

Hearing loss among patients with type 2 diabetes mellitus: a cross-sectional study

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BACKGROUND: Hearing loss is an underestimated comorbid condition in type 2 diabetes.

OBJECTIVES: Investigate hearing loss as a comorbidity associated with type 2 diabetes mellitus and evaluate the factors associated with hearing loss.

DESIGN: Cross-sectional.

SETTING: Tertiary care center, diabetes clinic.

PATIENTS AND METHODS: Patients with type 2 diabetes, aged 30 to 60 years, were randomly selected to participate. All patients underwent clinical ear examinations and were referred for full audiological evaluation. Otoacoustic emission was used to assess inner function, tympanometry to assess middle-ear function, and pure tone air/bone audiometry to assess hearing sensitivity. Risk factors for hearing loss were assessed by multivariate logistic regression.

MAIN OUTCOME MEASURES: Frequency, severity and risk factors for hearing loss.

SAMPLE SIZE: 157

RESULTS: Of the 157 patients, 77 had hearing loss in both ears (49.0%), 13 in the right ear only (8.3%), 14 in the left ear only (8.9%), and 53 (33.8%) had normal hearing. In the 181 ears with sensorineural hearing loss, 90 had mild loss (49.7%), 69 moderate loss (38.2%), 16 severe loss (8.8%) and 6 had profound loss (3.3%). Disabling hearing loss was observed in 46 (29%) patients. A higher frequency of hearing loss was present in patients with glycated hemoglobin levels $\geq 8\%$. In the multivariate logistic regression analysis, the most important factors associated with hearing loss were longer diabetes duration, poor glycemic control and the presence of hypertension.

CONCLUSIONS: Hearing loss is an underestimated comorbid condition in type 2 diabetes that warrants frequent hearing assessments and management. Strict glycemic and hypertension control is essential for the minimization of the effects of diabetes on hearing sensitivity.

LIMITATIONS: Small sample size, limited age window (30-60 years), which was chosen to eliminate the natural aging effect on hearing. Cross-sectional nature was not ideal for the assessment of causality.

CONFLICT OF INTEREST: None.

There is little awareness of hearing loss as a possible comorbid condition associated with type 2 diabetes among persons with diabetes as well as healthcare professionals, despite several studies having demonstrated the link between the two clinical conditions.¹ More than 43% of diabetes patients are likely to have some degree of hearing impairment related or unrelated to chronic hyperglycemia.² There is a requirement for further studies for the exploration of the relationship between diabetes and hearing abnormalities. The presence of hearing defects among diabetes patients could be related to hyperglycemia or other associated conditions like decreased immunity that may predispose one to ear infections involving the external, middle, or internal ear.³

In Saudi Arabia, type 2 diabetes is an epidemic,⁴ and it may be meaningful to assess the presence of hearing loss in this population of diabetes patients to gain a better understanding of the link between the two clinical conditions. Diabetic neuropathy, which affects the eighth cranial nerve directly or at the cochlear level, may present with variable degrees of hearing loss, while chronic infections like malignant otitis externa that affect the external ear are usually observed among diabetes patients and usually are associated with structural damage.³ Sufficient data support that hearing loss is one of the commonly occurring diseases in diabetes patients that could affect quality of life and lead to hearing disabilities and psychological depression.² Some studies have found positive correlations between hearing loss and diabetes duration or the degree of metabolic control. Although the findings of studies focusing on the relationship between hearing acuity and the degree of hyperglycemia by diabetes type are conflicting,⁵ several risk factors have been identified as being associated with hearing loss in diabetes patients.⁶ This study aimed to assess the prevalence of hearing loss and its severity among patients with type 2 diabetes in a tertiary diabetes center. The second aim of this study was to evaluate the factors associated with hearing loss.

PATIENTS AND METHODS

This cross-sectional study recruited Saudi nationals with type 2 diabetes at the University Diabetes Center, King Saud University, Riyadh, Saudi Arabia. Patients were selected from the general diabetes clinic using a systematic random technique (every third patient with type 2 diabetes) during the period from July 2015 to December 2017. Every patient was interviewed by a trained research physician in a special clinic. Demographic data including age, sex and diabetes history, including both

duration and complications were recorded. Data on treatment history that specified the drugs used and the dosages, as well as history of any associated diseases like hypertension and hyperlipidemia were collected. Body mass index was calculated based on height and weight measurements, and systolic blood pressure (SBP) and diastolic blood pressure (DBP) were both measured in a sitting position using a sphygmomanometer. Each patient was then referred to an ENT clinic for clinical examinations that included the nose, throat, and ears for any major pathology.

