ASSOCIATION BETWEEN TYPE II DIABETES MELLITUS AND NOISE-INDUCED HEARING LOSS

BY

Samir AM[1], Al-Fajjam SM[2], Kamel MI[3] and El-Saka SF[4]

[1]Department of Occupational and Environmental Medicine, Faculty of Medicine, Cairo University, Egypt,[2] Department of Occupational Health, Al Shuwaikh Industrial Medical Centre, Ministry of Health, Kuwait,[3] Department of Public Health, Community Medicine, Faculty of Medicine, Alexandria University, Egypt ,[4] Department of Public Health and Community Medicine, Faculty of Medicine, Mansoura University, Egypt.

***Corresponding author**: Samir AM. **E Mail**: aishasamir@kasralainy.edu.eg.*

***DOI**: 10.21608/ejom.2022.129759.1270*

***Submit Date**: 2022-04-06 **Revise Date**: 2022-06-13 **Accept Date**: 2022-06-19*

***Authors' contributions:** All authors contributed equally in this work.*

Abstract

Introduction: Noise-induced hearing loss is a serious health issue that affects people all over the world. Occupational noise-induced hearing loss (ONIHL) is one of the commonest occupational diseases. Several factors have been revealed to produce hearing loss including diabetes mellitus (DM). **Aim of Work:** To study the relation between type II DM and ONIHL. **Materials and Methods:** A total of 1292 workers from 3 companies, occupationally exposed to noise, were categorized into normal and hearing impairment groups by pure tone audiometry (PTA). The studied group was subjected to a specially designed detailed questionnaire about noise exposure at work and hearing problems. Blood pressure, fasting blood sugar, serum urea, creatinine, and glycated hemoglobin (HbA1c) were measured. Body mass index was calculated. **Results:** DM was more frequent among workers with NIHL (13.2%) than those without (4.8%). Diabetic workers tended to be significantly older than the non-diabetics (50.6 ±7.2 compared with 40.9 ± 9.6 years, $p < 0.001$), they also spend longer time exposed to noise at work (9.2 ± 6.6 years compared with 6.6 ± 5.7 years, $p= 0.002$). Both systolic and diastolic blood pressures were significantly higher among diabetic than non-diabetic workers. Diabetic workers had a higher loss of hearing levels at all studied frequencies. By multiple logistic regression analysis, diabetes mellitus, noise exposure years, and age were significant predictors of NIHL. Glycated hemoglobin (HbA1c) had a significant positive correlation with the overall hearing loss. **Conclusion and Recommendations:** Diabetes mellitus increase the risk of developing noise induced hearing loss among workers exposed to noise at the workplace. Diabetic workers in noisy occupations should undergo frequent audiological assessments, should have easier access to healthcare facilities and their blood glucose levels checked regularly including HbA1c testing.

Keywords: Type II Diabetes Mellitus; Hearing loss; Audiometry and Occupational noise-induced hearing loss (ONIHL)

Introduction

Exposure to noise at the workplace is one of the most recorded occupational disorders attributing to 22% of adult male hearing loss worldwide (Nelson et al., 2005). The burden of occupational noise-induced hearing loss (NIHL) is not distributed evenly among countries. It is generally higher in the less developed regions of the world. NIHL has long been recognized as an occupational disease contributing to 24% of hearing loss in the United States (Tak and Calvert, 2008). According to American Diabetes Association, 2014, Type II DM, incidence and prevalence is increasing and it has been correlated to sensorineural hearing impairment. In Saudi Arabia, for example, Ahmed et al. 2001, has shown that the prevalence of hearing impairment among workers exposed to noise was 39.3% in comparison to only 4.5% of other workers not exposed. Recently, Buqammaz et al. 2021, stated that one-fifth of Kuwait's migrant industrial workers suffer from some degree of hearing loss, most likely as a result of occupational exposure.

