13 workers.

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1 **Introduction**

2 Chronic kidney disease (CKD) has become a public health concern worldwide because
3 of its association with an increased prevalence of end-stage renal disease (ESRD) ¹⁻³. In
4 addition, several epidemiological observations and clinical studies have documented a
5 strong association between CKD and accelerated cardiovascular disease (CVD),
6 resulting in increased morbidity and mortality ^{1,4}. Recent studies have confirmed that
7 even the earlier stage of CKD constitutes a significant risk factor for cardiovascular
8 events and death ^{5,6}; however, CKD is asymptomatic in its earlier stages. Therefore, to
9 slow the progression of CKD, it is essential to develop better strategies for early
10 detection and intervention using modifiable lifestyle factors.

11 It is widely accepted that sleep is an essential part of a healthy lifestyle; however,
12 approximately 20% of the adult population in western countries and Japan experiences
13 sleep disturbances ^{7,8}. In addition, growing evidence indicates that short sleep duration
14 is associated with an increased risk of mortality ^{9,10}, CVD ¹¹⁻¹⁴, hypertension ^{15,16}, and
15 metabolic disorders such as type 2 diabetes mellitus ^{17,18}, insulin resistance ¹⁹, and
16 obesity ²⁰. However, research on the impact of sleep disturbances on earlier stages of
17 CKD is limited. Although a previous retrospective study suggested that short sleep
18 duration may be a modifiable risk factor for proteinuria ²¹, which is an important risk

1 factor for ESRD, it remains unclear whether sleep duration is a predictive factor for
2 CKD.

3 With the rapid progress of a 24-hour-a-day society, shift work and related health
4 problems have become common ^{22,23}. Epidemiological studies have reported that shift
5 workers are at a significantly increased risk of developing several vascular events,
6 including ischemic stroke ²⁴, ischemic heart disease ²⁵, type 2 diabetes ²⁶, and metabolic
7 syndrome ²⁷. A previous cross-sectional study reported that an association of night shift
8 work with decreased renal function in police officers ²⁸. However, to the best of our
9 knowledge, no prospective study has reported an association between shift work and
10 risk of CKD. In addition, shift workers are known to sleep less than day
11 workers ²². Recent reviews focused on the potential health effects of shift work
12 suggested that sleep disturbances induced by shift work contribute to development of
13 CVD and metabolic disorders ^{29,30}. However, there is no study focusing on the effect of
14 shift work in relation to sleep duration and CKD. Therefore, in the present study, we
15 examined the association of sleep duration and shift work with CKD among Japanese
16 civil servants. We also assessed whether shift work acts as an effect modifier in the
17 association between sleep duration and incident CKD.

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1 **Methods**

2 Study design and population

3 This prospective occupational study was conducted in Sapporo, Hokkaido Prefecture,
4 Japan. A total of 10,423 local government employees aged 35–62 years who underwent
5 annual health check-ups between April 2003 and March 2004 were contacted. Of these,
6 5,013 (response rate = 48.1%) returned a self-administered questionnaire after
7 completing the check-up. The questionnaire included questions regarding sleep duration,
8 medical history, family history, smoking, alcohol consumption, exercise frequency,
9 educational background, and occupational factors. A total of 1,203 participants were
10 excluded on account of the following reasons: those aged ≥ 59 years, because they were
11 due for retirement during the follow-up period ($n = 156$); those for whom data on
12 exposure or relevant covariates was missing ($n = 231$); those under medical treatment
13 for hypertension, diabetes mellitus, dyslipidemia, or renal disease ($n = 665$); or those
14 with a history of coronary disease or stroke ($n = 71$). In order to examine the predictors
15 of earlier stages of kidney disease, those with a baseline estimated glomerular filtration
16 rate (eGFR) of <60 mL/min/1.73 m² (calculated by the simplified Japanese GFR
17 inference formula equation ³¹) were also excluded ($n = 80$). Follow-up annual health
18 check-ups took place from 2004 to 2008. After excluding 210 (5.5%) participants who

1 never received check-ups even once during the follow-up periods, a total of 3600
2 participants (2798 men and 802 women) were included for longitudinal analysis. All
3 participants provided written informed consent, and the study protocol was approved by
4 the institutional ethical board for epidemiological studies of Hokkaido University
5 Graduate School of Medicine.