Audiological assessment included otoscopic examinations of the external and middle ear, 226 Hz tympanometry to assess middle-ear function, distortion product otoacoustic emission (DPOAE) to assess the outer hair cells in the cochlea, and air/bone pure tone audiometry to identify the hearing thresholds at octave frequencies including 250, 500, 1000, 2000, 4000 and 8000 Hz. All the testing equipment was professionally calibrated. Only participants with normal middle-ear function, as evidenced by a normal type A tympanogram, were included in the study. A total of 5 mL of venous blood was drawn from each patient. The collected blood samples were used to measure glycated hemoglobin (HbA1c) levels, blood lipid profile, creatinine levels, erythrocyte sedimentation rate, fasting blood sugar levels, and thyroid function—thyroid stimulating hormone (TSH), free T4 (FT4), and free T3 (FT3) levels.

Patients were identified as having type 2 diabetes based on their initial diagnosis using American Diabetes Association criteria, or on their consumption of oral hypoglycemic agents for more than one year, without a history of diabetic ketoacidosis. The presence of DPOAE was confirmed if the signal-to-noise ratio was at least 3 decibels (dB) at a minimum of three frequency bands in the testing spectrum. The type of hearing loss was determined using the relationship between the air and bone hearing thresholds. Sensorineural hearing loss is characterized by abnormal air and bone conduction hearing thresholds (hearing thresholds above 25 dBHL), while conductive hearing loss is characterized by normal bone conduction and an abnormal air conduction threshold. Mixed hearing loss, however, is characterized by abnormal air and bone conduction hearing thresholds, in addition to an air/bone gap greater than 10 dBHL. Hearing loss degree was classified according to the hearing thresholds at the octave frequencies, including 250 to 8000 Hz. Mild, moderate, severe, and profound hearing loss correspond to threshold ranges above 25 to 40, 40 to 70, 70 to 90, and 90 dBHL, respectively. Patients were considered to be hypertensive if the condition

was managed with anti-hypertensive medications, or if they were found to have an SBP ≥ 140 mm Hg and a DBP ≥ 90 mm Hg. Patients were reported to be hyperlipidemic if the condition was managed with the use of lipid-lowering agents at the time of recruitment, or if they had hypertriglyceridemia—serum triglyceride levels ≥ 150 mg/dL (1.7 mmol/L), and serum high-density lipoprotein cholesterol levels < 40 mg/dL (1.0 mmol/L) in men and < 50 mg/dL (1.3 mmol/L) in women. Vasculopathy was considered present in patients with peripheral vascular disease and cerebral vascular disease or coronary artery disease, while retinopathy was reported in patients with either non-proliferative diabetic retinopathy or proliferative diabetic retinopathy with or without macular edema. Diabetic nephropathy was reported in patients with microalbuminuria, macroalbuminuria or end-stage renal disease. Neuropathy was recorded in this study based on physicians' notes, with positive clinical examinations using a monofilament test or the presence of symptoms such as foot numbness and pain. This study was approved by the IRB committee of the Medical College at King Saud University, and all patients signed an informed consent after the different stages of the study were explained to them.

Data were analyzed using IBM SPSS version 21 (IBM Corporation, Armonk NY). A *t* test was used to identify differences between continuous variables, and a chi square test was used to assess the difference between categorical values. Mean and standard deviation was derived for all the parametric variables. Risk factors were adjusted for age and diabetes duration using multivariate logistic regression models. Odds ratios (ORs) and their 95% confidence intervals (CIs) were used to express different risks. A *P* value $< .05$ was considered statistically significant.

RESULTS

From 400 out of about 1000 patients, we selected 250 patients who agreed to attend a hearing assessment visit. Ninety-three of the 250 were excluded because of pregnancy in 13 patients, history of noise exposure in 15 patients, history of malignancy in 18 patients, use of medications that may affect hearing, such as gentamicin, quinine, loop diuretics and large doses of aspirin in 17 patients and nonattendance for 30 patients, leaving a sample of 157 patients. The age distribution was skewed toward the elderly and the study population was predominantly urban (Table 1). Of the 157, 77 patients had hearing loss in both ears (49.0%), 13 in the right ear only (8.3%), 14 in the left ear only (8.9%), and 53 (33.8%) had normal hearing. Of 314 ears, 181 had

Table 1. Demographic characteristics of the study population (n=157).

