Association Between Long Working Hours and Chronic Kidney Disease According to Diabetic Status

A Nationwide Study (Korean National Health and Nutrition Examination Survey 2010–2017)

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Objective: This study aimed to investigate the relationship between long working hours and chronic kidney disease (CKD) according to diabetic status. **Methods:** Twelve thousand seven hundred three full-time employees without diabetes and 2136 with diabetes were included in this study. Participants were grouped according to working hours: ≤40, 41 to 52, and >52 h/week. Multiple logistic regression was used to evaluate the association between working hours and CKD prevalence. **Results:** Participants with diabetes who worked 41 to 52 h/week showed 1.85 times higher odds of CKD (95% CI 1.15–2.96; $P = 0.0112$) compared with those who worked ≤40 h/week after adjusting for covariates. An interaction between diabetes and long working hours was observed (P for interaction = 0.0212) in the model. **Conclusion:** Long working hours are associated with CKD in participants with diabetes. An interaction between long working hours and diabetes leading to CKD development may exist.

Keywords: chronic kidney disease, diabetes mellitus, noncommunicable diseases, overtime work, working hour

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Ethical Considerations and Disclosure: This study was conducted according to the principles of the Declaration of Helsinki and was performed in accordance with current scientific guidelines. KNHANES data is publicly accessible and ethical approval is not required for the use of the data. This data were collected with prior consent before participating in the survey and respondents' information was completely anonymized for use for research purposes [1].

1. Kweon, S., et al., *Data resource profile: the Korea national health and nutrition examination survey (KNHANES).* International journal of epidemiology, 2014. **43**(1): p. 69–77.

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Clinical significance: In this study, we identified long working hours as an independent risk factor for chronic kidney disease in diabetic employees. Because working hour can be modified, it is important risk factor for CKD. Therefore, it should be considered when establishing healthcare policy and when educating patients.

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Learning Objectives

- Summarize the methods used in this nationally representative study of associations between working hours and chronic kidney disease (CKD) among diabetic and non-diabetic employees.
- Identify the observed associations with CKD, including interactions between diabetes status and categories of working hours.
- Discuss potential mechanisms of the reported associations and the implications for policy and patient education.

Diabetes mellitus (DM) is a disease characterized by pancreatic beta-cell dysfunction and can be diagnosed on the basis of fasting plasma glucose (FPG) levels, glucose tolerance testing, or glycated hemoglobin (HbA1c) levels.[1] DM is one of the most common chronic diseases, and its prevalence is still increasing. In 2017, the global prevalence of diabetes was estimated to be 8.8% in participants aged between 20 and 79 years, which is expected to increase by 9.9% by 2045. In addition, a total expenditure of 727 billion dollars was spent for DM care in 2017, which is expected to increase by 776 billion dollars by 2045.[2] Among the many complications of diabetes, chronic kidney disease (CKD) is one of the most important. CKD is defined as the impairment of kidney structure and function for ≥3 months, causing a high disease burden.[3] The prevalence of CKD is estimated to be 8% to 16% worldwide and is especially high in developing countries.[4] In South Korea, estimated prevalence of CKD in adults was 8.2%.[5] CKD develops in approximately 40% of patients with diabetes. Diabetic nephropathy is one of the most common causes of CKD.[6,7] The prevalence of diabetic kidney disease is still increasing, resulting in substantial healthcare expenditure.[8,9]

Although DM has several complications[10–12] and increases mortality rate,[13] individuals with diabetes can still lead a normal life and be employed.[14] The working environment affects several health conditions. Shift work can cause sleep disorders[15] and may be a risk factor for many other health conditions,[16] including hypertension.[17] Workers may be exposed to harmful chemical substances within the working space.[18,19] Extended working hours also have several noxious effects on health conditions. A meta-analysis study revealed that long working hours can deteriorate occupational health and work-related health.[20] Park et al suggested that long working hours impair the hearing function.[21]

South Korea is one of the countries with longest working hours worldwide. South Koreans work for an average of 1993 h annually, whereas the average working hours in countries included in the Organization for Economic Cooperation and Development was 1734 h in 2018.[22]

The hours spent on working is a modifiable factor among the many risk factors related to CKD. It is important to determine whether the long working hours are an independent risk factor for

CKD. However, evidence associating long working hours with CKD is largely absent at present. A cross-sectional study reported the existence of an association between shift work and CKD in manual labor workers.[23] Another study showed an association between CKD and sleep duration among shift workers.[24] However, to the best of our knowledge, no study has investigated the relationship between working hours and CKD. Therefore, this study aimed to determine the relationship between long working hours and CKD.