According to several studies (Wild et al., 2005, Dudarewicz et al., 2010 and Oh et al., 2014), there are other factors associated with hearing loss including age, smoking, diabetes mellitus and high blood pressure. A meta-analysis done by Akinpelu et al., 2014, has demonstrated a significant association between hearing impairment and type II DM. Diabetes mellitus have nearly doubled in prevalence among the adult population worldwide since 1980, rising from 4.7% to 8.5%. It is expected to be 9.3% (463 million people) in 2019, rising to 10.2% (578 million) in 2030 and 10.9 % (700 million) in 2045 (Saeedi et al., 2019). It is claimed to be associated with further increase in the prevalence of hearing loss. However, there is uncertainty whether workers with diabetes and exposed to noise are at a higher risk of developing NIHL than their co-workers who are non-diabetic and exposed to the same level of noise level.

The first sign of NIHL can be observed in the typical notch at 4 kHz observed on audiograms, with spread to the neighboring frequencies of 3 kHz and 6 kHz (Rabinowitz et al., 2006). With ongoing noise exposure, the notch can be deepened and widened, eventually involving lower frequencies including 2 kHz, 1 kHz, and 0.5 kHz, which is the speech communications range (Coles et al., 2000). The role of an occupational physician during workers' health surveillance is to identify ONIHL at an early stage to prevent its progression to speech frequencies, an issue that might affect the quality of workers' life, as well as communications with their families, friends, and co-workers.

Up to the author's knowledge, in Kuwait, no studies were done to investigate the relationship between diabetes mellitus and noise-induced hearing loss. This study was a trial to shed light on this topic in Kuwait industrial settings.

Aim of Work

To study the relation between type II diabetes mellitus (DM) and occupational noise-induced hearing loss (ONIHL).

Materials and Methods

Study design: It is a cross-sectional study.

Study place and duration: The study was conducted in an industrial medical center for occupational health services, south of Kuwait, during the period from 2020 to 2021.

Study subjects: All workers who presented for medical fitness during periodic medical examination and were exposed to noise at work were the target group of this study. Previous health records of these workers were reviewed to assess their harmful noise exposure at work. Further investigations revealed that all selected workers were affiliated to 3 factories with the main industrial activity of carpentry; they were exposed to occcupational noise levels exceeding 90 dB in multiple places. Exclusion criteria included workers who had non-occupational noise exposure, conductive deafness or unilateral hearing impairment, history of ear surgeries, history of ear infections in the past, chronic otitis, history of recent infections in the nose, throat, or ear, ototoxicity, acoustic trauma and malignancy. Workers with chemical exposures as solvents were excluded as well. Thereafter, a total of 1292 male workers were included in the current study.

Study methods

The whole studied group was subjected to:

1- Questionnaire including socio demographic characteristics, occupational noise exposure (at present or previous jobs, duration of exposure in years, and work hours per shift) and questions investigating other causes of hearing loss (head trauma, ototoxic medications, infection).

2- The mean arterial **blood pressure** was used to evaluate blood pressure as a continuous variable.

3- **Body Mass Index (BMI)** was calculated by dividing the weight in kilograms by the squared height in meters.

4- **Otoscopic examination** and history taking of ear diseases were done.

5-**Pure tone audiometry (PTA)** was performed by two experienced, well-trained nurses in a testing facility that met ISO 8253-1(1989) requirements. PTA thresholds were measured in both ears at frequencies of 250, 500, 1000, 2000, 3000, 4000, 6000, and 8000 Hz.

The degree of ONIHL is detected and quantified using PTA testing. This method provides a subjective measurement of hearing loss in workers who have been exposed to occupational noise and requires the person being tested to cooperate. In audiogram testing, the main features of ONIHL are symmetric and show typical signs of notching at high frequencies of 3000, 4000, or 6000 Hz with recovery at 8000 Hz. This notch appears at one of these frequencies and has no effect on nearby frequencies; however, once a notch appears, other frequencies may also show notches, and the prominence of this notch may be affected by age-related hearing loss. As a result, NHL must be distinguished from age-related hearing loss in the elderly (Chen et al., 2020). Study subjects were categorized into 2 groups normal, and hearing impairment groups according to PTA results.