Age (years)	51.0 (47.0-54.0)
Education	
Illiterate	22 (13.9)
Undergraduate	75 (48.1)
Post Graduate	60 (38.0)
Profession	
Laborer	11 (6.7%)
Technical/officer	35 (22.5%)
Professional	85 (53.9%)
Business	26 (16.9%)
Marital status	
Single	3 (2.0%)
Married	150 (95.5%)
Divorced/widow	4 (2.5%)
Residency	
Urban	136 (86.9%)
Rural	21 (13.1%)

Data are n (%) or mean (standard deviation) (median and interquartile range for age).

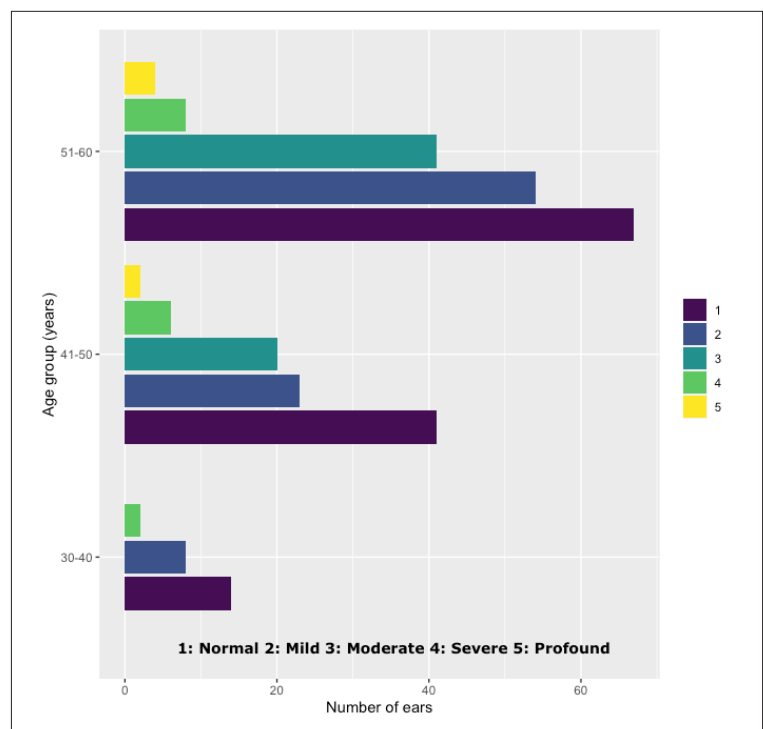


Figure 1. Severity of hearing loss by age group (n=314 ears).

sensorineural hearing loss, 90 had mild loss (49.7%), 69 moderate loss (38.2%), 16 severe loss (8.8%) and 6 had profound loss (3.3%) (**Table 2**). Profound hearing loss was more commonly observed among older patients, while the prevalence of severe hearing loss was more pronounced among patients aged older than 40 years (**Figure 1**). Disabling hearing loss (defined by the World Health Organization (WHO) as the presence of a hearing threshold higher than 40 db) was observed in 46 (29%) patients. Men had a higher prevalence of hearing loss than women, at rates of 61.6% and 53.3%, respectively. Women more frequently had severe hear-

ing loss while a higher number of men than women had profound hearing loss. The frequency of hearing loss progressed with diabetes duration progression. Hypertension, hyperlipidemia, and thyroid disease were more frequently observed among patients with hearing loss, particularly in those with severe and profound hearing loss. Chronic diabetes complications such as neuropathy, retinopathy, nephropathy and vasculopathy were observed in more than 50% of the cases. Aspirin use was more frequently observed among patients with hearing loss. The mean duration of diabetes was higher in patients with hearing loss

Table 2. Hearing status and severity of hearing loss by demographic and clinical characteristics.

