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Cross-sectional study of the association between long working hours and the risk of pre-diabetes: 2013-2017 Korea National Health and Nutrition Examination Survey

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ABSTRACT

OBJECTIVE: Long working hours have been associated with type 2 diabetes (T2DM). However, the relationship with pre-diabetes in the general population remains unexplored. We aimed to investigate whether long working hours were linked with an increased risk of pre-diabetes as determined by glycated hemoglobin (HbA1c) level.

DESIGN: Cross-sectional survey

PARTICIPANTS: This study included 5,536 men and 5,147 women without diabetes from the 2013-2017 Korean National Health and Nutrition Examination Survey (KNHANES).

PRIMARY OUTCOME MEASURES: The study outcome of interest was pre-diabetes, defined as HbA1c values 5.7-6.4%

RESULTS: Logistic regression was performed to obtain the odds ratios (OR) for pre-diabetes according to categories of work hour (≤ 40 hours/week, 41-52 hours/week, >52 hours/week), after adjusting for relevant covariates. Of the 10,683 eligible participants, 1,977 (35.7%) men and 1,713 (33.3%) women had pre-diabetes. After adjusting for age, educational attainment, monthly household income, life-style related factors, perceived stress, family history of diabetes, hypertension, hypercholesterolemia and other covariates, a multiple logistic regression analysis found that extended working hours (>52 hours per week) was associated with an increased likelihood of pre-diabetes in men (adjusted OR=1.40; 95%CI=1.19-1.65). In the subgroup analysis by occupational categories, the association was only apparent in green- and blue-collar worker groups.

CONCLUSION: Extended working hours were significant related to the increased risk of pre-diabetes, independent of conventional risk factors. Our results suggest prolonged working hours are associated with glucose metabolism among non-diabetic male workers in Korea.

Keywords: Pre-diabetes, Hba1c, working hours, Glucose metabolism

Strengths and limitations of this study

- As far as we are aware, this is the first report of an association between long working hours and pre-diabetes among individuals without diabetes using a nationally representative sample of Korean adults. We further compared associations by occupational categories.
- This study controlled for a range of factors that are known to affect HbA1c levels.
- Our analyses are based on cross-sectional data and, as such, preclude direct causal inference.

INTRODUCTION

Pre-diabetes, defined as an intermediate state of hyperglycemia with glycemic parameters above normal but below the diagnostic threshold for diabetes is considered an important risk factor for β-cell dysfunction[1] and the development of type 2 diabetes mellitus (T2DM).[2,3] According to the 2012 projection estimates, prevalence of pre-diabetes will continue to rise, and it is estimated that by 2030 over 470 million people will have pre-diabetes globally.[4] Approximately 70% of individuals diagnosed with pre-diabetes are expected to progress to T2DM within 10 years.[5] Given the high incidence rate of diabetes among pre-diabetic adults, identification of the modifiable risk factors of pre-diabetes in the general population is thus essential to effectively prevent or delay the onset of diabetes and its associated complications.

South Korea has one of the longest work hours among member states of the Organization for Economic Cooperation and Development (OECD), with people spending on average 2,069 hours at work annually compared to the OECD average of 1,764 hours.[6] There is increasing epidemiological evidence that working long hours raise the risk of various health outcomes, including coronary heart disease[7, 8], cognitive function [9], type 2 diabetes [2,10], as well as a high prevalence of anxiety[11], depressive symptoms [12, 13], and sleeping disturbances.[14] In a meta-analysis of epidemiological studies conducted in USA, Europe, Japan, and Australia, Kivimäki et al. reported a prospective association between long working hours and the incidence of diabetes, but only among employees with a low socioeconomic position.[15] Similarly, one study of Chinese male workers found that the risk of developing diabetes increased with longer hours of overtime work per week.[16] However, the relationship between long working hours and pre-diabetes in populations without diabetes remains unexplored. To fill this evidence gap, we investigated the relationship between weekly working hours and the risk of pre-diabetes using a cross-sectional survey of 10,683 workers in South Korea.

METHODS

Study population

Data were drawn from the 2013-2017 Korean National Health and Nutrition Examination Survey (KNHANES). KNHANES is an ongoing population based, cross-sectional study which is designed to assess the health and nutritional status of people residing in South Korea.[17] The survey's sampling strategy was designed to be representative of the non-institutionalized civilian population aged 1 year or over which was selected using a complex, multistage, stratified sampling design. Of the 39,225 participants (Men : 17,842, Women : 21,383) who participated in the 2013-2017 survey, 16,131 reported as being economically active and therefore were eligible to be asked job-related modules and 16,091 provided valid responses concerning weekly work hours. KNHANES participants under 30 or >70 years old and pregnant women were excluded from the analysis. We also excluded those who reported a previous clinical diagnosis of diabetes made by a physician or taking insulin or anti-diabetic medication or missing data on Hba1c, or Hba1c values greater than 6.5% (N=1,840). Finally, we excluded participants with missing covariate data (N=473), yielding a final sample of 10,683 participants (Men : 5,536 , Women : 5,147) (See Figure 1).

Patient and Public Involvement (PPI)

No patients were included in the design and planning of the study. Including PPI statements aligns closely with BMJ Open's values of transparency and inclusiveness. We hope that including PPI statements in all articles is the first step of many for BMJ Open in encouraging patient involvement.

Measures

Definition of Pre-diabetes

The main study outcome was glycated hemoglobin (HbA1c). HbA1c is a form of hemoglobin in which glucose is attached to its β-chain after exposure to high plasma levels of glucose. As such, it is used as an integrated index of long-term serum glucose regulation.[18] Fasting bloods samples were collected during a medical examination and HbA1c levels were measured via high performance liquid chromatography (HLC-723G7; Tosoh, Tokyo, Japan). Participants were identified as being normoglycemic if they had a HbA1c level below 5.7%; HbA1c level between 5.7 and 6.4 percent were indicative of pre-diabetes according to the 2018 American Diabetes Association (ADA) standards of care in diabetes.[19]

Working hours

In the KNHANES, participants were asked about their working hours using the following question: "During the last month, how many hours on average in a week did you work, including unpaid overtime work (excluding meal time)?" In Korea, statutory weekly work hours based on the Labor Standards Act (LSA) are 40 hours per week and 8 hours per day. The working hours stipulated in LSA Article 50 may be extended up to additional 12 hours by agreement between the parties. Therefore, in the current study we defined long working hours as working beyond the legal threshold of 52 hours. Participants reported their working hours as a continuous variable, and this was further categorized as follows: ≤ 40 hours, 41-52 hours, or >52 hours per week.

Covariates

Data on socio-demographic characteristics, lifestyle- and health-related factors were collected using interviewer-administered standardized questionnaires. Age was categorized into 30–39, 40–49, 50–59, and ≥ 60 years. Participants were categorized by educational attainment (elementary school, middle school, high school, and university degree or above), monthly household income quartiles, and occupational categories (white collar (managers, professionals), pink collar (clerks, service, and sales workers), green collar (agricultural, fishery or forestry workers) and blue collar (craft/trades workers, machine operators and assemblers, and elementary manual workers). Work schedules were assessed using the following question: "Do you work mostly during the day time, or do you work at a different time period?" Respondent who usually worked during the daytime (06:00-18:00), evening hours (14:00-24:00), or night-time (21:00-08:00) were categorized as fixed schedule workers, while those who worked 24-hours rotating shifts, split shifts, or irregular shifts were classified as shift schedule workers.

Health-related behaviours included smoking status (Never smoker, former smoker, and current smoker) alcohol consumption (Yes or no), muscle strengthening activity at least twice a week (yes/no), and sleep duration (< 6, 6-8, ≥9 hours). Body mass index (BMI [kg/m2]) was used to determine obesity status and calculated based on respondent's self-reported height and weight. A BMI of <18.5 was considered underweight, a BMI > 18.5 and <23.0 was considered normal weight, a BMI greater than or equal to 23.0 and <25.0 was considered overweight, and a BMI ≥ 25 was considered obese. The level of perceived stress was measured using the following question: “How stressed are you on a daily basis?” with possible answers ranging from ‘None’ coded 0 to ‘High’ coded 4. Respondents were reclassified into low (none/low) and high perceived stress (moderate/high). Hypercholesterolemia (yes/no) was defined as a serum total cholesterol level ≥240 mg/dL or the use of lipid-lowering medications. Hypertension (yes/no) was defined as a systolic blood pressure of 140 mmHg or higher, diastolic blood pressure of 90 mmHg or higher or on antihypertensive treatment. A family history of diabetes was ascertained by asking participants whether their first-degree relatives (parents or siblings) had ever been told they have diabetes (yes/no).

STATISTISTICAL ANALYSES

Statistical analyses were conducted using SAS version 9.4 (SAS Institute Inc., Cary, NC, USA). The SAS survey procedure was applied to reflect the stratification and clustering of the complex sampling design and sampling weights of the KNHANES and to ensure nationally representative prevalence estimates. Baseline characteristics of the study sample were described using frequency and weighted percentages. Chi-square test was used to compare the characteristics between normoglycemic and pre-diabetic subjects. Multivariable logistic regression analysis was used to evaluate the association between working hours and pre-diabetes status, and odds ratios (ORs) and 95% CI were calculated after adjusting for socio-demographic and health-related behavioural variables that showed significant association in univariate analysis and based on clinical relevance. Additionally, we evaluated whether the association between long working hours and pre-diabetes was dependent on age or work-related characteristics by testing interaction effects and conducting subgroup analyses. A multiplicative interaction term (working hour×effect modifier variable) was included in the multivariable logistic regression model along with the main effects. All analyses were performed separately for men and women and statistical significance set at $p < 0.05$.

RESULTS

General characteristics of the study population

Table 1 presents participants' general characteristics by Hba1c status in men and women. A total of 1,977 (34.42%) men and 1,713 (30.97%) women had pre-diabetes. Men who worked 40 hours or less had the lowest pre-diabetes prevalence (32.09%), followed by those working 41–52 hours (32.99%) and >52 hours (38.79%). Male workers with pre-diabetes were also more likely to be older, have a lower level of education, to be working in a blue-collar occupation, obese, current smokers; sleep less than 6 hours and to have a diagnosis of hypertension, hypercholesteremia and a family history of diabetes compared with normoglycemic subjects. The proportion of subjects who participated in muscle strengthening activity least twice a week was lower in the group with pre-diabetes. For women, we observed statistically significant differences in prevalence of pre-diabetes for most characteristics, except for smoking status, muscle strengthening activity, family history of diabetes and work schedule.

Table 1. General characteristics of the study population by HbA1c status, KNHANES 2013-2017

	Men (N=5,536)				Women (N=5,147)			
	Total	Pre-diabetes N (%)	Normoglycemia N (%)	p-value	Total	Pre-diabetes N (%)	Normoglycemia N (%)	p-value
Working hours per week (hours)				**0.0003**				**0.003**
40 or less	2,139 (37.3)	736 (32.1)	1,403 (67.9)		3,131 (60.9)	1,049 (31.0)	2,082 (68.99)	
41-52	1,762 (32.2)	598 (33.0)	1,164 (67.0)		1,133 (22.0)	332 (27.4)	801 (72.57)	
>52	1,635 (30.5)	643 (38.8)	992 (61.2)		883 (17.1)	332 (35.4)	551 (64.59)	
Age (years)				**<.0001**				**<.0001**
30-39	1,533 (31.7)	373 (23.7)	1,160 (76.3)		1,187 (24.9)	165 (13.7)	1,022 (86.3)	
40-49	1,654 (32.6)	563 (34.8)	1,091 (65.2)		1,592 (34.0)	379 (23.0)	1,213 (77.0)	
50-59	1,450 (25.8)	613 (41.8)	837 (58.2)		1,524 (29.2)	705 (45.3)	819(54.7)	
≥60	899 (9.9)	428 (48.1)	471 (51.9)		844 (11.9)	464 (54.9)	380 (45.1)	
Education				**<.0001**				**<.0001**
Elementary School	467 (6.5)	216 (45.5)	251 (54.5)		859 (13.4)	448 (51.2)	411 (48.8)	
Middle school	517 (8.1)	229 (43.6)	288 (56.4)		575 (10.7)	254 (42.1)	321 (57.9)	
High school	1,785 (32.7)	704 (39.0)	1,081 (61.0)		1,837 (38.0)	612 (31.7)	1,225 (68.3)	
University degree or above	2,767 (52.7)	828 (28.8)	1,939 (71.2)		1,876 (37.9)	399 (20.0)	1,477 (80.0)	
Total household income				0.106				**<.0001**
Low	314 (4.6)	126 (39.9)	188 (60.1)		500 (8.6)	218 (40.8)	282 (59.2)	
Middle-low	1,240 (21.8)	476 (36.3)	764 (63.7)		1,234 (22.7)	449 (34.1)	785 (65.9)	
Middle-high	1,889 (35.1)	660 (34.2)	1,229 (65.8)		1,625 (33.1)	520 (29.7)	1,105 (70.3)	
High	2,093 (38.5)	715 (32.9)	1,378 (67.1)		1,788 (35.6)	526 (27.8)	1,262 (72.2)	
Smoking status				**0.0001**				0.083
Never smoker	1,135 (20.8)	337 (29.6)	798 (70.4)		4,655 (89.8)	1,575 (31.5)	3,080 (68.5)	
Former smoker	2,144 (36.7)	764 (33.6)	1,380 (66.4)		234 (4.9)	62 (24.7)	172 (75.3)	
Current smoker	2,257 (42.5)	876 (37.5)	1,381 (62.5)		258 (5.3)	76 (27.7)	182 (72.3)	
Alcohol consumption				0.333				**<.0001**
No	175 (2.9)	66 (38.5)	109 (61.5)		615 (11.0)	289 (43.2)	326 (56.8)	
Yes	5,361 (97.1)	1,911 (34.3)	3,450 (65.7)		4,532 (89.0)	1,424 (29.5)	3,108 (70.5)	
Muscle strengthening activity				**0.053**				0.556
No	4,088 (74.0)	1,495 (35.3)	2,593 (64.7)		4483 (87.2)	1,491 (31.1)	2,992 (68.9)	
Yes	1,448 (26.0)	482 (32.1)	966 (67.9)		664 (12.8)	222 (29.9)	442 (70.1)	
BMI				**<.0001**				**<.0001**
Underweight	91 (1.7)	17 (18.4)	74 (81.6)		211 (4.4)	39 (15.9)	172 (84.1)	
Normal	1,627 (29.5)	468 (27.9)	1,159 (72.1)		2,429 (48.3)	582 (22.1)	1,847 (77.9)	
Overweight	1,548 (27.9)	534 (32.4)	1,014 (67.6)		1,138 (21.7)	433 (35.7)	705 (64.3)	
Obese	2,270 (40.9)	958 (41.2)	1,312 (58.8)		1,369 (25.6)	659 (46.3)	710 (53.7)	

