Rotating night shift work, exposure to light at night, and glomerular filtration rate: baseline results from a Chinese occupational cohort

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Research

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Abstract

Background The misalignment between the circadian clock and behavioral cycles has been implicated in pathogenesis of many diseases. However, whether the kidneys are also more prone to disease in the circumstances of chronic circadian rhythms disruption due to night shift work and light at night (LAN) is unclear. The main purpose of this study is to examine the association between rotating night shift work, exposure to light at night, and glomerular filtration rate among steelworkers in north China.

Methods A total of 6869 participants, aged 22 to 60 years, were included in this study. Multivariable logistic regression was used to examine the association between night shift work, the brightness of bedroom ambient light at night (LAN), and estimated glomerular filtration rate (eGFR) with adjustment for potential confounders. The relationship between duration of night shift work (continuous), cumulative number of night shifts (continuous), and eGFR were also examined using restricted cubic spline models.

Results Long duration of night shift work (≥29 years) had elevated odds of decreased eGFR (OR, 1.39, 95% CI 1.10–1.75) compared with day work after adjustment for potential confounders. Negative associations between duration of night shift work, cumulative number of night shifts, and eGFR (mL/min/1.73 m 2) were observed in RCS models. No significant associations were observed among the different brightness of bedroom ambient light levels: middle level (OR, 0.90, 95% CI 0.77–1.05), lightest level (OR, 0.94, 95% CI 0.75–1.17), and decreased eGFR compared with the darkest level.

Conclusion The increased duration of night shift work and cumulative number of night shifts among night shift workers, but not the brightness of bedroom ambient LAN, are associated with a slight decline of renal function among steelworkers.

Introduction

To maximize economic and societal benefit, modern society is depended on a 24 hours schedule. In this circumstance, rotating night shift work and exposure to artificial light at night (ALAN) have become commonplace, even though its negative impact on health has been shown in a considerable body of evidence from epidemiological and experimental studies [1]. Approximately 20% of workers in industry countries are engaged in a shift work schedule [2]. In addition to the night shift work, which inevitably exposes workers to LAN during their working hours, ALAN in the daily life has become a widespread environmental pollutant. It is estimated that 23% of the land surface experienced ALAN [3], and this exposure is increasing about 6% per year [4]. Moreover, the trend of exposure to night shift work and LAN parallels the increase in the percentage of patients with chronic kidney disease in China [5].

Several renal functions, including glomerular filtration rate, have circadian rhythms [6, 7]. Since the mid-19th century, circadian rhythms of most renal functions have been published [6]. The discovery of its molecular mechanism, circadian clock, which has been recognized with the awarding of the Nobel Prize in Physiology and Medicine in 2017, has rendered the study of renal circadian to a new era [8]. Misalignment between behavioral, such as altered meal timing and sleep displacement, and molecular

circadian clocks due to night shift work may increase the risk of type 2 diabetes [9, 10], obesity [11] and cardiovascular disease [12]. Moreover, according to the latest evaluation of the carcinogenicity of night shift work in 2019, the International Agency for Research on Cancer (IARC) has classified night shift work in Group 2A, “probably carcinogenic to humans”, based on limited evidence of cancer in humans, sufficient evidence of cancer in experimental animals, and strong mechanistic evidence in experimental animals [13]. Furthermore, asynchrony between circadian clocks and external world light/dark cycle due to LAN has associated with breast and prostate cancer [14], metabolic dysfunction [15] and cardiovascular disease [16]. However, whether the chronic disruption of circadian rhythms due to LAN and night shift work is responsible for the development of kidney disease remains unclear. To the best of our knowledge, there is currently no other study to examine the relationship between rotating night shift work, exposure to light at night, and eGFR based on a large-scale population. The aim of this study is to explore whether rotating night shift work and exposure to bedroom ambient LAN are associated with renal function.

Methods

Study Design and Population

This study reported results from the baseline survey conducted among steelworkers who were prospectively recruited at eleven steel production departments in north China[17]. All workers at this company underwent a legally required health examination each year. A total of 7661 participants were recruited from February to June, 2017. After excluding 390 participants without detailed information on current shift work status, 104 without brightness of bedroom ambient LAN, 43 without serum creatinine, and 255 with incomplete information on covariates, 6869 participants were included in this study (Figure 1). Compared with participants included, those who were excluded were older (44.2 ± 8.0 years versus 34.3 ± 7.6 years, P<0.001). Among the 6869 included participants, 91.5% were male workers (versus 93.7% among excluded, P=0.032). All participants gave informed consent before taking part in this study.

Assessment of GFR

Blood was drawn from the participant’s forearm venous between 08:00 and 09:30 after they have fasted for 12 hours. For night shift workers, blood was drawn in the morning of a day off work. Sarcosine oxidase method was used to test serum creatinine (CRE kit, Beijing Strong Biotechnologies, Inc., Beijing, China). Within-laboratory intra-and inter-assay variable coefficients for serum creatinine were <6% and <8%, respectively. Assessment of eGFR was based on the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) equation [18]. The CKD-EPI formula is as follows: eGFR (mL/min/1.73 m^2) = 141 × min (Scr/κ, 1)$^{\alpha}$ × max (Scr/κ, 1)$^{-1.209}$ × 0.993^{Age} × (1.018 if female) × (1.159 if black). Scr indicates serum creatinine (μmol/L), κ = 0.7 for females and 0.9 for males, α = -0.329 for females and -0.411 for males, min and max indicate the minimum of Scr/κ or 1, the maximum of Scr/κ or 1, respectively. According to the Kidney Disease Improving Global Outcomes 2012 recommendations, the range of GFR (mL/min/1.73 m^2) was classed into five categories: normal or high (GFR ≥90, G1), mildly decreased

