ORIGINAL RESEARCH

Long work hours and decreased glomerular filtration rate in the Korean working population

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ABSTRACT

Objectives We studied the association between long working hours and decreased kidney function, which was determined using estimated glomerular filtration rate (eGFR), among the working population in South Korea.

Methods We analysed nationally representative cross-sectional data for 20851 Korean workers ≥20 years of age. A negative binomial regression model was used to test differences in the prevalence of chronic kidney disease (eGFR <60 mL/min/1.73 m^2) among workers divided into groups according to weekly working hours (<30, 30–40, 41–51 and ≥52 hours/week). Multivariate linear regression analysis was performed to investigate the association between weekly working hours and eGFR, with adjustments made for age, sex/gender, income, education, shift work, occupation, smoking, alcohol use, hypertension, diabetes mellitus, body mass index, systolic blood pressure, fasting blood glucose and total serum cholesterol.

Results A 1-hour increase in weekly working hours was associated with 0.057 mL/min/1.73 m^2 (95% CI 0.005 to 0.109) decrease in eGFR among participants who worked ≥52 hours/week. Among participants without hypertension or diabetes, a 1-hour increase in weekly working hours was significantly associated with 0.248 and 0.209 mL/min/1.73 m^2 decrease in eGFR among participants who worked 30–40 hours/week and 41–51 hours/week, respectively.

Conclusion Long working hours are associated with decreased kidney function. We expect that our findings could call for more research regarding this association and provide policy-oriented perspectives.

Key messages

What is already known about this subject?

- Chronic kidney disease (CKD) is a growing health concern.
- Although some risk factors such as lead, cadmium and carbon disulfide have been reported as occupational risk factors for CKD, the association between long working hours and CKD has not been studied.

What are the new findings?

- There is a significant association between long working hours and decreased estimated glomerular filtration rate among the working population in South Korea.

How might this impact on policy or clinical practice in the foreseeable future?

- We identified working long hours as a new potential risk factor for kidney function impairment.
- Our findings could provide evidence for healthcare providers and public health officials to develop context-specific interventions to help reduce the risk of CKD.

INTRODUCTION

Chronic kidney disease (CKD) has become a growing global public health concern in recent years. Worldwide, CKD affects 13.4% of the general population,[1] and the total estimated prevalence among adults in Korea is 8.2%.[2] CKD is a predictor of end-stage renal disease and is an important risk factor for the onset of cardiovascular disease and mortality in individuals with such diseases.[3 4]

Occupational risk factors for CKD such as lead, cadmium and carbon disulfide have been reported.[5] However, the socioeconomic environment, which could be an important contributing factor in the progression of CKD and its complications, has been overlooked. The behavioural science literature suggests that exposure to stress associated with social and/or economic disadvantage can adversely affect vascular system functions and place individuals at a greater risk for CKD development and progression.[6] Given that overwork coincides with high job demands, which is a main component of job stress, long working hours may be linked to kidney function impairment and progression of CKD. Previous studies have investigated long work hours as a potential risk factor for various diseases.[7 8] In this regard, a relationship between work hours and the known risk factors for CKD, including hypertension (HTN) and diabetes mellitus (DM), has been reported.[9 10] Moreover, the disturbance in haemodynamic parameters associated with long work hours implies that they could induce damage to the renal microvasculature.[11–13] Nevertheless, there is a lack of epidemiological evidence to validate an association between long work hours and CKD.

We therefore considered it necessary to evaluate the relationship between work hours and CKD. Since estimated glomerular filtration rate (eGFR) testing is inexpensive and readily available worldwide, reduced eGFR could be considered a useful tool for predicting kidney disease and its consequences.[14] This study aimed to investigate the association between weekly work hours and decreased kidney function measured by eGFR among the working population in South Korea.

