

# Prevalence and Associated Factors of Sensorineural Hearing Impairment Among Patients with T2DM in Amhara Region, Northwest Ethiopia, 2022: A Multi-Centered Cross-Sectional Study

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**Background:** Generally, people with type 2 diabetes mellitus in various countries experience a significant rate of sensorineural hearing impairment. Nonetheless, there is scant evidence of sensorineural hearing impairment among type 2 diabetes mellitus patients in Northwest Ethiopian. Therefore, the objective of this study was to evaluate the occurrence rate and contributing factors of sensorineural hearing impairment in type 2 diabetics at comprehensive and specialized referral hospitals in Northwest Ethiopia.

**Methods:** A facility-based cross-sectional study design was carried out from May 3, 2022, to June 14, 2022, on 846 study participants in Ethiopia, with a response rate of 99.65%. The research subjects were chosen by simple random sampling techniques. Data was gathered by using audiometric measurements and structured interview-administered questionnaires and then entered into EPI data version 4.6. Finally, it was exported to STATA 14 for analysis. Binary logistic regression, chi-square test, and odds ratio were done to verify the assumptions and degree of association. Ultimately, factors exhibiting a p-value < 0.05 with a 95% CI were regarded as significant predictors of hearing impairment.

**Results:** The magnitude of sensorineural hearing impairment in this investigation was 50.49% (95% CI: 45.67%, 55.26%). Factors significantly associated with sensorineural hearing impairment were age (AOR=1.10, 95% CI: 1.07, 1.14), hyperlipidemia (AOR=2.86, 95% CI: 1.05, 7.82), duration of diabetes (AOR=2.26, 95% CI: 1.26, 4.06), hypertension (AOR=1.94, 95% CI: 1.02, 3.69) and regular physical exercise (AOR=0.25, 95% CI: 0.09, 0.68).

**Conclusions and Recommendations:** In this study, relatively high rates of sensorineural hearing impairment were observed. Stakeholders should establish routine hearing screening, and participants will advise to incorporate regular physical exercise into their routines.

**Keywords:** hearing loss, impairment, audiometer, diabetes, Ethiopia

## Introduction

Sensorineural hearing impairment (SNHI) is a disability in which an individual is unable to hear sounds in one or both ears within 25 dB.<sup>1,2</sup> In recent times, SNHI resulting from prolonged exposure to diabetes mellitus has emerged as a significant global public health issue.<sup>2</sup> Type 2 diabetes mellitus (T2DM) leads to a gradual, bilateral, and permanent SNHI.<sup>3</sup> Previous research has verified that prolonged exposure to elevated glucose levels can result in SNHI.<sup>4</sup> This was due to the excess production of free oxygen radicals in the body. Because of their high reactivity and ability to attach to a variety of molecules, free oxygen radicals have the potential to harm the inner ear's mitochondrial deoxyribonucleic acid.<sup>5</sup> If the mitochondria were impaired, oxidative phosphorylation and adenosine triphosphate production would be

diminished, causing anoxia. Anoxia in the inner ear causes a decline in endocochlear potential.<sup>4</sup> This results in SNHI by interfering with impulse conduction to the endocochlear nerve<sup>4,5</sup>. The World Health Organization (WHO) estimates that 20.3% of people worldwide have SNHI.<sup>6</sup> Furthermore, the European Center for Disease Control and Prevention (CDC) reports that the SNHI was 30% higher in type 2 diabetics than non-diabetic individuals.<sup>7,8</sup> In addition to this, the American Diabetes Association revealed that the magnitude of SNHI is twice as high in T2DM patients than without T2DM.<sup>9</sup> Moreover, a meta-analysis conducted in Canada reported that the prevalence of SNHI among T2DM patients ranged between 44–69.7%.<sup>10</sup> The prevalence of T2DM-related SNHI varied globally,<sup>11</sup> as well as in African countries. Sensorineural hearing impairment imposes a substantial social and economic burden on numerous nations.<sup>12</sup> As a prevalent public health concern, hearing impairment adversely affects an individual's capacity to learn, integrate into society, perform effectively at work, sustain relationships with others, and contribute productively. Furthermore, it exerts a negative impact on one's overall quality of life and well-being.<sup>12–14</sup> In Sub-Saharan Africa, particularly in Ethiopia, T2DM has become a significant public health concern.<sup>2</sup> Despite the rising prevalence of T2DM in Ethiopia, the extent of SNHI attributable by T2DM remains unclear. Therefore, the aim of this study was to assess the magnitude and factors associated with sensorineural hearing impairment among type 2 diabetes mellitus individuals in northwest Ethiopia.

## Methodology

### Study Design, Area, and Period

A multicenter, hospital-based cross-sectional study was conducted in comprehensive and specialized referral hospitals (CSRHs) within the Amhara region, Northwest Ethiopia, from May 3 to June 14, 2022. The Amhara region is one of the largest regions in Ethiopia, with its capital city being Bahir Dar, situated 565 km from Addis Ababa (the capital city of Ethiopia). Among all people, 16,375 people in the Amhara region had T2DM. In the Amhara region, there are eight CSRH, including Felege Hiwot, Woldia, Debre Tabor, Debre Berhan, the University of Gondar, Tibebe Gihon, Dessie, and Debre Markos. By using simple random sampling techniques, Tibebe Gihon, Debre Markos, and Debre Tabor CSRHs were selected. Debre Markos Comprehensive Specialized Referral Hospital was established in Debre Markos City, located 297 km from Addis Ababa. The hospital is providing comprehensive diabetic care services for 2104 T2DM individuals. Debre Tabor CSRH is situated in Debre Tabor City, which is 668 kilometers distant from Addis Ababa. It offers diabetic support services for 1052 type 2 diabetics. Tibebe Gihon CSRH is located in Bahir Dar, 565 kilometers away from the capital city of Ethiopia. It also offers diabetic services for 1644 individuals with T2DM.