Table 1 Continued

Hypertension				**<.0001**				**<.0001**
No	3,976 (73.25)	1,333 (32.37)	2,643(67.63)		4,180 (83.17)	1,239 (27.73)	2,941 (72.27)	
Yes	1,560 (26.75)	644 (40.05)	916 (59.95)		967 (16.83)	474 (47.00)	493 (53.00)	
Hypercholesterolemia				**<.0001**				**<.0001**
No	4,690 (85.63)	1,580 (32.43)	3,110 (67.57)		4,266 (84.08)	1,258 (27.52)	3,008 (72.48)	
Yes	846 (14.37)	397 (42.27)	449 (53.73)		881 (15.92)	455 (49.20)	426 (50.80)	
Family history of diabetes				**<.0001**				0.5349
No	4,356 (78.19)	1,505 (32.67)	2,851 (67.33)		3,878 (74.80)	1,275 (30.72)	2,604 (69.28)	
Yes	1,180 (21.81)	472 (40.71)	708 (59.29)		1,268 (25.20)	438 (31.71)	830 (68.29)	
Sleep duration (hours)				**0.0203**				**<.0001**
< 6	673 (12.06)	265 (38.15)	408 (61.85)		724 (14.42)	297 (39.11)	427 (60.89)	
6-8	4,394 (80.14)	1,563 (34.37)	2,831 (65.63)		3,824 (74.05)	1,259 (30.53)	2,565 (69.47)	
≥9	469 (8.00)	149 (29.15)	320 (70.85)		599 (11.52)	157 (23.61)	442 (76.39)	
Perceived stress				0.8854				**0.020**
None/Low	4,063 (72.01)	1,463 (34.48)	2,600 (65.52)		3,715 (71.71)	1,281 (32.00)	2,434 (67.99)	
Moderate/High	1,473 (27.99)	514 (34.26)	959 (65.74)		1,432 (28.29)	432 (28.36)	1,000 (71.64)	
Occupation				**<.0001**				**<.0001**
White collar	2,366 (44.45)	723 (29.39)	1,643 (70.61)		2,059 (41.36)	452 (20.32)	1,607 (78.68)	
Pink collar	721 (13.38)	259 (36.21)	462 (63.79)		1,521 (30.12)	594 (37.03)	927 (62.98)	
Green collar	375 (4.79)	166 (44.02)	209 (55.98)		305 (4.31)	156 (49.00)	149 (51.00)	
Blue collar	2,074 (37.38)	829 (38.53)	1,245 (61.47)		1,262 (24.21)	511 (38.43)	751 (61.57)	
Work schedule				0.896				0.392
Fixed	5,161 (93.44)	1,835 (34.40)	3,326 (65.60)		4,970 (96.33)	1,651 (30.85)	3,319 (69.15)	
Shift	375 (6.56)	142 (34.78)	233 (65.22)		177 (3.67)	62 (34.14)	115 (65.86)	
Participants		1,977 (34.42%)	3,559 (65.58%)			664 (30.97%)	3,434 (69.03)	

*Unless otherwise stated, unweighted frequency (weighted %) are shown.
†P value comparing prediabetes with normoglycemia

Association between long working hours and pre-diabetes

Adjusted odds ratios (ORs) from the multiple logistic regression analysis are shown in Table 2. We found no statistically significant associations between long working hours and pre-diabetes in women (adjusted OR: 0.86; 95% CI: 0.70-1.05; P = 0.137). In the case of men, those who worked >52 hours were 1.40 times more likely to have pre-diabetes after adjusting for covariates (adjusted Odds Ratio (OR): 1.40; 95% Confidence Interval (CI): 1.19-1.65; P<0.0001). Age, smoking status, hypercholesteremia, family history of diabetes and sleep duration were also found to considerably increase the risk of pre-diabetes in men, but there were no statistically significant differences based on educational level, monthly household income, alcohol consumption, muscle strengthening activity, hypertension, perceived stress, occupation and work schedule.

Table 3 presents the ORs for subgroup analyses by age and work-related characteristics. We did not observe a significant interaction between the number of hours worked per week and age (P for interaction =0.413) nor between work schedule and working hours (P=0.708). A tendency towards a more pronounced effect of long working hours on pre-diabetes among shift workers (41-52 hrs: aOR= 1.19, 95% CI: 0.57-2.52; >52 hrs: aOR= 1.56, 95% CI: 0.78-3.12; p for trend=0.186). However, this effect did not reach statistical significance. In the subgroup analysis by occupational categories, male workers who worked in green-collar occupation were likely to have pre-diabetes as their average weekly working hours increased, after adjustment for all covariates. The adjusted ORs were 1.03 (95% CI 0.56-1.88) and 1.91 (95% CI 1.05-3.48) for the 41-52 hrs and >52 hrs categories, respectively (p for trend= 0.041). Similar results were observed for blue-collar workers (41-52 hrs: aOR= 1.22, 95% CI: 0.93-1.61; >52 hrs: aOR= 1.82, 95% CI: 1.40-2.36; p for trend= <0.0001). The interaction effect by occupational categories was only marginally significant (p for interaction=0.063).

Table 2. Results of the multiple logistic regression analysis for the association between long working hours and pre-diabetes (HbA1c 5.7-6.4%)

Characteristics	Prediabetes (HbA1c 5.7–6.4%)					
	Men			Women		
	OR	95% CI	P-value	OR	95% CI	P-value
Working hours per week (hours)						
40 or less	1.00			1.00		
41-52	1.17	0.99-1.38	0.061	0.89	0.74-1.07	0.207
>52	**1.40**	**1.19-1.65**	**<0.0001**	0.86	0.70-1.05	0.137
Age (years)						
30-39	1.00			1.00		
40-49	**1.70**	**1.43-2.03**	**<0.0001**	**1.48**	**1.16-1.89**	**0.0015**
50-59	**2.40**	**1.98-2.92**	**<0.0001**	**3.53**	**2.76-4.57**	**<0.0001**
≥60	**3.30**	**2.59-4.22**	**<0.0001**	**4.84**	**3.52-6.66**	**<0.0001**
Education						
Elementary School	1.00			1.00		
Middle school	1.06	0.79-1.42	0.719	0.89	0.68-1.18	0.435
High school	1.09	0.83-1.44	0.536	1.07	0.83-1.39	0.588
University degree or above	0.85	0.63-1.16	0.311	0.95	0.69-1.30	0.750
Total household income						
Low	1.00			1.00		
Middle-low	1.03	0.75-1.40	0.872	1.07	0.81-1.41	0.627
Middle-high	0.99	0.73-1.34	0.925	1.11	0.84.1.47	0.483
High	0.96	0.70-1.31	0.802	1.12	0.84-1.49	0.451
Smoking status						
Never smoker	1.00			1.00		
Former smoker	0.98	0.82-1.18	0.848	1.04	0.71-1.52	0.858
Current smoker	**1.38**	**1.15-1.66**	**0.001**	1.06	0.76-1.47	0.733
Alcohol consumption						
No	1.00			1.00		
Yes	0.97	0.67-1.42	0.889	0.89	0.71-1.10	0.274
Muscle strengthening activity						
No	1.00			1.00		
Yes	0.91	0.78-1.06	0.214	0.96	0.78-1.19	0.727
BMI						
Underweight	1.00			1.00		
Normal	1.76	0.91-3.40	0.094	1.04	0.69-1.57	0.846
Overweight	2.19	1.13-4.28	**0.021**	**1.60**	**1.04-2.46**	**0.031**
Obese	**3.33**	**1.72-6.43**	**0.0003**	**2.50**	**1.64-3.83**	**<0.0001**

Table 2 Continued

Hypertension						
No	1.00			1.00		
Yes	0.99	0.85-1.15	0.886	1.08	0.90-1.30	0.423
Hypercholesterolemia						
No	1.00			1.00		
Yes	**1.61**	**1.35-1.92**	**<0.0001**	**1.42**	**1.18-1.71**	**0.001**
Family history of diabetes						
No	1.00			1.00		
Yes	**1.48**	**1.27-1.73**	**<0.0001**	**1.21**	**1.03-1.43**	**0.022**
Sleep duration (hours)						
< 6	1.01	0.84-1.22	0.905	1.20	0.98-1.48	0.080
6-8	1.00			1.00		
≥9	**0.75**	**0.59-0.97**	**0.027**	**0.75**	**0.59-0.94**	**0.013**
Perceived stress						
None/Low	1.00			1.00		
Moderate/High	1.06	0.92-1.23	0.415	0.91	0.78-1.08	0.284
Occupation						
White collar	1.00			1.00		
Pink collar	1.15	0.91-1.44	0.242	**1.34**	**1.08-1.66**	**0.007**
Green collar	1.17	0.86-1.58	0.324	1.41	0.99-2.01	0.060
Blue collar	1.12	0.93-1.34	0.254	1.17	0.93-1.48	0.182
Work schedule						
Fixed	1.00			1.00		
Shift	0.99	0.75-1.30	0.927	1.19	0.81-1.76	0.367

Table 3. Results of subgroup analysis of association between hba1c and working hours by age and work characteristics

Characteristics	Men Odds ratio (95% CI)			p for trend	p for interaction	Women Odds ratio (95% CI)			p for trend	p for interaction
	≤40 hrs	41-52 hrs	>52 hrs			≤40 hrs	41-52 hrs	>52 hrs		
Occupational categories					0.063					0.297
White collar	1.00	1.14 (0.90-1.44)	1.11 (0.84-1.48)	0.369		1.00	0.95 (0.70-1.28)	0.60 (0.36-1.00)	0.099	
Pink collar	1.00	1.29 (0.79-2.10)	1.11 (0.71-1.73)	0.728		1.00	0.76 (0.55-1.05)	0.81 (0.61-1.09)	0.133	
Green collar	**1.00**	**1.03 (0.56-1.88)**	**1.91 (1.05-3.48)**	**0.041**		1.00	1.38 (0.74-2.58)	1.41 (0.69-2.90)	0.306	
Blue collar	**1.00**	**1.22 (0.93-1.61)**	**1.82 (1.40-2.36)**	**<.0001**		1.00	0.89 (0.60-1.32)	0.89 (0.61-1.30)	0.473	
Work schedule					0.708					0.080
Fixed	**1.00**	**1.16 (0.98-1.38)**	**1.37 (1.15-1.63)**	**0.0003**		1.00	0.85 (0.71-1.03)	0.88 (0.71-1.08)	0.119	
Shift	1.00	1.19 (0.57-2.52)	1.56 (0.78-3.12)	0.186		1.00	2.86 (1.12-7.33)	0.73 (0.25-2.12)	0.895	
Age (years)					0.413					0.822
30-39	**1.00**	**1.51 (1.07-2.14)**	**1.73 (1.22-2.47)**	**0.002**		1.00	0.93 (0.60-1.44)	0.73 (0.36-1.49)	0.380	
40-49	1.00	0.92 (0.69-1.23)	1.22 (0.91-1.62)	0.218		1.00	0.79 (0.57-1.09)	0.74 (0.49-1.11)	0.084	
50-59	1.00	1.20 (0.89-1.60)	1.36 (0.99-1.86)	0.052		1.00	1.03 (0.76-1.40)	0.98 (0.73-1.33)	0.938	
≥60	**1.00**	**1.61 (1.07-2.44)**	**1.75 (1.18-2.60)**	**0.004**		1.00	0.78 (0.49-1.23)	0.69 (0.46-1.04)	0.061	

DISCUSSION

In this population-based study of Korean working adults without diabetes, we found that men who worked over 52 hours per week exhibited 40% increased risk of pre-diabetes than did those who worked ≤ 40 hours per week. This association was robust to adjustments for socio-demographic variables and lifestyle factors, such as obesity, participation in muscle strengthening activity, smoking, and alcohol consumption and other covariates. Importantly, the excess risk of pre-diabetes associated with long working hours was more marked in the case of the workers in manual occupations.

In the present study, the prevalence of pre-diabetes in the Korean working population was 34.4% and 30.9% for men and women, respectively. These prevalence estimates are comparable to general population estimates reported in the U.S [20], U.K [21], and those of other Asian countries.[22] Several previous studies have yielded prevalence estimates for pre-diabetes in Korea. Using the HbA1c cutoff, pre-diabetes prevalence in 2011 was reported to be 38.3% (Men: 41%; women: 35.7%) in a community-based cross-sectional study of Korean adults aged 30 years or over.[23] Another Korean study reported a pre-diabetes prevalence of 26.1% in men and 20.5% according to American diabetes association criteria.[24] However, this study was based on a sample from rural areas. Pre-diabetes is a well-recognized risk factors for future diabetes, that gives rise to micro- and macrovascular complications and have enormous social and economic burden [25, 26]; increased attention needs to be paid to the high prevalence of pre-diabetes in Korea.

We are not aware of other studies that has reported a relationship between long working hours and pre-diabetes, although our findings are comparable with a meta-analysis showing that long working hours is associated with the incidence of type 2 diabetes, only in individuals from low socioeconomic status groups.[15] Other studies also reported a similar finding, indicating that prevalence of pre-diabetes is positively correlated with longer working hours.[3, 14, 16] However, conflicting findings have also been reported in other studies where relative risks of T2DM significantly decreased with an increase in hours of work per day.[27]

The mechanisms underlying the association between long working hours and pre-diabetes are yet unknown. It is likely that a similar mechanism to that of diabetes could be responsible for the observed findings. Plausible explanations are that longer working hours impacts pre-diabetes risk via their association with behavioural risk factors. Prior research has indicated that working longer than recommended hours is linked to many behavioural risk factors, such as binge drinking [28,29] and low physical activity [30], possibly because individuals feel that they lack the time to engage in leisure-time physical activity due to demands and responsibilities at work. In the present study, working hour–pre-diabetes association attenuated but remained statistically significant after adjustment for behaviour risk factors. As such, conventional risk factors for pre-diabetes are likely to explain only part of the association between long working hours and pre-diabetes.

Meanwhile, there has been a proposition that extended working hours are related to cortisol secretion [31], a known risk factor for impaired glucose metabolism.[32] Cortisol induces the formation of glucose in the liver and have insulin-antagonistic effects in the peripheral tissues; both processes have the potential to contribute to risk of hyperglycemia. Furthermore, individuals work longer hours are more often exposed to harmful psychological factors in the work environment, such as job strain [33, 34] and effort-reward imbalance [35], which are known to be associated with subsequent elevation of Hba1c.[36] As such, stress-related mechanisms that trigger dysregulation of neuroendocrine pathways, might be a potentially promising areas for future research studying the differences in risk of pre-diabetes according to work hours.

The present study has several strengths. First, this study is based on a nationally representative survey, and to the best of our knowledge, this is the first report of an association between long working hours and pre-diabetes among individuals without diabetes. Second, blood samples were collected using standardized laboratory procedures, ensuring an accurate estimate of HbA1c. Finally, we were able to control for several important confounding variables, such as sleep duration and perceived control. However, this study is not without limitations. Our analyses are based on data from observational studies and, as such, preclude direct causal inference. Information on working hours and other covariates were self-reported and thus subject to recall bias. Moreover, we cannot exclude the possibility that the results were affected by residual confounding caused by imprecisely measured covariates or some other unmeasured occupational factors, such as job strain and job satisfaction. Working hours was measured at a single point in time that might not represent long-term exposure. In future studies, use of repeated measurements is needed to characterize longitudinal relation between long working hours and pre-diabetes.

CONCLUSIONS

In conclusion, long working hours was significantly correlated with pre-diabetes independent of conventional risk factors. Our results suggest prolonged working hours are related to glucose metabolism among non-diabetic male workers in Korea. Additional large-scale longitudinal studies are needed to verify these findings.

Ethical statement: The survey protocols for the KNHANES were approved by the Institutional Review Board of the Korea Centers for Disease Control and Prevention (IRB No. 2013-07CON-03-4C, 2013-12EXP-03-5C, and 2015-01-02-6C), and informed consent was obtained from all participants.

Conflict of interest: The authors have no conflict of interest to declare.

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Data sharing statement: Data used in this study are available from the KNHANES official website (http://knhanes.cdc.go.kr/).