METHODS

Study Population

The study data were obtained from the 2010 to 2017 Korean National Health and Nutrition Examination Survey (KNHANES). The KNHANES is a cross-sectional nationwide survey that has been conducted by the Korea Centers for Disease Control and Prevention since 1998.[25] The survey provides a representative sample of the noninstitutionalized South Korean population residing in Korea, using a complex, poststratified, multistage clustered probability design. A total of 64,759 participants enrolled in the KNHANES from 2010 to 2017. Among them, 27,393 full-time employees who worked >15 h/week with valid responses about working hours were assessed for eligibility for this study. We excluded participants aged <40 years ($N = 19{,}605$). Participants with missing data for assessing the CKD status and diabetic status were also excluded from the eligible participants ($N = 2726$). A total of 14,839 participants were finally considered eligible for analysis after excluding 196 participants with missing data on covariates. The participants were divided into 12,703 participants without diabetes and 2136 participants with diabetes (Fig. 1).

Working Hours

The International Labor Organization recommends regulating the hours of work, with a 40-h workweek in developed countries and a 48-h workweek in developing countries being considered normal working hours.[26] In Korea, the Labor Standards Act legislates 40 h/week and 8 h/day as the statutory weekly working hours, allowing extended work up to an additional 12 h based on agreements between employers and employees. To evaluate the working hours, the participants of KNHANES were asked the following question: "How many hours per week on average do you work at your workplace, including overtime work and night overtime? (excluding mealtime)." Considering the above-mentioned standards, we categorized full-time employees into three groups according to working hours (≤40 h/week, 41–52 h/week, and >52 h/week). In addition, more subdivided and expanded working hour criteria was used to analyze the detailed differences.

Diabetic Status

The study participants were classified according to diabetic status (with or without DM). DM can be diagnosed based on either the FPG or HbA1c.[1] Measuring HbA1c has some advantages over FPG measurement in diagnosing DM, including the availability of nonfasting blood samples and the stability of biological factors.[27] Fasting blood samples were collected and HbA1c was analyzed using high performance liquid chromatography (HLC-723G8,

