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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 mellitus (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 haemoglobin (HbA1c) level.

Design Cross-sectional survey.

Participants This study included 6324 men and 4001 women without diabetes from the 2010 to 2017 Korean National Health and Nutrition Examination Survey.

Primary outcome measures The study outcome of interest was pre-diabetes, defined as HbA1c values 5.7% to 6.4%

Results Logistic regression was performed to obtain the ORs for pre-diabetes according to categories of work hour (40 hours/week, 41 to 52 hours/week, >52 hours/week), after adjusting for relevant covariates. Of the 10 325 eligible participants, 2261 (34.4%) men and 1317 (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, lifestyle related factors, perceived stress, family history of diabetes, hypertension, hypercholesterolaemia and other covariates (adjusted OR=1.22; 95% CI 1.03 to 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 significantly related to 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.

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 glycated haemoglobin 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 hyperglycaemia with glycaemic 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 Organisation for Economic Cooperation and Development (OECD), with people spending on average 2069 hours at work annually compared with the OECD average of 1764 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

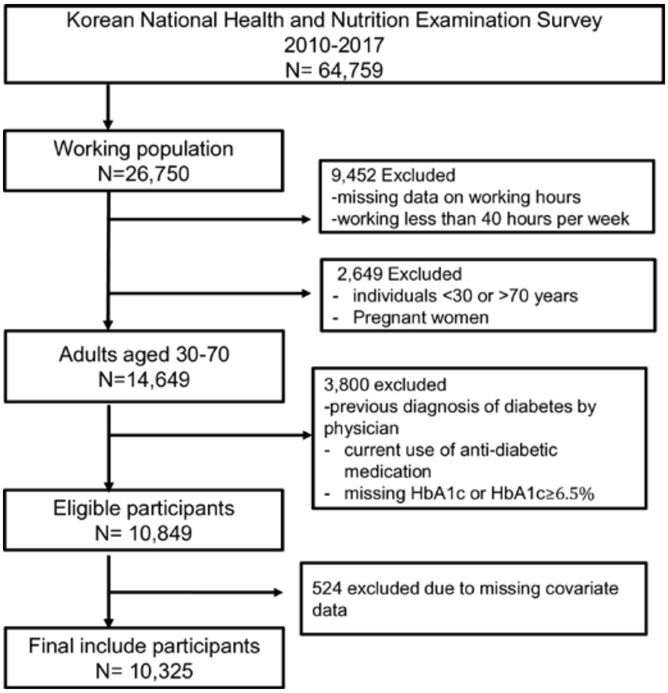

Figure 1 Flowchart of participant selection. HbA1c,glycated haemoglobin.

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 to 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-institutionalised 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 to 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=2649). We also excluded those who reported a previous clinical diagnosis of diabetes made by a physician or taking insulin or antidiabetic medication or missing data on glycated haemoglobin (HbA1c), or HbA1c values greater than 6.5% (n=3800). Finally, we excluded participants with missing covariate data (n=524), yielding a final sample of 10 325 participants (men: 6324, women: 4001) (see figure 1).

Patient and public involvement

No patients were included in the design and planning of the study. Including patientand public involvement (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 HbA1c. HbA1c is a form of haemoglobin 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 normoglycaemic if they had a HbA1c level below 5.7%; HbA1c level between 5.7 and 6.4 per cent were indicative of pre-diabetes according to the 2018 American Diabetes Association standards of care in diabetes.[17] Previous research has indicated that HbA1c and fasting blood glucose are equally in the detection of type 2 diabetes.[18] Also, HbA1c has several advantages to the fasting blood sugar, 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 Labour 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 categorised as follows: 40 hours, 41 to 52 hours or >52 hours per week.