(GFR: 60–89, G2), mildly to moderately decreased (GFR: 45–59, G3a), moderately to severely decreased (GFR: 30–44, G3b), severely decreased (GFR: 15–29, G4), and kidney failure (GFR <15, G5) [19]. Based on this classification criteria, only 22 (0.3%) participants had eGFR<60 mL/min/1.73 m^2 (G3a-G5), so we combined these categories into G2 in the subsequent analysis and defined them as “decreased eGFR”.

Assessment of shift work

Shift work in this study refers to rotating night shift work (mainly four-crew-three-shift system now). In the four-crew-three-shift system, each group has two morning-shifts (08:00–16:00), two afternoon-shifts (16:00–00:00), two night-shifts (00:00–08:00), and was then off-duty for two days. In this study the detailed lifetime employment history was collected by face-to-face personal interviews. Participants recruited were asked to report whether they were involved in rotating night shift work (working through 00:00 to 6:00) during their employment [20]. If yes, they would be further asked about the start and end dates of each shift system, the average number of night shifts per month in each shift system, and usual days off per month. All the reported information was verified with the company’s records. “Day work” indicates workers who always worked regular working hours (8:00 to 16:00). Using the above work schedule information, the duration of night shift work (years) (sum of years spent in all jobs including night shift work) and cumulative number of night shifts (nights) (sum of nights spent in all jobs including night shifts) were aggregated [21].

Assessment of bedroom light environment

Exposure to LAN was assessed through participants’ report about the brightness of the bedroom ambient at night. Participants were asked to class the brightness of their bedroom LAN into the following four categories: “you wear a mask or too dark to see your fingers”; “light enough to see your fingers but not to identify the indoor environment clearly”; “light enough to identify the indoor environment clearly but not enough to read”, “light enough to read”. The last two categories were merged due to the small number of the last brightest category (2.01%), and then the exposure level was divided into “darkest”, “middle”, “lightest” according to the brightness. The participants were also asked to report the usual times light on per night [22].

Assessment of covariates

Covariates mainly include age, sex, body mass index (BMI), ethnicity, smoking status, drinking status, educational level, physical activity, sleep duration, insomnia, diabetes, dyslipidemia, and elevated blood pressure. (see supplementary appendix)

Statistical analysis

Continuous variables are presented as means and standard deviations, and between-group comparisons were performed using Student's t test if the data were normally distributed. Otherwise, the median (upper quartile-lower quartile) and Wilcoxon Scores (Rank Sums) test were used to describe and compare these

continuous variables between groups. Initial bivariate associations between eGFR and potential confounders were also assessed with Pearson's correlation (r) or Spearman's rank correlation (r_s) for continuous variables according to its distribution characteristics. Categorical variables are presented as numbers and percentages, and the chi-square test was used to compare differences among groups.

Multivariate logistic regression models were used to examine the relationships between night shift work, the brightness of bedroom ambient, and decreased eGFR. Restricted cubic spline models were utilized to visually examine the association between duration of night shift work (continuous), cumulative number of night shifts (continuous), and eGFR (as a continuous variable and a categorical variable, respectively) with adjustment for potential confounders.

Subsequently, in subgroup analysis we introduced multiplicative interaction terms using duration of night shift work in quartiles and the stratifying factors including sex, BMI (<25, or ≥25 kg/m^2), bedroom ambient light level (darkest level/ middle or lightest level), diabetes (no/yes), hypertension (no/yes), dyslipidemia (no/yes), insomnia (no/yes), and short sleep duration (no/yes) to assess potential effect modification. Log likelihood ratio test was used to compare models with and without cross-product interaction terms. P<0.05 was regarded as significant for 2-sided tests. All statistical analyses were performed using SAS 9.3 (SAS Institute Inc., Cary, NC, USA).

Results

General characteristics of the participants

The baseline characteristics according to the eGFR status are shown in Table 1. The present study of 6869 included participants consisted of 91.5% males, with a mean age of 44.2 years, a mean BMI of 25.2 kg/m^2, and a mean eGFR of 101.7 mL/min/1.73 m^2. Approximately 85% participants current or ever engaged in night shift work. 11.8% of participants reported a lightest brightness of bedroom ambient LAN. 25.6% of participants with elevated blood pressure and 10.5% with diabetes. The prevalence of decreased eGFR in the present study population showed a positive association with the duration of night shift work, with the prevalences in day workers, Q1 (1-12 years), Q2 (13-20 years), Q3 (21-28 years), and Q4 (29-43 years) being 13.2%, 15.3%, 16.6%, 21.0%, and 34.0%, respectively. The basic characteristics of participants according to shift work status are shown in **Additional file 2: Table S1**. The prevalence of decreased eGFR in male workers was significantly higher than that in female workers (**Additional file 2:** Table S2). eGFR was correlated with BMI (r = -0.053, P <0.001), sleep duration (r = 0.063, P <0.001), fasting blood glucose (r_s= -0.123, P <0.001), systolic (r = -0.136, P <0.001) and diastolic blood pressure (r = -0.167, P <0.001), duration of night shift work (r = -0.201, P <0.001).