Author contributions: BYS, MK, GRK contributed to the conception and design of the study. BYS, MK, GRK, ECP contributed to analyses and interpretation of the data, BYS, MK, GRK drafted the manuscript. All authors read and approved the final manuscript.

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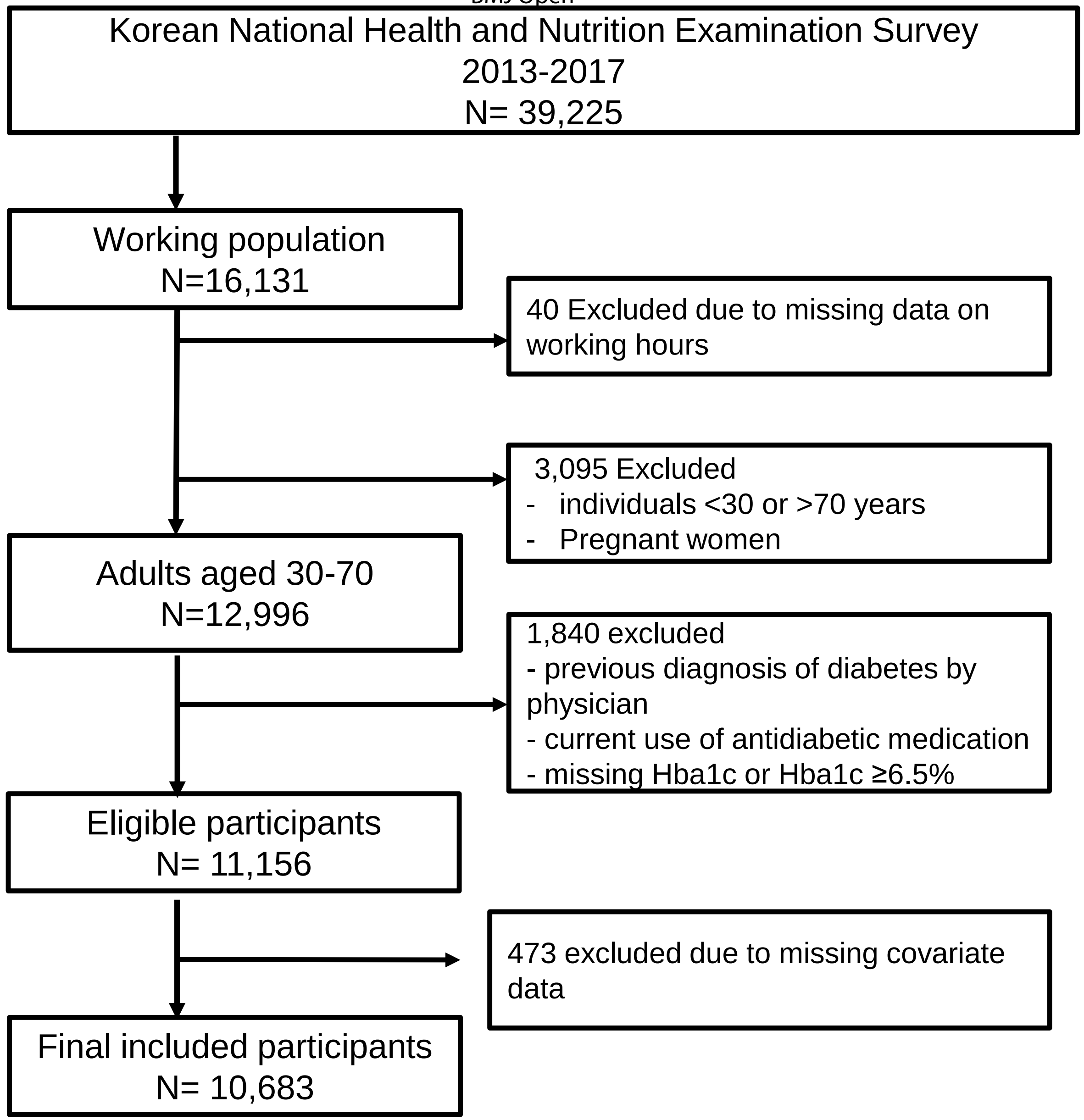

Figure 1 Flow chart of participant selection

STROBE Statement

Checklist of items that should be included in reports of observational studies

Section/Topic	Item No	Recommendation	Reported on Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	3	State specific objectives, including any prespecified hypotheses	3
Methods			
Study design	4	Present key elements of study design early in the paper	4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4,5,6
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	4
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	4,5,6
Data sources/measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	4,5,6
Bias	9	Describe any efforts to address potential sources of bias	6,7
Study size	10	Explain how the study size was arrived at	4
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	5,6,7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	6,7
		(*b*) Describe any methods used to examine subgroups and interactions	6,7
		(*c*) Explain how missing data were addressed	4
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	

Section/Topic	Item No	Recommendation	Reported on Page No
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	7
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	7,8,9
		(b) Indicate number of participants with missing data for each variable of interest	
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	
		Cross-sectional study—Report numbers of outcome events or summary measures	7
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	10, 11, 12
		(*b*) Report category boundaries when continuous variables were categorized	4
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	13
Discussion			
Key results	18	Summarise key results with reference to study objectives	14
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	15, 16
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	14, 15
Generalisability	21	Discuss the generalisability (external validity) of the study results	14
Other Information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	16

**Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.*

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

Cross-sectional study of the association between long working hours and pre-diabetes: 2010-2017 Korea National Health and Nutrition Examination Survey

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Cross-sectional study of the association between long working hours and pre-diabetes: 2010-2017 Korea National Health and Nutrition Examination Survey

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Figures: 1

ABSTRACT

OBJECTIVE: Long working hours have been shown to raise the risk of various health outcomes. However, epidemiological evidence has shown inconsistent result in relation to type 2 diabetes (T2DM) and the association between long working hours and pre-diabetes among non-diabetic adults remains largely unexplored. We thus aimed to investigate whether long working hours were linked with pre-diabetes as determined by glycated hemoglobin (HbA1c) level.

DESIGN: Cross-sectional survey

PARTICIPANTS: This study included 6,324 men and 4,001 women without diabetes from the 2010-2017 Korean National Health and Nutrition Examination Survey (KNHANES).

PRIMARY OUTCOME MEASURES: The study outcome of interest was pre-diabetes, defined as HbA1c values 5.7-6.4%

RESULTS: Logistic regression was performed to obtain the odds ratios (OR) for pre-diabetes according to categories of work hour (40 hours/week, 41-52 hours/week, >52 hours/week), after adjusting for relevant covariates. Of the 10,325 eligible participants, 2,261 (34.4%) men and 1,317 (31.0%) women had pre-diabetes. No statistically significant relationship was found for women. In men, extended working hours (>52 hours per week) was associated with an increased likelihood of pre-diabetes, after adjustment for age, educational attainment, monthly household income, life-style related factors, perceived stress, family history of diabetes, hypertension, hypercholesterolemia and other covariates (adjusted OR=1.22; 95% confidence interval=1.03-1.46). In the subgroup analysis by occupational categories, the association was only apparent among men in blue-collar worker groups.

CONCLUSION: Extended working hours were significant related to the increased risk of pre-diabetes in men, with no statistically significant association observed for women. Our results suggest prolonged working hours are associated with glucose metabolism among non-diabetic male workers in Korea.

Keywords: Pre-diabetes, Hba1c, working hours, Glucose metabolism

Strengths and limitations of this study

- As far as we are aware, this is the first report of an association between long working hours and pre-diabetes among individuals without diabetes using a nationally representative sample of Korean adults. We further compared associations by occupational categories.
- This study controlled for a range of factors that are known to affect HbA1c levels.
- Our analyses are based on cross-sectional data and, as such, preclude direct causal inference.

INTRODUCTION

Pre-diabetes, defined as an intermediate state of hyperglycemia with glycemic parameters above normal but below the diagnostic threshold for diabetes is considered an important risk factor for β-cell dysfunction[1] and the development of type 2 diabetes mellitus (T2DM).[2] According to the 2012 projection estimates, prevalence of pre-diabetes will continue to rise, and it is estimated that by 2030 over 470 million people will have pre-diabetes globally. [3] Approximately 70% of individuals diagnosed with pre-diabetes are expected to progress to T2DM within 10 years.[4] Given the high incidence rate of diabetes among pre-diabetic adults, identification of the modifiable risk factors of pre-diabetes in the general population is thus essential to effectively prevent or delay the onset of diabetes and its associated complications.

South Korea has one of the longest work hours among member states of the Organization for Economic Cooperation and Development (OECD), with people spending on average 2,069 hours at work annually compared to the OECD average of 1,764 hours.[5]

Several studies have assessed long working hours in relationship with the risk of various health outcomes, including coronary heart disease[6 7], cognitive function [8], as well as a high prevalence of anxiety[9] and sleeping disturbances.[10] However, epidemiological evidence have shown inconsistent result in relation to diabetes [11-14] and the association between long working hours and pre-diabetes in populations without diabetes remains largely unexplored. In a meta-analysis of epidemiological studies conducted in USA, Europe, Japan, and Australia, Kivimäki et al. reported a prospective association between long working hours and the incidence of diabetes, but only among employees with a low socioeconomic position.[12] Similarly, one study of Chinese male workers found that the risk of developing diabetes increased with longer hours of overtime work per week.[13] In contrast, in a study of Japanese male workers, the relative risk of type 2 diabetes significantly decreased among those who worked over 10 hours a day compared with those who worked 7 to 8 hours.[14] To fill this evidence gap, we investigated the relationship between weekly working hours and the pre-diabetes using a cross-sectional survey of 10,325 workers in South Korea.

METHODS

Study population

Data were drawn from the 2010-2017 Korean National Health and Nutrition Examination Survey (KNHANES). KNHANES is an ongoing population based, cross-sectional study which is designed to assess the health and nutritional status of people residing in South Korea.[15] The survey's sampling strategy was designed to be representative of the non-institutionalized civilian population aged 1 year or over which was selected using a complex, multistage, stratified sampling design. Of the 64,759 participants (Men : 29,458, Women : 35,301) who participated in the 2010-2017 survey, 26,750 reported as being economically active and therefore were eligible to be asked job-related modules and 26,696 provided valid responses concerning weekly work hours. We restricted analyses to individuals working 40 hours or more per week, as participants who worked for less than 40 hours are likely to do so due to health reasons (N=17,298). Additionally, KNHANES participants under 30 or >70 years old and pregnant women were excluded from the analysis (N=2,649). We also excluded those who reported a previous clinical diagnosis of diabetes made by a physician or taking insulin or anti-diabetic medication or missing data on Hba1c, or Hba1c values greater than 6.5% (N=3,800). Finally, we excluded participants with missing covariate data (N=524), yielding a final sample of 10,325 participants (Men : 6,324 , Women : 4,001) (See Figure 1).

Patient and Public Involvement (PPI)

No patients were included in the design and planning of the study. Including PPI statements aligns closely with BMJ Open's values of transparency and inclusiveness. We hope that including PPI statements in all articles is the first step of many for BMJ Open in encouraging patient involvement.

Measures

Definition of Pre-diabetes

The main study outcome was glycated hemoglobin (HbA1c). HbA1c is a form of hemoglobin in which glucose is attached to its β-chain after exposure to high plasma levels of glucose. As such, it is used as an integrated index of long-term serum glucose regulation.[16] Fasting bloods samples were collected during a medical examination and HbA1c levels were measured via high performance liquid chromatography (HLC-723G7; Tosoh, Tokyo, Japan). Participants were identified as being normoglycemic if they had a HbA1c level below 5.7%; HbA1c level between 5.7 and 6.4 percent were indicative of pre-diabetes according to the 2018 American Diabetes Association (ADA) standards of care in diabetes.[17] Previous research has indicated that HbA1c and fasting plasma glucose (FPG) are equally in the detection of Type 2 diabetes.[18] Also, HbA1c has several advantages to the FPG, including the ability to use non-fasting blood samples, greater pre-analytical stability, and less day-to-day perturbations during periods of stress and illness.[19]

Working hours

In the KNHANES, participants were asked about their working hours using the following question: "During the last month, how many hours on average in a week did you work, including unpaid overtime work (excluding meal time)?" In Korea, statutory weekly work hours based on the Labor Standards Act (LSA) are 40 hours per week and 8 hours per day. The working hours stipulated in LSA Article 50 may be extended up to additional 12 hours by agreement between the parties. Therefore, in the current study we defined long working hours as working beyond the legal threshold of 52 hours. Participants reported their working hours as a continuous variable, and this was further categorized as follows: 40 hours, 41-52 hours, or >52 hours per week.

Covariates

Data on socio-demographic characteristics, lifestyle- and health-related factors were collected using interviewer-administered standardized questionnaires. Age was categorized into 30–39, 40–49, 50–59, and ≥ 60 years. Participants were categorized by educational attainment (elementary school, middle school, high school, and university degree or above), monthly household income quartiles, and occupational categories (white collar (managers, professionals), pink collar (clerks, service, and sales workers), green collar (agricultural, fishery or forestry workers) and blue collar (craft/trades workers, machine operators and assemblers, and elementary manual workers)[20 21]. Work schedules were assessed using the following question: "Do you work mostly during the day time, or do you work at a different time period?" Respondent who usually worked during the daytime (06:00-18:00), evening hours (14:00-24:00), or night-time (21:00-08:00) were categorized as fixed schedule workers, while those who worked 24-hours rotating shifts, split shifts, or irregular shifts were classified as shift schedule workers.

Health-related behaviours included smoking status (Never smoker, former smoker, and current smoker) alcohol consumption (Yes or no), muscle strengthening activity at least twice a week (yes/no), participation in aerobic activity, defined as walking at least 10 minutes at a time, for 30 minutes or more per day, on 5 or more per days during the 7 days preceding the survey, and sleep duration (< 6, 6-8, ≥9 hours). Body mass index (BMI [kg/m2]) was used to determine obesity status and calculated based on respondent's self-reported height and weight. A BMI of <18.5 was considered underweight, a BMI > 18.5 and <23.0 was considered normal weight, a BMI greater than or equal to 23.0 and <25.0 was considered overweight, and a BMI ≥ 25 was considered obese. The level of perceived stress was measured using the following question: "How stressed are you on a daily basis?" with possible answers ranging from 'None' coded 0 to 'High' coded 4. Respondents were reclassified into low (none/low) and high perceived stress (moderate/high). Hypercholesterolemia (yes/no) was defined as a serum total cholesterol level ≥240 mg/dL or the use of lipid-lowering medications. Hypertension (yes/no) was defined as a systolic blood pressure of 140 mmHg or higher, diastolic blood pressure of 90 mmHg or higher or on antihypertensive treatment. A family history of diabetes was ascertained by asking participants whether their first-degree relatives (parents or siblings) had ever been told they have diabetes (yes/no).

STATISTISTICAL ANALYSES

Statistical analyses were conducted using SAS version 9.4 (SAS Institute Inc., Cary, NC, USA). The SAS survey procedure was applied to reflect the stratification and clustering of the complex sampling design and sampling weights of the KNHANES and to ensure nationally representative prevalence estimates. Baseline characteristics of the study sample were described using frequency and weighted percentages. Chi-square test was used to compare participant characteristics across working hours and between normoglycemic and pre-diabetic subjects. Multivariable logistic regression analysis was used to evaluate the association between working hours and pre-diabetes status, and odds ratios (ORs) and 95% confidence interval (CI) were calculated after adjusting for socio-demographic and health-related behavioural variables that showed significant association in univariate analysis and based on clinical relevance. Additionally, we evaluated whether the association between long working hours and pre-diabetes was dependent on age or work-related characteristics by testing interaction effects and conducting subgroup analyses. Interaction was assessed by including a cross-product interaction term (working hour×effect modifier variable) wasin the logistic regression model along with the main effect. All analyses were performed separately for men and women. All reported P values were based on 2-sided tests; statistical significance was set at $p < 0.05$.