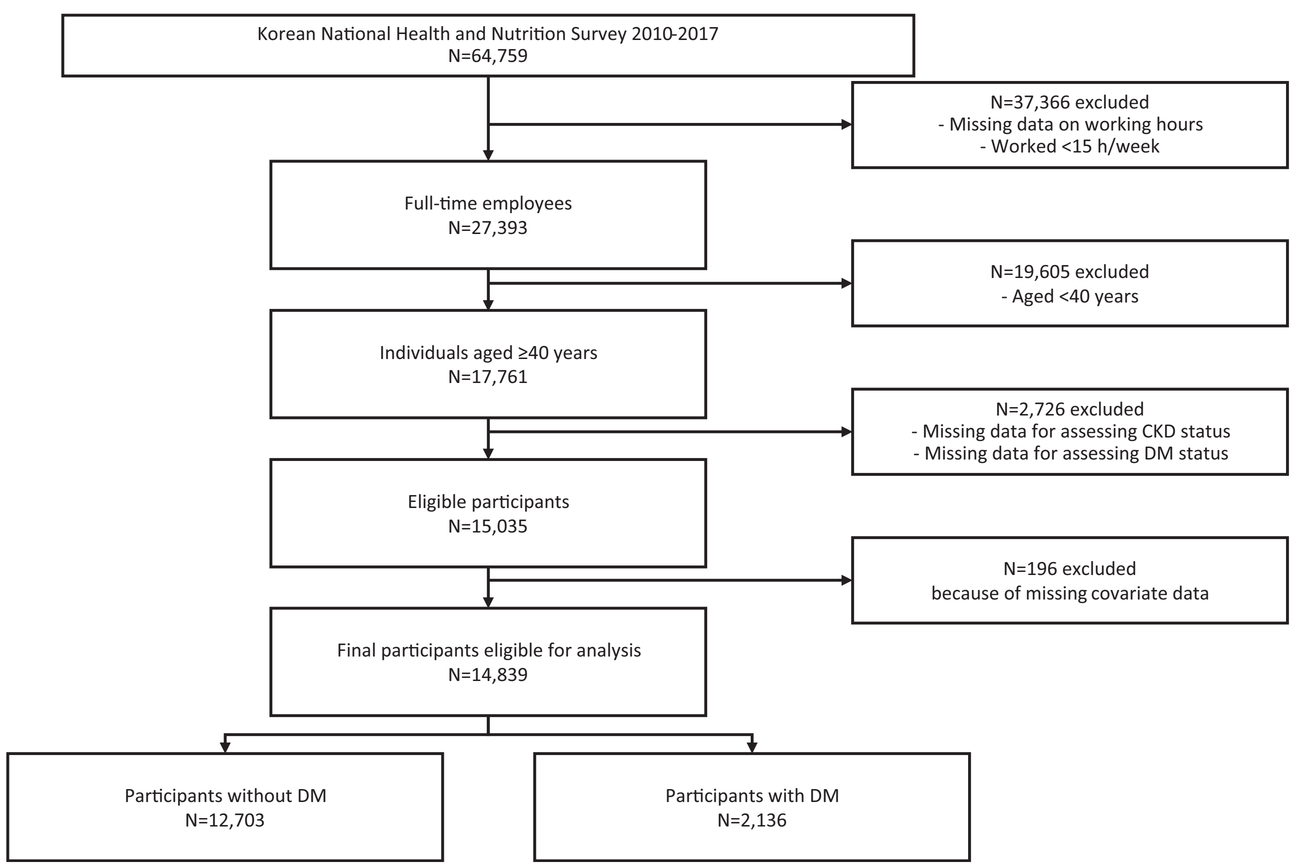

FIGURE 1. Flow diagram of the study population (12,703 participants without DM, and 2136 participants with DM).CKD, chronic kidney disease; DM, diabetes mellitus.

Tosoh G8; Tosoh/Japan). Participants who had HbA1c levels >6.5%, who were diagnosed with DM by a doctor or were using medications for diabetes were identified as the diabetic group and the others were identified as the nondiabetic group.

CKD Status

The Modification of Diet in Renal Disease (MDRD) equation is known to be an accurate formula for estimating the glomerular filtration rate (GFR).[28] Estimated GFR (eGFR) calculated using the MDRD equation can be used to evaluate kidney function.[29] In this study, GFR was calculated on the basis of the serum creatinine level according to the MDRD equation as follows: $175 \times$ serum creatinine$^{-1.154} \times$ age $^{-0.203}$ ($\times 0.742$ if female).[30] Serum creatinine levels were measured using fasting blood samples with the Jaffe rate-blanked and compensated method (Hitachi Automatic Analyzer 7600–210; Hitachi/Japan, CREA, Rosche/Germany). Participants with an eGFR of $<60\,mL/min/1.73\,m^2$ were considered to have significant loss of renal function and were classified into the CKD group.[29,31]

Other Covariates

Data on demographic characteristics and social and lifestyle-related factors were obtained using standardized health interview questionnaires. Health examination data, including anthropometric measurements, blood pressure levels, and laboratory test results, were collected by trained medical personnel and using periodically calibrated equipment.[25] The participants were grouped according to age (40–49, 50–59, 60–69, and ≥70 years), educational status (≤elementary school, middle school, high school, or ≥college), and household income quartiles. They were also grouped into manual workers (skilled workers in agriculture, forestry, and fishery; craft and related workers; machine operators and assemblers; or simple manual workers), nonmanual worker (managers, professionals and related workers, clerks, service workers, and salespeople), and others (homemakers, students) according to the extent of occupational physical strain (soldiers were excluded). Working schedules were categorized into regular day work and shift work: participants who worked during the daytime (06:00–18:00) were defined as daytime workers, and the remaining others (14:00–24:00, 21:00–08:00, regular day–night shift work, 24-h shift work, split-shift, irregular shift work) were defined as shift workers.

Factors related to the health condition of participants were also assessed. Physical activity was defined as performing at least 150 min of moderate-intensity physical activity 75 min of vigorous-intensity physical activity, or an equivalent combination of physical activity per week.[32] With respect to the smoking status, the participants were grouped into never smokers, past smokers and current smokers. Problem drinking was defined as drinking ≥6 units of alcohol two or more times per week in men and ≥4 units of alcohol two or more times per week in women. Body mass index (BMI) was used to determine the obesity status: BMI $<18.5\,kg/m^2$ was defined as underweight, $18.5\,kg/m^2 \leq BMI < 25\,kg/m^2$ was defined as normal weight, and $BMI \geq 25\,kg/m^2$ was defined as obesity.[33] Systolic blood pressure (SBP) and diastolic blood pressure (DBP) were measured thrice and the mean of the second and third measurements was used to determine the hypertensive status. Hypertension was defined as SBP ≥ 140 mm Hg, DBP ≥ 90 mm Hg or use of antihypertensive medications.