Covariates

Data on socio-demographic characteristics, lifestyle-related and health-related factors were collected using interviewer-administered standardised questionnaires. Age was categorised into 30 to 39, 40 to 49, 50 to 59 and ≥60 years. Participants were categorised 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 to 18:00), evening hours (14:00 to 24:00) or night-time (21:00 to 08:00) were categorised 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 min at a time, for 30 min or more per day, on five or more per days during the 7 days preceding the survey and sleep duration (<6, 6 to 8, ≥9 hours). Body mass index (BMI) was used to determine obesity status and calculated based on respondent's self-reported height and weight. A BMI of <18.5 kg/m2 was considered underweight, a BMI >18.5–22.9 kg/m^2 was considered normal weight, a BMI 23.0–24.9 kg/m^2 was considered overweight and a BMI ≥25.0 kg/m^2 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). Hypercholesterolaemia (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 mm Hg or higher, diastolic blood pressure of 90 mm Hg 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 V.9.4 (SAS Institute Inc, Cary, North Carolina, 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. X^2 test was used to compare participant characteristics across working hours and between normoglycaemic and pre-diabetic subjects. Multivariable logistic regression analysis was used to evaluate the association between working hours and pre-diabetes status, and 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. 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 two-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 2261 (34.43%) men and 1317 (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 to 52 hours (32.88%) and >52 hours (38.00%). Male workers with pre-diabetes were also more likely to be older, have lower levels of household income and education, to be working in a manual occupations, obese, current smokers, sleep less than 6 hours and to have a diagnosis of hypertension, hypercholesterolaemia and a family history of diabetes compared with normoglycaemic 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 1399 (22.08%) male participants reported 40 hours of work per week, 2483 (39.03%) reported 41 to 52 hours and 2442 (38.89%) reported more than 52 hours of work per week; the corresponding values for women were 1086 (27.49%), 1574 (39.19%) and 1341 (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 with men who work 40 hours per week. As regard health-related variables, subjects who worked more than 52 hours tended to be current smoker, non-drinker, have shorter sleep duration

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

	Men (n=6324)				Women (n=4001)			
		Pre-diabetes	Normoglycaemia			Pre-diabetes	Normoglycaemia	
	Total	N (%)	N (%)	†P value	Total	N (%)	N (%)	†P value
Working hours per week (hours)				**0.0001**				<0.0001
40	1399 (22.08)	447 (30.92)	952 (69.08)		1086 (27.49)	298 (27.15)	788 (72.85)	
41–52	2483 (39.03)	867 (32.88)	1616 (67.12)		1574 (39.19)	492 (29.21)	1082 (70.79)	
>52	2442 (38.89)	947 (38.00)	1495 (62.00)		1341 (33.32)	527 (36.40)	814 (63.60)	
Age group (years)				<0.0001				<0.0001
30–39	1966 (34.77)	497 (24.41)	1469 (75.59)		994 (26.69)	143 (14.97)	851 (85.03)	
40–49	2016 (34.82)	687 (34.75)	1329 (65.25)		1241 (34.82)	313 (24.39)	928 (75.61)	
50–59	1569 (23.31)	685 (43.40)	884 (56.59)		1220 (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				<0.0001				<0.0001
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	2083 (33.96)	816 (37.42)	1267 (62.58)		1508 (40.55)	495 (31.69)	1013 (68.31)	
University degree or above	3221 (52.35)	979 (29.60)	2242 (70.40)		1318 (33.28)	252 (18.33)	1066 (81.67)	
Total household income				**0.016**				<0.0001
Low	265 (3.59)	113 (44.21)	152 (55.79)		319 (7.07)	140 (42.38)	179 (57.62)	
Middle-low	1444 (22.78)	549 (35.74)	895 (64.26)		942 (22.85)	344 (33.56)	598 (66.44)	
Middle-high	2172 (35.26)	765 (34.22)	1407 (65.78)		1308 (34.11)	420 (30.06)	888 (69.94)	
High	2443 (38.37)	834 (32.94)	1609 (67.06)		1432 (35.97)	413 (28.12)	1019 (71.88)	
Smoking status				<0.0001				**0.019**
Never smoker	1250 (20.05)	365 (28.66)	885 (71.34)		3624 (8927)	1229 (31.90)	2395 (68.10)	
Former smoker	2373 (35.12)	830 (33.37)	1543 (66.63)		163 (4.76)	34 (22.21)	129 (77.79)	
Current smoker	2701 (44.83)	1066 (37.85)	1635 (62.15)		214 (5.97)	54 (25.21)	160 (74.79)	
Alcohol consumption				0.263				<0.0001
No	201 (2.95)	79 (38.78)	122 (61.22)		464 (10.18)	212 (43.03)	252 (56.97)	
Yes	6123 (97.05)	2182 (34.30)	3941 (65.70)		3537 (89.82)	1105 (29.68)	2432 (70.32)	
Aerobic activity								
No	4008 (63.30)	1451 (35.08)	2557 (64.92)	0.223	2643 (65.73)	868 (30.34)	1775 (69.66)	0.254
Yes	2316 (36.70)	810 (33.33)	1506 (66.67)		1358 (34.27)	449 (32.36)	909 (67.64)	
Muscle strengthening activity				0.242				0.969
No	4651 (73.63)	1681 (34.92)	2970 (65.08)		3528 (87.71)	1167 (31.05)	2361 (68.95)	
Yes	1673 (26.37)	580 (33.08)	1093 (66.92)		473 (12.29)	150 (30.95)	323 (69.05)	
BMI				<0.0001				<0.0001
Underweight	113 (1.93)	23 (19.02)	90 (80.98)		166 (4.22)	29 (14.14)	137 (85.86)	
Normal	1934 (29.94)	557 (27.12)	1377 (72.88)		1869 (47.18)	438 (21.87)	1431 (78.13)	
Overweight	1733 (27.61)	602 (33.77)	1131 (66.23)		890 (22.09)	324 (35.11)	566 (64.89)	
Obese	2544 (40.52)	1079 (41.02)	1465 (58.98)		1076 (26.51)	526 (46.64)	550 (53.36)	
Hypertension				<0.0001				<0.0001
No	4639 (74.63)	1531 (31.96)	3108 (68.04)		3252 (82.90)	958 (28.05)	2294 (71.95)	
Yes	1685 (25.37)	730 (41.70)	955 (58.30)		749 (17.10)	359 (45.53)	390 (54.47)	
Hypercholesterolaemia				<0.0001				<0.0001
No	5469 (87.19)	1852 (32.59)	3617 (67.41)		3423 (86.67)	1017 (28.18)	2406 (71.82)	
Yes	855 (12.81)	409 (46.96)	446 (53.04)		578 (13.33)	300 (49.58)	278 (50.42)	