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7 Assessment of sleep duration and shift work

8 Information on sleep was obtained from the self-administered questionnaire. Sleep
9 duration was assessed by the question “On average, how long, in hours and minutes, do
10 you normally sleep?” The responses were then categorized into ≤ 5 h, 6-7 h, and ≥ 8 h,
11 because previous studies have suggested that individuals with a sleep duration of ≤ 5 h
12 are at a significantly higher risk of proteinuria ²¹, whereas those with a sleep duration of
13 6–7 h are at the lowest risk of cardiometabolic disease ³². Because of the small number
14 of participants, we chose to combine participants with a sleep duration of 8h and ≥ 9 h
15 into a single group (≥ 8 h).

16 Information regarding shift work was collected from the self-administered
17 questionnaires at baseline, which included the following question: “Do you work in
18 shifts?” The possible responses were “Yes, without night shifts,” “Yes, with night shifts,”

1 or “No.” Night shift was defined as work schedule from 22:00 to 05:00. Because the
2 number of participants without night shifts was small, we categorized shift work into 2
3 categories: “Yes” and “No.”

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5 Assessment of renal function and follow-up

6 Creatinine levels were measured using an enzymatic assay (Kanto Kagaku, Tokyo,
7 Japan). Kidney function was assessed in terms of eGFR, which was calculated using the
8 simplified Japanese GFR inference formula developed by the Japanese Society of
9 Nephrology³¹: $GFR (mL/min/1.73 m^2) = 194 \times \text{serum creatinine (mg/dL)}^{-1.094} \times \text{age}^{-0.287}$
10 ($\times 0.739$ if female). Onset of CKD was defined as an eGFR of $<60 mL/min/1.73 m^2$
11 after the first health check-up and confirmed annually. For participants who had more
12 than one CKD event during the follow-up period, only the first event was included for
13 statistical analyses. The date of onset of CKD was defined as the intermediate day
14 between the first CKD event and the last eGFR measurement.

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16 Assessment of covariates

17 Anthropometric measurements (height and body weight) at the health check-ups were
18 assessed using a standardized protocol. Body mass index (BMI) was calculated as

1 weight/height (kg/m^2). Systolic and diastolic blood pressure (SBP and DBP,
2 respectively) was measured using an automated sphygmomanometer (USM-700G Si;
3 Ueda Avancer Corp., Tokyo, Japan) placed on the arm of a seated participant who had
4 rested in the sitting position for a few minutes before measurement. Blood samples were
5 drawn after a 12-h fast from the antecubital vein of seated participants with minimal
6 tourniquet use. Specimens were collected in siliconized glass vacuum tubes containing
7 sodium fluoride for analysis of blood glucose levels, which were measured by an
8 amperometric method (Arkray, Kyoto, Japan). Enzymatic assays were used to measure
9 levels of total cholesterol (TC) (Wako, Osaka, Japan), triglycerides (TG) (Daiichi Pure
10 Chemicals, Tokyo, Japan), and uric acid (UA) (Daiichi Pure Chemicals, Tokyo, Japan).
11 C-reactive protein (CRP) levels were measured by nephelometry with a latex
12 particle-enhanced immunoassay (N Latex CRP II ; Dade Behring, Tokyo, Japan),
13 which could detect 0.004 mg/dL of CRP. Undetectable CRP values were recorded as
14 0.002 mg/dL. Urine dipstick tests were interpreted and categorized as negative or $\geq 1+$.

15 Educational background was categorized as “high school or less” or “more than high
16 school.” Frequency of leisure time exercise (with perspiration) was categorized as
17 “rarely or never,” “1–2 times/week,” or “ ≥ 3 times/week.” Smoking status was
18 categorized as “non-smoker” (never smoked), “ex-smoker,” or “current smoker.” The

1 average daily alcohol consumption, based on the alcohol concentration of each beverage
2 type (g/day, ethanol equivalent), was estimated according to the frequency and amount
3 of consumption and was categorized into the following 4 categories: non-drinkers, <30
4 g/day, 30–59 g/day, and ≥ 60 g/day. Working hours were calculated as the average
5 number of working hours, including overtime, per week during the previous month.
6 Occupational stress was assessed using the demand–control model (DCM)^{33, 34}. The
7 Japanese version of the DCM consists of 5 questions on psychological demands (job
8 demands, time pressures, and conflicting demands) and 6 questions on decision latitude
9 (influence or control over work, job variety, and opportunities for learning new skills).
10 Each question has 4 frequency-based response categories ranging from “never” (1
11 point) to “always” (4 points). Job strain was defined as the ratio of demand to job
12 control³⁴.