Diabetes-related factors were also assessed. The duration of diabetes was measured using the age at the diagnosis of diabetes. If diabetes was not yet diagnosed by a doctor, the duration of diabetes was considered 0. The participants were grouped according to DM duration as follows: 0, 1 to 10, 11 to 20, 21 to 30, and >30 years. Glycemic control was evaluated using the HbA1c level, and participants with diabetes were classified into three groups: HbA1c <7%, 7% to 9%, and >9%.[34]

Statistical Analysis

In this study, analyses were performed considering the complex sampling design, which included multistage clustering and stratification to represent the South Korean population. Baseline characteristics are presented as frequencies and weighted percentages. The Rao-Scott χ^2 test was used to compare the general characteristics of the DM and non-DM groups according to working hours. Multiple logistic regression was performed to calculate the odds ratios (ORs) and 95% confidence intervals (CIs). The association between working hours and CKD according to diabetic status was examined before and after adjusting for covariates. SAS (version 9.4M6; SAS Institute Inc, Cary, NC) was used for all statistical analyses. Two-sided *P*-values were used to evaluate statistical significance. Statistical significance was set at $P < 0.05$.

RESULTS

General Characteristics of the Study Population

The 14,839 total participants were divided into the non-DM group ($N = 12{,}703$) and the DM group ($N = 2136$). The groups were compared according to working hours. In the non-DM group, 5851 participants worked <40 h/week, 3324 participants worked 41 to 52 h/week, and 3528 participants worked >52 h/week. In the DM group, 989 participants worked <40 h/week, 465 participants worked 41 to 52 h/week, and 682 participants worked >52 h/week.

In the non-DM group, an age difference was observed according to working hours. Participants with longer working hours tended to be male-dominant and were less likely to be physically active. In addition, the proportions of current smokers and participants with problem drinking were larger in the longer working hour groups. A higher prevalence of obesity and hypertension was observed in the groups with longer working hours. The prevalence of CKD did not differ among working hour groups ($P = 0.2074$).

In the DM group, an age difference was observed according to working hours. Participants with longer working hours tended to be male. The proportion of current smokers was higher in the group with longer working hours. No difference was observed in the prevalence of obesity and hypertension among the working hour groups. In addition, there was no difference in the prevalence of CKD among the working hour groups ($P = 0.0977$). The detailed general characteristics of the study population are presented in Table 1.

Association Between Working Hours and CKD According to Diabetic Status

The association between working hours and CKD is shown in Table 2. The association was assessed according to diabetic status, and the interaction between diabetic status and working hours was also analyzed. The overall *P* for interaction in the crude model was 0.1584. The *P* for interaction was 0.0683 in the adjusted model 1 (adjusted for age, sex, educational status, household income, physical activity, smoking and drinking status, obesity, hypertension, worker type, and working schedule). In the crude model, *P* for interaction was 0.0553 and 0.5105 in the 41 to 52, and >52 h/week groups, respectively, compared with the ≤40 h/week group. In the adjusted model, there was an interaction effect in the 41 to 52 h/week group ($P = 0.0212$) but not in >52 h/week group ($P = 0.2490$).

The crude model presented the relationship between working hours and CKD without any adjustment. Those working for ≤40 h/week were set as the reference group. In participants without DM, the OR of having CKD in the 41 to 52 and >52 h/week groups was 0.85 (95% CI 0.62–1.18, $P = 0.3312$) and 0.75 (95% CI 0.53–1.05, $P = 0.0955$), respectively. In those with DM, the OR was 1.44 (95% CI 0.94–2.19, $P = 0.0908$) in the 41 to 52 h/week group and 0.90 (95% CI 0.59–1.36, $P = 0.6080$) in the >52 h/week group.