Continued

Table 1 Continued

		Men (n=6324)				Women (n=4001)		
		Pre-diabetes	Normoglycaemia			Pre-diabetes	Normoglycaemia	
	Total	N (%)	N (%)	†P value	Total	N (%)	N (%)	†P value
Family history of diabetes				<0.0001				0.579
No	5045 (79.35)	1739 (32.70)	3306 (67.30)		3086 (76.91)	1003 (30.79)	2083 (69.21)	
Yes	1279 (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	5167 (82.16)	1850 (34.59)	3317 (65.41)		3083 (76.56)	996 (29.91)	2087 (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	4513 (70.82)	1633 (34.68)	2880 (65.32)		2743 (67.68)	945 (32.51)	1798 (67.49)	
Moderate/high	1811 (29.18)	628 (33.83)	1183 (66.17)		1258 (32.32)	372 (27.94)	886 (72.06)	
Occupation				<0.0001				<0.0001
White-collar	2774 (44.48)	845 (29.50)	1929 (70.50)		1527 (38.26)	311 (19.16)	1216 (80.84)	
Pink-collar	859 (14.05)	317 (36.50)	542 (63.50)		1263 (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	2335 (37.27)	936 (38.40)	1399 (61.60)		902 (23.61)	344 (37.15)	558 (62.85)	
Work schedule				0.998				0.290
Fixed	5801 (92.25)	2060 (34.43)	3741 (65.57)		3826 (32.11)	1255 (30.83)	2571 (69.17)	
Shift	523 (7,75)	201 (34.44)	322 (65.56)		175 (22.05)	62 (35.09)	113 (64.91)	
Participants		2261 (34.43)	4063 (65.57)			1317 (31.04)	2684 (68.96)	

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

†P value comparing pre-diabetes with normoglycaemia

BMI, body mass index; HbA1c, glycated haemoglobin; KNHANES, Korean National Health and Nutrition Examination Survey.

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.