6- Investigations: The following parameters were done:

a- Fasting blood sugar for screening purposes. After fasting for at least 8 hours, blood samples were taken. The normal group consisted of people who had a fasting blood glucose level of less than 5.5 mmol/L. The DM group included people who had fasting blood glucose of more than 6.1 mmol/L, were taking anti-diabetic medications and had a self-reported history of diabetes.

b- Glycated hemoglobin (HbA1c) with ethylenediaminetetraacetic acid (EDTA) using high-performance liquid chromatography (HPLC) and hexokinase using a Cobas C311 analyzer: (Roche Inc., Indianapolis). A normal HbA1c level is below 5.7%, a level of 5.7% to 6.4% indicates prediabetes, and a level of 6.5% or more indicates diabetes.

c- Blood urea; normal range (5-20 mg/dl) .

d- Serum creatinine ; normal range (60-110 μmol/L).

Consent

A written consent to participate in the study was obtained from all workers who were eligible and agreed to participate in the study.

Ethical Approval

The study protocol was approved from the standing committee for Coordination of Health and Medical Research, Ministry of Health , Kuwait.

Data Management

Statistical procedures were performed using SPSS version 26. Continuous variables, such as age, duration of noise exposure at work, and blood pressure were expressed as mean and standard deviations. Categorical variables, such as gender, marital status, and nationality were presented as numbers and percentages. For continuous variables, the student t-test was used, and for categorical variables, the Pearson chi-square test or Fisher exact test was used. To investigate the relationship between ONIHL and other predictors, the study used multivariate logistic regression with a forwarding likelihood model and reported odds ratios to investigate the independent factors associated with NIHL. Multivariate logistic regression was used to elucidate the relationship between the outcome and variables after adjusting for other predictors. Age, blood pressure, and duration of exposure were treated as confounding risk factors and were adjusted during multivariate analysis. For all tests, a significance level of $P < 0.05$ was used. Pearson correlation was employed to investigate the relation between hearing loss indicators and both fasting blood sugar and glycated hemoglobin

Results

In the current study, 96 (7.4%) workers were diabetics from a total of 1292(100%) exposed to noise at work. The total number of exposed workers who had noise-induced hearing loss (NIHL) was 408 (31.6%). Diabetes mellitus is more likely to be encountered among workers suffering from NIHL 54 (13.2%). This difference is statistically significant, $p< 0.001$(results were not tabulated)

Table (1): Comparison of sociodemographic and clinical characteristics between diabetic and non-diabetic workers suffering from noise-induced hearing loss.

Characteristics	**Diabetic workers No=54**	**Non-diabetic workers No=354**	**p**
Age (years)	50.6 $\pm$ 7.2	40.9 $\pm$ 9.6	**< 0.001***
Exposure to noise at work (years)	9.2 $\pm$ 6.6	6.6 $\pm$ 5.7	**0.002***
BMI (kg/m^2)	27.0 $\pm$ 2.7	26.1 $\pm$ 3.40	0.934
SBP (mmHg)	132.4 $\pm$ 23.1	121.1 $\pm$ 13.8	**< 0.001***
DBP (mmHg)	84.7 $\pm$ 9.1	79.7 $\pm$ 8.9	**< 0.001***
Duration of diabetes (years)	4.61 + 4.43	-	-
Treatment of diabetes (insulin)	6 (11.1)	-	-
HbA1c (%)	9.1 $\pm$ 1.4	6.9 $\pm$ 1.6	**< 0.001***
Fasting blood glucose (mmol/dl)	9.2 $\pm$ 2.4	5.9 $\pm$ 0.9	**< 0.001***
Serum creatinine (µmol/L)	76.9 $\pm$ 19.8	78.7 $\pm$ 14.4	0.417
Blood urea (mg/dl)	5.0 $\pm$ 1.8	5.8 $\pm$ 1.9	0.751

BMI: Body Mass Index. SBP: systolic blood pressure DBP: diastolic blood pressure
HbA1c: Glycated hemoglobin A1c *: Statistically significant.