TABLE 1. General Characteristics of the Study Population

	Non-DM (N = 12,703)				DM (N = 2136)			
Variables	≤40 h/week (N = 5851)	41–52 h/week (N = 3324)	>52 h/week (N = 3528)	P	≤40 h/week (N = 989)	41–52 h/week (N = 465)	>52 h/week (N = 682)	P
Age (years)				<0.0001				0.0001
40–49	2152 (43.98)	1423 (50.28)	1207 (43.71)		155 (21.15)	110 (31.37)	114 (24.18)	
50–59	2026 (36.83)	1166 (35.21)	1331 (37.95)		309 (37.61)	155 (37.54)	244 (41.13)	
60–69	1166 (14.04)	546 (11.35)	735 (14.41)		350 (28.48)	138 (23.14)	250 (27.79)	
≥70	507 (5.15)	189 (3.16)	255 (3.93)		175 (12.76)	62 (7.94)	74 (6.90)	
Sex				<0.0001				<0.0001
Female	3247 (50.73)	1375 (34.93)	1423 (33.32)		403 (37.43)	136 (24.66)	204 (26.57)	
Male	2604 (49.27)	1949 (65.07)	2105 (66.68)		586 (62.57)	329 (75.34)	478 (73.43)	
Education				<0.0001				0.0001
≤ Elementary school	1143 (14.82)	548 (12.12)	743 (15.97)		316 (26.94)	106 (17.82)	201 (23.15)	
Middle school	773 (12.43)	422 (11.37)	659 (16.96)		183 (18.33)	91 (18.93)	153 (21.85)	
High school	1931 (35.86)	1161 (37.05)	1280 (39.15)		274 (29.46)	147 (33.89)	223 (37.06)	
≥College	2004 (36.89)	1193 (39.46)	846 (27.92)		216 (25.27)	121 (29.36)	105 (17.94)	
Household income (quartile)				<0.0001				0.0039
1/4	863 (12.30)	329 (7.79)	370 (8.25)		242 (20.13)	67 (11.79)	124 (17.05)	
2/4	1380 (23.29)	799 (22.96)	1061 (29.32)		262 (25.83)	138 (27.59)	214 (29.80)	
3/4	1607 (29.30)	1012 (31.96)	1085 (31.80)		237 (25.86)	116 (27.63)	183 (29.80)	
4/4	2001 (35.12)	1184 (37.28)	1012 (30.63)		248 (28.18)	144 (33.00)	161 (23.36)	
Physical activity				<0.0001				0.5467
Yes	810 (15.73)	436 (15.25)	374 (12.01)		94 (11.14)	56 (13.18)	66 (10.89)	
No	5041 (84.27)	2888 (84.75)	3154 (87.99)		895 (88.86)	409 (86.82)	616 (89.11)	
Smoking status				<0.0001				<0.0001
Never smoker	3552 (56.81)	1692 (45.64)	1769 (44.25)		480 (45.98)	180 (36.33)	254 (34.96)	
Past smoker	1236 (22.16)	845 (27.16)	865 (25.74)		294 (29.15)	161 (33.38)	197 (28.94)	
Current smoker	1063 (21.02)	787 (27.20)	894 (30.01)		215 (24.87)	124 (30.30)	231 (36.10)	
Problem drinking				0.0016				0.3747
Yes	778 (15.88)	525 (17.73)	600 (19.45)		153 (18.22)	85 (22.07)	115 (19.55)	
No	5073 (84.12)	2799 (82.27)	2928 (80.55)		836 (81.78)	380 (77.93)	567 (80.45)	
Obesity (BMI, kg/m^2)				0.0058				0.8603
Underweight (<18.5)	132 (2.15)	73 (2.04)	79 (2.00)		11 (0.91)	4 (1.22)	8 (0.91)	
Normal (18.5–25)	3827 (64.74)	2061 (61.60)	2186 (60.75)		492 (49.93)	225 (48.01)	320 (46.9)	
Obese (≥25)	1892 (33.10)	1190 (36.35)	1263 (37.26)		486 (49.16)	236 (50.77)	354 (52.12)	
Hypertension				0.0106				0.7451
Yes	1815 (29.15)	1017 (29.03)	1192 (32.39)		558 (51.54)	260 (53.73)	389 (53.38)	
No	4036 (70.85)	2307 (70.97)	2336 (67.61)		431 (48.47)	205 (46.27)	293 (46.62)	
Worker type				<0.0001				0.3787
Manual worker	2435 (39.64)	1451 (42.50)	1695 (46.80)		514 (46.95)	237 (49.39)	366 (52.71)	
Nonmanual worker	2854 (51.40)	1631 (50.61)	1576 (46.71)		367 (42.81)	181 (40.22)	255 (38.68)	
Others	562 (8.96)	242 (6.89)	257 (6.49)		108 (10.25)	47 (10.38)	61 (8.60)	
Working schedule				<0.0001				<0.0001
Daytime work	5114 (86.94)	2880 (86.33)	2792 (79.08)		896 (88.25)	401 (86.58)	526 (76.84)	
Shift work	737 (13.06)	444 (13.67)	736 (20.92)		93 (11.75)	64 (13.42)	156 (23.16)	
Chronic kidney disease (MDRD, GFR < 60 mL/min/1.73 m^2)				0.2074				0.0977
Yes	152 (2.23)	79 (1.91)	79 (1.68)		78 (6.95)	51 (9.69)	49 (6.28)	
No	5699 (97.77)	3245 (98.09)	3449 (98.32)		911 (93.05)	414 (90.31)	633 (93.72)	
DM duration (years)								0.3479
≤0					333 (35.43)	166 (37.64)	257 (40.57)	
1–10					476 (47.76)	228 (48.52)	311 (45.76)	
11–20					139 (13.18)	55 (10.93)	88 (10.84)	
21–30					30 (2.47)	14 (2.68)	22 (2.37)	
>30					11 (1.16)	2 (0.23)	4 (0.46)	
DM control (HbA1c, %)								0.1078
<7					492 (50.29)	231 (49.86)	308 (44.55)	
7–9					393 (38.87)	174 (35.95)	276 (40.01)	
≥9					104 (10.84)	60 (14.19)	98 (15.44)	