Night shift work, LAN, and eGFR

Multivariate adjusted ORs between night shift work, LAN, and decreased eGFR are shown in Table 2. Compared with day work, significant increased odds ratios of decreased eGFR were observed in the higher exposure groups of “duration of night shift work (years)” among night shift workers (P trend

<0.001, Model 1). After adjustment for age and gender (Model 2), this association remained robust. After additionally adjusting for other potential confounders, the odds of decreased eGFR in the last quartile of the duration of night shift work was attenuated but remained significantly elevated with the OR (95% CI) of 1.39 (1.10 to 1.75) (Model 3). In addition, positive associations were observed between duration of night shift work (continuous), cumulative number of night shifts (continuous), and odds of decreased eGFR (bivariate), while negative associations were observed between duration of night shift work (continuous), cumulative number of night shifts (continuous), and eGFR (continuous) in the RCS models (Figure 2). However, no significant association between brightness of bedroom ambient LAN, number of times light on, and decreased eGFR was observed, regardless of whether the corresponding confounders were adjusted.

Compared with day work, elevated odds of decreased eGFR were observed in the higher exposure groups of the duration of night shift work in all subgroup analyses, except for the female group, although this association was no longer significant in some subgroups due to case numbers (Table 3).

Sensitivity analyses

Considering that dust, heat stress, noise, and carbon monoxide are the major occupational hazards to the current steelworkers, we further adjusted these exposures on the basis of Model 3, and the results were similar to the previous ones (**Additional file 2:** Table S3). Moreover, in order to avoid the influence of the maximum value on the fitting result of restricted cubic splines, we removed the last 1% quantile of the duration of night shift work and cumulative number of night shifts, and the relationships remained comparable (**Additional file 2:** Figure S1).

Discussion

Main results

Our findings support that night shift work is significantly associated with a slight decline of renal function (estimated by eGFR) in steelworkers and provide additional evidence concerning dose-response relationships between duration of night shift work, cumulative number of night shifts, and eGFR among night shift workers, which have never been reported in previous studies. However, no significant association is observed between the brightness of bedroom ambient LAN and decreased eGFR.

Comparison with previous findings

Our findings are consistent with a small sample cross-sectional study conducted in 354 police officers, which concluded that night shift work was associated with decreased kidney function [23]. They also reported that percentage of hours worked on the night shift work was inversely associated with mean levels of eGFR, which was comparable to our results when it comes to the relationship between duration of night shift work, cumulative number of night shifts and eGFR. In line with our findings, another observational study also reported that small increase in albuminuria, a marker of kidney damage, was

associated with disruption of the circadian rhythms due to shift work rather than exposure to low concentrations of nephrotoxic chemicals [24].

Notably, asynchrony between circadian clocks and external world light/dark cycle due to LAN has been associated with many negative health outcomes in previous studies. A previous largely epidemiological data showing a positive association between odds of obesity and lightness of the room slept in at night (we used the same LAN assessment method as in the above study), even after adjustment for potential confounders including night shift work [22]. However, no relationship was discovered between the brightness of bedroom ambient LAN and decreased eGFR in our study. This may be related to the overall lower level exposure of bedroom ambient LAN in our study population. In addition, considering that approximately 85% of participants are current or ever night shift workers, which is also a main cause of exposure to LAN. Therefore, the absence of brightness assessment during night work may result in bias. But this bias could be largely controlled after adjustment for the duration of night shift work, since night shift workers in this company spend most of their working hours in the central control room where the indoor environment was built according to uniform standards with the unified lighting system. Meanwhile, our results also can be supported by a finding which observed a significant association between the duration of night shift work and breast cancer (OR=1.13, 95% CI: 1.03-1.48), but not bedroom ambient light levels (OR=1.1, 95% CI: 0.9-1.2) and other lighting habits [25].

Biologic plausibility

One key assumption that explain this association is night shift work induces misalignment between the external behavioral and the endogenous molecular circadian clocks. Kidneys are organs with peripheral circadian clocks, which enable GFR to show a self-sustained rhythmicity [26]. Studies in animals and humans have shown that feeding time play a dominant role in resetting peripheral circadian oscillators, even in the absence of the synchronization of central circadian clock in the suprachiasmatic nucleus (SCN) [27, 28]. Since light is the primary external world synchronizer of central circadian clock in SCN, it may be reasonable to hypothesis that chronic circadian disruption due to night shift work, other than light, may be responsible for decreased eGFR through peripheral circadian oscillators. Therefore, altered meal timing due to night shift work could explain, at least in part, the relationship between night shift work and eGFR. Moreover, the disruption of circadian sleep/wake rhythm are much more prevalent in end-stage renal disease, which indicates that the displaced sleep/wake cycle due to night shift work may also be responsible for the decline of GFR [29]. In terms of sleep, it is noteworthy that in addition to sleep rhythm, sleep duration and sleep quality may also play a role in renal function [30, 31]. While, after adjustment for insomnia and sleep duration, the relationship between night shift work and eGFR remained robust, which suggest that sleep rhythm may be a contributor to this association. As for the gender difference between duration of night shift work and decreased eGFR, it may be related to the protective effects of estrogens in women and/or the damaging effects of testosterone, together with unhealthier lifestyles in men, which might cause renal function to decline faster in men than in women [32].

