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■ Original Article

The Association between Duration of Noise Exposure in the Workplace and Glucose Metabolism Status: Evidence from the Korea National Health and Nutrition Examination Survey

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Background: This study aimed to evaluate the association between the duration of workplace noise exposure and glucose metabolism status in a nationally representative Korean sample.
Methods: This cross-sectional study included 3,534 participants aged ≥40 years without tinnitus or hearing loss from the Korea National Health and Nutrition Examination Survey (2018). The primary exposure was noise in the workplace and its duration. We divided the noise exposure group into four groups according to the duration of noise exposure (<3 years, 3–10 years, 10–20 years, and ≥20 years). The primary outcomes were fasting blood sugar (FBS), hemoglobin A1c (HbA1c), and pre-diabetes and diabetes diagnosed using FBS. Logistic and linear regression analyses were used to test the association between noise exposure and glycemic status.
Results: After adjustment, HbA1c levels were significantly higher in the noise exposure than in the non-noise exposure group. HbA1c levels were significantly higher in those exposed to occupational noise for more than 20 years than in others. In the subgroup analysis among those who had been exposed to noise for >20 years, the non-aerobic physical activity group had significantly higher HbA1c levels than the physical activity group. Furthermore, among those who had been exposed to noise for >20 years, the without hearing protection group had significantly higher HbA1c levels than those using hearing protection.
Conclusion: The association between noise exposure and the prevalence of diabetes is unclear. However, our study clearly suggests that there is a relationship between elevated HbA1c levels and workplace noise exposure and that a long period of workplace noise exposure, no physical activity, and not wearing a hearing protection device could increase the risk of diabetes.

Keywords: Occupational Noise; Diabetes Mellitus; Glucose Metabolism Disorder; Occupational Exposure

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INTRODUCTION

Owing to the rapid industrialization of modern society, noise has become a problem. The effects of noise exposure on the auditory system are known as indicated by the laws regarding hearing loss due to workplace noise exposure. Furthermore, noise exposure is associated with several negative health effects, including high blood pressure, myocardial infarction, and cognitive impairment.[1-4)]

Observational and experimental studies in humans and animals have suggested that both acute and chronic noise exposure can be stressors that stimulate the sympathetic nervous system and increase stress hormones (including catecholamines and glucocorticoids), resulting in adverse health consequences.[1,5-7)] Gan et al.[8)] reported, based on objective indicators of personal chronic exposure to loud noise, that exposure to loud noise in the workplace is associated with chronic heart disease. Recently, exposure to residential traffic noise has been found to be related to an increased risk of type 2 diabetes (T2DM) in Danish population-based cohorts including more than 57,000 participants, suggesting the impact of noise on diabetes.[9)]

In addition, excessive stress hormones, such as corticosteroids, are associated with the development of T2DM in human participants and rodent models.[10-13)] A study examined the effects of noise exposure on cortisol and glucose serum levels in adult male rats. It revealed significant differences in glucose and cortisol levels between groups exposed to noise (with or without diabetes) and controls.[14)]

A small study of 100 workers showed that chronic exposure to noise above 80 dB increased blood sugar and cortisol levels. In the present study, 80 adjusted decibels (dBA) was the maximum volume at which hormone homeostasis was maintained. The sympathetic nervous system becomes overactive at noise levels above 80 dBA.[15)]

Animal experimental studies have reported the effects of noise exposure on blood sugar, and many studies have shown that noise exposure is associated with sympathetic nervous system activation and stress hormone elevation; however, there are few studies on the direct association between occupational noise exposure and diabetes.

Therefore, this study aimed to examine the association between workplace noise exposure and glucose metabolism status.

METHODS

1. Study Population

Data were obtained from the 2018 Korea National Health and Nutrition Examination Survey (KNHANES), a series of cross-sectional, nationally representative Korean surveys and laboratory examinations (N=7,992). Participants were excluded if they were <40 years old (n=3,279); were treated with an oral hypoglycemic agent or insulin (n=543); were using hearing aids or artificial wares due to hearing difficulties (n=62); or had missing data on noise exposure, body mass index (BMI), education, fasting plasma glucose, or HbA1c (n=574). After these exclusions, data of 3,534 participants were included in the analysis (Figure 1).

Participants who were being administered oral hypoglycemic agents or insulin were excluded because these medications have significant glucose-lowering effect, and we could not predict changes in blood glucose levels due to changes in medication.