RESULTS

General characteristics of the study population

Table 1 presents participants' general characteristics by HbA1c status in men and women. A total of 2,261 (34.43%) men and 1,317 (31.04%) women had pre-diabetes. Men who worked 40 hours per week had the lowest pre-diabetes prevalence (30.92%), followed by those working 41–52 hours (32.88%) and >52 hours (38.00%). Male workers with pre-diabetes were also more likely to be older, work over 52 hours/week, have a lower level of education, to be working in a manual occupations, obese, current smokers, sleep less than 6 hours and to have a diagnosis of hypertension, hypercholesteremia and a family history of diabetes compared with normoglycemic subjects. For women, we observed statistically significant differences in prevalence of pre-diabetes for most characteristics, except for participation in aerobic activity, muscle strengthening activity, family history of diabetes and work schedule.

Table 2 shows characteristics of study participants according to categories of working hours. A total of 1,399 (22.08%) male participants reported 40 hours of work per week, 2,483 (39.03%) reported 41–52 hours, and 2,442 (38.89%) reported more than 52 hours of work per week; the corresponding values for women were 1,086 (27.49%), 1,574 (39,19%), and 1,341 (33.32%), respectively. Compared with men working 40 hours per week, a higher proportion of those who worked more than 52 hours were older, had a lower education, lower household income, higher self perceived stress, in blue-collar occupation, and have shift work schedule. As regard health-related related variables, subjects who worked more than 52 hours tended to be current smoker, non-drinker, physically inactive, have shorter sleep. Among women, no appreciable differences in smoking status, muscle strengthening activity, and work schedule were apparent across working hours per week.

Table 1. General characteristics of the study population by HbA1c status, KNHANES 2010-2017

	Men (N=6,324)				Women (N=4,001)			
	Total	Pre-diabetes N (%)	Normoglycemia N (%)	p-value	Total	Pre-diabetes N (%)	Normoglycemia N (%)	p-value
Working hours per week (hours)				**0.0001**				**<.0001**
40	1,399 (22.08)	447 (30.92)	952 (69.08)		1,086 (27.49)	298 (27.15)	788 (72.85)	
41-52	2,483 (39.03)	867 (32.88)	1,616 (67.12)		1,574 (39.19)	492 (29.21)	1,082 (70.79)	
>52	2,442 (38.89)	947 (38.00)	1,495 (62.00)		1,341 (33.32)	527 (36.40)	814 (63.60)	
Age group (years)				**<.0001**				**<.0001**
30-39	1,966 (34.77)	497 (24.41)	1,469 (75.59)		994 (26.69)	143 (14.97)	851 (85.03)	
40-49	2,016 (34.82)	687 (34.75)	1,329 (65.25)		1,241 (34.82)	313 (24.39)	928 (75.61)	
50-59	1,569 (23.31)	685 (43.40)	884 (56.59)		1,220 (28.79)	564 (46.11)	656 (53.89)	
≥60	773 (7.10)	392 (52.54)	381 (47.46)		546 (9.70)	297 (54.31)	249 (45.69)	
Education				**<.0001**				**<.0001**
Elementary School	480 (5.94)	227 (49.18)	253 (50.82)		698 (14.10)	359 (51.00)	339 (49.00)	
Middle school	540 (7.75)	239 (42.72)	301 (57.28)		477 (12.07)	211 (40.56)	266 (59.44)	
High school	2,083 (33.96)	816 (37.42)	1,267 (62.58)		1,508 (40.55)	495 (31.69)	1,013 (68.31)	
University degree or above	3,221 (52.35)	979 (29.60)	2,242 (70.40)		1,318 (33.28)	252 (18.33)	1,066 (81.67)	
Total household income				**0.016**				**<.0001**
Low	265 (3.59)	113 (44.21)	152 (55.79)		319 (7.07)	140 (42.38)	179 (57.62)	
Middle-low	1,444 (22.78)	549 (35.74)	895 (64.26)		942 (22.85)	344 (33.56)	598 (66.44)	
Middle-high	2,172 (35.26)	765 (34.22)	1,407 (65.78)		1,308 (34.11)	420 (30.06)	888 (69.94)	
High	2,443 (38.37)	834 (32.94)	1,609 (67.06)		1,432 (35.97)	413 (28.12)	1,019 (71.88)	
Smoking status				**<.0001**				**0.019**
Never smoker	1,250 (20.05)	365 (28.66)	885 (71.34)		3,624 (89,27)	1,229 (31.90)	2,395 (68.10)	
Former smoker	2,373 (35.12)	830 (33.37)	1,543 (66.63)		163 (4.76)	34 (22.21)	129 (77.79)	
Current smoker	2,701 (44.83)	1,066 (37.85)	1,635 (62.15)		214 (5.97)	54 (25.21)	160 (74.79)	
Alcohol consumption				0.263				**<.0001**
No	201 (2.95)	79 (38.77)	122 (61.22)		464 (10.18)	212 (43.03)	252 (56.97)	
Yes	6,123 (97.05)	2,182 (34.30)	3,941 (65.70)		3,537 (89.82)	1,105 (29.68)	2,432 (70.32)	
Aerobic activity								
No	4,008 (63.30)	1,451 (35.08)	2,557 (64.92)	0.223	2,643 (65.73)	868 (30.34)	1,775 (69.66)	0.254
Yes	2,316 (36.70)	810 (33.33)	1,506 (66.67)		1,358 (34.27)	449 (32.36)	909 (67.64)	
Muscle strengthening activity				0.242				0.969
No	4,651 (73.63)	1,681 (34.92)	2,970 (65.08)		3,528 (87.71)	1,167 (31.05)	2,361 (68.95)	

Table 1 continued								
Yes	1,673 (26.37)	580 (33.08)	1,093 (66.92)		473 (12.29)	150 (30.95)	323 (69.05)	
BMI				**<.0001**				**<.0001**
Underweight	113 (1.93)	23 (19.02)	90 (80.98)		166 (4.22)	29 (14.14)	137 (85.86)	
Normal	1,934 (29.94)	557 (27.12)	1,377 (72.88)		1,869 (47.18)	438 (21.87)	1,431 (78.13)	
Overweight	1,733 (27.61)	602 (33.77)	1,131 (66.23)		890 (22.09)	324 (35.11)	566 (64.89)	
Obese	2,544 (40.52)	1,079 (41.02)	1,465 (58.98)		1,076 (26.51)	526 (46.64)	550 (53.36)	
Hypertension				**<.0001**				**<.0001**
No	4,639 (74.63)	1,531 (31.96)	3,108 (68.04)		3,252 (82.90)	958 (28.05)	2,294 (71.95)	
Yes	1,685 (25.37)	730 (41.70)	955 (58.30)		749 (17.10)	359 (45.53)	390 (54.47)	
Hypercholesterolemia				**<.0001**				**<.0001**
No	5,469 (87.19)	1,852 (32.59)	3,617 (67.41)		3,423 (86.67)	1,017 (28.18)	2,406 (71.82)	
Yes	855 (12.81)	409 (46.96)	446 (53.04)		578 (13.33)	300 (49.58)	278 (50.42)	
Family history of diabetes				**<.0001**				0.579
No	5,045 (79.35)	1,739 (32.70)	3,306 (67.30)		3,086 (76.91)	1,003 (30.79)	2,083 (69.21)	
Yes	1,279 (20.65)	522 (41.09)	757 (58.91)		915 (23.09)	314 (31.87)	601 (68.13)	
Sleep duration (hours)				0.069				**0.0002**
< 6	738 (11.62)	282 (36.32)	456 (63.68)		562 (14.49)	223 (39.68)	339 (60.32)	
6-8	5,167 (82.16)	1,850 (34.59)	3,317 (65.41)		3,083 (76.56)	996 (29.91)	2,087 (70.09)	
≥9	419 (6.22)	129 (28.90)	290 (71.10)		356 (8.95)	98 (26.69)	258 (73.31)	
Perceived stress				0.553				**0.008**
None/Low	4,513 (70.82)	1,633 (34.68)	2,880 (65.32)		2,743 (67.68)	945 (32.51)	1,798 (67.49)	
Moderate/High	1,811 (29.18)	628 (33.83)	1,183 (66.17)		1,258 (32.32)	372 (27.94)	886 (72.06)	
Occupation				**<.0001**				**<.0001**
White collar	2,774 (44.48)	845 (29.50)	1,929 (70.50)		1,527 (38.26)	311 (19.16)	1,216 (80.84)	
Pink collar	859 (14.05)	317 (36.50)	542 (63.50)		1,263 (32.68)	493 (36.87)	770 (63.13)	
Green collar	356 (4.20)	163 (44.57)	193 (55.43)		309 (5.45)	169 (52.94)	140 (47.06)	
Blue collar	2,335 (37.27)	936 (38.40)	1,399 (61.60)		902 (23.61)	344 (37.15)	558 (62.85)	
Work schedule				0.998				0.290
Fixed	5,801 (92.25)	2,060 (34.43)	3,741 (65.57)		3,826 (32.11)	1,255 (30.83)	2,571 (69.17)	
Shift	523 (7,75)	201 (34.44)	322 (65.56)		175 (22.05)	62 (35.09)	113 (64.91)	
Participants		2,261 (34.43)	4,063 (65.57)			1,317 (31.04)	2,684 (68.96)	

*Unless otherwise stated, unweighted frequency (weighted %) are shown.
†P value comparing prediabetes with normoglycemia

Table 2. General characteristics of the study population according to working hours per week , KNHANES 2010-2017

	Men (N=6,324)				Women (N=4,001)			p-value
	40 hrs N (%)	41-52 hrs N (%)	>52 hrs N (%)	p-value	40 hrs N (%)	41-52 hrs N (%)	>52 hrs N (%)	
Age (years)				**<.0001**				**<.0001**
30-39	444 (22.67)	820 (41.31)	702 (36.02)		372 (35.53)	446 (44.41)	176 (20.06)	
40-49	481 (22.78)	804 (38.88)	731 (38.34)		401 (30.75)	490 (39.41)	350 (29.84)	
50-59	351 (22.13)	592 (36.99)	626 (40.88)		242 (20.61)	434 (35.34)	544 (44.05)	
≥60	123 (15.66)	267 (35.32)	383 (49.02)		71 (14.14)	404 (35.47)	271 (50.39)	
Education				**<.0001**				**<.0001**
Elementary School	48 (10.13)	169 (33.71)	263 (56.16)		84 (12.00)	156 (37.23)	358 (50.77)	
Middle school	64 (12.65)	201 (36.98)	275 (50.37)		62 (14.79)	166 (32.69)	249 (52.52)	
High school	396 (18.74)	780 (37.96)	907 (43.30)		413 (26.86)	575 (38.06)	520 (35.08)	
University degree or above	891 (27.00)	1,333 (40.64)	997 (32.36)		527 (39.44)	577 (43.76)	214 (16.80)	
Total household income				**<.0001**				**<.0001**
Low	38 (16.03)	97 (36.36)	130 (47.61)		56 (21.14)	133 (38.21)	130 (40.65)	
Middle-low	234 (16.57)	539 (36.83)	671(46.60)		201 (22.13)	359 (38.21)	382 (39.66)	
Middle-high	454 (21.04)	888 (41.13)	830 (37.83)		373 (28.63)	492 (37.81)	444 (33.56)	
High	673 (26.88)	959 (38.67)	811 (34.45)		457 (31.06)	590 (41.32)	385 (27.62)	
Smoking status				**0.0003**				0.207
Never smoker	288 (23.71)	512 (41.10)	450 (35.19)		997 (27.99)	1,416 (39.05)	1,211 (32.96)	
Former smoker	578 (24.17)	908 (38.77)	887 (37.06)		41 (24.07)	74 (44.36)	48 (31.57)	
Current smoker	533 (19.72)	1,063 (38.31)	1,105 (41.97)		48 (22.70)	64 (37.19)	82 (40.11)	
Alcohol consumption				**0.009**				**0.002**
No	24 (13.30)	76 (37.13)	101 (49.57)		95 (20.48)	178 (39.32)	191 (40.20)	
Yes	1,375 (22.35)	2,407 (39.09)	2,341 (38.56)		991 (28.29)	1,396 (39.18)	1,150 (32.53)	
Aerobic activity				0.104				
No	866 (21.83)	1,547 (38.19)	1,595 (39.98)		662 (25.15)	1,042 (39.47)	939 (35.38)	**0.0001**
Yes	533 (22.52)	936 (40.50)	847 (36.98)		424 (31.99)	532 (38.65)	402 (29.36)	
Muscle strengthening activity				**0.005**				0.385
No	980 (21.21)	1,809 (38.70)	1,862 (40.09)		948 (27.34)	1,375 (38.89)	1,205 (33.77)	
Yes	419 (24.54)	674 (39.96)	580 (35.50)		138 (28.56)	199 (41.32)	136 (30.12)	
BMI				0.548				**<.0001**
Underweight	22 (19.73)	41 (37.30)	50 (42.97)		50 (28.13)	76 (46.74)	40 (25.13)	
Normal	405 (21.00)	760 (38.59)	769 (40.41)		578 (31.10)	848 (39.54)	543 (29.36)	
Overweight	415 (23.76)	655 (38.80)	663 (37.44)		217 (24.53)	344 (39.30)	329 (36.17)	
Obese	557 (21.86)	1,027 (39.60)	960 (38.54)		241 (23.43)	406 (37.28)	429 (39.29)	

Table 2 Continued

Hypertension				0.163				**<.0001**
No	1,024 (22.07)	1,844 (39.75)	1,771 (38.18)		947 (29.03)	1,290 (39.70)	1,015 (31.27)	
Yes	375 (22.13)	639 (36.93)	671 (40.94)		139 (20.06)	284 (36.75)	326 (43.19)	
Hypercholesterolemia				**0.027**				**0.005**
No	1,187 (21.52)	2,149 (39.13)	2,133 (39.35)		967 (28.28)	1,353 (39.34)	1,103 (32.38)	
Yes	212 (25.93)	334 (38.36)	309 (35.71)		119 (22.34)	221 (38.25)	238 (39.41)	
Family history of diabetes				0.549				**0.033**
No	1,103 (21.75)	1,991 (39.18)	1,951 (39.07)		799 (26.53)	1,211 (39.04)	1,076 (34.43)	
Yes	296 (23.38)	492 (38.47)	491 (38.15)		287 (30.69)	363 (39.68)	265 (29.63)	
Sleep duration (hours)				**<.0001**				**0.004**
< 6	120 (16.41)	256 (36.01)	362 (47.58)		128 (22.88)	209 (38.82)	225 (38.30)	
6-8	1,182 (22.74)	2,070 (39.52)	1,915 (37.74)		836 (27.65)	1,223 (39.06)	1024 (33.29)	
≥9	97 (24.00)	157 (38.20)	165 (37.80)		122 (33.60)	142 (40.91)	92 (25.49)	
Perceived stress				**<.0001**				**0.005**
None/Low	1,083 (23.75)	1,785 (39.25)	1,645 (37.00)		788 (29.16)	1,076 (39.03)	879 (31.81)	
Moderate/High	316 (18.04)	698 (38.51)	797 (43.45)		298 (24.00)	498 (39.53)	462 (36.47)	
Occupation				**<.0001**				**<.0001**
White collar	873 (30.54)	1,200 (43.04)	701 (26.42)		665 (43.28)	672 (43.74)	190 (12.98)	
Pink collar	130 (16.12)	252 (28.51)	477 (55.37)		168 (13.42)	419 (33.54)	676 (53.04)	
Green collar	25 (6.30)	132 (34.54)	199 (59.16)		17 (4.22)	124 (41.57)	168 (54.21)	
Blue collar	371 (16.02)	899 (38.73)	1,065 (45.25)		236 ()	359 ()	307 ()	
Work schedule				**<.0001**				0.283
Fixed	1,334 (22.84)	2,297 (39.09)	2,170 (38.07)		1034 (27.20)	1,507 (39.42)	1,285 (33.38)	
Shift	65 (13.09)	186 (38.39)	272 (48.52)		52 (33.35)	67 (34.66)	56 (31.99)	
Participants	1,399 (22.08)	2,483 (39.03)	2,442 (38.89)		1,086 (27.49)	1,574 (39.19)	1,341 (33.32)	

*Unless otherwise stated, unweighted frequency (weighted %) are shown.