Another potential mechanism by which night shift work might cause the decline of eGFR is the presence of psychological and psychosocial stressors [33]. Shift-workers are subject to heavier stress loads compared to non-shift workers [34]. Stress can cause renal vasoconstriction by stimulating the sympathetic nervous system, resulting in decreased renal plasma flow (RPF) and GFR. Besides, persistent stimulation of the hypothalamic-pituitary-adrenal (HPA) axis by external chronic stressors due to night shift work can active the sympathetic nervous system (SNS), and the activation of renal SNS may also affect the renal function through the renin-angiotensin-aldosterone system (RAAS) [35]. Moreover, the over-activation of RAAS can not only lead to an increase in intra-glomerular pressure but also to the damage of vascular endothelial cells, the activation of reactive oxygen species (ROS), and the inhibition of sympathetic hyperactivity and nitric oxide (NO), and all of them are involved in the pathophysiology of renal damage [36, 37].

Strengths and limitations

The major strengths of our study include the detailed shift work information, lifestyle information, health status related to CKD and large sample size. However, our research also has certain limitations. First, we are unable to infer temporality of shift work and GFR in a cross-sectional study. Second, the assessment of LAN is based on the self-reported information rather than the objective measurement of intensity. Third, we did not collect chronotype information, which may have led to a confounding bias. Fourth, those who are competent for long duration night shift work are more likely to have better physical fitness (healthy worker effect) or have tolerated to night shift work, which may underestimate the association between the exposure and outcome. Fifth, our survey population consisted of steelworkers, the vast majority of whom are male workers in north China, which limits our ability to generalize these results to the general population.

Conclusion

The increased duration of night shift work and cumulative number of night shifts among night shift workers, but not the brightness of bedroom ambient LAN, are associated with a slight decline of renal function among steelworkers. Considering the small number of female steelworkers in this study and the gender difference in renal function, the relationship between night shift work and renal function in females need to be further confirmed. Meanwhile, well-designed prospective research should be conducted with objective assessment of LAN exposure to explore the association between the intensity of LAN and renal function.

Abbreviations

LAN: Light at night; eGFR: Estimated glomerular filtration rate; GFR: Glomerular filtration rate; OR: Odds ratio; CI: Confidence interval; ALAN: Artificial light at night; IARC: International Agency for Research on Cancer; BMI: body mass index; SCN: Suprachiasmatic nucleus; RPF: Renal plasma flow; HPA:

Hypothalamic-pituitary-adrenal; SNS: Sympathetic nervous system; RAAS: Renin-angiotensin-aldosterone system; ROS: Reactive oxygen species; NO: Nitric oxide

Declarations

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Authors' contributions

SZ raised the study concept and drafted the manuscript. YW designed this work. ZW and HW analyzed the data. CX and QL provided inputs and revisions. JY and WG supervised the fieldwork of this project. All authors agree to submit this article.

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Availability of data and materials

The datasets generated and/or analyzed during the current study are not publicly available due other analyses are proceeding but are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

This research was approved by the Ethics Committee of North China University of Science and Technology (No.15006). All participants gave informed consent before taking part in this study.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Tables

Table 1 Basic characteristics according to eGFR status

Variables	Overall (*N*=6869)	Without decreased eGFR (n=5860)	With decreased eGFR (n=1009)	*P* value
Age (year)	44.2 ± 8.0	43.6 ± 8.1	47.9 ± 6.3	<0.001
Sex, n (%)				
Male	6283 (91.5)	5370 (91.6)	913 (90.5)	0.226
Female	586 (8.5)	490 (8.4)	96 (9.5)	
Ethnicity				0.494
Han	6727 (97.9)	5736 (97.9)	991 (98.2)	
Others	142 (2.1)	124 (2.1)	18 (1.8)	
BMI (kg/m^2), n (%)	25.2 ± 3.4	25.1 ± 3.4	25.7 ± 3.3	<0.001
Smoking status, n (%)				0.196
Never	2817 (41.0)	2409 (41.1)	408 (40.4)	
Ever	549 (8.0)	454 (7.6)	95 (9.4)	
Current	3503 (51.0)	2997 (51.1)	506 (50.2)	
Alcohol consumption, n (%)				0.233
Never	3936 (57.3)	3353 (57.2)	583 (57.8)	
Ever	393 (5.7)	325 (5.6)	68 (6.7)	
Current	2540 (37.0)	2182 (37.2)	358 (35.5)	
Education level, n (%)				<0.001
Primary or illiterate	86 (1.3)	71 (1.2)	15 (1.5)	
Middle or high school	5326 (77.5)	4483 (76.5)	843 (83.6)	
University or college	1457 (21.2)	1306 (22.3)	151 (15.0)	
Physical activity, n (%)				0.270
Low	80 (1.2)	70 (1.2)	10 (1.0)	
Moderate	522 (7.6)	457 (7.8)	65 (6.4)	
High	6267 (91.2)	5333 (91.0)	934 (92.6)	
Duration of night shift work (years)				<0.001
Day work	1029 (15.0)	896 (15.3)	133 (13.2)	
Q1 (1–12)	1471 (21.4)	1317 (22.5)	154 (15.3)	
Q2 (13–20)	1495 (21.8)	1328 (22.7)	167 (16.6)	
Q3 (21–28)	1314 (19.1)	1102 (18.8)	212 (21.0)	
Q4 (29–43)	1560 (22.7)	1217 (20.8)	343 (34.0)	
Brightness of bedroom ambient LAN, n (%)				0.856
Darkest level	3782 (55.1)	3222 (55.0)	560 (55.5)	
Middle level	2276 (33.1)	1949 (33.2)	327 (32.4)	
Lightest level	811 (11.8)	689 (11.8)	122 (12.1)	
Number of times light on (times/night), n (%)				0.645
0	4194 (61.1)	3584 (61.2)	610 (60.5)	
1	2172 (31.6)	1854 (31.6)	318 (31.5)	
≥2	503 (7.3)	422 (7.2)	81 (8.0)	
Sleep duration (h)	6.8 ± 1.2	6.8 ± 1.2	6.8 ± 1.2	0.005
Insomnia, n (%)				0.990
No	4560 (66.4)	3890 (66.4)	670 (66.4)	
Yes	2309 (33.6)	1970 (33.6)	339 (33.6)	
Diabetes, n (%)				0.150
No	6147 (89.5)	5257 (89.7)	890 (88.2)	
Yes	722 (10.5)	603 (10.3)	119 (11.8)	
Fasting blood glucose (mmol/L)	5.8 (5.4~6.3)	5.8 (5.4~6.3)	5.9 (5.5~6.4)	<0.001