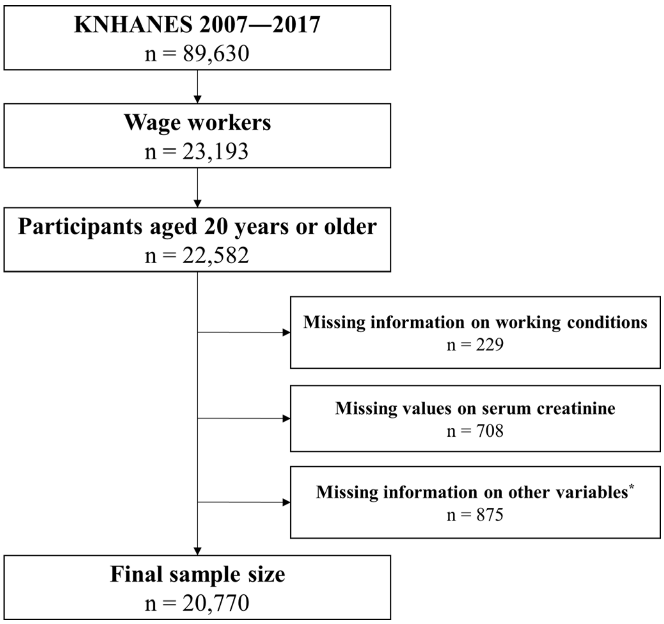

Figure 1 Study participants. *Other variables included occupation, shift work, employment status, income status, education level, body mass index, hypertension status, diabetes status, smoking and problematic alcohol drinking. KNHANES, Korean National Health and Nutrition Examination Survey.

MATERIALS AND METHODS

Study design and participants

The Korea National Health and Nutrition Examination Survey (KNHANES), a cross-sectional nationally representative survey, was initiated in 1998 and has been undertaken annually since 2007 by the Korea Centers for Disease Control and Prevention (KCDC). The representativeness of the KNHANES is based on multistage probability cluster sampling with stratification by geographical location, sex/gender and age. The survey provides information on participants' socioeconomic status, anthropometric measures and health status, whereas a health examination and nutrition survey are conducted by trained interviewers. All participants provided written informed consent.

We used anonymised KNHANES data from 2007 to 2017 for data consistency and compatibility. Of the 89 630 survey participants, we included wage workers aged 20 years or older (n=22 582). We also excluded participants with missing information on weekly work hours and shift work (n=229), and also excluded those with missing data for serum creatinine (n=708) or other variables used in the study, including occupation, shift work, employment status, income status, education level, body mass index (BMI), HTN status, DM status, smoking and problematic alcohol drinking (n=794). Finally, a sample of 20 851 participants were included in the analysis (figure 1). There were no significant differences in sex, weekly working hours, BMI and HTN between participants included and excluded in the analysis (n=245), but there were differences in age, occupation, shift work, employment status, income status, education level, DM, smoking and problematic alcohol drinking (online supplementary table S1). Among participants excluded due to missing information other than serum creatinine, lower eGFR (87.9 mL/min/1.73 m^2) and higher CKD prevalence (3.8%) were found and compared with eGFR (89.7 mL/min/1.73 m^2) and CKD prevalence (1.4%) of the included participants (online supplementary table S2).

Data collection

During the KNHANES, completed questionnaires were obtained and reviewed by trained staff. The weekly work hours of participants were determined by asking 'How long do you work, including extra hours and excluding mealtime?' Weekly working hours of participants were classified into four groups according to the Labor Standards Act in South Korea as follows: <30 (short weekly working hours), 30–40 (standard and the most frequent weekly working hours), 41–52 (usually permitted overtime work) and >52 hours (overtime work allowed in extraordinary situations). The classified work groups also included any schedule other than daytime work, such as day–night shift, fixed night, regular rotation, 24-hour shift, split shift and irregular shifts.

Serum creatinine level was measured using fasting blood samples (12 hours overnight) obtained through antecubital venepuncture. Serum creatinine levels were measured using the Jaffe rate-blanked and compensated method with the ADVIA 1650 (Siemens, New York, USA) and CREAT reagent (Siemens) from 2007 to 2008, and with the Hitachi Automatic Analyzer 7600 (Hitachi, Tokyo, Japan) and CREA reagent (Roche Diagnostics, Mannheim, Germany) from 2009 to 2017. eGFR was calculated using the Modification of Diet in Renal Disease study equation.[15] Participants with an eGFR lower than 60 mL/min/1.73 m^2 were defined as CKD cases.[16]