Table (1) showed that diabetic workers were statistically significantly older than non-diabetics, they had a longer duration of noise exposure, had significantly higher systolic, diastolic blood pressure higher glycated hemoglobin and fasting blood glucose. (HbA1c).

Table (2): Comparison of audiological findings (hearing level in dB) between diabetic and non-diabetic workers suffering from noise-induced hearing loss.

Findings	Diabetic workers		Non diabetic workers	
	Right side	Left side	Right side	Left side
0.5 KHz	18.2 ± 7.9	18.4 ± 8.7	17.8 ± 17.7	16.7 ± 7.1
1.0 KHz	17.5 ± 7.5	19.1 ± 9.2	17.0 ± 7.7	16.5 ± 7.6
2.0 KHz	18.8 ± 9.2	21.9 ± 11.6	16.6 ± 11.0	16.4 ± 10.8
3.0 KHz	31.2 ± 15.2	32.0 ± 15.7	27.4 ± 16.3	24.9 ± 14.7
4.0 KHz	40.7 ± 15.8	41.6 ± 18.0	36.1 ± 17.8	32.8 ± 16.0
6.0 KHz	46.9 ± 16.4	48.7 ± 17.6	39.8 ± 17.1	39.1 ± 15.2
8.0 KHz	34.3 ± 15.3	34.2 ± 17.2	26.9 ± 16.9	25.3 ± 15.8
Total by side	34.3 ± 15.34	36.0 ± 12.4	30.3 ± 12.1	28.7 ± 11.1
Total hearing loss of both ear#	**35.4 ±10.5***		**29.5 ± 10.9***	
Worse ear##	**25.1 ± 8.0****		**21.7 ± 8.2****	

#: Total hearing loss of both ears comparing diabetic to nondiabetic workers *p <0.001

##: Worse ear comparingx diabetic to nondiabetic workers **p <0.01.

*: Statistically significant. **: Highly statistically significant.

Table (2) showed that diabetic workers had higher losses of hearing levels at all the studied frequencies. Total hearing loss was higher among the diabetic workers than the non-diabetic $p < 0.001$. Also, the level of deafness was higher in the worse ear of the diabetic workers compared to the non-diabetics $p < 0.01$.

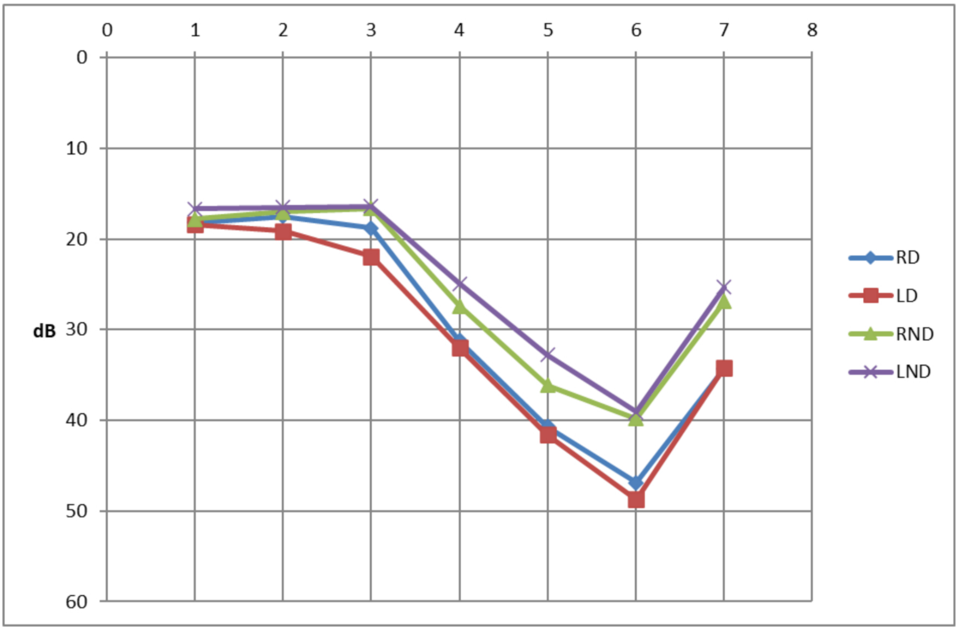

Figure (1): Audiometric findings of diabetic and non-diabetic workers with noise-induced hearing loss.