Hypertension, n (%)				<0.001
No	5109 (74.4)	4447 (75.9)	662 (65.6)	
Yes	1760 (25.6)	1413 (24.1)	347 (34.4)	
Systolic blood pressure (mmHg)	129.0 ± 16.0	128.5 ± 15.8	131.8 ± 17.2	<0.001
Diastolic blood pressure (mmHg)	82.5 ± 10.4	82.2 ± 10.2	84.7 ± 11.0	<0.001
Dyslipidemia, n (%)				<0.001
No	4074 (59.3)	3541 (60.4)	533 (52.8)	
Yes	2795 (40.7)	2319 (39.6)	476 (47.2)	
[a] Proteinuria (mg/dl)				<0.001
A1 (<30)	6745 (98.2)	5772 (98.5)	973 (96.4)	
A2-A3 (≥30)	124 (1.8)	88 (1.5)	36 (3.6)	

P-values were from Pearson's chi-square test for categorical variables and Student's t test or Wilcoxon Scores (Rank Sums) for continuous variables. [a] Categories of proteinuria were defined as negative and trace (proteinuria<30 mg/dl, A1), 1+ (proteinuria: 30–300 mg/dl, A2), and 2+ (proteinuria>300 mg/dl, A3).

Table 2 Multivariable logistic regression analyses for association between night shift work, bedroom ambient light level, and decreased eGFR

Exposure metrics	Decreased eGFR (mL/min/1.73 m^2)		OR (95% CI)		
	No (≥90)	Yes (<90)	Model 1	Model 2	Model 3
Duration of night shift (years)					
Day work	896 (87.1)	133 (13.2)	1.00	1.00	1.00
Q1 (1–12)	1317 (89.5)	154 (10.5)	0.79 (0.61 to 1.01)	1.10 (0.85 to 1.42)	1.07 (0.82 to 1.38)
Q2 (13–20)	1328 (88.8)	167 (11.2)	0.84 (0.66 to 1.08)	1.12 (0.87 to 1.44)	1.06 (0.82 to 1.37)
Q3 (21–28)	1102 (83.9)	212 (16.1)	1.29 (1.02 to 1.63)	1.32 (1.04 to 1.68)	1.29 (1.01 to 1.64)
Q4 (29–43)	1217 (78.0)	343 (22.0)	1.89 (1.52 to 2.36)	1.40 (1.12 to 1.75)	1.39 (1.10 to 1.75)
P for trend			<0.001	<0.001	0.001
Brightness of bedroom ambient LAN					
Darkest level	3222 (85.2)	560 (14.8)	1.00	1.00	1.00
Middle level	1949 (85.6)	327 (14.4)	0.96 (0.83 to 1.12)	0.91 (0.78 to 1.06)	0.90 (0.77 to 1.05)
Lightest level	689 (85.0)	122 (15.0)	0.99 (0.80 to 1.23)	0.97 (0.78 to 1.20)	0.94 (0.75 to 1.17)
Number of times light on (times/night)					
0	3584 (85.5)	610 (60.5)	1.00	1.00	1.00
1	1854 (31.6)	318 (31.5)	0.98 (0.85 to 1.14)	0.97 (0.84 to 1.13)	0.96 (0.83 to 1.12)
≥2	422 (83.9)	81 (16.1)	1.07 (0.83 to 1.39)	1.02 (0.79 to 1.32)	1.00 (0.77 to 1.29)

Model 1: unadjusted; Model 2: adjusted for age and gender; Model 3: further adjusted for BMI (<25, 25–30, or ≥30 kg/m^2), ethnicity, smoking status, drinking status, education level, physical activity, sleep duration (<7, or ≥7 hours), insomnia, diabetes, hypertension, and dyslipidemia.

Table 3 Association between duration of night shift work and decreased eGFR stratified by sex, BMI, brightness of bedroom ambient LAN, diabetes, hypertension, dyslipidemia, insomnia, and short sleep duration.