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 to 1.61; p for trend <0.0001) and 1.54 (95% CI 1.25 to 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 to 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 OR: 1.22; 95% CI: 1.03 to 1.46; p for trend 0.017). Age, smoking status, hypercholesterolaemia, family history of diabetes and sleep duration were also found to be associated with increased odds of prediabetes 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, although not statistically significantly, (41 to 52 hours: adjusted OR (aOR)=1.64, 95% CI 0.77 to 3.47; >52 hours: aOR=1.64, 95% CI 0.78 to 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 to 1.53) and 1.54 (95% CI 1.15 to 2.06) for the 41 to 52 hours and >52 hours categories, respectively (p for trend=0.041). However, the interaction effect by occupational categories was not statistically significant (p for interaction=0.146).

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

	Men (n=6324)				Women (n=4001)			
	40 hours	41–52 hours	>52 hours		40 hours	41–52 hours	>52 hours	
	N (%)	N (%)	N (%)	P value	N (%)	N (%)	N (%)	P value
Age (years)				<0.0001				<0.0001
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)	204 (8.78)	271 (14.68)	
Education				<0.0001				<0.0001
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)	1333 (54.50)	997 (43.57)		527 (47.74)	577 (37.15)	214 (16.78)	
Total household income				<0.0001				<0.0001
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)		372 (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)	1416 (88.95)	1211 (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)	1063 (44.00)	1105 (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	1375 (98.22)	2407 (97.19)	2341 (96.24)		991 (92.42)	1396 (89.79)	1150 (87.72)	
Aerobic activity				0.104				
No	866 (62.56)	1547 (61.92)	1595 (65.10)		662 (60.13)	1042 (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)	1809 (73.00)	1862 (75.92)		948 (87.24)	1375 (87.05)	1205 (88.89)	
Yes	419 (29.30)	674 (27.00)	580 (24.08)		138 (12.76)	199 (12.95)	136 (11.11)	
BMI				0.548				<0.0001
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)	1027 (41.11)	960 (40.16)		241 (22.60)	406 (25.22)	429 (31.26)	
Hypertension				0.163			<0.0001	
No	1024 (74.57)	1844 (76.00)	1771 (73.29)		947 (82.52)	1290 (83.96)	1015 (77.83)	
Yes	375 (25.43)	639 (24.00)	671 (26.71)		139 (12.48)	284 (16.04)	326 (22.17)	
Hypercholesterolaemia				**0.027**				**0.005**
No	1187 (84.96)	2149 (87.411)	2133 (88.24)		967 (89.16)	1353 (86.99)	1103 (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	1103 (78.15)	1991 (79.65)	1951 (79.74)		799 (74.23)	1211 (76.63)	1076 (79.47)	
Yes	296 (21.85)	492 (20.35)	491 (20.26)		287 (25.77)	363 (23.37)	265 (20.53)	

Continued

Table 2 Continued

	Men (n=6324)				Women (n=4001)			
	40 hours	41–52 hours	>52 hours		40 hours	41–52 hours	>52 hours	
	N (%)	N (%)	N (%)	P value	N (%)	N (%)	N (%)	P value
Sleep duration (hours)				<0.0001				**0.004**
<6	120 (8.63)	256 (10.72)	362 (14.22)		128 (12.06)	209 (14.35)	225 (16.65)	
6–8	1182 (84.61)	2070 (83.19)	1915 (79.74)		836 (76.99)	1223 (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				<0.0001				**0.005**
None/low	1083 (76.16)	1785 (71.21)	1645 (67.39)		788 (71.80)	1076 (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				<0.0001				<0.0001
White-collar	873 (61.51)	1200 (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)	1065 (43.37)		236 (22.98)	359 (23.55)	307 (24.22)	
Work schedule				<0.0001				0.283
Fixed	1334 (95.41)	2297 (92.38)	2170 (90.33)		1034 (94.20)	1507 (95.77)	1285 (95.41)	
Shift	65 (4.59)	186 (7.62)	272 (9.67)		52 (5.80)	67 (4.23)	56 (4.59)	
Participants	1399 (22.08)	2483 (39.03)	2442 (38.89)		1086 (27.49)	1574 (39.19)	1341 (33.32)	

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

Row percentages are shown.