RD: Right ear of diabetic workers. LD: Left ear of diabetic workers.

RND: Right ear of non-diabetic workers. LND: Left ear of non-diabetic workers

Figure 1 showed that both diabetic and non-diabetic workers showed a “V” pattern of hearing loss with the bottom of the “V” at 4.0 K Hz frequency.

Table (3): Significant predictors of noise-induced hearing loss using multiple logistic regression forward likelihood model.

Predictors	β	Significance	Exp(B)	95% Confidence limits
Diabetes mellitus	0.56	**0.019***	1.74	1.10 – 2.77
Noise exposure (years)	0.11	**< 0.001***	1.12	1.09 – 1.15
Age (years)	0.03	**< 0.001***	1.03	1.02 – 1.05
Constant	-2.56	**0.014***	-	-

*: Statistically significant difference.

Table (3) showed that the presence of diabetes mellitus; years of exposure to noise and age were significant predictors of NIHL after controlling the confounding effects of other variables. The model succeeded incorrectly predicting 29.2% of those suffering from NIHL, 94.5% of those not suffering from NIHL, and 73.8% of the studied workers exposed to noise.

Table (4): Correlation among diabetes indicators and hearing levels of diabetic workers suffering from noise-induced hearing loss.

Diabetes indicators	Overall hearing loss	The hearing level at 4.0 kHz	Worse ear level
HbA1c	**0.407 (0.002*)**	**0.393 (0.003*)**	**0.373 (0.005*)**
Fasting blood glucose	0.086 (0.539)	0.030 (0.828)	-0.026 (0.851)

*: Statistically significant.

Table (4) showed Pearson correlation coefficients of diabetic and hearing loss indicators. Glycated hemoglobin (HbA1c) had a significant positive correlation with the overall hearing loss ($r=0.407$, $p = 0.002$), the hearing level at 4.0 kHz ($r=0.393$, $p = 0.003$), and hearing level of the worse ear ($r=0.373$, $p = 0.005$) while fasting blood glucose did not show significant correlation with any of the hearing indicators.

Discussion

Various studies have postulated hypotheses about how diabetes causes hearing loss. Microangiopathy could induce cochlear damage (Taslıpınar et al., 2011). Diabetic peripheral neuropathy may cause injury to the auditory nerve (Sonneville et al., 2012). Hearing loss is more prone to occur at high and low frequencies due to genetic and complicating factors such as diabetes (Yamasoba et al., 2013). Hearing loss is common in diabetics, and it is aggravated when are exposed to loud noise. A meta-analysis by Horikawa et al., 2003, suggested that diabetic patients had a higher prevalence of hearing impairment than non-diabetic patients.

The current study showed that the prevalence of type II DM among workers with early signs of developing NIHL was significantly higher than among workers with normal audiograms (Table 1). These results were similar to that found in a study done in USA by Ishii et al., 1992, on manufacturing workers at metal assembly plants. In their study, the prevalence of type II DM was 16.4% among workers with severe NIHL compared to 4.8% of workers without NIHL. All the studied workers were males, and the majority was Indians; gender and race as risk factors were not considered. Furthermore, all subjects wore hearing ear muffs for protection against noise at work by their company policies.