Occupation was divided into six classes, and these were classified into two groups: non-manual workers (managers and professionals, office workers, and service and sales workers) and manual workers (agriculture, forestry and fisheries workers, craft, device and machine operators, assembly workers, and simple labourers). Employment status was obtained using a question about their regular job, temporary job or work as a daily-wage labourer. Income level was classified into low, mid-low, mid-high and high according to the individual income quartile of age and the 5-year age groups in the year of the survey. Education level was defined as elementary school, middle school, high school, and college or higher according to the highest education level attained. BMI was calculated as weight in kilograms divided by height in metres squared (both measured during the physical examination). The average of two systolic and diastolic blood pressure (SBP and DBP, respectively) readings, which were recorded at an interval of 5 min, was used for analysis. In the survey, HTN was defined as (1) SBP ≥140 mm Hg or DBP ≥90 mm Hg; (2) medical diagnosis of HTN by a doctor; or (3) ongoing treatment with oral hypertensive medication. Participants were considered to have DM if they met one of the following conditions: (1) fasting plasma glucose level ≥126 mg/dL, measured from cubital venous blood samples after a 12-hour overnight fast; (2) medical diagnosis of DM by a trained medical professional; or (3) ongoing treatment with oral antiglycaemic agents or insulin injections. Smoking status was classified as non-smoker, former smoker and current smoker, and problematic alcohol drinking was defined as ≥7 drinks at a time and >2 times/week in men and ≥5 drinks at a time and >2 times/week in women.

Statistical analysis

We computed 11-year sampling weights, as recommended by the KCDC, and then used statistical methods for complex survey structure and sampling weights. First, we presented the unweighted frequencies and weighted percentages of the participants by their demographic characteristics. Thereafter, we derived the number and unweighted percentage of participants with CKD and the arithmetic mean and SD of eGFR. The χ^2 test was conducted to test differences in CKD prevalence, and the Student's t-test or analysis of variance was used to test differences in eGFR by demographic characteristics. Second, we performed multivariate negative binomial regression to test differences in the prevalence of CKD according to weekly working hours groups, with adjustments made for age, sex/gender, income, education, shift work, occupation group, smoking, problematic drinking, HTN, DM, BMI, SBP, fasting blood glucose and total serum cholesterol. The potential confounders adjusted in the model were selected a priori. Negative binomial regression models were used to determine the prevalence ratio (PR) and 95% CI.[17] Third, non-parametric associations between weekly work hours and eGFR were explored by constructing the generalised additive model after stratifying for DM and HTN, which could be potential confounders. We used the GAM package of R V.3.4.4 (R Foundation for Statistical Computing, Vienna, Austria) for statistical analyses. These analyses were conducted after stratifying by sex/gender. Finally, we performed multivariate linear regression analyses to investigate how weekly work hours are associated with eGFR. These analyses were conducted after the stratification of weekly work hours (<30, 30–40, 41–52 and >52 hours), sex/gender and disease prevalence status (HTN and DM), with the adjustment for the same variables included in the negative binomial models. The scatter plot of predicted eGFR values and residuals was inspected to test the assumption of linearity, and the assumption of normality was regarded as fulfilled, since we believe that the number of observations was sufficient (n≥100) to overcome moderate non-normality, according to Lumley *et al*.[18] All statistical analyses were performed with SAS V.9.4 and R V.3.4.4 (R Foundation for Statistical Computing). Two-tailed *p* values <0.05 indicated statistical significance.

RESULTS

Table 1 shows the demographic characteristics of the study participants. In the final analytic sample of 20 770 participants, there were 10 712 (58.8%) men and 10 058 (41.2%) women. There were 390 (1.4%) participants with CKD (eGFR <60 mL/min/1.73 m^2). Participants aged 60 years or older had a CKD prevalence of 7.9%, whereas those aged 20–29 years had a CKD prevalence of 0.04%. Participants with manual occupations (2.0%) had a higher prevalence of CKD than participants with non-manual occupations (1.0%). Similarly, a regular job (1.1%) resulted in a lower prevalence of CKD than a temporary job (2.1%) and work as a daily-wage labourer (2.0%). Participants who had an elementary school education (5.0%) had higher CKD prevalence than those with middle school (2.1%), high school (1.0%) and college (0.9%) education. Participants with higher BMI (≥25 kg/m^2, 1.9%), HTN (4.5%) and DM (6.0%) were more likely to have CKD than participants without these characteristics. The prevalence of CKD was higher among former smokers (2.2%) than among non-smokers (1.4%) and current smokers (0.9%), and lower in participants with problematic alcohol drinking (0.3%) than in those without (1.5%).