BMI, body mass index; KNHANES, Korean National Health and Nutrition Examination Survey.

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

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 — although 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 USA,[23] UK[24] and those of other Asian countries.[25] Several previous studies have yielded prevalence estimates for pre-diabetes in Korea. Using the HbA1c cut-off, 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-recognised risk factor for future diabetes, that gives rise to microvascular 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

Table 3 Results of the logistic regression analysis for the association between long working hours and pre-diabetes (HbA1c 5.7% to 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=6324)											
Working hours per week (hours)											
40	447	1399	1.00			1.00			1.00		
41–52	867	2483	1.09	0.93 to 1.29	0.278	1.10	0.93 to 1.29	0.279	1.07	0.90 to 1.27	0.477
>52	947	2442	**1.37**	**1.17 to 1.61**	**0.0001**	**1.31**	**1.11 to 1.55**	**0.001**	**1.22**	**1.03 to 1.46**	**0.026**
P for trend			**<0.0001**				**0.001**			**0.017**	
Women (n=4001)											
Working hours per week (hours)											
40	298	1086	1.00			1.00			1.00		
41–52	492	1574	1.11	0.91 to 1.35	0.307	0.98	0.80 to 1.20	0.84	0.89	0.72 to 1.12	0.338
>52	527	1341	**1.54**	**1.25 to 1.88**	**<0.0001**	1.06	0.84 to 1.32	0.64	0.90	0.70 to 1.15	0.405
P for trend				**<0.0001**			0.601			0.436	

Model one adjusted for age.
HbA1c, glycated haemoglobin.

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 hyperglycaemia. Furthermore, individuals working 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 standardised 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

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

Characteristics	Case	Participants	OR (95% CI) 40 hours	41–52 hours	>52 hours	P for trend	P for interaction
Men (n=6324)							
Occupational categories							0.146
White-collar	845	2774	1.00	1.04 (0.83 to 1.30)	1.06 (0.82 to 1.38)	0.664	
Pink-collar	317	859	1.00	1.22 (0.72 to 2.06)	0.99 (0.60 to 1.65)	0.714	
Green-collar	163	356	1.00	0.52 (0.16 to 1.65)	0.90 (0.32 to 2.55)	0.247	
Blue-collar	936	2335	1.00	1.13 (0.84 to 1.53)	**1.54 (1.15 to 2.06)**	**0.001**	
Work schedule							0.864
Fixed	2060	5801	1.00	1.04 (0.87 to 1.25)	**1.21 (1.01 to 1.45)**	**0.031**	
Shift	201	523	1.00	1.64 (0.77 to 3.47)	1.64 (0.78 to 3.44)	0.317	
Age (years)							0.309
30–39	497	1966	1.00	1.31 (0.94 to 1.83)	**1.44 (1.01 to 2.06)**	**0.047**	
40–49	687	2016	1.00	0.89 (0.67 to 1.19)	1.20 (0.89 to 1.61)	0.124	
50–59	685	1569	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=4001)							
Occupational categories							0.442
White-collar	311	1527	1.00	1.14 (0.82 to 1.60)	0.78 (0.48 to 1.27)	0.619	
Pink-collar	493	1263	1.00	0.62 (0.39 to 0.98)	0.77 (0.50 to 1.19)	0.706	
Green-collar	169	309	1.00	1.42 (0.45 to 4.45)	0.94 (0.30 to 2.93)	0.309	
Blue-collar	344	902	1.00	0.89 (0.58 to 1.35)	0.93 (0.59 to 1.45)	0.769	
Work schedule							0.202
Fixed	1255	3826	1.00	0.85 (0.68 to 1.06)	0.87 (0.68 to 1.11)	0.302	
Shift	62	175	1.00	2.71 (0.88 to 8.30)	2.57 (0.80 to 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 to 1.58)	0.451	
40–49	313	1241	1.00	0.89 (0.62 to 1.31)	0.81 (0.54 to 1.23)	0.327	
50–59	564	1220	1.00	0.95 (0.64 to 1.39)	1.02 (0.69 to 1.52)	0.828	
≥60	297	546	1.00	0.94 (0.46 to 1.92)	0.82 (0.42 to 1.62)	0.485	

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 characterise 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.

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