2. Noise Exposure

The presence of workplace noise exposure was assessed using a questionnaire. This included the question "have you ever worked in a noisy place such as one with a machine or generator for more than 3 months?" The responses were yes, no, or no response. However, there was insufficient evidence for the three-month period. Therefore, using the same criteria for industrial accidents with noise-induced hearing loss,[16)] occupational noise exposure for less than 3 years was categorized as no noise exposure. The duration of noise exposure was assessed by asking the following question: "how many months have you worked?" In this study, we divided the noise exposure group into four groups based on the duration of workplace noise exposure (less than 3 years, more than 3 years but less than 10 years,[17)] more than 10 years but less than 20 years, and more than 20 years[18)]). In addition, the use of hearing protection equipment was assessed by asking the following question: "do you wear equipment to protect your hearing in the workplace? The expected responses were yes or no.

3. Pre-diabetes and Diabetes Mellitus

Blood glucose levels were measured in two ways: fasting blood sugar

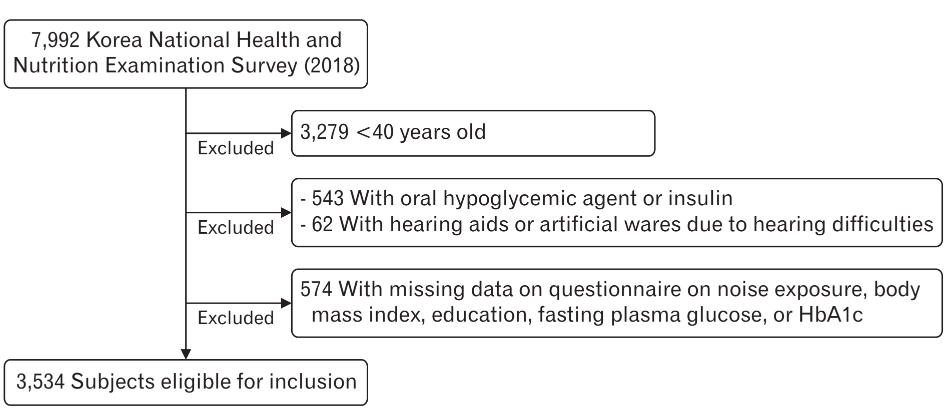

Figure 1. Flowchart of study participants.

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(FBS) and HbA1c. The blood tests were conducted after fasting for more than 8 hours.

A person was said to have diabetes if they have a FBS >126 mg/dL, were diagnosed with diabetes by a doctor, or are being administered oral hypoglycemic agent or insulin. Normal was defined as FBS <100 mg/dL. A person with impaired fasting glucose was one who was not included in the normal or diabetes group, with FBS of between 100 mg/dL and 126 mg/dL.

4. Covariates

Age was considered a continuous variable. BMI was calculated using measured weight and height. Education was categorized as middle school graduate or lower, high school graduate, or college graduate or higher. Tobacco and alcohol use and physical activity were self-reported. Smoking status was classified as current, former, or never smoker. Alcohol consumption was classified as non-drinker, moderate drinker (<14 drinks/wk), and heavy drinker (≥14 drinks/wk). Physical activity was evaluated in terms of aerobic physical activity. The definition of aerobic physical activity was the practice of medium-intensity physical activity for more than 2 hours 30 minutes per week, or high-intensity physical activity for more than 1 hour 15 minutes per week, or practice of the time equivalent of each activity by mixing medium and high-intensity physical activities (1 minute of high-intensity activity equals 2 minutes of medium-intensity activity). Physical activity was categorized as yes or no.

5. Analysis

We conducted χ^2 tests for categorical variables and analysis of variance for continuous variables. Multivariate logistic regression analysis was used to examine the association between the duration of noise exposure as the independent variable and glycemic status as the dependent variable. We fitted three nested regression models: adjusted for age (model 1); additionally adjusted for education, income, and sex (model 2); and additionally adjusted for physical activity, BMI, alcohol intake, and cigarette use (model 3). We conducted a subgroup analysis by age (40–64-year-old and 65 years or older age groups), physical activity, and hearing protection equipment use. Analyses were conducted using STATA ver. 16.1 (Stata Corp., College Station, TX, USA).