Diabetic studied workers with ONIHL were significantly older than non-diabetic, there was a statistically significant difference between them regarding the duration of noise exposure at work (Table 1). Aging and noise exposure are common risk factors for sensorineural hearing loss in adults (Oh et al., 2014). Some studies have found that the interaction of age and noise exposure is not additive. According to Austin et al. 2009, diabetes is linked to an increased risk of hearing loss, especially in people under the age of 50. Younger people had early high-frequency hearing loss similar to early presbycusis in a 5-year prospective study reported by Vaughan et al., 2007; additionally, the difference in hearing loss between diabetic and nondiabetic patients was reduced after the age of 60.

Recently, Gopinath et al., 2021 in their study on population-based data for occupational noise exposure and risk of age-related hearing loss, they assessed cross-sectional and longitudinal associations of workplace noise exposure with hearing loss in older adults. They concluded that workplace noise exposure increased the risk of incident hearing loss in older adults.

Both systolic and diastolic blood pressure was significantly higher among the diabetic compared to non-diabetic studied workers (Table 1).

According to Bener et al., 2017, hypertension is linked to hearing loss due to vascular physiopathology as rise in blood viscosity, decreased capillary blood flow, and reduction in oxygen transport; thus leads to tissue hypoxia and then auditory dysfunction as well as hearing loss.

Serum creatinine level done to the studied group showed no significant difference between diabetic and nondiabetic workers (Table 1); which agreed with Jang et al., 2011, who found no significant association between serum creatinine and ONIHL among diabetic and nondiabetic workers.

Pure Tone Audiometry (PTA) results demonstrated that diabetic workers tended to have higher losses of hearing levels at all the studied frequencies (Table 2). These results were consistent with many other studies, Austin et al. 2009, in their study on diabetes related changes in hearing and detected that, there were significant hearing differences at all frequencies, but only at 1,000 Hz and below for type II DM subjects, and at 10,000 Hz and above for type I DM subjects. Another work conducted by Jang et al. 2011, in their study on the association between impaired fasting glucose and noise-induced hearing loss, they revealed that a significantly hearing thresholds difference between the three groups of people with normal, impaired fasting glucose and diabetes. The impaired fasting glucose and diabetes groups had higher levels than the normal fasting glucose group. Meanwhile, Yadav and Yadav, 2018 in their study on Indian workers found that only for mixed bilateral hearing loss, NIHL analysis by audiometry revealed significant differences between diabetic and non-diabetic groups. Another study conducted by Kim et al. 2019, which analyze the effect of diabetes on hearing impairment in workers exposed to similar noise levels from 2013 to 2017. The study subjects included 2,087 male workers exposed to noise in a single company, who underwent health examinations at the same hospital in Ulsan city, Korea .They found that the average PTA thresholds and their average changes between 2013 and 2017 were significantly higher in the diabetes mellitus (DM) group compared to the normal and impaired fasting glucose group.

In the multiple logistic regression analysis, age, duration of exposure, and type II DM were significant predictors of NIHL among the studied group (Table 3). These findings were in accordance with that of Jang et al. 2011, who determined that age, noise exposure, and impaired fasting blood glucose are risk factors for NHL. This confirms the role of type II DM as a risk factor for NIHL. Prior studies done by (Ooley et al., 2017; Nagahama et al., 2018; Atsmoni et al., 2019) had revealed that the risk of sensorineural hearing loss increases as the HbA1c value used to monitor the risk of diabetes complications rises.

The current study detected a significant positive correlation between HbA1c and overall hearing loss (Table 4). According to Nagahama et al. 2018, hearing test results from patients with HbA1c of 7.3 or higher showed significantly higher hearing loss at higher frequencies compared to other groups. Another study done by Kang et al. 2016, noticed that there was an association between HbA1c and hearing loss in non-diabetic patients and that HbA1c's high value was related to hearing loss in non-diabetic patients. In the contrary, Ashkezari et al. (2018) found that there is no link between HbA1c and hearing loss in diabetic patients.