Values with unweighted frequency (weighted %) are presented. *P*-value among working hour groups.
BMI, body mass index; DM, diabetes mellitus; eGFR, estimated glomerular filtration rate; HbA1c, glycated hemoglobin; MDRD, modification of diet in renal disease.

TABLE 2. Odds Ratios and 95% Confidence Intervals for Chronic Kidney Disease According to Working Hour Groups in Participants with and Without Diabetes

		Crude Model		Adjusted Model 1		Adjusted Model 2	
	Participants	OR (95% CI)	P	OR (95% CI)	P	OR (95% CI)	P
Non-DM	12,703						
≤40 h/week	5,851	Reference = 1.00	Reference = 1.00	N/A			
41–52 h/week	3,324	0.85 (0.62–1.18)	0.3312	0.92 (0.66–1.27)	0.6021	N/A	N/A
>52 h/week	3,528	0.75 (0.53–1.05)	0.0955	0.72 (0.50–1.03)	0.0695	N/A	N/A
DM	2,136						
≤40 h/week	989	Reference = 1.00	Reference = 1.00	Reference = 1.00			
41–52 h/week	465	1.44 (0.94–2.19)	0.0908	1.85 (1.15–2.96)	0.0112	1.92 (1.20–3.08)	0.0063
>52 h/week	682	0.90 (0.59–1.36)	0.6080	0.97 (0.61–1.53)	0.8786	1.01 (0.62–1.62)	0.9781

"Adjusted model 1" was adjusted for age, sex, educational status, household income, physical activity, smoking and drinking status, obesity, hypertension, worker type, and working schedule. In adjusted model 1, the *P* for interaction of working hours and DM in the 41–52 h/week group was 0.0212. "Adjusted model 2" was adjusted for age, sex, educational status, household income, physical activity, smoking and drinking status, obesity, hypertension, worker type, working schedule.

CI, confidence interval; DM, diabetes mellitus; DM, duration and glycemic control; OR, odds ratio.

The model after adjusting for covariates including age, sex, educational status, household income, physical activity, smoking and drinking status, obesity, hypertension, and working environment (adjusted model 1) was also analyzed. In the non-DM group, compared with participants who worked ≤40 h/week, those who worked 41 to 52 h/week showed an OR of 0.92 (95% CI 0.66–1.27, $P = 0.6021$) and those who worked >52 h/week showed an OR of 0.72 (95% CI 0.50–1.03, $P = 0.0695$). In the DM group, the 41 to 52 h/week group had 1.85 times higher odds of having CKD (adjusted OR 1.85, 95% CI 1.15–2.96, $P = 0.0112$) than the <40 h/week group. The OR in the >52 h/week group, compared with the ≤40 h/week group, was 0.97 (95% CI 0.61–1.53, $P = 0.8786$).