6. Ethics Statement

This study was approved by the Institutional Review Board of Seoul National University Hospital (IRB approval no., 2106-166-1230). The

Table 1. Socio-demographic characteristics and health behaviors according to duration of noise exposure in the workplace

Characteristic	Total	Duration of noise exposure				P-value
		0–3 y	3–10 y	10–20 y	≥20 y	
No. of participants	3,534	3,121	125	143	145	
Age (y)		57.95±11.58	56.38±9.79	56.08±10.29	60.67±9.36	<0.000
Sex						<0.000
Male	1,466 (41.48)	1,209 (38.74)	60 (48.00)	84 (58.74)	113 (77.93)	
Female	2,068 (58.52)	1,912 (61.26)	65 (52.00)	59 (41.26)	32 (22.07)	
Body mass index (kg/m^2)						0.725
Underweight (<18.5)	82 (2.32)	74 (2.37)	1 (0.80)	5 (3.50)	2 (1.38)	
Normal weight (18.5–25.0)	1,344 (38.03)	1,196 (38.32)	50 (40.00)	47 (32.87)	51 (35.17)	
Overweight (25.0–30.0)	864 (24.45)	752 (24.09)	32 (25.60)	38 (26.57)	42 (28.97)	
Obese (≥30.0)	1,244 (35.20)	1,099 (35.21)	42 (33.60)	53 (37.06)	50 (34.48)	
Smoking status						<0.000
Never	2,177 (61.71)	2,000 (64.14)	70 (56.45)	62 (43.66)	45 (31.25)	
Ex	749 (21.23)	621 (19.92)	28 (22.58)	49 (34.51)	51 (35.42)	
Current	602 (17.06)	497 (15.94)	26 (20.97)	31 (21.83)	48 (33.33)	
Income						0.085
Low	1,703 (48.35)	1,482 (47.62)	69 (55.20)	80 (55.94)	72 (50.70)	
High	1,819 (51.65)	1,630 (52.38)	56 (44.80)	63 (44.06)	70 (49.30)	
Education						<0.000
Middle or lower	1,252 (35.43)	1,063 (34.06)	50 (40.00)	66 (46.15)	73 (50.34)	
High school	1,180 (33.39)	1,026 (32.87)	52 (41.60)	48 (33.57)	54 (37.24)	
College or higher	1,102 (31.18)	1,032 (33.07)	23 (18.40)	29 (20.28)	18 (12.41)	
Alcohol						<0.000
Never	1,020 (28.90)	924 (29.63)	24 (19.20)	30 (20.98)	42 (29.17)	
Appropriate	2,065 (58.50)	1,831 (58.72)	80 (64.00)	87 (60.84)	67 (46.53)	
Risky	445 (12.61)	363 (11.64)	21 (16.80)	26 (18.18)	35 (24.31)	
Physical activity						0.138
No	2,178 (61.77)	1,942 (62.38)	69 (55.20)	87 (60.84)	80 (55.17)	
Yes	1,348 (38.23)	1,171 (37.62)	56 (44.80)	56 (39.16)	65 (44.83)	

Values are presented as mean±standard error or number (%). P-values were calculated using the chi-square test or t-test of variance. P<0.05 indicate statistical significance.

requirement for informed consent was waived because the participants' consent had been obtained for the KNHANES. The dataset was in the public domain and did not include individually identifiable information.

RESULTS

Of the 3,534 participants, 190 (5.38%) had diabetes, 1,193 (33.76%) had impaired fasting glucose, and the remaining 2,151 (60.87%) were normal. Age (P=0.000), sex (P=0.000), income (P=0.085), education (P=0.000), alcohol intake (P=0.000), and smoking (P=0.000) varied with the duration of noise exposure in the workplace, but physical activity (P=0.138) and BMI (P=0.725) did not (Table 1).

1. Presence of Noise Exposure in Workplace

Exposure to noise in the workplace was not significantly associated with diabetes (odds ratio [OR], 1.11; 95% confidence interval [CI], 0.70–1.76 vs. no exposure P=0.648) or impaired fasting glucose (OR, 1.19; 95% CI, 0.96–1.48 vs. no exposure P=0.119). However, workplace noise exposure was associated with a significantly higher fasting blood glucose level than non-exposure (coefficient=2.20, P=0.027); nevertheless, the association was statistically insignificant after adjusting for confounding variables (coefficient=0.63, P=0.53) (Figure 2A, B). A positive association between noise exposure and HbA1c level was also observed (coefficient=0.08, P=0.014), and this was statistically significant after adjustment for confounding variables (coefficient=0.07, P=0.03) (Figure 2C, D).