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14 Statistical analysis

15 The Cox proportional-hazards model was used to estimate hazard ratios (HRs) and
16 95% confidence intervals (CIs) of the risk of CKD associated with sleep duration and
17 shift work using the following 2 models: (1) adjusted for age, sex, and eGFR at baseline
18 and (2) adjusted for model 1 variables plus SBP, BMI, TC, TG, fasting glucose, UA,

1 CRP, proteinuria $\geq 1+$, family history of renal disease, lifestyle factors (smoking,
2 exercise, and alcohol consumption), educational background, working hours, and job
3 strain. In addition, to assess whether the association between sleep duration and CKD
4 was modified by shift work, we stratified the analyses by shift work.

5 All analyses were performed using JMP software version 10.0.0 for Windows (SAS
6 Institute, Cary, NC, USA). A two-tailed probability (*P*) value of <0.05 was considered
7 statistically significant.

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1 **Results**

2 Over an average follow-up period of 4.4 years, a total of 182 cases of CKD (148 in
3 men and 34 in women) were identified. The mean age of the study cohort was $47.0 \pm$
4 6.7 years. Mean eGFR and sleep duration at baseline were 84.3 ± 13.1 mL/min/1.73 m²
5 and 6.6 ± 0.9 h, respectively. Baseline characteristics according to sleep duration
6 categories are presented in Table 1. Compared with participants reporting a sleep
7 duration of 6–7 h, those with a sleep duration of ≤ 5 h and ≥ 8 h were more likely to be
8 shift workers. Short sleep duration was associated with younger age; female gender;
9 lower SBP, DBP, TG, fasting glucose, UA, and CRP levels; higher possibility of being
10 non-smoker and non-drinker; more exercise; higher levels of education; longer working
11 hours; and higher job strain. Table 2 shows baseline characteristics according to shift
12 work. Compared with participants without shift work, those with shift work were more
13 likely to be young, males, non-smokers and non-drinkers, less educated, and engaged in
14 more exercise, with longer working hours, and higher job strain.

15 The results of longitudinal multivariate analyses using Cox proportional hazards
16 models to examine the impact of sleep duration and shift work on CKD are presented in
17 Table 3. Neither sleep duration nor shift work was associated with the risk of CKD. The
18 results of stratification by shift work are presented in Table 4. In model 1, compared

1 with participants reporting a sleep duration of 6–7 h, those reporting a sleep duration \leq 5
2 h had a significantly increased risk of CKD among shift workers (HR = 3.60; 95% CI =
3 1.38–8.41); in contrast, no association was observed among non-shift workers (HR
4 =0.52; 95% CI = 0.20–1.12). After adjustment for potential confounders, a significant
5 association between short sleep duration and CKD was confined to shift workers (HR =
6 4.22; 95% CI = 1.52–10.68).

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1 **Discussion**

2 The results of the present study showed no significant association of sleep duration
3 and shift work with the risk of CKD. However, short sleep duration was associated with
4 a significantly higher risk of CKD in shift workers but not in non-shift workers.

5 Only few studies have examined the effects of sleep duration on earlier stages of CKD
6 ^{21, 35}. Previous studies have indicated an association between sleep duration of ≤ 5 h and
7 proteinuria, even among non-shift workers. In contrast to the results of these previous
8 studies, a significant association between short sleep duration and CKD was confined to
9 shift workers in the present study. There are several possible explanations for this
10 disparity. The first is the difference in the distribution of sleep duration.
11 Compared with previous studies ²¹, the participants in our study reported a
12 longer average sleep duration, with only a small proportion of participants
13 reporting a short sleep duration; this possibly reduce the effect of sleep
14 duration on the incidence of CKD. The second reason is that the definition of
15 CKD was based on eGFR, which could be affected by several factors, including muscle
16 mass and protein intake ³¹. In addition, eGFR can decrease regardless of the presence of
17 renal disorders ³⁶. Previous studies have assessed proteinuria using dipstick tests.
18 Proteinuria is a useful marker of decreased renal function and rapid progression of

1 kidney damage³⁷; however, the dipstick urine test for proteinuria has low sensitivity³⁸.
2 In the present study, we used eGFR to quantitatively evaluate renal dysfunction. This
3 difference in the definition of CKD may have influenced these conflicting
4 results.