Groups	Duration of night shift (years)					
	Day work	Q1 (1–12)	Q2 (13–20)	Q3 (21–28)	Q4 (29–43)	*P* for interaction
Sex	0.098					
Male, OR (95% CI)	1.00	1.02 (0.77 to 1.34)	1.08 (0.82 to 1.41)	1.38 (1.06 to 1.78)	1.43 (1.12 to 1.82)	
n without decreased eGFR	796 (87.5)	1219 (90.4)	1216 (89.1)	990 (83.5)	1149 (78.0)	
n with decreased eGFR	114 (12.5)	130 (9.6)	149 (10.9)	195 (16.5)	325 (22.1)	
Female, OR (95% CI)	1.00	1.06 (0.51 to 2.22)	0.70 (0.32 to 1.53)	0.61 (0.28 to 1.32)	0.86 (0.38 to 1.93)	
n without decreased eGFR	100 (84.0)	98 (80.3)	112 (86.2)	112 (86.8)	68 (79.1)	
n with decreased eGFR	19 (16.0)	24 (19.7)	18 (13.9)	17 (13.2)	18 (20.9)	
BMI	0.878					
<25, OR (95% CI)	1.00	1.21 (0.83 to 1.77)	1.38 (0.95 to 2.01)	1.49 (1.04 to 2.13)	1.60 (1.14 to 2.23)	
n without decreased eGFR	521 (89.5)	687 (90.6)	641 (89.3)	556 (85.8)	632 (80.6)	
n with decreased eGFR	60 (10.5)	71 (9.4)	77 (10.7)	92 (14.2)	152 (19.4)	
≥25, OR (95% CI)	1.00	0.95 (0.67 to 1.36)	0.87 (0.62 to 1.24)	1.13 (0.81 to 1.57)	1.21 (0.88 to 1.67)	
n without decreased eGFR	384 (84.0)	630 (88.4)	687 (88.4)	546 (82.0)	585 (75.4)	
n with decreased eGFR	73 (16.0)	83 (11.6)	90 (11.6)	120 (18.0)	191 (24.6)	
Brightness of bedroom ambient LAN	0.926					
Darkest level, OR (95% CI)	1.00	1.07 (0.74 to 1.54)	1.09 (0.76 to 1.55)	1.38 (0.98 to 1.95)	1.47 (1.06 to 2.05)	
n without decreased eGFR	424 (87.6)	714 (89.4)	799 (88.7)	632 (83.2)	653 (77.9)	
n with decreased eGFR	60 (12.4)	85 (10.6)	102 (11.3)	128 (16.8)	185 (22.1)	
Middle or Lightest level, OR (95% CI)	1.00	1.08 (0.75 to 1.56)	1.08 (0.74 to 1.58)	1.24 (0.87 to 1.76)	1.33 (0.97 to 1.84)	
n without decreased eGFR	472 (86.6)	603 (89.7)	529 (89.1)	470 (84.8)	564 (78.1)	
n with decreased eGFR	73 (13.4)	69 (10.3)	69 (10.3)	84 (15.2)	158 (21.9)	
Diabetes	0.763					
No, OR (95% CI)	1.00	1.02 (0.78 to 1.34)	1.04 (0.80 to 1.36)	1.26 (0.97 to 1.62)	1.31 (1.02 to 1.67)	
n without decreased eGFR	807 (87.1)	1213 (89.9)	1218 (88.7)	989 (83.8)	1030 (78.2)	
n with decreased eGFR	120 (12.9)	137 (10.2)	155 (11.3)	191 (16.2)	287 (21.8)	
Yes, OR (95% CI)	1.00	1.61 (0.70 to 3.70)	1.33 (0.53 to 3.32)	1.83 (0.81 to 4.14)	2.02 (0.99 to 4.11)	
n without decreased eGFR	89 (87.3)	104 (86.0)	110 (90.2)	113 (84.3)	187 (76.9)	
n with decreased eGFR	13 (12.8)	17 (14.1)	12 (9.8)	21 (15.7)	56 (23.1)	
Hypertension	0.536					
No, OR (95% CI)	1.00	1.05 (0.77 to 1.43)	0.99 (0.73 to 1.34)	1.19 (0.89 to 1.60)	1.40 (1.06 to 1.86)	
n without decreased eGFR	684 (88.4)	1064 (90.7)	1061 (90.4)	828 (86.1)	810 (78.9)	
n with decreased eGFR	90 (11.6)	109 (9.3)	113 (9.6)	134 (13.9)	216 (21.1)	
Yes, OR (95% CI)	1.00	1.08 (0.67 to 1.73)	1.27 (0.80 to 2.02)	1.53 (0.99 to 2.36)	1.37 (0.92 to 2.05)	
n without decreased eGFR	212 (83.1)	253 (84.9)	267 (81.2)	274 (77.8)	407 (76.2)	
n with decreased eGFR	43 (16.9)	45 (15.1)	54 (16.8)	78 (22.2)	127 (23.8)	
Dyslipidemia	0.399					