2. Duration of Noise Exposure in the Workplace

We divided the duration of noise exposure in the workplace into four groups: <3 years, 3–10 years, 10–20 years, and ≥20 years. When we performed logistic regression analyses, we found statistically significant positive associations between occupational noise exposure and diabetes mellitus or pre-diabetes for exposures of greater than 20 years (Table 2). However, these associations were not statistically significant after adjustment for confounding variables.

Moreover, when we performed linear regression analyses, we found that a longer duration of noise exposure in the workplace tended to be

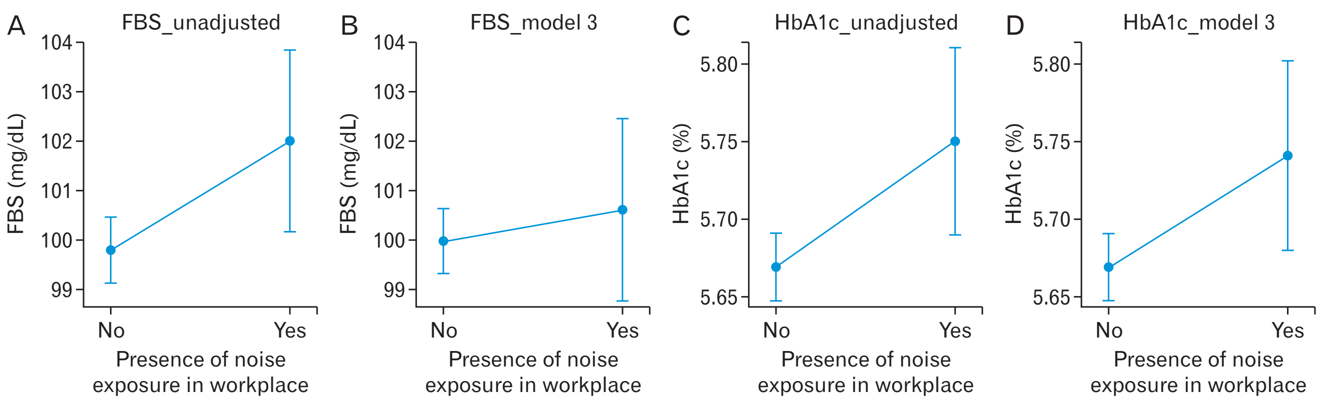

Figure 2. Association between workplace noise exposure and fasting plasma sugar (FBS) or hemoglobin A1c (HbA1c) level. Model 3: adjusted for age, education, income, sex, body mass index, physical activity, alcohol intake, and smoking. (A, B) FBS. (C, D) HbA1c. Linear regression analysis showing the relationship between the presence of noise exposure in the workplace and FBS or HbA1c levels.

Table 2. Association between duration of noise exposure in the workplace and prevalence of diabetes mellitus or pre-diabetes

	3–10 y		10–20 y		≥20 y	
	OR (95% CI)	P-value	OR (95% CI)	P-value	OR (95% CI)	P-value
Diabetes mellitus						
Unadjusted	0.8 (0.32–2.00)	0.627	0.75 (0.32–1.73)	0.497	1.88 (1.00–3.54)	0.049
Model 1	0.8 (0.32–2.00)	0.628	0.75 (0.32–1.74)	0.505	1.84 (0.98–3.46)	0.059
Model 2	0.69 (0.27–1.76)	0.441	0.53 (0.23–1.25)	0.149	1.16 (0.60–2.23)	0.658
Model 3	0.71 (0.28–1.81)	0.474	0.57 (0.24–1.36)	0.209	1.28 (0.66–2.51)	0.463
Pre-diabetes						
Unadjusted	1.23 (0.84–1.78)	0.282	0.9 (0.63–1.30)	0.572	1.51 (1.07–2.15)	0.020
Model 1	1.07 (0.83–1.37)	0.597	1.42 (0.98–2.05)	0.063	1.47 (0.94–2.30)	0.095
Model 2	0.93 (0.72–1.19)	0.548	1.14 (0.78–1.67)	0.492	1 (0.63–1.59)	0.998
Model 3	0.91 (0.70–1.19)	0.497	1.21 (0.82–1.80)	0.337	1.04 (0.65–1.67)	0.878

Model 1: adjusted for age; model 2: adjusted for model 1 plus education, income, and sex; and model 3: adjusted for model 2 plus body mass index, physical activity, alcohol intake, and smoking. ORs and P-values were estimated using multivariate logistic regression analysis after adjusting for age, education, income, sex, body mass index, physical activity, alcohol intake, and smoking.
OR, odds ratio; CI, confidence interval.