5 Our results indicated that shift work acted as an effect modifier in the association
6 between sleep duration and CKD. Epidemiological studies have reported that shortened
7 sleep duration is the most common health-related problem of shift work and most shift
8 workers suffer from disruptions in circadian rhythms^{22, 23}. Recent reviews have
9 hypothesized that sleep disturbances induced by shift work contribute to the
10 development of CVD and other metabolic disorders^{29, 39}. Some prospective studies
11 have investigated the impact of shift work on the association between sleep duration and
12 health outcomes; however, the results have been conflicting^{15, 40}. For example, the
13 Nurses' Health Study investigated the effects of short sleep duration on hypertension
14 and found that shift work did not act as an effect modifier¹⁵, whereas another study
15 indicated that shift work enhanced the association between short sleep duration and
16 obesity⁴⁰. It is not clear why the conflicting results were found, but they may be related
17 to differences in the methods used for assessment of outcomes or participants. Shift
18 work is related not only to insufficient sleep, but also to lifestyle factors and job strain⁴¹,

1 ⁴². In the present study, we considered these factors and found that the risk of CKD in
2 shift workers with short sleep duration was significantly increased even after adjusting
3 for lifestyle factors such as smoking status, alcohol consumption, exercise, and job
4 strain. Our results indicated that the interaction of shift work and short sleep duration
5 may promote the development of CKD. Because this is the first study to investigate the
6 association of risk for CKD with sleep duration and shift work, more studies are needed
7 to confirm or refute these findings.

8 The possible reasons for the increased risk of CKD in shift workers with short sleep
9 duration remain unknown. Shift work has been shown to disrupt circadian rhythms ⁴³.
10 Experimental data have suggested a role of altered circadian organization in the
11 development of severe renal diseases, such as proteinuria, tubular dilation, and cellular
12 apoptosis ⁴⁴. It is possible that disturbances in circadian rhythms induced by shift work
13 may enhance the association between sleep duration and CKD. In addition, it has also
14 been proposed that shift work could result in stress ⁴⁵, leading to metabolic disturbances
15 that involve increased secretion of glucocorticoids and catecholamines as well as
16 activation of the sympathetic nervous system ⁴⁶. It is possible that these factors may
17 increase the progression of renal dysfunction.

18 The pathophysiology of sleep duration and the underlying mechanisms of association

1 with CKD remain unknown. A plausible biological mechanism is activation of the
2 sympathetic nervous system. Disturbed sleep induces activation of the sympathetic
3 nervous system, higher evening cortisol levels, and attenuation of the sleep-induced
4 decrease in blood pressure (referred to as non-dipping), which could lead to kidney
5 dysfunction ⁴⁷⁻⁵⁰. A previous prospective study also indicated non-dipping as a risk
6 factor for decreased renal function among non-CKD patients ⁵¹. In addition,
7 mechanisms that promote inflammation could possibly mediate the link between short
8 sleep duration and renal dysfunction ^{52, 53}. However, in the present study, levels of CRP,
9 marker of inflammation were not associated with a higher risk of CKD. Another
10 possible mechanism is objective sleep apnea (OSA). A limited small study suggested
11 that OSA influences renal hemodynamics ⁵⁴ and that treatment with continuous positive
12 airway pressure improves this effect ⁵⁵. However, further research is necessary to better
13 elucidate the association between sleep disturbance and CKD.

14 The strengths of our study include its prospective design and detailed information on
15 potential confounders. However, this study had some limitations as well. First, our sleep
16 duration measure relied on a self-administered questionnaire, which could be
17 susceptible to misclassification, particularly with respect to sleep duration on weekends.
18 The daily average sleep duration of Japanese workers is reportedly 7 h on weekdays, 7.5

1 h on Saturdays, and 8 h on Sundays ⁵⁶. The differences in sleep duration between
2 weekdays and weekends may have influenced the results of our study. In addition, sleep
3 duration was only evaluated once at the beginning of the follow-up period; therefore,
4 we could not examine the possible effects of time-dependent changes in sleeping habits.
5 Assessment of self-reported exposures may result in some misclassification. However,
6 in many similar epidemiological studies, a self-reported measure was used to assess
7 sleep duration and shift work. Moreover, because the outcome was assessed
8 prospectively using blood samples, any misclassification is likely to be non-differential
9 with respect to CKD. Second, we did not have any information on whether workers
10 were engaged in fixed or rotating shift work. One previous study reported that fixed
11 shift work (working mainly at night and the same time every day) was not associated
12 with ischemic heart disease ²⁵. Further research is needed to assess the effect of patterns
13 of shift work. ~~However, we were unable to assess the effect of fixed shift work~~
14 ~~because rotating shifts are common among Japanese civil servants.~~ Third, the outcome
15 variable of serum creatinine levels was measured once a year and we used eGFR to
16 define CKD without measurement of urinary albumin excretion. However, annual
17 health examinations are common in Japan and this approach has been used in several
18 previous studies ^{57, 58}. Fourth, the response rate of our study was rather low (48.1%), so