Association between long working hours and pre-diabetes

Results from the logistic regression analysis are shown in Table 3. In univariate logistic regression analyses, long working hours was significantly associated with increased odds of having pre-diabetes in both men and women. Compared with the individuals who worked 40 hours, the ORs of pre-diabetes for the those who belong to the >52 hours category were 1.37 (95% CI 1.17-1.61; p for trend <0.0001) and 1.54 (95% CI 1.25-1.88; p for trend <0.0001) for men and women, respectively. For women, the positive association between the working hours and pre-diabetes was no longer significant after controlling for age, with OR of 1.06 (95% CI 0.84-1.32). In the case of men, those who worked >52 hours were 1.22 times more likely to have pre-diabetes after adjusting for covariates (multivariable-adjusted Odds Ratio (OR): 1.40; 95% Confidence Interval (CI): 1.03-1.46; P for trend 0.017). Age, smoking status, hypercholesteremia, family history of diabetes and sleep duration were also found to considerably increase the risk of pre-diabetes in men, but there were no statistically significant differences based on educational level, monthly household income, alcohol consumption, muscle strengthening activity, hypertension, perceived stress, occupation and work schedule.

Table 4 presents the ORs for subgroup analyses by age and work-related characteristics. We did not observe a significant interaction between the number of hours worked per week and age (Men:P for interaction =0.309) nor between work schedule and working hours (Men: P for interaction 0.864). The relationship between long working hours and pre-diabetes was more pronounced among male shift workers, albeit not statistically significantly, (41-52 hrs: aOR= 1.64, 95% CI: 0.77-3.47; >52 hrs: aOR= 1.64, 95% CI: 0.78-3.44; p for interaction=0.864). In the subgroup analysis by occupational categories, male workers who worked in blue-collar occupation were likely to have pre-diabetes as their average weekly working hours increased, after adjustment for all covariates. The adjusted ORs were 1.13 (95% CI 0.84-1.53) and 1.54 (95% CI 1.15-2.06) for the 41-52 hrs and >52 hrs categories, respectively (p for trend= 0.041). However, the interaction effect by occupational categories was not statistically significant (p for interaction=0.146).

Table 3. Results of the logistic regression analysis for the association between long working hours and pre-diabetes (HbA1c 5.7-6.4%)

			Crude			Model 1			Model 2		
	Case	Participants	OR	95% CI	P-value	OR	95% CI	P-value	OR	95% CI	P-value
Men (N=5,536)											
Working hours per week (hours)											
40	447	1,399	1.00			1.00			1.00		
41-52	867	2,483	1.09	0.93-1.29	0.278	1.10	0.93-1.29	0.279	1.07	0.90-1.27	0.477
>52	947	2,442	**1.37**	**1.17-1.61**	**0.0001**	**1.31**	**1.11-1.55**	**0.001**	**1.22**	**1.03-1.46**	**0.026**
P for trend				**<0.0001**			**0.001**			**0.017**	
Women (N=5,147)											
Working hours per week (hours)											
40	298	1,086	1.00			1.00			1.00		
41-52	492	1,574	1.11	0.91-1.35	0.307	0.98	0.80-1.20	0.84	0.89	0.72-1.12	0.338
>52	527	1,341	**1.54**	**1.25-1.88**	**<0.0001**	1.06	0.84-1.32	0.64	0.90	0.70-1.15	0.405
P for trend				**<0.0001**			0.601			0.436	

Note: OR, Odds ratio; CI, confidence interval;

Model 1 adjusted for age

Model 2 adjusted for age, educational attainment, total household income, obesity, smoking status, alcohol consumption, participation in aerobic activity, muscle strengthening activity, hypertension, hypercholesterolemia, family history of diabetes, sleep duration, perceived stress, occupation, work schedule

Table 4. Results of subgroup analysis of association between hba1c and working hours by age and work characteristics

Characteristics	Men Odds ratio (95% CI)					Women Odds ratio (95% CI)				
	40 hrs	41-52 hrs	>52 hrs	p for trend	p for interaction	40 hrs	41-52 hrs	>52 hrs	p for trend	P for interaction
Occupational categories					0.146					0.442
White collar	1.00	1.04 (0.83-1.30)	1.06 (0.82-1.38)	0.664		1.00	1.14 (0.82-1.60)	0.78 (0.48-1.27)	0.619	
Pink collar	1.00	1.22 (0.72-2.06)	0.99 (0.60-1.65)	0.714		1.00	0.62 (0.39-0.98)	0.77 (0.50-1.19)	0.706	
Green collar	1.00	0.52 (0.16-1.65)	0.90 (0.32-2.55)	0.247		1.00	1.42 (0.45-4.45)	0.94 (0.30-2.93)	0.309	
Blue collar	1.00	1.13 (0.84-1.53)	**1.54 (1.15-2.06)**	**0.001**		1.00	0.89 (0.58-1.35)	0.93 (0.59-1.45)	0.769	
Work schedule					0.864					0.202
Fixed	1.00	1.04 (0.87-1.25)	1.21 (1.01-1.45)	**0.031**		1.00	0.85 (0.68-1.06)	0.87 (0.68-1.11)	0.302	
Shift	1.00	1.64 (0.77-3.47)	1.64 (0.78-3.44)	0.317		1.00	2.71 (0.88-8.30)	2.57 (0.80-8.25)	0.121	
Age (years)					0.309					0.978
30-39	1.00	1.31 (0.94 to 1.83)	**1.44 (1.01 to 2.06)**	**0.047**		1.00	0.79 (0.48 to 1.29)	0.79 (0.39-1.58)	0.451	
40-49	1.00	0.89 (0.67 to 1.19)	1.20 (0.89 to 1.61)	0.124		1.00	0.89 (0.62-1.31)	0.81 (0.54-1.23)	0.327	
50-59	1.00	1.05 (0.76 to 1.47)	1.11 (0.80 to 1.55)	0.529		1.00	0.95 (0.64-1.39)	1.02 (0.69-1.52)	0.828	
≥60	1.00	1.29 (0.77 to 2.17)	1.12 (0.68 to 1.87)	0.079		1.00	0.94 (0.46-1.92)	0.82 (0.42-1.62)	0.485	

DISCUSSION

In this population-based study of Korean working adults without diabetes, we found that men who worked over 52 hours per week exhibited 22% increased risk of pre-diabetes than did those who worked 40 hours per week. This association was robust to adjustments for socio-demographic variables and lifestyle factors, such as obesity, participation in aerobic and muscle strengthening activity, smoking, and alcohol consumption and other covariates. Importantly, we found that the increased odds of pre-diabetes associated with long working hours was – albeit not statistically significant – more pronounced among workers of blue collar occupations and shift workers. These findings are in line with the evidence from a prospective study conducted in Japan which found that long working hours are related to the risk of incident diabetes among shift workers.[22] Further studies with larger sample sizes are warranted to explore whether the lack of statistical significance observed is a results of sample size, or reflects a true lack of association. Additionally, assessment of additive interaction between long working hours and lifestyle factors would be a fruitful venue for further research for more in depth understanding of the impacts of such interaction.

In the present study, the prevalence of pre-diabetes in the Korean working population was 34.4% and 31.0% for men and women, respectively. These prevalence estimates are comparable to general population estimates reported in the U.S [23], U.K [24] and those of other Asian countries.[25] Several previous studies have yielded prevalence estimates for pre-diabetes in Korea. Using the HbA1c cutoff, pre-diabetes prevalence in 2011 was reported to be 38.3% (Men: 41%; women: 35.7%) in a community-based cross-sectional study of Korean adults aged 30 years or over.[26] Another Korean study reported a pre-diabetes prevalence of 26.1% in men and 20.5% according to American diabetes association criteria.[27] However, this study was based on a sample from rural areas. Pre-diabetes is a well-recognized risk factors for future diabetes, that gives rise to micro- and macrovascular complications and have enormous social and economic burden [28, 29]; increased attention needs to be paid to the high prevalence of pre-diabetes in Korea.

We are not aware of other studies that has reported a relationship between long working hours and pre-diabetes, although our findings are comparable with a meta-analysis showing that long working hours is associated with the incidence of type 2 diabetes among individuals from low socioeconomic status groups.[12] Another study have also reported a similar finding, indicating that extended working hours is positively correlated with non-insulin dependent diabetes mellitus in men.[30] However, our results conflict with a previous study that found relative risks of T2DM significantly decreased with an increase in hours of work per day.[14]

The mechanisms underlying the association between long working hours and pre-diabetes are yet unknown. It is likely that a similar mechanism to that of diabetes could be responsible for the observed findings. Plausible explanations are that longer working hours impacts pre-diabetes risk via their association with behavioural risk factors. As shown in this study, prior research has indicated that working longer than recommended hours is linked to many behavioural risk factors, such as binge drinking [31, 32] and low physical activity [33], possibly because individuals feel that they lack the time to engage in leisure-time physical activity due to demands and responsibilities at work. In the present study, working hour–pre-diabetes association attenuated but remained statistically significant in men after adjustment for behavioural risk factors. As such, conventional risk factors for pre-diabetes are likely to explain only part of the association between long working hours and pre-diabetes.

Meanwhile, there has been a proposition that extended working hours are related to cortisol secretion [34], a known risk factor for impaired glucose metabolism.[35] Cortisol induces the formation of glucose in the liver and have insulin-antagonistic effects in the peripheral tissues; both processes have the potential to contribute to risk of hyperglycemia. Furthermore, individuals work longer hours are more often exposed to harmful psychological factors in the work environment, such as job strain [36, 37] and effort-reward imbalance [38], which are known to be associated with subsequent elevation of Hba1c.[39] As such, stress-related mechanisms that trigger dysregulation of neuroendocrine pathways, might be a potentially promising areas for future research studying the differences in risk of pre-diabetes according to work hours.

The present study has several strengths. First, this study is based on a nationally representative survey, and to the best of our knowledge, this is the first report of an association between long working hours and pre-diabetes among individuals without diabetes. Second, blood samples were collected using standardized laboratory procedures, ensuring an accurate estimate of HbA1c. Finally, we were able to control for several important confounding variables, such as sleep duration and perceived control. However, this study is not without limitations. Our analyses are based on data from observational studies and, as such, preclude direct causal inference. Information on working hours and other covariates were self-reported and thus subject to recall bias. Moreover, we cannot exclude the possibility that the results were affected by residual confounding caused by imprecisely measured covariates or some other unmeasured occupational factors, such as job strain and job satisfaction. Working hours was measured at a single point in time that might not represent long-term exposure. In future studies, use of repeated measurements is needed to characterize longitudinal relation between long working hours and pre-diabetes.

CONCLUSIONS

In conclusion, extended working hours in men was significantly correlated with the odds of pre-diabetes, independent of conventional risk factors. No statistically significant relationship was found for women. Our results suggest prolonged working hours are related to glucose metabolism among non-diabetic male workers in Korea. Additional large-scale longitudinal studies are needed to verify these findings.

Ethical statement: The survey protocols for the KNHANES were approved by the Institutional Review Board of the Korea Centers for Disease Control and Prevention (IRB No. 2013-07CON-03-4C, 2013-12EXP-03-5C, and 2015-01-02-6C), and informed consent was obtained from all participants.

Conflict of interest: The authors have no conflict of interest to declare.

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Data sharing statement: Data used in this study are available from the KNHANES official website (http://knhanes.cdc.go.kr/).

Author contributions: BYS, MK, GRK contributed to the conception and design of the study. BYS, MK, GRK, ECP contributed to analyses and interpretation of the data, BYS, MK, GRK drafted the manuscript. All authors read and approved the final manuscript.

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Figure legends

Figure 1 Flowchart of participant selection

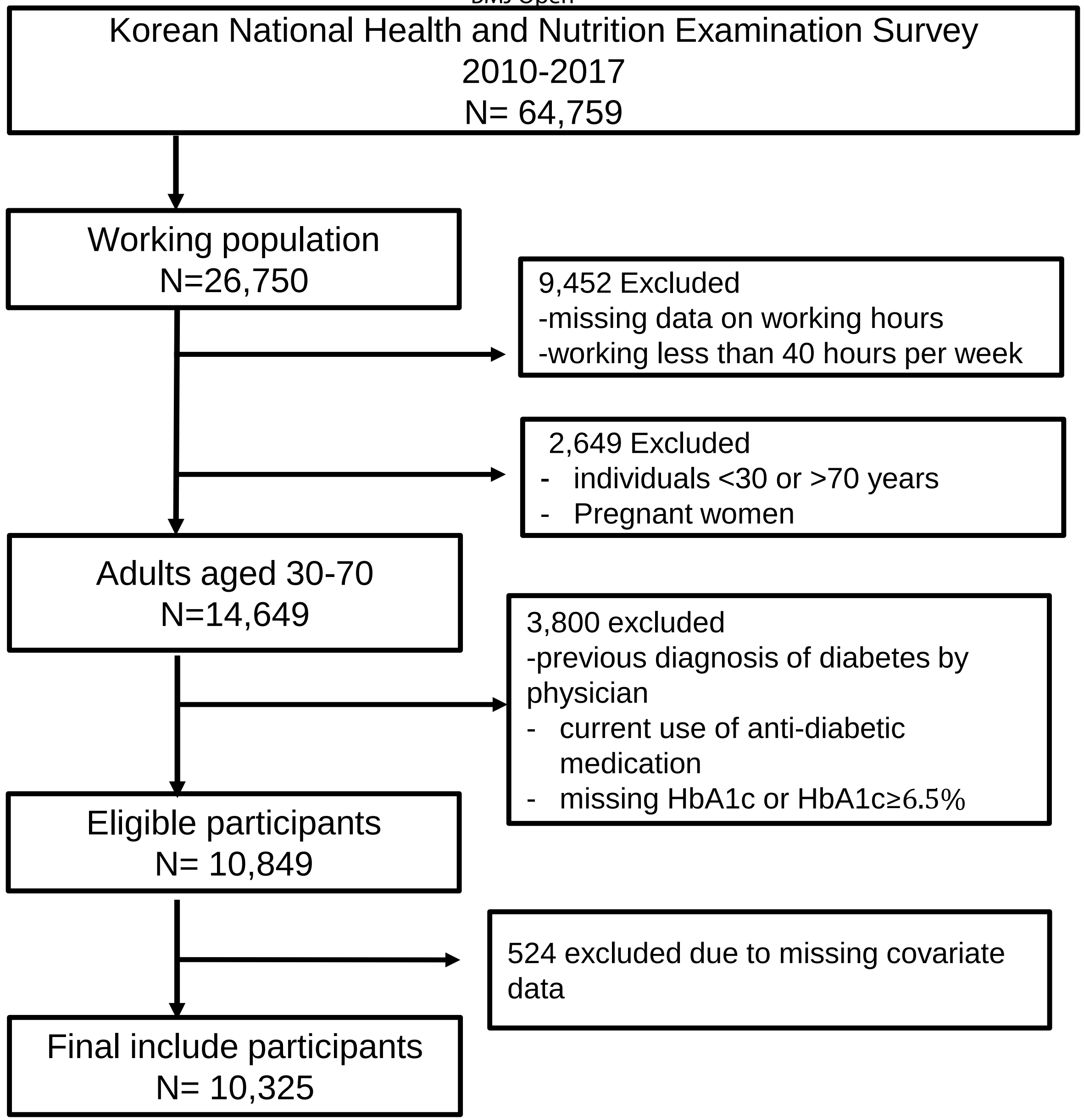

Figure 1 Flow chart of participant selection

STROBE Statement

Checklist of items that should be included in reports of observational studies

Section/Topic	Item No	Recommendation	Reported on Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	3	State specific objectives, including any prespecified hypotheses	3
Methods			
Study design	4	Present key elements of study design early in the paper	4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4,5,6
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	4
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	4,5,6
Data sources/measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	4,5,6
Bias	9	Describe any efforts to address potential sources of bias	6,7
Study size	10	Explain how the study size was arrived at	4
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	5,6,7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	6,7
		(*b*) Describe any methods used to examine subgroups and interactions	6,7
		(*c*) Explain how missing data were addressed	4
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	