Figure 2 depicts the non-parametric associations between weekly work hours and eGFR. The results show a significant non-parametric function of weekly work hours on eGFR according to sex/gender and the prevalence of HTN and DM. All groups showed M-shaped associations between weekly work hours and eGFR; this implies weekly work hours are associated with eGFR among participants who worked relatively long and short hours, respectively, in a week.

The results of negative binomial regression analysis showed no significantly higher PRs for the long working hours group compared with the reference group. Those who worked <30 hours per week had significantly higher PRs for CKD compared with participants who worked 30–40 hours a week (1.52; 95% CI 1.14 to 2.01). After stratifying the prevalence status of HTN and DM, the associations were similarly significant among participants with HTN and among participants without DM (online supplementary table S3).

Table 2 presents the results of the linear regression analyses for weekly work hours and eGFR. In the long work hours group (≥52 hours/week), there was a significant negative association between weekly work hours and eGFR; one additional weekly work hour was associated with a significant decrease in eGFR. This association was better observed after excluding participants with HTN and/or DM. Among participants who worked 30–40 hours a week and 41–51 hours a week, a 1-hour increase in weekly work hour was significantly associated with 0.248 mL/min/1.73 m^2 (95% CI −0.468 to 0.029) and 0.209 mL/min/1.73 m^2 (95% CI −0.395 to 0.023) decrease in eGFR, respectively. Work hours of participants did not show significant difference by comorbidity status of HTN or DM (online supplementary table S4).

DISCUSSION

This study aimed to assess the relationship between work hours and eGFR and to further clarify the role of long work hours in kidney function impairment among Korean workers. We found a negative and linear association between work hours and eGFR, especially among participants who worked relatively long hours (≥52 hours/week). These findings indicate that long work hours might have harmful effects on kidney function.

Moreover, our results showed an increased prevalence of CKD among participants who worked <30 hours a week, which means those who worked <30 hours a week tended to have worse kidney function compared with participants who worked 30–40 hours a week. With regard to this result, we considered the probability of selection processes into labour market participants and working hours. Health disadvantages as well as advantages may have influenced how much people worked. Individuals with reduced kidney function may decrease their working hours. However, our cross-sectional study design could not ascertain the direction in which the selection process may have occurred; therefore, the selection process could lead to an underestimation of the true association. Thus, to identify causal relations, the results still need to be tested in a longitudinal study.

Work hours may influence health in several ways, either directly or indirectly. Insufficient physical recovery is a primary route to chronic health impairment. Long work hours are well known to be associated with shorter recovery time and limited relaxation time after work.[19] According to the effort-recovery model, a short rest from work could lead to recovery under optimal circumstances, but if no adequate recovery takes place, the psycho-physiological systems continue to remain strained.[20]

Another important pathway to chronic health impairment is the close association of long work hours with high job demand. In a Dutch study that investigated the relationship between working overtime and psychosocial work characteristics, the results showed a positive relationship between overtime hours and need for recovery in high strain jobs (high demand, low control).[21] Repeated mental stressors can cause enhanced sympathetic nervous system activity, stimulating glucocorticoid