An additional analysis was performed to determine whether there was an association between long working hours and CKD after adjusting for diabetes-related factors. Additional adjustment for the duration of diabetes and control of HbA1c was performed (adjusted model 2). In the adjusted model 2, the OR was 1.92 (95% CI 1.20–3.08, $P = 0.0063$) in participants who worked 41 to 52 h/week and 1.01 (95% CI 0.62–1.62, $P = 0.9781$) in those who worked >52 h/week.

Association Between Working Hours and CKD in Multiple Working Hour Criteria

The association between working hours and CKD was analyzed according to multiple working hour criteria. The association was analyzed based on three different working hour criteria in participants with diabetes. Each model was analyzed after adjusting for covariates including age, sex, educational status, household income, physical activity, smoking and drinking status, obesity, hypertension, working environments, and diabetes-related factors.

In criterion 1, participants were classified into those who work ≤40 h/week, 41 to 60 h/week, >60 h/week. Those working for ≤40 h/week were set as the reference group. The OR of having CKD in the 41 to 60 h/week group and >60 h/week group was 1.61 (95% CI 1.05–2.47, $P = 0.0294$) and 0.95 (95% CI 0.53–1.68, $P = 0.8470$), respectively.

In criterion 2, participants were classified into those who work ≤35 h/week, 36 to 50 h/week, >50 h/week. Those working for ≤35 h/week were set as the reference group. The OR of having CKD in the 35 to 50 h/week group and >50 h/week group was 2.27 (95% CI 1.40–3.68, $P = 0.0009$) and 1.35 (95% CI 0.80–2.27, $P = 0.2655$), respectively.

In criterion 3, participants were classified into seven groups (≤35 h/week, 36–40 h/week, 41–45 h/week, 46–50 h/week, 51–55 h/week, 56–60 h/week, and > 60 h/week) and those working for ≤35 h/week were set as the reference group. The OR of having CKD was significantly higher in 36 to 40 h/week group (adjusted OR 1.91, 95% CI 1.03–3.53, $P = 0.0399$), 41 to 45 h/week group (adjusted OR 2.77, 95% CI 1.43–5.38, $P = 0.0026$), and 46 to 50 h/week group (adjusted OR 2.50, 95% CI 1.35–4.61, $P = 0.0035$). The detailed results are presented in Table 3.

DISCUSSION

In this study, we evaluated the association between weekly working hours and CKD according to diabetic status using representative data of the Korean population. Participants without diabetes who worked 41 to 52 h/week showed no difference from those who working ≤40 h/week. However, full-time employees with diabetes who worked 41 to 52 h/week had 1.85 times higher odds of having CKD than those who worked ≤40 h/week, and a statistically significant interaction between working hours and diabetes

TABLE 3. Association Between Working Hour Groups and Chronic Kidney Disease in Participants with Diabetes According to Multiple Working Hour Criteria

Criterion	Participants	OR (95% CI)	P
Criterion 1			
≤40 h/week	989	Reference = 1.00	
41–60 h/week	754	1.61 (1.05–2.47)	0.0294
>60 h/week	393	0.95 (0.53–1.68)	0.8470
Criterion 2			
≤35 h/week	617	Reference = 1.00	
36–50 h/week	809	2.27 (1.40–3.68)	0.0009
>50 h/week	710	1.35 (0.80–2.27)	0.2655
Criterion 3			
≤35 h/week	617	Reference = 1.00	
36–40 h/week	372	1.91 (1.03–3.53)	0.0399
41–45 h/week	189	2.77 (1.43–5.38)	0.0026
46–50 h/week	248	2.50 (1.35–4.61)	0.0035
51–55 h/week	136	1.94 (0.81–4.66)	0.1398
56–60 h/week	181	1.25 (0.58–2.68)	0.5715
>60 h/week	393	1.21 (0.66–2.24)	0.5334

Each model was adjusted for age, sex, educational status, household income, physical activity, smoking and drinking status, obesity, hypertension, worker type, working schedule, DM duration and glycemic control.

CI, confidence interval; DM, diabetes mellitus; OR, odds ratio.

was observed. Long working hours have a possible relationship to suboptimal glycemic control,[35] and the interaction and association may be due to this relationship. However, full-time employees with diabetes who worked 41 to 52 h/week had 1.92 times higher odds of having CKD even after adjusting for diabetes-related factors. In addition, multiple working hour analyses also confirmed this association.