Section/Topic	Item No	Recommendation	Reported on Page No
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	7
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	7,8,9,10,11,12
		(b) Indicate number of participants with missing data for each variable of interest	
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	
		Cross-sectional study—Report numbers of outcome events or summary measures	7,14
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	13,14
		(*b*) Report category boundaries when continuous variables were categorized	5,6
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	13,15
Discussion			
Key results	18	Summarise key results with reference to study objectives	16
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	17,18
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	16, 17
Generalisability	21	Discuss the generalisability (external validity) of the study results	16,17
Other Information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	19

**Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.*

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Cross-sectional study of the association between long working hours and pre-diabetes: 2010-2017 Korea National Health and Nutrition Examination Survey

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Cross-sectional study of the association between long working hours and pre-diabetes: 2010-2017 Korea National Health and Nutrition Examination Survey

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ABSTRACT

OBJECTIVE: Long working hours have been shown to raise the risk of various health outcomes. However, epidemiological evidence has shown inconsistent result in relation to type 2 diabetes (T2DM) and the association between long working hours and pre-diabetes among non-diabetic adults remains largely unexplored. We thus aimed to investigate whether long working hours were linked with pre-diabetes as determined by glycated hemoglobin (HbA1c) level.

DESIGN: Cross-sectional survey

PARTICIPANTS: This study included 6,324 men and 4,001 women without diabetes from the 2010-2017 Korean National Health and Nutrition Examination Survey (KNHANES).

PRIMARY OUTCOME MEASURES: The study outcome of interest was pre-diabetes, defined as HbA1c values 5.7-6.4%

RESULTS: Logistic regression was performed to obtain the odds ratios (OR) for pre-diabetes according to categories of work hour (40 hours/week, 41-52 hours/week, >52 hours/week), after adjusting for relevant covariates. Of the 10,325 eligible participants, 2,261 (34.4%) men and 1,317 (31.0%) women had pre-diabetes. No statistically significant relationship was found for women. In men, extended working hours (>52 hours per week) was associated with an increased likelihood of pre-diabetes, after adjustment for age, educational attainment, monthly household income, life-style related factors, perceived stress, family history of diabetes, hypertension, hypercholesterolemia and other covariates (adjusted OR=1.22; 95% confidence interval=1.03-1.46). In the subgroup analysis by occupational categories, the association was only apparent among men in blue-collar worker groups.

CONCLUSION: Extended working hours were significant related to the increased risk of pre-diabetes in men, with no statistically significant association observed for women. Further subgroup analysis by occupational categories revealed that the increased odds of pre-diabetes associated with long working hours was only apparent among male workers of blue collar occupations and shift workers.

Keywords: Pre-diabetes, Hba1c, working hours, Glucose metabolism

Strengths and limitations of this study

- As far as we are aware, this is the first report of an association between long working hours and pre-diabetes among individuals without diabetes using a nationally representative sample of Korean adults. We further compared associations by occupational categories.
- This study controlled for a range of factors that are known to affect HbA1c levels.
- Our analyses are based on cross-sectional data and, as such, preclude direct causal inference.

INTRODUCTION

Pre-diabetes, defined as an intermediate state of hyperglycemia with glycemic parameters above normal but below the diagnostic threshold for diabetes is considered an important risk factor for β-cell dysfunction[1] and the development of type 2 diabetes mellitus (T2DM).[2] According to the 2012 projection estimates, prevalence of pre-diabetes will continue to rise, and it is estimated that by 2030 over 470 million people will have pre-diabetes globally. [3] Approximately 70% of individuals diagnosed with pre-diabetes are expected to progress to T2DM within 10 years.[4] Given the high incidence rate of diabetes among pre-diabetic adults, identification of the modifiable risk factors of pre-diabetes in the general population is thus essential to effectively prevent or delay the onset of diabetes and its associated complications.

South Korea has one of the longest work hours among member states of the Organization for Economic Cooperation and Development (OECD), with people spending on average 2,069 hours at work annually compared to the OECD average of 1,764 hours.[5]

Several studies have assessed long working hours in relationship with the risk of various health outcomes, including coronary heart disease[6 7], cognitive function [8], as well as a high prevalence of anxiety[9] and sleeping disturbances.[10] However, epidemiological evidence have shown inconsistent result in relation to diabetes [11-14] and the association between long working hours and pre-diabetes in populations without diabetes remains largely unexplored. In a meta-analysis of epidemiological studies conducted in USA, Europe, Japan, and Australia, Kivimäki et al. reported a prospective association between long working hours and the incidence of diabetes, but only among employees with a low socioeconomic position.[12] Similarly, one study of Chinese male workers found that the risk of developing diabetes increased with longer hours of overtime work per week.[13] In contrast, in a study of Japanese male workers, the relative risk of type 2 diabetes significantly decreased among those who worked over 10 hours a day compared with those who worked 7 to 8 hours.[14] To fill this evidence gap, we investigated the relationship between weekly working hours and the pre-diabetes using a cross-sectional survey of 10,325 workers in South Korea.

METHODS

Study population

Data were drawn from the 2010-2017 Korean National Health and Nutrition Examination Survey (KNHANES). KNHANES is an ongoing population based, cross-sectional study which is designed to assess the health and nutritional status of people residing in South Korea.[15] The survey's sampling strategy was designed to be representative of the non-institutionalized civilian population aged 1 year or over which was selected using a complex, multistage, stratified sampling design. Of the 64,759 participants (Men : 29,458, Women : 35,301) who participated in the 2010-2017 survey, 26,750 reported as being economically active and therefore were eligible to be asked job-related modules and 26,696 provided valid responses concerning weekly work hours. We restricted analyses to individuals working 40 hours or more per week, as participants who worked for less than 40 hours are likely to do so due to health reasons (N=17,298). Additionally, KNHANES participants under 30 or >70 years old and pregnant women were excluded from the analysis (N=2,649). We also excluded those who reported a previous clinical diagnosis of diabetes made by a physician or taking insulin or anti-diabetic medication or missing data on Hba1c, or Hba1c values greater than 6.5% (N=3,800). Finally, we excluded participants with missing covariate data (N=524), yielding a final sample of 10,325 participants (Men : 6,324 , Women : 4,001) (See Figure 1).

Patient and Public Involvement (PPI)

No patients were included in the design and planning of the study. Including PPI statements aligns closely with BMJ Open's values of transparency and inclusiveness. We hope that including PPI statements in all articles is the first step of many for BMJ Open in encouraging patient involvement.

Measures

Definition of Pre-diabetes

The main study outcome was glycated hemoglobin (HbA1c). HbA1c is a form of hemoglobin in which glucose is attached to its β-chain after exposure to high plasma levels of glucose. As such, it is used as an integrated index of long-term serum glucose regulation.[16] Fasting bloods samples were collected during a medical examination and HbA1c levels were measured via high performance liquid chromatography (HLC-723G7; Tosoh, Tokyo, Japan). Participants were identified as being normoglycemic if they had a HbA1c level below 5.7%; HbA1c level between 5.7 and 6.4 percent were indicative of pre-diabetes according to the 2018 American Diabetes Association (ADA) standards of care in diabetes.[17] Previous research has indicated that HbA1c and fasting blood glucose (FBG) are equally in the detection of Type 2 diabetes.[18] Also, HbA1c has several advantages to the FBS, including the ability to use non-fasting blood samples, greater pre-analytical stability, and less day-to-day perturbations during periods of stress and illness.[19]

Working hours

In the KNHANES, participants were asked about their working hours using the following question: “During the last month, how many hours on average in a week did you work, including unpaid overtime work (excluding meal time)?” In Korea, statutory weekly work hours based on the Labor Standards Act (LSA) are 40 hours per week and 8 hours per day. The working hours stipulated in LSA Article 50 may be extended up to additional 12 hours by agreement between the parties. Therefore, in the current study we defined long working hours as working beyond the legal threshold of 52 hours. Participants reported their working hours as a continuous variable, and this was further categorized as follows: 40 hours, 41-52 hours, or >52 hours per week.

Covariates

Data on socio-demographic characteristics, lifestyle- and health-related factors were collected using interviewer-administered standardized questionnaires. Age was categorized into 30–39, 40–49, 50–59, and ≥ 60 years. Participants were categorized by educational attainment (elementary school, middle school, high school, and university degree or above), monthly household income quartiles, and occupational categories (white collar (managers, professionals), pink collar (clerks, service, and sales workers), green collar (agricultural, fishery or forestry workers) and blue collar (craft/trades workers, machine operators and assemblers, and elementary manual workers)[20 21]. Work schedules were assessed using the following question: "Do you work mostly during the day time, or do you work at a different time period?" Respondent who usually worked during the daytime (06:00-18:00), evening hours (14:00-24:00), or night-time (21:00-08:00) were categorized as fixed schedule workers, while those who worked 24-hours rotating shifts, split shifts, or irregular shifts were classified as shift schedule workers.

Health-related behaviours included smoking status (Never smoker, former smoker, and current smoker) alcohol consumption (Yes or no), muscle strengthening activity at least twice a week (yes/no), participation in aerobic activity, defined as walking at least 10 minutes at a time, for 30 minutes or more per day, on 5 or more per days during the 7 days preceding the survey, and sleep duration (< 6, 6-8, ≥9 hours). Body mass index (BMI [kg/m2]) was used to determine obesity status and calculated based on respondent's self-reported height and weight. A BMI of <18.5 was considered underweight, a BMI > 18.5 and <23.0 was considered normal weight, a BMI greater than or equal to 23.0 and <25.0 was considered overweight, and a BMI ≥ 25 was considered obese. The level of perceived stress was measured using the following question: "How stressed are you on a daily basis?" with possible answers ranging from 'None' coded 0 to 'High' coded 4. Respondents were reclassified into low (none/low) and high perceived stress (moderate/high). Hypercholesterolemia (yes/no) was defined as a serum total cholesterol level ≥240 mg/dL or the use of lipid-lowering medications. Hypertension (yes/no) was defined as a systolic blood pressure of 140 mmHg or higher, diastolic blood pressure of 90 mmHg or higher or on antihypertensive treatment. A family history of diabetes was ascertained by asking participants whether their first-degree relatives (parents or siblings) had ever been told they have diabetes (yes/no).

STATISTISTICAL ANALYSES

Statistical analyses were conducted using SAS version 9.4 (SAS Institute Inc., Cary, NC, USA). The SAS survey procedure was applied to reflect the stratification and clustering of the complex sampling design and sampling weights of the KNHANES and to ensure nationally representative prevalence estimates. General characteristics of the study sample were described using frequency and weighted percentages. Chi-square test was used to compare participant characteristics across working hours and between normoglycemic and pre-diabetic subjects. Multivariable logistic regression analysis was used to evaluate the association between working hours and pre-diabetes status, and odds ratios (ORs) and 95% confidence interval (CI) were calculated after adjusting for socio-demographic and health-related behavioural variables that showed significant association in univariate analysis and based on clinical relevance. Additionally, we evaluated whether the association between long working hours and pre-diabetes was dependent on age or work-related characteristics by testing interaction effects and conducting subgroup analyses. Interaction was assessed by including a cross-product interaction term (working hour×effect modifier variable) in the logistic regression model along with the main effect. All analyses were performed separately for men and women. All reported P values were based on 2-sided tests; statistical significance was set at $p < 0.05$.

RESULTS

General characteristics of the study population

Table 1 presents participants' general characteristics by HbA1c status in men and women. A total of 2,261 (34.43%) men and 1,317 (31.04%) women had pre-diabetes. Men who worked

40 hours per week had the lowest pre-diabetes prevalence (30.92%), followed by those working 41–52 hours (32.88%) and >52 hours (38.00%). Male workers with pre-diabetes were also more likely to be older, work over 52 hours/week, have a lower level of education, to be working in a manual occupations, obese, current smokers, sleep less than 6 hours and to have a diagnosis of hypertension, hypercholesteremia and a family history of diabetes compared with normoglycemic subjects. For women, we observed statistically significant differences in prevalence of pre-diabetes for most characteristics, except for participation in aerobic activity, muscle strengthening activity, family history of diabetes and work schedule.

Table 2 shows characteristics of study participants according to categories of working hours. A total of 1,399 (22.08%) male participants reported 40 hours of work per week, 2,483 (39.03%) reported 41–52 hours, and 2,442 (38.89%) reported more than 52 hours of work per week; the corresponding values for women were 1,086 (27.49%), 1,574 (39,19%), and 1,341 (33.32%), respectively. Participants who worked more than 52 hours were more likely to be older, have lower education, lower household income, higher self perceived stress, in blue-collar occupation, and have shift work schedule compared to men who work 40 hours per week. As regard health-related related variables, subjects who worked more than 52 hours tended to be current smoker, non-drinker, have shorter sleep duration and less likely to engage in muscle strengthening activity. Among women, no appreciable differences in smoking status, muscle strengthening activity, and work schedule were apparent across working hours per week.