	Total (n=157)	Hearing status (n=314 ears)		Hearing loss severity (n=314 ears)			
		Normal	Hearing loss	Mild	Moderate	Severe	Profound
Age (years)	51 (28)	51 (28)	51 (24)	51.5 (24)	51 (14)	49 (20)	52 (7)
Gender							
Men	82 (52.2)	63 (38.4)	101 (61.6)	46 (45.5)	42 (41.6)	8 (7.9)	5 (5.0)
Women	75 (47.8)	70 (46.7)	80 (53.3)	44 (55.0)	27 (33.8)	8 (10.0)	1 (1.2)
Family history of diabetes mellitus	136 (86.6)	106 (39.0)	166 (61.0)	86 (51.8)	61 (36.8)	14 (8.4)	5 (3.0)
Family history of hearing loss	17 (10.8)	19 (55.9)	15 (44.1)	4 (26.7)	8 (53.3)	2 (13.3)	1 (6.7)
Diabetes duration (years)	12.9 (7.2)	11.8 (7.5)	13.1 (6.7)	13.7 (6.7)	14.0 (7.3)	13.3 (5.5)	11.3 (7.2)
Diabetes duration group (years)							
1-5	34 (21.7)	36 (52.9)	32 (47.1)	17 (53.1)	12 (37.5)	2 (6.3)	1 (3.1)
6-10	28 (17.8)	26 (46.4)	30 (53.6)	9 (30.0)	13 (43.3)	5 (16.7)	3 (10)
>10	95 (60.5)	71 (37.4)	119 (62.6)	64 (53.7)	44 (37.0)	9 (7.6)	2 (1.7)
Smoking	13 (8.3)	7 (26.9)	20 (76.9)	8 (40.0)	9 (45)	0	3 (15.0)
Diabetes complications							
Neuropathy	42 (26.8)	38 (45.2)	46 (54.8)	25 (54.3)	16 (34.8)	4 (8.7)	1 (2.2)
Retinopathy	34 (21.7)	29 (42.6)	39 (57.4)	20 (51.3)	14 (35.9)	4 (10.3)	1 (2.5)
Nephropathy	12 (3.8)	9 (37.5)	15 (62.5)	9 (60.0)	3 (20.0)	2 (13.3)	1 (6.7)
Vasculopathy	12 (3.8)	7 (29.2)	17 (70.8)	6 (35.3)	9 (52.9)	1 (5.9)	1 (5.9)
Aspirin use	98 (62.4)	81 (41.3)	115 (58.7)	55 (47.8)	46 (40.0)	9 (7.8)	5 (4.4)
HbA1c (%)	8.6 (1.8)	8.2 (1.8)	8.8 (1.7)	8.8 (1.6)	8.8 (1.7)	9.7 (1.4)	7.9 (1.9)
HbA1c <8%	60 (38.2)	62 (51.7)	58 (48.3)	34 (58.6)	18 (31.0)	2 (3.4)	4 (6.9)
HbA1c ≥8%	97 (61.8)	72 (37.1)	122 (62.9)	62 (50.8)	44 (36.0)	14 (11.5)	2 (1.6)

Data are n (%) or mean (standard deviation); median (interquartile range) for age.

(Table 2). The mean HbA1c level was higher in those with hearing loss. The highest mean HbA1c level was observed among patients with severe hearing defects. Additionally, patients with poor diabetes control with HbA1c $\geq 8\%$ had higher rates of hearing loss compared with patients with HbA1c $< 8\%$ (62.9% vs 48.3%). Increasing levels of HbA1c was positively correlated with the severity of sensorineural hearing loss ($P < .001$).

There was no significant correlation between most clinical and metabolic parameters and the presence or absence of otoacoustic emissions (OAEs) (**Table 3**).

The SBP and DBP were significantly higher in patients with the absence of OAEs. The mean HbA1c and creatinine levels were significantly higher among patients with the absence of OAEs. Thyroid function tests, expressed as the measurements of TSH, FT3 and FT4, did not demonstrate any significant difference between patients with the presence or absence of OAEs. The multivariate regression analysis showed that longer diabetes duration, poor glycemic control and history of hypertension were the only significant risk factors associated with hearing loss, while age, male sex and the

Table 3. Otoacoustic emission by clinical and metabolic parameters.