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associated with higher HbA1c levels. In particular, the group exposed to noise for more than 20 years showed a significantly higher HbA1c level than that of other groups after adjustment for confounding variables (Table 3).

3. Subgroup Analysis

1) Physical activity

A subgroup analysis was conducted based on aerobic physical activity status. As shown in Table 4, there was a clear tendency that the longer the noise exposure period, the higher the HbA1c level in the non-aerobic physical activity group. This tendency was higher in the non-aerobic than in the aerobic physical activity group. Furthermore, there was a significantly higher HbA1c level in the non-aerobic than in the aerobic physical activity group among those with noise exposure of greater than 20 years after adjusting for other confounding variables (Table 4).

2) Hearing protection equipment

Subgroup analysis was conducted based on whether hearing protection equipment was worn. When hearing protection equipment was not worn, a longer noise exposure period was associated with higher HbA1c levels. This tendency was relatively weak when hearing protection was used. In addition, it was confirmed that if hearing protection was not used, the HbA1c level was significantly higher among those

Table 3. Association between duration of noise exposure in the workplace and HbA1c level

	3–10 y			10–20 y			≥20 y		
	HbA1c (%)	Coef.	P-value	HbA1c (%)	Coef.	P-value	HbA1c (%)	Coef.	P-value
Unadjusted	5.66	-0.01	0.894	5.72	0.05	0.359	5.86	0.19	0
Model 1	5.67	0.04	0.948	5.73	0.06	0.239	5.84	0.17	0.001
Model 2	5.66	-0.01	0.859	5.71	0.04	0.433	5.81	0.14	0.009
Model 3	5.67	0.00	0.958	5.73	0.06	0.271	5.82	0.15	0.006

Model 1: adjusted for age; model 2: adjusted for model 1 plus education, income, and sex; and model 3: adjusted for model 2 plus body mass index, physical activity, alcohol intake, and smoking. Multivariate regression analysis of relationship between duration of noise exposure in the workplace and HbA1c level using a linear regression analysis.
HbA1c, hemoglobin A1c; Coef., coefficient.

Table 4. Association between duration of noise exposure in the workplace and HbA1c level depending on aerobic physical activity

	3–10 y			10–20 y			≥20 y		
	HbA1c (%)	Coef.	P-value	HbA1c (%)	Coef.	P-value	HbA1c (%)	Coef.	P-value
No									
Unadjusted	5.67	-0.01	0.946	5.79	0.12	0.083	5.96	0.28	0
Model 1*	5.68	0.00	0.991	5.81	0.13	0.056	5.92	0.24	0.001
Yes									
Unadjusted	5.65	0.00	0.96	5.60	-0.05	0.527	5.74	0.08	0.311
Model 1*	5.68	0.02	0.782	5.61	-0.05	0.568	5.70	0.05	0.567

Prespecified subgroup analyses were additionally performed using linear regression model stratified by aerobic physical activity.
*Adjusted for age, education, income, sex, body mass index, alcohol intake, and smoking.
HbA1c, hemoglobin A1c; Coef., coefficient.

Table 5. Association between duration of noise exposure in the workplace and HbA1c level depending on wearing hearing protection equipment

	3–10 y			10–20 y			≥20 y		
	HbA1c (%)	Coef.	P-value	HbA1c (%)	Coef.	P-value	HbA1c (%)	Coef.	P-value
No									
Unadjusted	5.69	0.10	0.433	5.74	0.17	0.212	5.98	0.40	0.003
Model 1	5.68	0.11	0.416	5.74	0.17	0.202	5.98	0.41	0.003
Model 2	5.71	0.16	0.251	5.76	0.20	0.134	5.95	0.39	0.005
Model 3	5.73	0.20	0.149	5.77	0.24	0.08	5.95	0.42	0.003
Yes									
Unadjusted	5.61	-0.42	0.081	5.66	-0.36	0.118	5.60	-0.42	0.07
Model 1	5.61	-0.42	0.08	5.66	-0.37	0.114	5.61	-0.41	0.079
Model 2	5.65	-0.43	0.083	5.63	-0.45	0.068	5.60	-0.48	0.057
Model 3	5.62	-0.45	0.087	5.72	-0.36	0.178	5.53	-0.55	0.038

Prespecified subgroup analyses were additionally performed using linear regression model stratified by wearing hearing protection equipment.
Model 1: adjusted for age; model 2: adjusted for model 1 plus education, income, and sex; and model 3: adjusted for model 2 plus body mass index, physical activity, alcohol intake, and smoking.
HbA1c, hemoglobin A1c; Coef., coefficient.

with noise exposure for more than 20 years than if hearing protection was used (Table 5).