Table 1. General characteristics of the study population by HbA1c status, KNHANES 2010-2017

	Men (N=6,324)				Women (N=4,001)			
	Total	Pre-diabetes N (%)	Normoglycemia N (%)	p-value	Total	Pre-diabetes N (%)	Normoglycemia N (%)	p-value
Working hours per week (hours)				**0.0001**				**<.0001**
40	1,399 (22.08)	447 (30.92)	952 (69.08)		1,086 (27.49)	298 (27.15)	788 (72.85)	
41-52	2,483 (39.03)	867 (32.88)	1,616 (67.12)		1,574 (39.19)	492 (29.21)	1,082 (70.79)	
>52	2,442 (38.89)	947 (38.00)	1,495 (62.00)		1,341 (33.32)	527 (36.40)	814 (63.60)	
Age group (years)				**<.0001**				**<.0001**
30-39	1,966 (34.77)	497 (24.41)	1,469 (75.59)		994 (26.69)	143 (14.97)	851 (85.03)	
40-49	2,016 (34.82)	687 (34.75)	1,329 (65.25)		1,241 (34.82)	313 (24.39)	928 (75.61)	
50-59	1,569 (23.31)	685 (43.40)	884 (56.59)		1,220 (28.79)	564 (46.11)	656 (53.89)	
≥60	773 (7.10)	392 (52.54)	381 (47.46)		546 (9.70)	297 (54.31)	249 (45.69)	
Education				**<.0001**				**<.0001**
Elementary School	480 (5.94)	227 (49.18)	253 (50.82)		698 (14.10)	359 (51.00)	339 (49.00)	
Middle school	540 (7.75)	239 (42.72)	301 (57.28)		477 (12.07)	211 (40.56)	266 (59.44)	
High school	2,083 (33.96)	816 (37.42)	1,267 (62.58)		1,508 (40.55)	495 (31.69)	1,013 (68.31)	
University degree or above	3,221 (52.35)	979 (29.60)	2,242 (70.40)		1,318 (33.28)	252 (18.33)	1,066 (81.67)	
Total household income				**0.016**				**<.0001**
Low	265 (3.59)	113 (44.21)	152 (55.79)		319 (7.07)	140 (42.38)	179 (57.62)	
Middle-low	1,444 (22.78)	549 (35.74)	895 (64.26)		942 (22.85)	344 (33.56)	598 (66.44)	
Middle-high	2,172 (35.26)	765 (34.22)	1,407 (65.78)		1,308 (34.11)	420 (30.06)	888 (69.94)	
High	2,443 (38.37)	834 (32.94)	1,609 (67.06)		1,432 (35.97)	413 (28.12)	1,019 (71.88)	
Smoking status				**<.0001**				**0.019**
Never smoker	1,250 (20.05)	365 (28.66)	885 (71.34)		3,624 (89,27)	1,229 (31.90)	2,395 (68.10)	
Former smoker	2,373 (35.12)	830 (33.37)	1,543 (66.63)		163 (4.76)	34 (22.21)	129 (77.79)	
Current smoker	2,701 (44.83)	1,066 (37.85)	1,635 (62.15)		214 (5.97)	54 (25.21)	160 (74.79)	
Alcohol consumption				0.263				**<.0001**
No	201 (2.95)	79 (38.77)	122 (61.22)		464 (10.18)	212 (43.03)	252 (56.97)	
Yes	6,123 (97.05)	2,182 (34.30)	3,941 (65.70)		3,537 (89.82)	1,105 (29.68)	2,432 (70.32)	
Aerobic activity								
No	4,008 (63.30)	1,451 (35.08)	2,557 (64.92)	0.223	2,643 (65.73)	868 (30.34)	1,775 (69.66)	0.254
Yes	2,316 (36.70)	810 (33.33)	1,506 (66.67)		1,358 (34.27)	449 (32.36)	909 (67.64)	
Muscle strengthening activity				0.242				0.969
No	4,651 (73.63)	1,681 (34.92)	2,970 (65.08)		3,528 (87.71)	1,167 (31.05)	2,361 (68.95)	

Table 1 continued

Yes	1,673 (26.37)	580 (33.08)	1,093 (66.92)		473 (12.29)	150 (30.95)	323 (69.05)	
BMI				**<.0001**				**<.0001**
Underweight	113 (1.93)	23 (19.02)	90 (80.98)		166 (4.22)	29 (14.14)	137 (85.86)	
Normal	1,934 (29.94)	557 (27.12)	1,377 (72.88)		1,869 (47.18)	438 (21.87)	1,431 (78.13)	
Overweight	1,733 (27.61)	602 (33.77)	1,131 (66.23)		890 (22.09)	324 (35.11)	566 (64.89)	
Obese	2,544 (40.52)	1,079 (41.02)	1,465 (58.98)		1,076 (26.51)	526 (46.64)	550 (53.36)	
Hypertension				**<.0001**				**<.0001**
No	4,639 (74.63)	1,531 (31.96)	3,108 (68.04)		3,252 (82.90)	958 (28.05)	2,294 (71.95)	
Yes	1,685 (25.37)	730 (41.70)	955 (58.30)		749 (17.10)	359 (45.53)	390 (54.47)	
Hypercholesterolemia				**<.0001**				**<.0001**
No	5,469 (87.19)	1,852 (32.59)	3,617 (67.41)		3,423 (86.67)	1,017 (28.18)	2,406 (71.82)	
Yes	855 (12.81)	409 (46.96)	446 (53.04)		578 (13.33)	300 (49.58)	278 (50.42)	
Family history of diabetes				**<.0001**				0.579
No	5,045 (79.35)	1,739 (32.70)	3,306 (67.30)		3,086 (76.91)	1,003 (30.79)	2,083 (69.21)	
Yes	1,279 (20.65)	522 (41.09)	757 (58.91)		915 (23.09)	314 (31.87)	601 (68.13)	
Sleep duration (hours)				0.069				**0.0002**
< 6	738 (11.62)	282 (36.32)	456 (63.68)		562 (14.49)	223 (39.68)	339 (60.32)	
6-8	5,167 (82.16)	1,850 (34.59)	3,317 (65.41)		3,083 (76.56)	996 (29.91)	2,087 (70.09)	
≥9	419 (6.22)	129 (28.90)	290 (71.10)		356 (8.95)	98 (26.69)	258 (73.31)	
Perceived stress				0.553				**0.008**
None/Low	4,513 (70.82)	1,633 (34.68)	2,880 (65.32)		2,743 (67.68)	945 (32.51)	1,798 (67.49)	
Moderate/High	1,811 (29.18)	628 (33.83)	1,183 (66.17)		1,258 (32.32)	372 (27.94)	886 (72.06)	
Occupation				**<.0001**				**<.0001**
White collar	2,774 (44.48)	845 (29.50)	1,929 (70.50)		1,527 (38.26)	311 (19.16)	1,216 (80.84)	
Pink collar	859 (14.05)	317 (36.50)	542 (63.50)		1,263 (32.68)	493 (36.87)	770 (63.13)	
Green collar	356 (4.20)	163 (44.57)	193 (55.43)		309 (5.45)	169 (52.94)	140 (47.06)	
Blue collar	2,335 (37.27)	936 (38.40)	1,399 (61.60)		902 (23.61)	344 (37.15)	558 (62.85)	
Work schedule				0.998				0.290
Fixed	5,801 (92.25)	2,060 (34.43)	3,741 (65.57)		3,826 (32.11)	1,255 (30.83)	2,571 (69.17)	
Shift	523 (7,75)	201 (34.44)	322 (65.56)		175 (22.05)	62 (35.09)	113 (64.91)	
Participants		2,261 (34.43)	4,063 (65.57)			1,317 (31.04)	2,684 (68.96)	

*Unless otherwise stated, unweighted frequency (weighted %) are shown.
†P value comparing prediabetes with normoglycemia

Table 2. General characteristics of the study population according to working hours per week , KNHANES 2010-2017

	Men (N=6,324)				Women (N=4,001)			
	40 hrs N (%)	41-52 hrs N (%)	>52 hrs N (%)	p-value	40 hrs N (%)	41-52 hrs N (%)	>52 hrs N (%)	p-value
Age (years)				**<.0001**				**<.0001**
30-39	444 (35.69)	820 (36.80)	702 (32.21)		372 (34.49)	446 (30.24)	176 (16.07)	
40-49	481 (35.91)	804 (34.68)	731 (34.33)		401 (38.94)	490 (35.01)	350 (31.18)	
50-59	351 (23.36)	592 (22.09)	626 (24.51)		242 (21.58)	434 (25.97)	544 (38.07)	
≥60	123 (5.04)	267 (6.43)	383 (8.95)		71 (4.99)	104 (8.78)	271 (14.68)	
Education				**<.0001**				**<.0001**
Elementary School	48 (2.72)	169 (5.13)	263 (8.58)		84 (6.16)	256 (13.40)	358 (21.49)	
Middle school	64 (4.44)	201 (7.34)	275 (10.03)		62 (6.49)	166 (10.07)	249 (19.03)	
High school	396 (28.82)	780 (33.03)	907 (37.82)		413 (39.61)	575 (39.38)	520 (42.70)	
University degree or above	891 (64.02)	1,333 (54.50)	997 (43.57)		527 (47.74)	577 (37.15)	214 (16.78)	
Total household income				**<.0001**				**<.0001**
Low	38 (2.60)	97 (3.34)	130 (4.39)		56 (5.44)	133 (6.89)	130 (8.63)	
Middle-low	234 (17.09)	539 (21.49)	671(27.30)		201 (18.39)	359 (22.28)	382 (27.19)	
Middle-high	454 (33.59)	888 (37.15)	830 (34.31)		373 (35.53)	492 (32.91)	444 (34.67)	
High	673 (46.72)	959 (38.02)	811 (34.00)		457 (40.64)	590 (37.92)	385 (29.81)	
Smoking status				**0.0003**				0.207
Never smoker	288 (21.54)	512 (21.12)	450 (18.15)		997 (90.90)	1,416 (88.95)	1,211 (88.30)	
Former smoker	578 (28.44)	908 (34.88)	887 (33.46)		41 (4.17)	74 (5.38)	48 (4.51)	
Current smoker	533 (40.02)	1,063 (44.00)	1,105 (48.39)		48 (4.93)	84 (5.67)	82 (7.19)	
Alcohol consumption				**0.009**				**0.002**
No	24 (1.78)	76 (2.81)	101 (3.76)		95 (7.58)	178 (10.21)	191 (12.28)	
Yes	1,375 (98.22)	2,407 (97.19)	2,341 (96.24)		991 (92.42)	1,396 (89.79)	1,150 (87.72)	
Aerobic activity				0.104				
No	866 (62.56)	1,547 (61.92)	1,595 (65.10)		662 (60.13)	1,042 (66.20)	939 (69.80)	**0.0001**
Yes	533 (37.44)	936 (38.08)	847 (34.90)		424 (39.87)	532 (33.80)	402 (30.20)	
Muscle strengthening activity				**0.005**				0.385
No	980 (70.70)	1,809 (73.00)	1,862 (75.92)		948 (87.24)	1,375 (87.05)	1,205 (88.89)	
Yes	419 (29.30)	674 (27.00)	580 (24.08)		138 (12.76)	199 (12.95)	136 (11.11)	
BMI				0.548				**<.0001**
Underweight	22 (1.72)	41 (1.84)	50 (2.13)		50 (4.32)	76 (5.03)	40 (3.18)	
Normal	405 (28.47)	760 (29.61)	769 (31.12)		578 (53.37)	748 (47.60)	543 (41.58)	
Overweight	415 (29.70)	655 (27.44)	663 (26.59)		217 (19.71)	344 (22.15)	329 (23.98)	
Obese	557 (40.11)	1,027 (41.11)	960 (40.16)		241 (22.60)	406 (25.22)	429 (31.26)	

Table 2 Continued

Hypertension				0.163			**<.0001**	
No	1,024 (74.57)	1,844 (76.00)	1,771 (73.29)		947 (82.52)	1,290 (83.96)	1,015 (77.83)	
Yes	375 (25.43)	639 (24.00)	671 (26.71)		139 (12.48)	284 (16.04)	326 (22.17)	
Hypercholesterolemia				**0.027**				**0.005**
No	1,187 (84.96)	2,149 (87.411)	2,133 (88.24)		967 (89.16)	1,353 (86.99)	1,103 (84.23)	
Yes	212 (15.04)	334 (12.59)	309 (11.76)		119 (10.84)	221 (13.01)	238 (15.77)	
Family history of diabetes				0.549				**0.033**
No	1,103 (78.15)	1,991 (79.65)	1,951 (79.74)		799 (74.23)	1,211 (76.63)	1,076 (79.47)	
Yes	296 (21.85)	492 (20.35)	491 (20.26)		287 (25.77)	363 (23.37)	265 (20.53)	
Sleep duration (hours)				**<.0001**				**0.004**
< 6	120 (8.63)	256 (10.72)	362 (14.22)		128 (12.06)	209 (14.35)	225 (16.65)	
6-8	1,182 (84.61)	2,070 (83.19)	1,915 (79.74)		836 (76.99)	1,223 (76.30)	1024 (76.50)	
≥9	97 (6.76)	157 (6.09)	165 (6.04)		122 (10.95)	142 (9.35)	92 (6.85)	
Perceived stress				**<.0001**				**0.005**
None/Low	1,083 (76.16)	1,785 (71.21)	1,645 (67.39)		788 (71.80)	1,076 (67.40)	879 (64.41)	
Moderate/High	316 (23.84)	698 (28.79)	797 (32.61)		298 (28.20)	498 (32.60)	462 (35.39)	
Occupation				**<.0001**				**<.0001**
White collar	873 (61.51)	1,200 (49.05)	701 (30.23)		665 (60.23)	672 (42.70)	190 (14.90)	
Pink collar	130 (10.25)	252 (10.26)	477 (20.01)		168 (15.96)	419 (27.97)	676 (52.01)	
Green collar	25 (1.20)	132 (3.72)	199 (6.39)		17 (0.83)	124 (5.78)	168 (8.87)	
Blue collar	371 (27.04)	899 (36.97)	1,065 (43.37)		236 (22.98)	359 (23.55)	307 (24.22)	
Work schedule				**<.0001**				0.283
Fixed	1,334 (95.41)	2,297 (92.38)	2,170 (90.33)		1,034 (94.20)	1,507 (95.77)	1,285 (95.41)	
Shift	65 (4.59)	186 (7.62)	272 (9.67)		52 (5.80)	67 (4.23)	56 (4.59)	
Participants	1,399 (22.08)	2,483 (39.03)	2,442 (38.89)		1,086 (27.49)	1,574 (39.19)	1,341 (33.32)	

*Unless otherwise stated, unweighted frequency (weighted %) are shown.
Row percentages are shown.

Association between long working hours and pre-diabetes

Results from the logistic regression analysis are shown in Table 3. In univariate logistic regression analyses, long working hours was significantly associated with increased odds of having pre-diabetes in both men and women. Compared with the individuals who worked 40 hours, the ORs of pre-diabetes for the those who belong to the >52 hours category were 1.37 (95% CI 1.17-1.61; p for trend <0.0001) and 1.54 (95% CI 1.25-1.88; p for trend <0.0001) for men and women, respectively. For women, the positive association between the working hours and pre-diabetes was no longer significant after controlling for age, with OR of 1.06 (95% CI 0.84-1.32). In the case of men, those who worked >52 hours were 1.22 times more likely to have pre-diabetes after adjusting for covariates (multivariable-adjusted Odds Ratio (OR): 1.40; 95% Confidence Interval (CI): 1.03-1.46; P for trend 0.017). Age, smoking status, hypercholesteremia, family history of diabetes and sleep duration were also found to associated with increased odds of pre-diabetes in men, but there were no statistically significant differences based on educational level, monthly household income, alcohol consumption, muscle strengthening activity, hypertension, perceived stress, occupation and work schedule.