Table 1 Demographic characteristics of the study participants

	Total		CKD (eGFR <60 mL/min/1.73 m^2)			eGFR (mL/min/1.73 m^2)	
	n	%*	n	%†	p value‡	Mean±SD	p value§
Total	20 770	100.0	390	1.4		89.7±16.3	
Sex/gender							
Male	10 712	58.8	221	1.4	0.519	86.9±14.8	<0.001
Female	10 058	41.2	169	1.3		92.7±17.3	
Age (years)							
20–29	3308	22.0	2	0.04	<0.001	99.6±15.7	<0.001
30–39	5301	26.7	9	0.1		92.6±15.1	
40–49	5249	25.8	44	0.8		88.2±14.7	
50–59	4009	17.2	105	2.5		85.8±15.3	
60–	2903	8.2	230	7.9		81.1±16.5	
Occupation							
Non-manual	13 037	64.1	164	1.0	<0.001	91.1±16.2	<0.001
Manual	7733	35.9	226	2.0		87.7±16.4	
Shift work							
No	17 246	82.1	314	1.3	0.405	89.6±16.3	0.322
Yes	3524	17.9	76	1.5		89.9±16.6	
Employment status							
Regular	14 823	72.8	211	1.1	<0.001	89.6±15.7	0.048
Temporary	3873	18	126	2.1		90.2±18.1	
Daily-wage labourer	2074	9.2	53	2.0		89.3±17.1	
Income status							
Low	4306	21.4	83	1.3	0.619	90.8±17.1	<0.001
Middle-low	5446	26.3	107	1.3		90.0±15.9	
Middle-high	5586	27.0	103	1.2		89.3±16.3	
High	5432	25.4	97	1.5		88.9±16.2	
Education level							
Elementary school	2563	8.7	146	5.0	<0.001	84.7±17.2	<0.001
Middle school	1791	7.6	48	2.1		87.5±16.3	
High school	7239	37.6	96	1.0		91.0±16.1	
College or above	9177	46.1	100	0.9		90.5±15.9	
Body mass index							
<25 kg/m^2	14 222	68.0	219	1.1	<0.001	90.6±16.3	<0.001
≥25 kg/m^2	6548	32.0	171	1.9		87.6±16.3	
Hypertension							
No	16 172	80.5	125	0.6	<0.001	91.2±15.8	<0.001
Yes	4598	19.5	265	4.5		84.5±17.0	
Diabetes mellitus							
No	19 337	94.0	278	1.1	<0.001	90.0±16.1	<0.001
Yes	1433	6.0	112	6.0		85.3±19.1	
Smoking							
Non-smoker	11 253	49.3	209	1.4	<0.001	91.2±16.9	<0.001
Former smoker	3295	16.2	105	2.2		86.0±15.3	
Current smoker	6222	34.6	76	0.9		88.9±15.5	
Problematic alcohol drinking¶							
No	17 851	84.1	378	1.5	<0.001	89.5±16.5	<0.001
Yes	2919	15.9	12	0.3		90.9±15.4	

*Unweighted frequencies and weighted percentage.
†Unweighted frequencies and weighted percentage in a row.
‡^{2} test was performed to test differences in CKD prevalence by demographic characteristics.
§Student's t-test or analysis of variance was performed to test differences in eGFR according to demographic characteristics.
¶Problematic drinking was defined as ≥7 drinks at a time and >2 times/week in men and ≥5 drinks at a time and >2 times/week in women.
CKD, chronic kidney disease; eGFR, estimated glomerular filtration rate.

secretion and potential risk of inflammation. These factors contribute to a higher prevalence of HTN, DM and vascular disease, which are all major risk factors for CKD.[6] Furthermore, there may be a significant influence of sociocultural elements that affect eating behaviour and obesity, and this may be related to job stress.[22] In our study, we observed that obese workers