DISCUSSION

The association between noise exposure and the prevalence of diabetes or pre-diabetes was unclear after adjusting for confounding variables. However, we found a statistically significant relationship between elevated HbA1c levels and occupational noise exposure.

Previous studies have demonstrated a link between noise exposure and blood pressure, heart rate, cardiovascular disease, and cortisol imbalance, but the results have been inconsistent. This discrepancy may be related to differences in workplace noise levels, noise exposure duration, exposure evaluation methods, research designs, and sample sizes across studies.[15]

However, there are few studies on the direct association between occupational noise exposure and diabetes. When we assessed the association between occupational noise exposure status and diabetes prevalence, no statistically significant associations were found. One meta-analysis had a similar context as that of our study. The meta-analysis synthesized the available evidence and showed an increased risk of diabetes associated with long-term exposure to transport noise, especially air traffic noise. However, the study found no significant increase in the risk of diabetes with occupational noise exposure.[19]

However, in our study, through further analysis, we found that HbA1c levels were significantly higher when there was noise than when there was no noise exposure in the workplace. In addition, when we investigated the association between the duration of occupational noise exposure and glucose metabolism, we found a positive relationship between longer noise exposure and higher HbA1c levels. In particular, the group exposed to noise for >20 years showed significantly higher HbA1c levels than other groups.

In the meta-analysis mentioned above, the use of protective equipment, high physical activity, and healthy worker effects in those exposed to occupational noise could account for insignificant findings.[19] However, in our study, we performed sub-analysis by whether hearing protection devices were worn and each individual's physical activity through surveys, which revealed the following results.

In this study, we performed a subgroup analysis based on physical activity status and hearing protection equipment use. In the sub-analysis based on physical activity status, among those with noise exposure for greater than 20 years, HbA1c was significantly higher among those that did not engage in aerobic physical activity than among those that did. Prolonged exposure to occupational noise and lack of physical activity can increase the risk of diabetes. Further research is required to validate these results.

In the sub-analysis based on hearing protection equipment use, we found that the longer the duration of noise exposure, the higher the HbA1c levels among those not wearing hearing protection. Particularly, among those exposed to noise for more than 20 years, the HbA1c level was higher among those not wearing hearing protection than among those wearing hearing protection. This suggests a protective effect of hearing protection devices on the risk of diabetes mellitus due to occupational noise exposure.

Our study had several limitations. First, it was a cross-sectional study. Therefore, the results may have been overestimated due to the unclear causal direction of the relationship between diabetes and noise exposure. Prospective studies are required to understand the relationship between the duration of occupational noise exposure and diabetes. Second, as mentioned above, participants treated with oral hypoglycemic agents or insulin were excluded. Consequently, it is possible that patients with relatively mild diabetes may have been selected as participants. Third, our study considered noise exposure duration as a primary exposure but not noise levels in each workplace. In the KNHANES survey, it was difficult to determine the noise level of each worker's workplace; therefore, we only surveyed some occupational noise environments using machines or generators that are known to cause noise.

Despite these limitations, this study has several strengths. First, it was a population-based study with a large sample size and a relatively high response rate. Second, this is the first large cross-sectional study to investigate associations between the duration of occupational noise exposure and blood glucose parameters or the prevalence of diabetes mellitus in an Asian population. However, additional epidemiological and clinical randomized controlled trials are needed to clarify the role of occupational noise in diabetes mellitus.

In this study, we found that workers who experienced occupational noise exposure had significantly higher HbA1c levels than those who did not. Considering this result, occupational noise exposure may have contributed to the continued increase in the global prevalence of diabetes.

Meanwhile, we found that noise exposure duration of greater than 20 years was associated with a significantly higher HbA1c level, especially in the non-aerobic physical activity group. Similarly, in one study, the observed positive association between noise and pre-diabetes decreased among those with high levels of physical activity.[20] Therefore, aerobic physical activity should be recommended for workers who are exposed to noise in the workplace to prevent hearing loss and diabetes.