1 our participants may not necessarily be representative of civil servants in general in
2 Japan. However, because the average sleep duration in our study did not differ from that
3 of middle-aged Japanese people in general ⁵⁶, we believe that our results are minimally
4 affected by the low response rate. In addition, only 5% of participants were lost to
5 follow-up, which strengthens our findings.

6 In conclusion, short sleep duration was significantly associated with an increased risk
7 of CKD in shift workers. Additional large prospective studies are needed to confirm this
8 finding and to investigate the possible biological mechanisms underlying this
9 association.

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Table 1. Association of demographic and clinical characteristics with sleep duration at baseline

	Baseline Sleep Duration		
	≤5 h (n = 295)	6–7 h (n = 2619)	≥8 h (n = 686)
Shift work			
No	196 (66.4)	2033 (77.6)	495 (72.2)
Yes	99 (33.6)	586 (22.4)	191 (27.8)
Age	44.9 ± 6.8	47.0 ± 6.4	48.3 ± 6.4
Sex (male)	198 (67.1)	2001 (76.4)	599 (87.3)
SBP (mmHg)	112.7 ± 15.1	115.5 ± 15.6	117.8 ± 15.8
DBP (mmHg)	68.4 ± 10.2	71.0 ± 11.3	73.1 ± 11.1
BMI	23.1 ± 3.3	23.3 ± 3.0	23.3 ± 2.9
Total cholesterol (mg/dL)	206.3 ± 33.2	207.4 ± 32.2	208.8 ± 35.4
Triglyceride (mg/dL) ^a	92.1 (86.2–98.4)	95.2 (93.2–97.2)	103.4 (99.2–108.0)
Fasting glucose (mg/dL)	90.3 ± 11.9	92.1 ± 15.7	94.2 ± 18.0
Uric acid (mg/dL)	5.4 ± 1.2	5.5 ± 1.3	5.7 ± 1.2
CRP (mg/dL) ^a	0.037 (0.032–0.042)	0.040 (0.039–0.042)	0.042 (0.039–0.046)
eGFR (mL/min/1.73 m ²)	86.0 ± 14.5	84.1 ± 12.8	84.1 ± 13.2
Proteinuria			
≥1+	4 (1.4)	34 (1.3)	16 (2.3)
Family history of renal disease	7 (2.4)	77 (2.4)	18 (2.6)
Frequency of exercise			
Rarely or never	169 (57.5)	1533 (58.6)	355 (51.8)
1-2 times/week	71 (24.2)	722 (27.6)	214 (31.2)
3 times/week or more	54 (18.3)	361 (13.8)	117 (17.0)
Smoking status			
Non-smoker	108 (36.6)	906 (34.6)	170 (24.8)
Ex-smoker	43 (14.6)	582 (22.2)	185 (27.0)
Current	144 (48.8)	1131 (43.2)	331 (48.2)
Alcohol consumption (g/day)			
Non-drinker	103 (35.8)	813 (31.2)	184 (26.9)
1-29	119 (40.6)	957 (36.7)	197 (28.8)
30-59	36 (12.3)	498 (19.1)	168 (24.6)
≥60	33 (11.3)	338 (13.0)	135 (19.7)
Educational background			
high school or less	141 (47.8)	1393 (53.2)	427 (62.2)
more than high school	154 (52.2)	1266 (46.8)	259 (37.8)
Working hours (h/week)	49.7 ± 11.6	44.9 ± 8.2	43.6 ± 7.2
Job strain			
Low	68 (23.1)	851 (32.7)	259 (38.0)
Medium	93 (31.6)	890 (34.2)	216 (31.7)
High	133 (45.3)	863 (33.1)	207 (30.3)

Variables are presented as mean ± standard deviation (SD), geometric mean (interquartile range), or number (percentage).

^a Log-transformed data were analyzed, and median (interquartile range) were back-transformed.