Elibol and Baran, 2020, did a study to determine the correlation between glycated hemoglobin (HbA1c) levels and the audiometric parameters in diabetic patients. Their studied group included 724 patients and was classified as follows: the first group was 192 patients with an HbA1c value < 4.5, 176 patients with an HbA1c value between 4.5 - 5 as Group 2, 177 patients with an HbA1c value between 5 - 6 as Group 3, and 179 patients that had an HbA1c value greater than 6 as Group 4. They concluded that according to HbA1c levels, the severity of diabetes can affect high to all frequencies of hearing functions negatively.

Limitations of the study; being a cross-sectional study, the study had a limitation inherent to its design. Also, it would have been supportive of the study if personal noise dosimetry was measured. Therefore, larger prospective studies with larger number of workers and variables are required

Conclusion and Recommendations:

The current study showed that diabetic workers had hearing loss at all studied frequencies. A strong positive correlation between HbA1c and overall hearing loss was demonstrated. We recommend that diabetic workers in noisy occupations should undergo more frequent audiological assessments, should have more access to health care centers and regular monitoring of blood glucose levels by HbA1c testing.

Conflict of Interest

The authors declared no potential conflict of interest concerning this research.

Funding

The authors received no financial support.

Acknowledgement

The authors would like to acknowledge the contribution of all individuals who participated in this study.

References

1. Ahmed HO, Dennis JH, Badran O, Ismail M, Ballal SG, et al. (2001): Occupational noise exposure and hearing loss of workers in two plants in eastern Saudi Arabia. Ann Occup Hyg; 45(5):371-80.
2. Akinpelu OV, Mujica-Mota M and Daniel SJ (2014): Is type 2 diabetes mellitus associated with alterations in hearing? A systematic review and meta-analysis. The Laryngoscope ; 124(3):767-76.
3. American Diabetes Association (2014): Diagnosis and classification of diabetes mellitus. Diabetes Care;1:S81–S90.
4. Ashkezari SJ, Namiranian N, Rahmanian M, Atighechi S, Mohajeri-Tehrani MR et al. (2018): Is hearing impairment in diabetic patients correlated to other complications? Diabetes Metab Syndr; 17(2):173-9.
5. Atsmoni SC, Brener A and Roth Y (2019): Diabetes in the practice of otolaryngology. Diabetes Metab Syndr;13(2):1141-50.
6. Austin DF, Konrad Martin D, Griest S, McMillan GP, McDermott D, et al. (2009): Diabetes related changes in hearing. The Laryngoscope; 119(9):1788-96.
7. Bener A, Al-Hamaq AO, Abdulhadi K, Salahaldin AH, and Gansan L (2017): Interaction between diabetes mellitus and hypertension on the risk of hearing loss in highly endogamous population. Diabetes Metab Syndr; 11:S45-51.
8. Buqammaz M, Gasana J, Alahmad B, Shebl M and Albloushi (2021): Occupational noise-induced hearing loss among migrant workers in Kuwait. Int J Environ Res Public Health; 18(10):5295.
9. Chen KH, Su SB and Chen KT (2020): An overview of occupational noise-induced hearing loss among workers: epidemiology, pathogenesis, and preventive measures. Environ Health Prev Med;25(1):65.
10. Coles RR, Lutman ME and Buffin JT (2000): Guidelines on the diagnosis of noise-induced hearing loss for medicolegal purposes. Clin Otolaryngol Allied Sci; 25(4):264-73.
11. Dudarewicz A, Toppila E, Pawlaczyk-Łuszczyńska M and Śliwińska-Kowalska M (2010): The influence of selected risk factors on the hearing threshold level of noise exposed employees. Arch Acoust;35(3):371-82.
12. Elibol E and Baran H (2020): The Association Between Glycolyzed Hemoglobin A1c and Hearing Loss in Diabetic Patients. Cureus; 12(9): e10254.