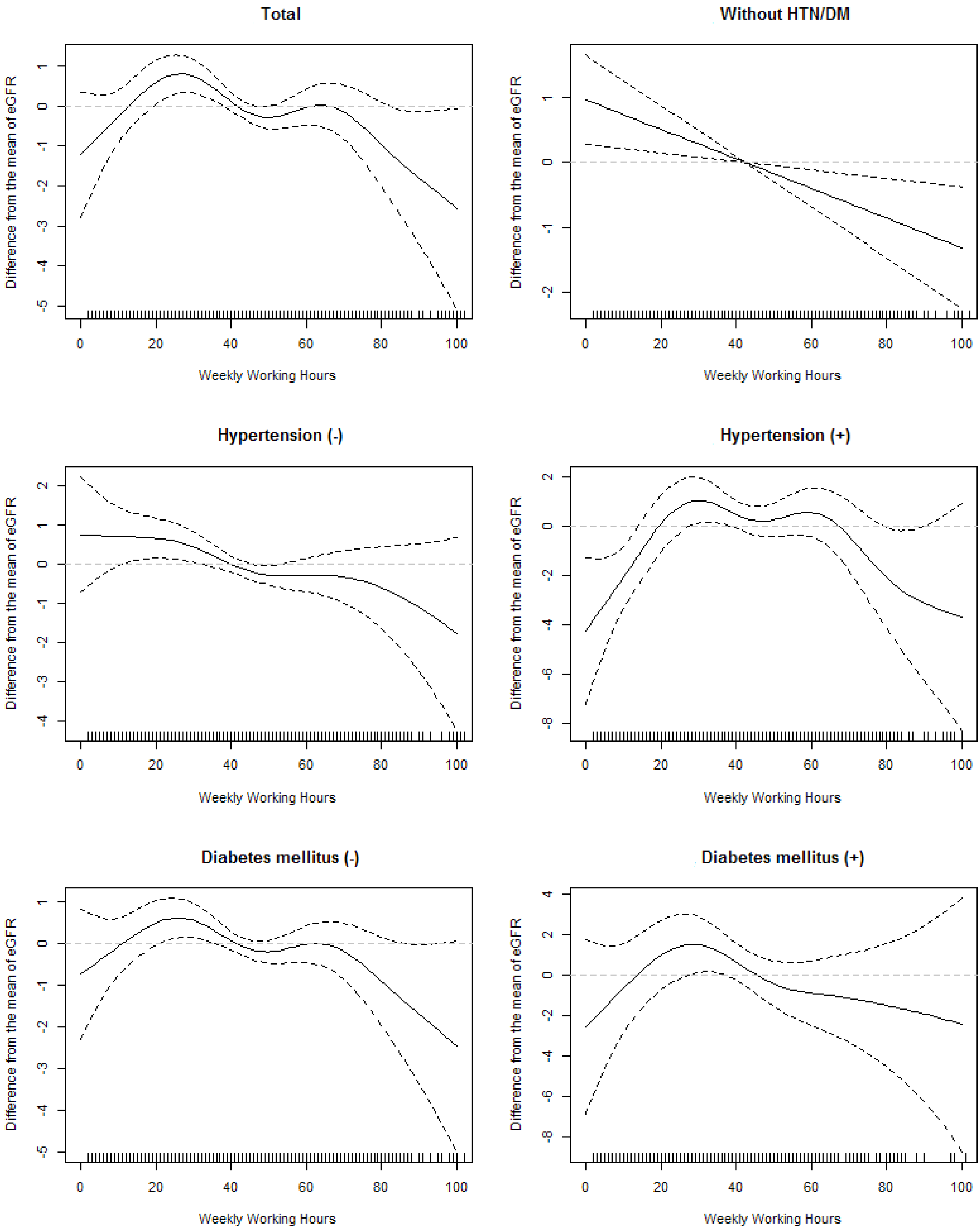

Figure 2 Non-parametric association between weekly working hours and estimated glomerular filtration rate (eGFR). Adjusted for age, sex/gender, income, education, shift work, occupation group, smoking and alcohol consumption frequency, hypertension (HTN), diabetes mellitus (DM), body mass index, systolic blood pressure, fasting blood glucose, and total serum cholesterol.

Table 2 Results of linear regression analysis for working hours and eGFR

Group	Weekly working hours	Total n	Total eGFR change per 1-hour increase in weekly working hours (95% CI)		Male n	Male eGFR change per 1-hour increase in weekly working hours (95% CI)		Female n	Female eGFR change per 1-hour increase in weekly working hours (95% CI)	
Total	Total	20770	0.003	(−0.014 to 0.020)	10712	0.008	(−0.014 to 0.030)	10058	−0.003	(−0.029 to 0.023)
	<30	4184	−0.016	(−0.091 to 0.059)	1167	0.015	(−0.111 to 0.141)	3017	−0.028	(−0.120 to 0.064)
	30–40	6253	**−0.248**	**(−0.441 to −0.055)**	2987	**−0.321**	**(−0.594 to −0.049)**	3266	−0.167	(−0.426 to 0.092)
	41–51	6001	−0.132	(−0.297 to 0.033)	3542	−0.106	(−0.299 to 0.087)	2459	−0.146	(−0.431 to 0.139)
	≥52	4332	**−0.057**	**(−0.109 to −0.005)**	3016	−0.031	(−0.091 to 0.029)	1316	**−0.126**	**(−0.235 to −0.017)**
Without HTN/DM	Total	16513	−0.003	(−0.022 to 0.016)	7437	0.009	(−0.017 to 0.035)	8076	−0.015	(−0.044 to 0.013)
	<30	2915	−0.064	(−0.151 to 0.024)	691	−0.049	(−0.204 to 0.107)	2224	−0.072	(−0.177 to 0.032)
	30–40	4768	**−0.248**	**(−0.468 to −0.029)**	2024	−0.293	(−0.607 to 0.022)	2744	−0.200	(−0.485 to 0.086)
	41–51	4697	**−0.209**	**(−0.395 to −0.023)**	2615	−0.208	(−0.422 to 0.006)	2082	−0.207	(−0.518 to 0.105)
	≥52	3133	−0.048	(−0.107 to 0.011)	2107	−0.019	(−0.087 to 0.05)	1026	**−0.131**	**(−0.257 to −0.005)**

Adjusted for age, sex/gender, income, education, shift work, occupation group, smoking, problematic alcohol drinking, HTN, DM, body mass index, systolic blood pressure, fasting blood glucose and total serum cholesterol.