Abbreviation: SBP, systolic blood pressure; DBP, diastolic blood pressure; BMI, body mass index; CRP, C-reactive protein; eGFR, estimated glomerular filtration rate

Table 2. Association of demographic and clinical characteristics with shift work at baseline

	Non-shift worker (n =2724)	Shift worker (n = 876)
Age	47.4 ± 6.6	46.1 ± 6.5
Sex (male)	2063 (75.7)	735 (83.9)
SBP (mmHg)	115.3 ± 15.8	116.9 ± 15.0
DBP (mmHg)	71.0 ± 11.3	71.7 ± 11.1
BMI	23.1 ± 2.9	23.6 ± 3.2
Total cholesterol (mg/dL)	208.4 ± 33.2	205.1 ± 32.5
Triglyceride (mg/dL) ^a	92.5 (65.0–137.0)	98.0 (67.2–145.7)
Fasting glucose (mg/dL)	92.5 ± 16.7	91.7 ± 13.1
Uric acid (mg/dL)	5.5 ± 1.2	5.6 ± 1.3
CRP (mg/dL) ^a	0.036 (0.019–0.073)	0.041 (0.020–0.086)
eGFR (mL/min/1.73 m ²)	84.0 ± 13.1	85.1 ± 13.0
Proteinuria		
≥1+	40 (1.5)	14 (1.6)
Family history of renal disease	83 (3.1)	19 (2.2)
Frequency of exercise		
Rarely or never	1620 (59.5)	437 (50.0)
1-2 times/week	756 (27.8)	251 (28.7)
3 times/week or more	346 (12.7)	186 (21.3)
Smoking status		
Non-smoker	983 (36.1)	201 (23.0)
Ex-smoker	1136 (41.7)	470 (53.6)
Current	605 (22.2)	205 (23.4)
Alcohol consumption (g/day)		
Non-drinker	389 (14.3)	117 (13.4)
1-29	514 (19.0)	188 (21.5)
30-59	954 (35.2)	319 (36.6)
≥60	853 (31.5)	249 (28.5)
Educational background		
high school or less	1344 (49.3)	617 (70.4)
more than high school	1380 (50.7)	259 (29.6)
Working hours (h/week)	43.8 ± 7.2	48.8 ± 10.9
Job strain		
Low	945 (34.8)	233 (26.9)
Medium	927 (34.2)	272 (31.4)
High	841 (31.0)	362 (41.7)

Variables are presented as mean ± standard deviation (SD), geometric mean (interquartile range), or number (percentage).

^aLog-transformed data were analyzed, and median (interquartile range) were back-transformed.

Table 3. HR (95% CI) for incidence of CKD (eGFR <60 mL/min/1.73 m²) according to sleep duration and shift work

	Person-years	No. of cases	Model 1	Model 2
Sleep Duration				
≥8 h	2,948	37	1.00 (0.68–1.43)	1.06 (0.72–1.54)
6–7 h	11,699	131	1.00	1.00
≤5 h	1,343	14	1.01 (0.52–1.85)	0.99 (0.53–1.73)
Shift work				
(–)	11,993	146	1.00	1.00
(+)	3,997	36	0.96 (0.66–1.38)	1.01 (0.67–1.50)

Model 1: age, sex, and eGFR at baseline

Model 2: Model1 + SBP, BMI, TC, TG, fasting glucose, UA, CRP, proteinuria ≥ 1+, family history of renal disease, smoking, alcohol, exercise, education, work hours, and job strain

Table 4. HR (95% CI) for incidence of CKD (eGFR <60 mL/min/1.73 m²) according to sleep duration stratified by shift work

	Person-years	No. of cases	Model 1	Model 2
Non-shift worker				
≥8 h	2,108	28	0.86 (0.55–1.29)	0.95 (0.60–1.45)
6–7 h	8,918	111	1.00	1.00
≤5 h	904	7	0.58 (0.24–1.17)	0.52 (0.20–1.12)
Shift worker				
≥8 h	840	9	1.69 (0.72–3.71)	1.77 (0.70–4.29)
6–7 h	2,718	20	1.00	1.00
≤5 h	439	7	3.60 (1.38–8.41)	4.22 (1.52–10.68)

Model 1: age, sex, and eGFR at baseline

Model 2: Model1 + SBP, BMI, TC, TG, fasting glucose, UA, CRP, proteinuria ≥ 1+, family history of renal disease, smoking, alcohol, exercise, education, work hours, and job strain