13. Gopinath B, McMahon C, Tang D, Burlutsky G and Mitchell P (2021): Workplace noise exposure and the prevalence and 10-year incidence of age-related hearing loss. PLoS ONE 16(7): e0255356.
14. Horikawa C, Kodama S, Tanaka S, Fujihara K, Hirasawa R, et al. (2013): Diabetes and risk of hearing impairment in adults: a meta-analysis. J Clin Endocrinol Metab; 98(1):51-8.
15. Ishii EK, Talbott EO, Findlay RC, D'Antonio JA and Kuller LH (1992): Is NIDDM a risk factor for noise-induced hearing loss in an occupationally noise-exposed cohort? Sci Total Environ; 127(1-2):155-65.
16. Jang TW, Kim BG, Kwon YJ and Im HJ (2011): The association between impaired fasting glucose and noise-induced hearing loss. J Occup Health; 53(4):274-9.
17. Kang SH, Jung DJ, Cho KH, Park JW, Lee KY et al. (2016): Association between HbA1c level and hearing impairment in a non diabetic adult population. Metab Syndr Relat Disord; 14(2):129-34.
18. Kim DY, Kim AR, Sung JH, Lee CR and Lee J (2019): The effect of diabetes on 4-year changes of hearing thresholds in male workers exposed to noise in a single company: a longitudinal study. Ann Occup Environ Med; 31:e11.
19. Nagahama S, Kashino I, Hu H, Nanri A, Kurotani K, et al. (2018): Haemoglobin A1c and hearing impairment: longitudinal analysis using a large occupational health check-up data of Japan. BMJ; 8(9):e023220.
20. Nelson DI, Nelson RY, Concha-Barrientos M and Fingerhut M (2005): The global burden of occupational noise induced hearing loss. Am J Ind Med; 48(6):446-58.
21. Oh IH, Lee JH, Park DC, Kim M, Chung JH, et al. (2014) Hearing Loss as a Function of Aging and Diabetes Mellitus: A Cross Sectional Study. PLoS ONE 9(12): e116161.
22. Oley C, Jun W, Le K, Kim A, Rock N, Cardenal M, et al. (2017): Correlational study of diabetic retinopathy and hearing loss. Optom Vis Sci; 94(3):339-44.
23. Rabinowitz PM, Galusha D, Slade MD, Dixon-Ernst C, Sircar KD, et al. (2006): Audiogram notches in noise-exposed workers. Ear Hear; 27(6):742-50.
24. Saeedi P, Petersohn I, Salpea P, Malanda B, Karuranga S, et al. (2019): Global and regional diabetes prevalence estimates for 2019 and projections for 2030 and 2045: Results from the International Diabetes Federation Diabetes Atlas, 9th edition. Diabetes Res Clin Pract; 157: 107843.
25. Sonneville R, den Hertog HM, Güiza F, Gunst J, Derese I, et al. (2012): Impact of hyperglycemia on neuropathological alterations during critical illness. Clin Endocrinol Metab; 97(6):2113-23.
26. Tak S and Calvert GM (2008): Hearing difficulty attributable to employment by industry and occupation: an analysis of the National Health Interview Survey—United States, 1997 to 2003. J Occup Environ Med; 50(1):46-56.
27. Taslıpınar A, Yaman H, Yılmaz MI, Demırbas S, Saglam M, et al. (2011): The relationship between inflammation, endothelial dysfunction and proteinuria in patients with diabetic nephropathy. Scand J Clin Lab Invest; 71(7):606-12.
28. Vaughan N, James K, McDermott D, Griest S and Fausti S (2007): Auditory brainstem response differences in diabetic and non-diabetic veterans. J Am Acad Audiol; 18(10):863-71.
29. Wild DC, Brewster MJ and Banerjee AR (2005): Noise-induced hearing loss is exacerbated by long term smoking. Clin Otolaryngol; 30(6):517-20.
30. Yadav MK and Yadav KS (2018): Etiology of noise-induced hearing loss (NIHL) and its symptomatic correlation with audiometry observations in type II diabetes. Indian J Otolaryngol Head Neck Surg; 70(1):137-44.
31. Yamasoba T, Lin FR, Someya S, Kashio A, Sakamoto T, et al. (2013): Current concepts in age-related hearing loss: epidemiology and mechanistic pathways. Hear Res; 303:30-8.