No, OR (95% CI)	1.00	0.89 (0.63 to 1.27)	1.07 (0.76 to 1.51)	1.24 (0.90 to 1.72)	1.40 (1.04 to 1.90)
n without decreased eGFR	562 (88.0)	829 (91.9)	756 (89.7)	672 (85.8)	722 (79.6)
n with decreased eGFR	77 (12.1)	73 (8.1)	87 (10.3)	111 (14.2)	185 (20.4)
Yes, OR (95% CI)	1.00	1.27 (0.87 to 1.87)	1.05 (0.71 to 1.54)	1.35 (0.93 to 1.96)	1.36 (0.96 to 1.94)
n without decreased eGFR	334 (85.6)	488 (85.8)	572 (87.7)	430 (81.0)	495 (75.8)
n with decreased eGFR	56 (14.4)	81 (14.2)	80 (12.3)	101 (19.0)	158 (24.2)
Insomnia	0.691				
No, OR (95% CI)	1.00	0.99 (0.73 to 1.36)	1.00 (0.74 to 1.34)	1.18 (0.88 to 1.57)	1.38 (1.04 to 1.82)
n without decreased eGFR	614 (86.6)	868 (89.6)	881 (89.2)	750 (84.4)	777 (77.3)
n with decreased eGFR	95 (13.4)	101 (10.4)	107 (10.8)	139 (15.6)	228 (22.7)
Yes, OR (95% CI)	1.00	0.85 (0.53 to 1.35)	0.99 (0.66 to 1.49)	1.27 (0.86 to 1.89)	1.26 (0.83 to 1.83)
n without decreased eGFR	282 (88.1)	449 (89.4)	447 (88.2)	352 (82.8)	440 (79.3)
n with decreased eGFR	38 (11.9)	53 (10.6)	60 (11.8)	73 (17.2)	115 (20.7)
Short sleep duration	0.925				
No, OR (95% CI)	1.00	0.84 (0.56 to 1.26)	0.99 (0.70 to 1.40)	1.25 (0.90 to 1.73)	1.23 (0.90 to 1.73)
n without decreased eGFR	309 (85.8)	562 (88.8)	610 (88.0)	570 (82.7)	734 (77.3)
n with decreased eGFR	51 (14.2)	71 (11.2)	83 (12.0)	119 (17.3)	216 (22.7)
Yes, OR (95% CI)	1.00	1.00 (0.71 to 1.40)	0.99 (0.72 to 1.38)	1.16 (0.84 to 1.62)	1.36 (0.98 to 1.89)
n without decreased eGFR	587 (87.7)	755 (90.1)	718 (89.5)	532 (85.1)	483 (79.2)
n with decreased eGFR	82 (12.3)	83 (9.9)	84 (10.5)	93 (14.9)	127 (20.8)

P values for interaction were estimated using a log likelihood ratio test to compare models with and without cross-product interaction terms; The variables adjusted in each subgroup were the same as Model 3 in Table 2 except for the stratification variable.