To the best of our knowledge, there is no evidence showing a direct association between working hours and CKD itself in relation to diabetic status. Lee et al suggested long working hours as a possible risk factor for decreased eGFR.[36] However, they did not suggest the association with CKD itself. Several studies have attempted to explain the relationship between the working environment and CKD. In addition, several studies have shown that shift work is related to CKD. Previous studies have attempted to demonstrate that shift work can be a risk factor for CKD in relation to sleep duration[24] and manual work.[23] Other studies have reported an association between CKD and exposure to harmful substances in the workplace. A case–control study performed in the United States suggested a possible relationship between occupational silica exposure and CKD risk.[37] A cohort study showed that organic solvent exposure increases the risk of CKD.[38] Some studies have suggested a relationship between working hours and other health conditions that are risk factors for CKD. Hypertension is a well-known risk factor for CKD.[39] Poor glycemic control can also lead to CKD.[40,41] Yang et al suggested long working hours as a possible risk factor for hypertension.[42] Long working hours may also increase the risk of type 2 DM when combined with low socioeconomic status.[43] Some studies have also indicated that long working hours is a risk factor for prediabetes and poor glycemic control.[35,44,45] Given the evidences, the working environment potentially influences the development of CKD in many ways. Therefore, further studies, including the present study, are needed to investigate the association between long working hours and CKD.

The prevalence of diabetes among full-time workers in this study was 14.4%. This was consistent with the previously reported prevalence in Korea, which was 14.4% in participants >30 years.[46] This prevalence is also comparable to that reported by the International Diabetes Federation (IDF) for the North American and Caribbean, Southeast Asian, Middle East and North African, and Western Pacific regions.[2] According to IDF Diabetes Atlas, the age-adjusted prevalence of diabetes was 11.1% in the North American and Caribbean regions, 12.2% in the Middle East and North African, 11.4% in the Western Pacific regions, and the 11.3% in the Southeast Asian regions.

Some explanations can be proposed for the associations shown in this study. Work-related stress can increase with increasing working hours. Considering that work related stress could stimulate systemic inflammation,[47,48] employees with long working hours have a greater chance of developing systemic inflammation. Diabetes can also be interpreted as a disease of systemic inflammation.[49] The inflammation may worsen with long working hours, aggravating the complications of diabetes. In addition, long working hours can lead to more exposure to harmful substances in the working environment. A previous study reported that exposure to heavy metals, industrial chemicals, and possible infectious diseases in the workplace might be associated with CKD.[50] Exposure to environmental toxic substances in the workplace may result in beta-cell dysfunction in individuals with diabetes,[51] leading to diabetic nephropathy. No meaningful difference was observed in participants with diabetes who worked >52 h/week. A possible explanation for this finding is that the employees with CKD may not have the capability to work for >52 h/week.

This study has several strengths. To the best of our knowledge, this study provides the first evidence of the association between long working hours and CKD in relation to diabetic status. Moreover, our study is based on KNHANES, which represents the entire Korean population. The prevalence of diabetes observed in this study was consistent with that reported in a previous study. Because we evaluated blood glucose level using the HbA1c level, which can reflect the long-term blood glucose level, the diabetic status of the participants is reliable despite the cross-sectional nature of the study. Finally, the results were meaningful after adjusting for known important covariates, such as the status of HbA1c control. However, this study also has some limitations. In diagnosing CKD, structural abnormality is an important factor. Since the data of albuminuria was only available in KNHANES 2011 to 2014 and imaging studies including ultrasound are not available in this dataset, CKD prevalence may have been underestimated in this study. Because this study is both cross-sectional and observational in nature, we could not infer clear causal association between the variables of interest. Reverse causality is an important issue in cross-sectional studies. However, it is more reasonable to interpret that long working hours can be a risk factor for CKD development than vice versa. Owing to the cross-sectional design, the variables of interest were collected at one point which might make the reported values unreliable. Moreover, several variables, including working hours, was self-reported. Variables evaluated with self-reported values may be imprecise. In addition, other confounding factors, including dietary factors, which can play an important role in developing CKD were excluded in this study, because of their availability and credibility.

In conclusion, long working hours were associated with CKD in full-time employee with diabetes, independent of known risk factors. No relationship was observed between long working hours and CKD among employees without diabetes. An interaction between diabetes and long working hours leading to CKD development may exist. Additional longitudinal studies are required to confirm these findings.

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