Table 4 presents the ORs for subgroup analyses by age and work-related characteristics. We did not observe a significant interaction between the number of hours worked per week and age (Men:P for interaction =0.309) nor between work schedule and working hours (Men: P for interaction 0.864). The relationship between long working hours and pre-diabetes was more pronounced among male shift workers, albeit not statistically significantly, (41-52 hrs: aOR= 1.64, 95% CI: 0.77-3.47; >52 hrs: aOR= 1.64, 95% CI: 0.78-3.44; p for interaction=0.864). In the subgroup analysis by occupational categories, male workers who worked in blue-collar occupation were likely to have pre-diabetes as their average weekly working hours increased, after adjustment for all covariates. The adjusted ORs were 1.13 (95% CI 0.84-1.53) and 1.54 (95% CI 1.15-2.06) for the 41-52 hrs and >52 hrs categories, respectively (p for trend= 0.041). However, the interaction effect by occupational categories was not statistically significant (p for interaction=0.146).

Table 3. Results of the logistic regression analysis for the association between long working hours and pre-diabetes (HbA1c 5.7-6.4%)

			Crude			Model 1			Model 2		
	Case	Participants	OR	95% CI	P-value	OR	95% CI	P-value	OR	95% CI	P-value
Men (N=6,324)											
Working hours per week (hours)											
40	447	1,399	1.00			1.00			1.00		
41-52	867	2,483	1.09	0.93-1.29	0.278	1.10	0.93-1.29	0.279	1.07	0.90-1.27	0.477
>52	947	2,442	**1.37**	**1.17-1.61**	**0.0001**	**1.31**	**1.11-1.55**	**0.001**	**1.22**	**1.03-1.46**	**0.026**
P for trend				**<0.0001**			**0.001**			**0.017**	
Women (N=4,001)											
Working hours per week (hours)											
40	298	1,086	1.00			1.00			1.00		
41-52	492	1,574	1.11	0.91-1.35	0.307	0.98	0.80-1.20	0.84	0.89	0.72-1.12	0.338
>52	527	1,341	**1.54**	**1.25-1.88**	**<0.0001**	1.06	0.84-1.32	0.64	0.90	0.70-1.15	0.405
P for trend				**<0.0001**			0.601			0.436	

Note: OR, Odds ratio; CI, confidence interval;

Model 1 adjusted for age

Model 2 adjusted for age, educational attainment, total household income, obesity, smoking status, alcohol consumption, participation in aerobic activity, muscle strengthening activity, hypertension, hypercholesterolemia, family history of diabetes, sleep duration, perceived stress, occupation, work schedule

Table 4. Results of subgroup analysis of association between pre-diabetes and working hours by age and work characteristics

Characteristics	Case	Participants	Odds ratio (95% CI)			p for trend	p for interaction
			40 hrs	41-52 hrs	>52 hrs		
Men (N=6,324)							
Occupational categories							0.146
White collar	845	2,774	1.00	1.04 (0.83-1.30)	1.06 (0.82-1.38)	0.664	
Pink collar	317	859	1.00	1.22 (0.72-2.06)	0.99 (0.60-1.65)	0.714	
Green collar	163	356	1.00	0.52 (0.16-1.65)	0.90 (0.32-2.55)	0.247	
Blue collar	936	2,335	1.00	1.13 (0.84-1.53)	**1.54 (1.15-2.06)**	**0.001**	
Work schedule							0.864
Fixed	2,060	5,801	1.00	1.04 (0.87-1.25)	**1.21 (1.01-1.45)**	**0.031**	
Shift	201	523	1.00	1.64 (0.77-3.47)	1.64 (0.78-3.44)	0.317	
Age (years)							0.309
30-39	497	1,966	1.00	1.31 (0.94 to 1.83)	**1.44 (1.01 to 2.06)**	**0.047**	
40-49	687	2,016	1.00	0.89 (0.67 to 1.19)	1.20 (0.89 to 1.61)	0.124	
50-59	685	1,569	1.00	1.05 (0.76 to 1.47)	1.11 (0.80 to 1.55)	0.529	
≥60	392	773	1.00	1.29 (0.77 to 2.17)	1.12 (0.68 to 1.87)	0.079	
Women (N=4,001)							
Occupational categories							0.442
White collar	311	1,527	1.00	1.14 (0.82-1.60)	0.78 (0.48-1.27)	0.619	
Pink collar	493	1,263	1.00	0.62 (0.39-0.98)	0.77 (0.50-1.19)	0.706	
Green collar	169	309	1.00	1.42 (0.45-4.45)	0.94 (0.30-2.93)	0.309	
Blue collar	344	902	1.00	0.89 (0.58-1.35)	0.93 (0.59-1.45)	0.769	
Work schedule							0.202
Fixed	1,255	3,826	1.00	0.85 (0.68-1.06)	0.87 (0.68-1.11)	0.302	
Shift	62	175	1.00	2.71 (0.88-8.30)	2.57 (0.80-8.25)	0.121	
Age (years)							0.978
30-39	143	994	1.00	0.79 (0.48 to 1.29)	0.79 (0.39-1.58)	0.451	
40-49	313	1,241	1.00	0.89 (0.62-1.31)	0.81 (0.54-1.23)	0.327	
50-59	564	1,220	1.00	0.95 (0.64-1.39)	1.02 (0.69-1.52)	0.828	
≥60	297	546	1.00	0.94 (0.46-1.92)	0.82 (0.42-1.62)	0.485	

DISCUSSION

In this population-based study of Korean working adults without diabetes, we found that men who worked over 52 hours per week exhibited 22% increased odds for pre-diabetes than did those who worked 40 hours per week. This association was robust to adjustments for socio-demographic variables and lifestyle factors, such as obesity, participation in aerobic and muscle strengthening activity, smoking, and alcohol consumption and other covariates. Importantly, we found that the increased odds of pre-diabetes associated with long working hours was – albeit not statistically significant – more pronounced among workers of blue collar occupations and shift workers. These findings are in line with the evidence from a prospective study conducted in Japan which found that long working hours are related to the risk of incident diabetes among shift workers.[22] Further studies with larger sample sizes are warranted to explore whether the lack of statistical significance observed is a result of sample size, or reflects a true lack of association. Additionally, assessment of additive interaction between long working hours and lifestyle factors would be a fruitful venue for further research for more in depth understanding of the impacts of such interaction.

In the present study, the prevalence of pre-diabetes in the Korean working population was 34.4% and 31.0% for men and women, respectively. These prevalence estimates are comparable to general population estimates reported in the U.S [23], U.K [24] and those of other Asian countries.[25] Several previous studies have yielded prevalence estimates for pre-diabetes in Korea. Using the HbA1c cutoff, pre-diabetes prevalence in 2011 was reported to be 38.3% (Men: 41%; women: 35.7%) in a community-based cross-sectional study of Korean adults aged 30 years or over.[26] Another Korean study reported a pre-diabetes prevalence of 26.1% in men and 20.5% according to American diabetes association criteria.[27] However, this study was based on a sample from rural areas. Pre-diabetes is a well-recognized risk factors for future diabetes, that gives rise to micro- and macrovascular complications and have enormous social and economic burden [28, 29]; increased attention needs to be paid to the high prevalence of pre-diabetes in Korea.

We are not aware of other studies that has reported a relationship between long working hours and pre-diabetes, although our findings are comparable with a meta-analysis showing that long working hours is associated with the incidence of type 2 diabetes among individuals from low socioeconomic status groups.[12] Another study have also reported a similar finding, indicating that extended working hours is positively correlated with non-insulin dependent diabetes mellitus in men.[30] However, our results conflict with a previous study that found relative risks of T2DM significantly decreased with an increase in hours of work per day.[14]

The mechanisms underlying the association between long working hours and pre-diabetes are yet unknown. It is likely that a similar mechanism to that of diabetes could be responsible for the observed findings. Plausible explanations are that longer working hours impacts pre-diabetes risk via their association with behavioural risk factors. As shown in this study, prior research has indicated that working longer than recommended hours is linked to many behavioural risk factors, such as binge drinking [31, 32] and low physical activity [33], possibly because individuals feel that they lack the time to engage in leisure-time physical activity due to demands and responsibilities at work. In the present study, working hour–pre-diabetes association attenuated but remained statistically significant in men after adjustment for behavioural risk factors. As such, conventional risk factors for pre-diabetes are likely to explain only part of the association between long working hours and pre-diabetes.

Meanwhile, there has been a proposition that extended working hours are related to cortisol secretion [34], a known risk factor for impaired glucose metabolism.[35] Cortisol induces the formation of glucose in the liver and have insulin-antagonistic effects in the peripheral tissues; both processes have the potential to contribute to risk of hyperglycemia. Furthermore, individuals work longer hours are more often exposed to harmful psychological factors in the work environment, such as job strain [36, 37] and effort-reward imbalance [38], which are known to be associated with subsequent elevation of Hba1c.[39] As such, stress-related mechanisms that trigger dysregulation of neuroendocrine pathways, might be a potentially promising areas for future research studying the differences in risk of pre-diabetes according to work hours.

The present study has several strengths. First, this study is based on a nationally representative survey, and to the best of our knowledge, this is the first report of an association between long working hours and pre-diabetes among individuals without diabetes. Second, blood samples were collected using standardized laboratory procedures, ensuring an accurate estimate of HbA1c. Finally, we were able to control for several important confounding variables, such as sleep duration and perceived control. However, this study is not without limitations. Our analyses are based on data from observational studies and, as such, preclude direct causal inference. Information on working hours and other covariates were self-reported and thus subject to recall bias. Moreover, we cannot exclude the possibility that the results were affected by residual confounding caused by imprecisely measured covariates or some other unmeasured occupational factors, such as job strain and job satisfaction. Working hours was measured at a single point in time that might not represent long-term exposure. In future studies, use of repeated measurements is needed to characterize longitudinal relation between long working hours and pre-diabetes.

CONCLUSIONS

In conclusion, extended working hours in men was significantly correlated with the odds of pre-diabetes, independent of conventional risk factors. No statistically significant relationship was found for women. In the subgroup analysis, the association between long working hours and pre-diabetes was apparent only in male workers of blue collar occupations and shift workers. Additional large-scale longitudinal studies are needed to verify these findings.

Ethical statement: The survey protocols for the KNHANES were approved by the Institutional Review Board of the Korea Centers for Disease Control and Prevention (IRB No. 2013-07CON-03-4C, 2013-12EXP-03-5C, and 2015-01-02-6C), and informed consent was obtained from all participants.

Conflict of interest: The authors have no conflict of interest to declare.

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Data sharing statement: Data used in this study are available from the KNHANES official website (http://knhanes.cdc.go.kr/).

Author contributions: BYS, MK, GRK contributed to the conception and design of the study. BYS, MK, GRK, ECP contributed to analyses and interpretation of the data, BYS, MK, GRK drafted the manuscript. All authors read and approved the final manuscript.

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Figure legends

Figure 1 Flowchart of participant selection

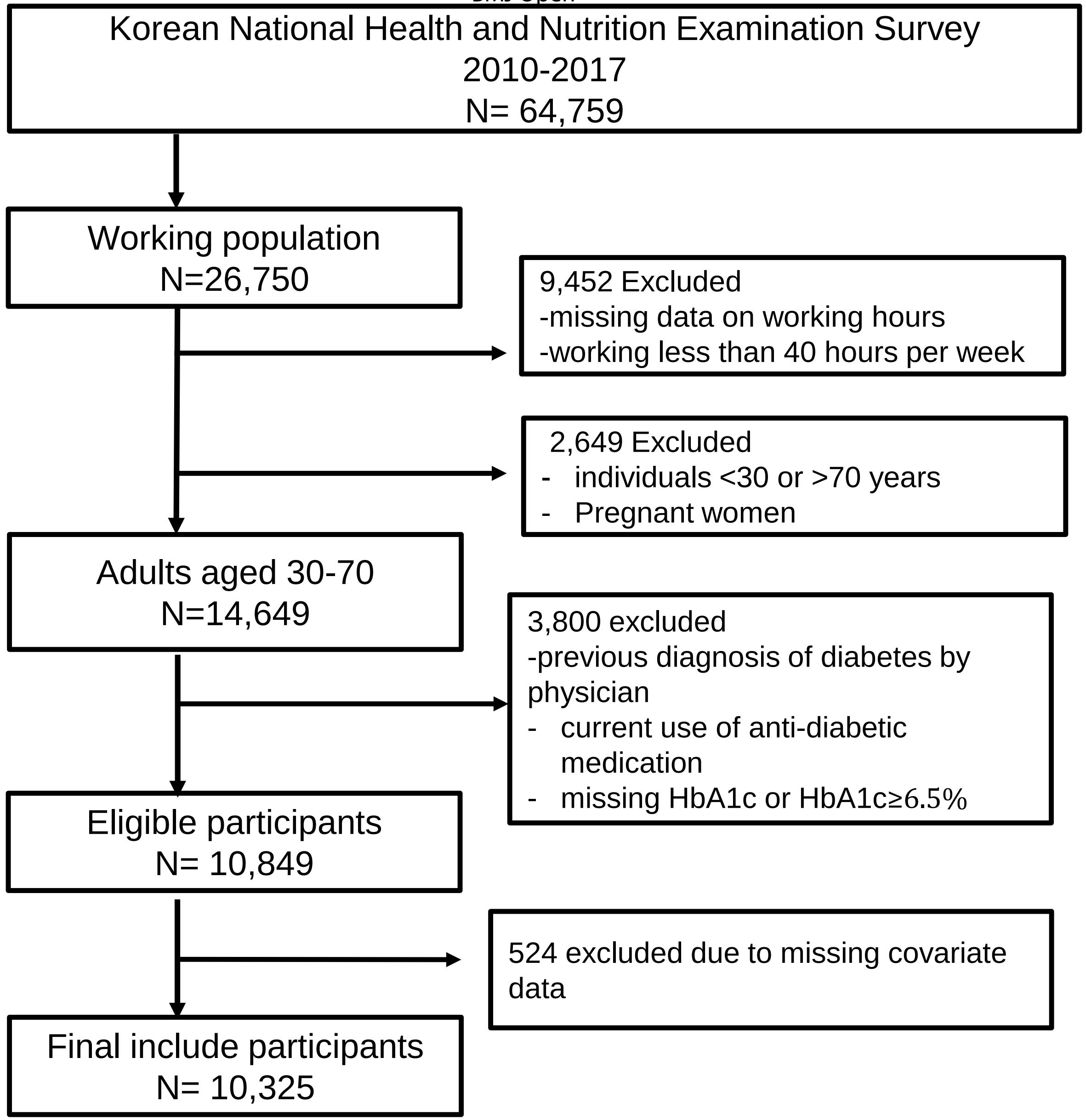

Figure 1 Flow chart of participant selection

STROBE Statement

Checklist of items that should be included in reports of observational studies

Section/Topic	Item No	Recommendation	Reported on Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	3	State specific objectives, including any prespecified hypotheses	3
Methods			
Study design	4	Present key elements of study design early in the paper	4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4,5,6
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	4
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	4,5,6
Data sources/measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	4,5,6
Bias	9	Describe any efforts to address potential sources of bias	6,7
Study size	10	Explain how the study size was arrived at	4
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	5,6,7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	6,7
		(*b*) Describe any methods used to examine subgroups and interactions	6,7
		(*c*) Explain how missing data were addressed	4
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	

Section/Topic	Item No	Recommendation	Reported on Page No
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	7
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	7,8,9,10,11,12
		(b) Indicate number of participants with missing data for each variable of interest	
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	
		Cross-sectional study—Report numbers of outcome events or summary measures	7,14
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	13,14
		(*b*) Report category boundaries when continuous variables were categorized	5,6
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	13,15
Discussion			
Key results	18	Summarise key results with reference to study objectives	16
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	17,18
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	16, 17
Generalisability	21	Discuss the generalisability (external validity) of the study results	16,17
Other Information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	19

**Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.*

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.