	Total (n=157)	Otoacoustic emission present (n=129, 80.3%)	Otoacoustic emission absent (n=28, 19.7%)	P value
Age (years)	51.0 (47.0-54.0)	51.0 (47-53)	51.5 (47.8-55.0)	.1
Diabetes duration (years)	13.0 (7-18)	13.0 (7-18)	12.0 (7-17)	.2
Blood pressure (mm Hg)				
Systolic	127 (15)	126.2 (15.2)	133.8 (16.1)	.001
Diastolic	74.1 (9.3)	73.3 (9.5)	77.4 (8)	.002
Anthropometric				
Height (cm)	162.8 (9.2)	162.8 (6.7)	163 (5.2)	.8
Weight (kg)	86 (16.1)	85.4 (14.9)	88.4 (20)	.2
Body mass index (kg/m ²)	32.46 (5.5)	32.4 (5.1)	33.9 (7.1)	.06
Laboratory tests				
Hemoglobin (g/dL)	13.6 (1.63)	13.7 (1.7)	13.7 (1.5)	.7
Erythrocyte sedimentation rate (mm/hr)	18.6 (17.5)	19 (17.3)	16.7 (18.3)	.5
Fasting blood sugar (mmol/L)	9.6 (3.3)	9.5 (3.4)	10.2 (3.2)	.1
Hemoglobin A1c (%)	8.5 (1.8)	8.4 (1.8)	9 (1.6)	.02
Cholesterol (mmol/L)	4.3 (1.0)	4.4 (1.1)	4.4 (1)	.9
Low density lipoprotein (mmol/L)	2.6 (0.9)	2.6 (1)	2.5 (.8)	.3
High density lipoprotein (mmol/L)	1.2 (0.3)	1.2 (0.3)	1.2 (.3)	.8
Triglyceride (mmol/L)	1.5 (1.0)	1.5 (1.2)	1.7 (.8)	.4
Creatinine (μ mol/L)	68.7 (25.9)	67.3 (20.2)	74.6 (41.5)	.05
Thyroid stimulating hormone (mIU/L)	3.0 (2.3)	2.9 (2.2)	3.4 (3.2)	.2
Free T4 (pmol/L)	15.2 (3.9)	15.1 (4.2)	16 (2.9)	.1
Free T3 (pmol/L)	4.8 (1.2)	4.8 (1.3)	4.7 (.7)	.5

Data are mean (standard deviation) and median (interquartile range) for age and duration of diabetes.

Table 4. Multivariate logistic regression analysis of factors assessed for association with hearing loss (n=100) vs normal hearing (n=49).

	Odds ratio (95% CI)	P value
Age≥50	1.5 (.77-2.98)	.2
Male gender	1.55 (.78-2.96)	.2
Duration of diabetes (>10 years)	2.68 (1.33-5.39)	.005
HgA1c ≥8%	2.14 (1.09-4.21)	.02
History of hypertension	2.55 (1.26-5.14)	.009
Neuropathy	.77 (.37-1.61)	.4
Retinopathy	1.1 (.49-2.48)	.8
Nephropathy	1.02 (.29-3.56)	.9
Vasculopathy	1.58 (.41-6.1)	.5
Smoking	2.2 (.45-10.84)	.3
Family history of hearing impairment	.64 (.27-1.51)	.3

Reference level the opposite or absence of the factor. Model fit parameters: Deviance=122.778; Likelihood ratio test chi-square=26.15, $P=.004$, McFadden $R^2=.139$

presence of microvascular or macrovascular complications were not significantly associated with an increased risk (Table 4).

DISCUSSION

The high frequency of hearing loss in our study, among the highest reported,¹ could be attributed to the relatively high mean age and complicated diabetes of the patients we studied. The 29% prevalence of disabling hearing loss is higher than that reported by the WHO in the Middle East and North Africa (3.5%).⁷ A questionnaire-based study that investigated the Saudi community reported a prevalence rate of 17.4% in terms of hearing loss among elderly people.⁸ Half of all the hearing loss cases were classified as being of mild severity, while around 40% of the studied cases had moderate-severity hearing loss. These findings are inconsistent with those reported in other ethnicities.¹ The remaining 10% of the cases had either severe or profound hearing loss; this proportion is still higher than that reported by the WHO in the Middle East.⁷ In this study, hearing loss was more prevalent among older patients and among men, which is consistent with the findings of different cross-sectional and prospective studies investigating hearing loss.¹ The age effect on hearing loss is expected to be more profound among patients with diabetes, as a result of sclerotic changes and tissue stiffness observed in both the middle and inner ears in such patients.⁹ The effect of wax

on hearing loss is stronger in older people, and this may contribute to the increased rate of hearing loss in older patients;¹⁰ however, this factor was eliminated in the present study. The men in our study had higher prevalence rates of hearing loss than the women, possibly as a result of excess exposure of men to occupational and environmental factors.⁸

In line with the findings of most studies that investigated hearing loss among diabetes patients, better diabetes control, as reflected by lower HbA1c levels, was associated with hearing loss in this study. The duration of diabetes was a significant risk factor for hearing loss, as also reported by other studies, regardless of patient age.¹ This could be explained by the fact that patients with longer diabetes durations could have microvascular diseases that may affect microvascular structure and lead to neuropathy. In this study, patients with diabetes durations longer than 10 years accounted for more than 50% of the total population with hearing loss. The percentages of severe and profound hearing loss peaked at a diabetes duration of 5 to 10 years which in line with findings of Gupta et al, where a longer duration of type 2 diabetes (≥8 years) was associated with a higher risk of moderate or worse hearing loss.¹²