Figures

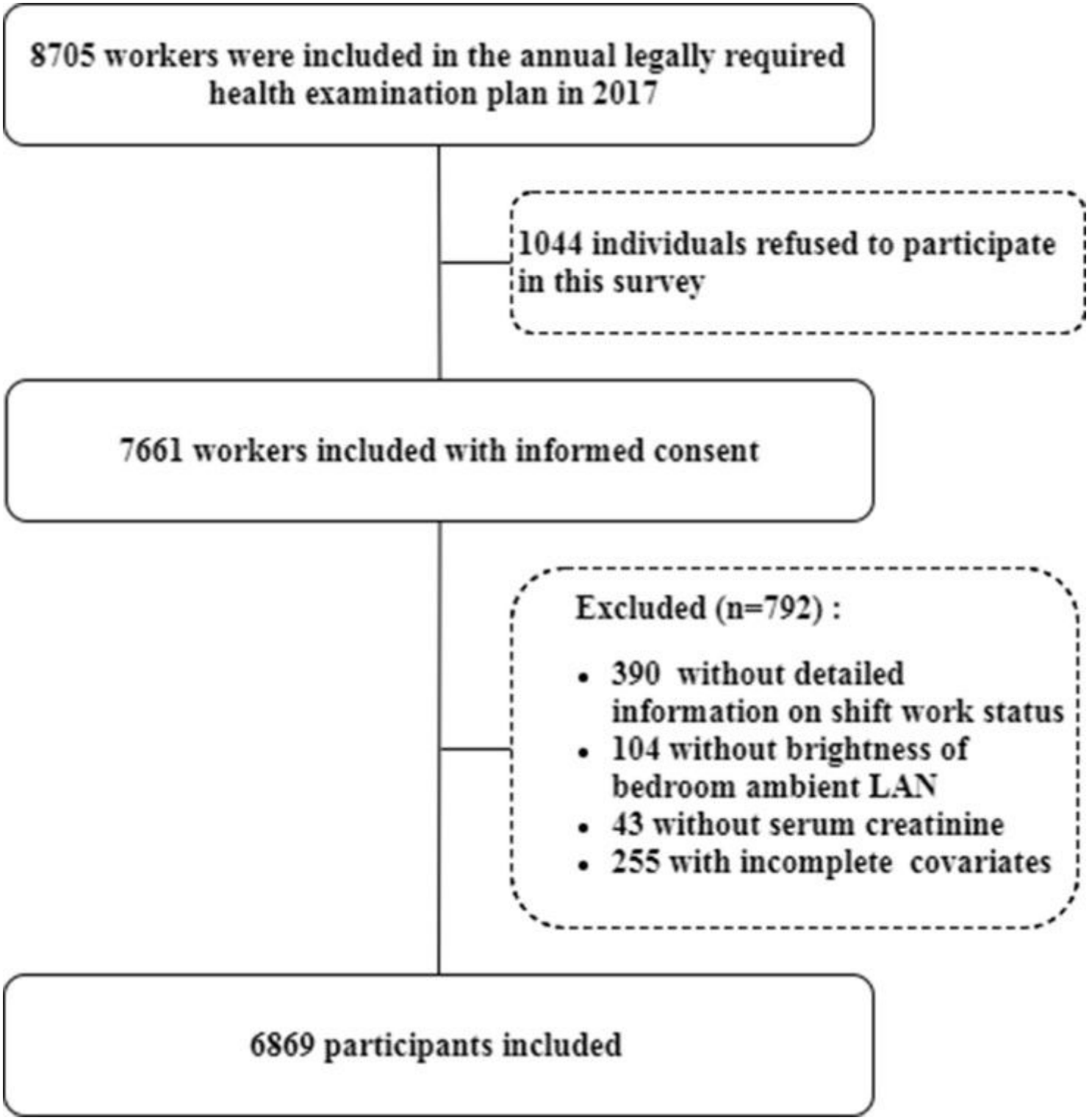

Figure 1

Flow chart of selection of participants.

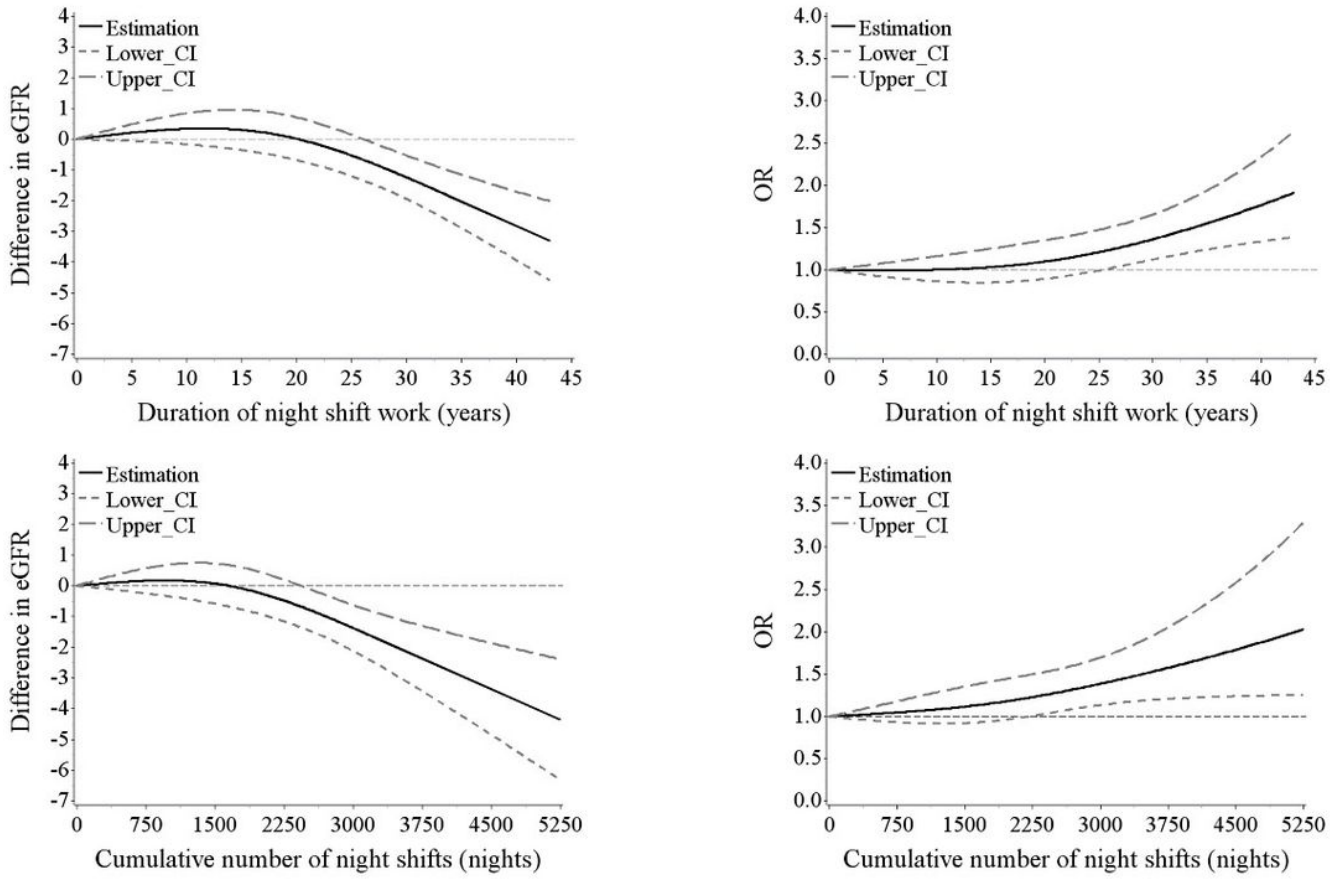

Figure 2

The association between duration of night shift work (continuous), cumulative number of night shifts (continuous), and eGFR. “Difference in eGFR” indicates difference in eGFR (mL/min/1.73 m2) where the reference value for duration of night shift work or cumulative number of night shifts is 0 (day work). “CI” indicates 95% confidence interval. Adjusted for age, gender, BMI (<25, 25–30, or ≥30 kg/m2), ethnicity, smoking status, drinking status, education level, physical activity, brightness of bedroom ambient LAN, number of times light on, sleep duration (<7, or ≥7 hours), insomnia, diabetes, hypertension, and dyslipidemia.

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