In conclusion, our study clearly suggests that there is a relationship between elevated HbA1c levels and workplace noise exposure, and a long duration of workplace noise exposure, no physical activity, and not wearing a hearing protection device could increase the risk of diabetes.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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REFERENCES

1. Basner M, Babisch W, Davis A, Brink M, Clark C, Janssen S, et al. Auditory and non-auditory effects of noise on health. Lancet 2014;383:1325-32.
2. Cheng L, Wang SH, Chen QC, Liao XM. Moderate noise induced cognition impairment of mice and its underlying mechanisms. Physiol Behav 2011;104:981-8.
3. Cui B, Wu M, She X, Liu H. Impulse noise exposure in rats causes cognitive deficits and changes in hippocampal neurotransmitter signaling and tau phosphorylation. Brain Res 2012;1427:35-43.
4. Fonseca J, Martins-dos-Santos J, Oliveira P, Laranjeira N, Aguas A, Castelo-Branco N. Noise-induced gastric lesions: a light and electron microscopy study of the rat gastric wall exposed to low frequency noise. Arq Gastroenterol 2012;49:82-8.
5. Kight CR, Swaddle JP. How and why environmental noise impacts animals: an integrative, mechanistic review. Ecol Lett 2011;14:1052-61.
6. Munzel T, Gori T, Babisch W, Basner M. Cardiovascular effects of environmental noise exposure. Eur Heart J 2014;35:829-36.
7. Pascuan CG, Uran SL, Gonzalez-Murano MR, Wald MR, Guelman LR, Genaro AM. Immune alterations induced by chronic noise exposure: comparison with restraint stress in BALB/c and C57Bl/6 mice. J Immunotoxicol 2014;11:78-83.
8. Gan WQ, Moline J, Kim H, Mannino DM. Exposure to loud noise, bilateral high-frequency hearing loss and coronary heart disease. Occup Environ Med 2016;73:34-41.
9. Sorensen M, Andersen ZJ, Nordsborg RB, Becker T, Tjonneland A, Overvad K, et al. Long-term exposure to road traffic noise and incident diabetes: a cohort study. Environ Health Perspect 2013;121:217-22.
10. Beaudry JL, Riddell MC. Effects of glucocorticoids and exercise on pancreatic β-cell function and diabetes development. Diabetes Metab Res Rev 2012;28:560-73.
11. Geer EB, Islam J, Buettner C. Mechanisms of glucocorticoid-induced insulin resistance: focus on adipose tissue function and lipid metabolism. Endocrinol Metab Clin North Am 2014;43:75-102.
12. Yuen KC, Chong LE, Riddle MC. Influence of glucocorticoids and growth hormone on insulin sensitivity in humans. Diabet Med 2013;30:651-63.
13. Zardooz H, Zahedi Asl S, Gharib Naseri MK, Hedayati M. Effect of chronic restraint stress on carbohydrate metabolism in rat. Physiol Behav 2006;89:373-8.
14. Taban E, Mortazavi SB, Vosoughi S, Khavanin A, Mahabadi HA. Noise exposure effects on blood glucose, cortisol and weight changes in the male mice. Health Scope 2017;6:e36108.
15. Fezil M, Narmadha MP, Benson B. Influence of occupational noise on insulin, blood glucose, homocysteine, blood pressure and heart rate. Int J Pharm Res 2015;6:1-7.
16. Industrial Accident Compensation Insurance Act, Law No. 18913 (Jun 10, 2022).
17. Li X, Dong Q, Wang B, Song H, Wang S, Zhu B. The influence of occupational noise exposure on cardiovascular and hearing conditions among industrial workers. Sci Rep 2019;9:11524.
18. Wang D, Zhou M, Li W, Kong W, Wang Z, Guo Y, et al. Occupational noise exposure and hypertension: the Dongfeng-Tongji Cohort Study. J Am Soc Hypertens 2018;12:71-9.
19. Zare Sakhvidi MJ, Zare Sakhvidi F, Mehrparvar AH, Foraster M, Dadvand P. Association between noise exposure and diabetes: a systematic review and meta-analysis. Environ Res 2018;166:647-57.
20. Eriksson C, Hilding A, Pyko A, Bluhm G, Pershagen G, Ostenson CG. Long-term aircraft noise exposure and body mass index, waist circumference, and type 2 diabetes: a prospective study. Environ Health Perspect 2014;122:687-94.