However, a meta-analysis showed a progressive increase in hearing loss with increasing diabetes durations.¹³ The peak observed in this study could have resulted from the sampling technique employed, as the selected patients were aged between 30 and 60 years. The use of this technique may have eliminated a large number of patients with hearing loss older than 60 years of age. The other explanation could be related to the increase in the prevalence of chronic complications, particularly neuropathy and nephropathy that usually peak during that period.¹⁴

The effect of hypertension on hearing loss was very profound in this study, as also reported by Hlayisi et al.¹ This could be explained by the fact that hypertension accelerates for the degeneration of the hearing apparatus.¹⁵ The pathology of the circulatory system may directly affect hearing in different ways, such as through increases in blood viscosity which may, in turn, reduce oxygen transport and tissue hypoxia rates, and through arterial hypertension that causes ionic changes in cell potential, leading to hearing loss.¹⁶ The first explanation could also provide clarity on the higher percentage of hearing loss observed among patients with hyperlipidemia in this study. The prevalence of hypothyroidism, which is associated with type 2 diabetes and hearing loss, was higher in our study than in the literature, and this may explain the high prevalence of hearing loss observed in this study.¹⁷

The presence of microvascular and macrovascular complications was associated with hearing loss in this cohort, which is in line with the findings of several studies, particularly in terms of neuropathy and nephropathy. Neuropathy may contribute directly to nerve damage in the cochlea. Most ototoxic medications are also nephrotoxic, and vice versa. Due to the similar physiology of the stria vascularis and glomerulus, specifically in terms of electrolyte and active fluid transportation;¹⁸ therefore, if the kidney fails, the cochlea may be affected for the same reason. In the present study, aspirin use did not demonstrate an increased risk of hearing loss, which could be explained by the low dose used by the patients.

The absence of OAEs is solid evidence of outer hair cell damage and cochlear function impairment, both of which result in sensory hearing loss. The high observed SBP and DBP were of significance in patients with the absence of OAEs. Poorer glycemic control, as evidenced by the elevated HbA1c values, was significant in patients with OAEs. High plasma creatinine levels have a direct toxic effect on the inner ear.¹⁹ Other factors such as age, duration of diabetes and body weight did not show significant effects on OAE response, most likely due to low test sensitivity. Lipid parameters and thyroid hormones did not affect OAE responses significantly. This could be related to the controlled lipid level and normal thyroid hormone levels.

In the multivariate regression analysis, in addition to age and diabetes duration, a duration of diabetes longer than 10 years, HbA1c levels ≥ 8 and the presence of hypertension were significant risk factors for hearing loss. Other factors, including neuropathy, retinopathy, nephropathy and vasculopathy did not increase the risk for hearing loss in the multivariate regression anal-

ysis. Neither smoking nor a family history of hearing impairment showed any significant effect; this could be related to the very low prevalence of smoking among women in Saudi Arabia.²⁰ The strength of this paper lies in the fact that it identified an unexpectedly high prevalence of hearing loss in Saudi Arabia, a country known to have a type 2 diabetes epidemic. This study focused on people in the most productive age spectrum, in whom hearing disability could affect productivity, quality of life and wellbeing.

In conclusion, more than 60% of the type 2 diabetes patients in this study, aged between 30 and 60 years, had hearing loss of varying degrees, with 50% of them having moderate-to-severe degree hearing loss. These findings highlight the importance of conducting hearing assessments in type 2 diabetes patients. Although factors other than diabetes contribute to hearing loss, early glycemic control for type 2 diabetic patients may reduce the incidence rate of this disease. Other comorbidities including hypertension and hyperlipidemia must be considered in the formulation of strategies to reduce the risk of hearing loss. The most important risk factors related to hearing loss among the diabetes patients in our study, such as poor glycemic control and hypertension, are modifiable in nature. Male sex and longer duration of diabetes are non-modifiable risk factors that may contribute to an increased prevalence of hearing loss. Awareness must be raised on the significance of hearing loss as a commonly occurring comorbidity in diabetes among healthcare providers. Hearing acuity screening should be a part of routine screening for diabetes patients, and should be conducted on a regular basis to avoid the devastating consequences of this often-overlooked medical condition.

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