Bold values indicate $p<0.05$.

CI, confidence interval; DM, diabetes mellitus; eGFR, estimated glomerular filtration rate; HTN, hypertension.

(BMI ≥25 kg/m^2) had a higher prevalence of CKD and reduced kidney function (table 1).

Nevertheless, there have been no reports of a direct relationship between long work hours and the risk of CKD thus far, although long work hours are a well-known risk factor for cardiovascular disease.[23 24] Several reports have shown that the risk for cardiovascular disease is notably increased in individuals with CKD. In a cohort study with a 2.84-year follow-up, an independent, graded association was observed between a reduced eGFR and the risk of cardiovascular events in a large, community-based population.[4] This could be attributable to these two diseases sharing common risk factors, such as smoking, obesity, HTN, dyslipidaemia and DM.[3] Thus, patients with CKD should be considered among the highest risk groups for cardiovascular events and diseases. A previous Korean study showed work hours were significantly related to the risk factors of cardiovascular disease, such as blood pressure, cholesterol levels, DM and smoking habits.[25]

Among disease conditions, HTN and DM are the most important risk factors for CKD.[26] Although both HTN and DM are related to long work hours,[10 27] kidney function could be affected by long work hours even in the absence of these risk factors. When we conducted analysis using only participants without HTN or DM, we observed a linearly negative relationship between work hours and eGFR (figure 2).

The association between eGFR and working hours differed by shift work status (online supplementary table S5). Among workers without shift work, the change in eGFR according to one additional working hour per week was 0.004, while it was −0.076 among workers with shift work. These results are in line with the findings of previous studies showing that shift work is associated with reduced kidney function and increased risk of CKD.[28–31] However, the underlying mechanisms of association remain unknown thus far. As such, further research is necessary to better elucidate the association between shift work and CKD.

There are several limitations inherent in the design of this study. First, the cross-sectional nature of the study does not enable the establishment of a causal relationship between exposure and health outcomes. It is possible that participants with pre-existing kidney problems may reduce their work hours to prevent worsening of symptoms, which can lead to an underestimation of actual risk. Thus, to find a causal relationship, the questions raised by this study still need to be further tested in a longitudinal study. Second, despite attempts to control for confounding variables, we could not preclude the influence of other factors, such as low birth weight, family history of kidney disease, dietary habit, use of analgesic medications or job stress, which might affect the relationship between work hours and kidney function. Third, this study was based on a single eGFR measurement, so misclassification of kidney function could have occurred. According to the definition of CKD, abnormalities of kidney structure or function should be present at least for 3 months. However, in this study, CKD cases could not be matched against the definition of CKD because our data were collected at only one time point. Therefore, there is the possibility that patients with acute kidney injury were included.

Nevertheless, these limitations are balanced by several strengths. First, to our best knowledge this is the first study investigating the relationship between work hours and kidney function. Second, this study was undertaken in a representative sample of the general Korean population. Third, this study population with relatively longer work hours (compared with other countries) provided a better opportunity to evaluate the association between work hours and kidney function.

CONCLUSIONS

Long work hours are associated with reduced kidney function, based on an analysis of representative data from the Korean adult population. The results of the study can have implications for clinical and policy-oriented perspectives. Identifying high-risk groups for CKD associated with long work hours would help both clinicians and policy-makers to develop context-specific interventions to prevent the risk of CKD development and progression.

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Contributors All authors discussed the results and commented on the manuscript. Specifically, M-YK conceptualised and designed the study and supervised the study conduct. D-WL collected and analysed the data. M-YK and D-WL wrote and prepared the manuscript. JL, H-RK and KYJ revised it critically as regards important intellectual content.

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Competing interests None declared.

Patient consent for publication Not required.

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Data availability statement Data are available in a public, open access repository (Korea National Health and Nutrition Examination Survey, https://knhanes.cdc.go.kr/knhanes/eng/index.do).

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