### Population

The source population for this study comprised all individuals diagnosed with T2DM in the Amhara region. The study population included all T2DM patients in the selected Amhara region in comprehensive and specialized referral hospitals.

### Eligibility Criteria

The study included individuals with T2DM who were  $\geq 18$  years old, not severely ill, and non-congenitally impaired. Those who did not meet these criteria were excluded from the study.

### Sampling Techniques and Sample Size Estimation

Since, no previous similar study has been conducted in Ethiopia, the sample size of the study was established using a single population proportion formula by taking the following parameters: proportion of sensorineural hearing impairment (P) = 50%, CI: 95%, error of margin (d) = 5%, and design effect (De) = 2.

$$n_i = \frac{(Z\alpha/2)^2 * P(1 - P)}{d^2} * De = \frac{(1.96)^2 * 0.5(1 - 0.5)}{(0.05)^2} * 2 = \frac{(384.16)2}{(0.05)^2} = 768.32$$

Where,  $n_i$  = initial sample size

With a 10% contingency rate, the final sample size was 846.

The study hospitals were chosen through a simple random sampling technique. Subsequently, for the selection of study participants, a systematic random sampling technique was employed after proportional allocation was made for each of the selected hospitals.

## Study Variables

**Dependent variable:** Hearing impairment

**Independent variables:** Sociodemographic characteristics like age, sex, occupation, educational level, income, family history, and institutional noise level were assessed. Behavioral and medical elements such as cigarette smoking, alcohol drinking, regular physical exercise, earphone utilization, hypertension, ear infection, hyperlipidemia, cardiac disease, body mass index, family history, glycemic control, and ototoxic drug utilization (Aminoglycoside, Aspirin, Chemotherapy, Loop diuretics, and NSAID) were also assessed.

## Operational Definitions

Sensorineural hearing impairment: Was an average hearing threshold above 25 decibels at 0.5, 1, 2, 4 and 8 kHz.<sup>1,2</sup>

Severity of hearing impairment: Categorized as mild (25–40 dB), moderate (40–55 dB), moderately severe (55–70 dB), severe (70–90 dB), and profound (91+ dB).<sup>6</sup>

Body mass index: according to WHO BMI is classified as underweight, normal weight, overweight, and obese when weight over height is  $<18.5 \text{ kg/m}^2$ ,  $18.5\text{--}24.9 \text{ kg/m}^2$ ,  $25\text{--}29.9 \text{ kg/m}^2$ , and  $\geq 30 \text{ kg/m}^2$ <sup>15</sup> respectively.

Blood glucose regulation: Good glycemic control was defined as having a fasting blood glucose level within the range of 70–126 mg/dl, including the boundary points. Conversely, poor glycemic control was determined when the fasting blood glucose level was below 70 or above 126 mg/dl.<sup>16</sup>

## Data Collection Procedures and Instruments

Structured interviewer-administered questionnaires were utilized to collect data from participants ([Supplementary File 1](#)). The questionnaire, originally crafted in English, underwent translation into the participant's local language (Amharic). To ensure accuracy, the translated version was then back translated into English by experts proficient in both languages. Three individuals with Bachelor of Science degrees in Nursing conducted the interviews under the supervision of a principal investigator. In addition to this, audiometric and institutional noise levels were used to measure the hearing threshold of participants and environmental sound levels, respectively.

## Audiometric Measurement

The study participants' hearing status was assessed by audiologists using a pure-tone audiometer

Daily calibration of the pure-tone audiometer was carried out using individuals with presumed normal hearing prior to any audiometric evaluations. Audiometric tests were consistently conducted in a noise-controlled environment with a background noise level maintained between 36 and 40 dB. This practice was implemented prior to workers entering their workstations to mitigate the potential impact of transitory threshold shifts caused by ongoing exposure to noise in the workplace. This precautionary measure aims to ensure the accuracy and reliability of the audiometric evaluations by minimizing any extraneous noise interference during the testing process. Participants were informed in advance about the scheduled audiometric test, allowing them the opportunity to observe an "acoustic rest" or "quiet time" ideally lasting 16 hours before the actual test.<sup>17</sup> Respondents received comprehensive instructions about the test, including guidance to sit still and refrain from talking. The audiometer was carefully plugged and placed on the participants' ears. Before determining the threshold, respondents were introduced to the signal by presenting it at an intensity sufficient to elicit a clear response. Subsequently, the audiometer machine was adjusted to consecutively test the right and left ears of participants. Participants were then instructed to press the audiometer pointer when they heard the sound. Three successive audiometric measurements were conducted, and the average of these three records was analyzed. Ultimately, a diagnosis of hearing impairment was established if an individual exhibited a hearing threshold of  $\geq 25 \text{ dB}$ .<sup>18,19</sup>

## Institution Noise Level

A sound level meter (Model SL-5868I) was employed to measure the noise level in workstations, providing a reliable indicator of the ambient noise in the working area. The meter has a measurement range spanning from 25 to 130 dB. The initial step preceding the measurement of institutional sound involved identifying the location of the major source of noise. After identifying the location of the noise source, the subsequent step involved selecting a suitable position for the instrument. This placement was strategically chosen to be away from any obstruction or vibration. Subsequently, the instrument was elevated to a height of 1.2–1.5 meters above the ground and positioned 3.5 meters away from the noise source. Following this, the sound level meter was activated, and measurements were taken. The recorded data included the sound pressure level obtained from the display screen. Measurements were conducted during specific periods: from 7 a.m. to 6 p.m. during the daytime, from 6 p.m. to 10 p.m. in the evening, and from 10 p.m. to 7 a.m. at night on three days. A sound level of greater than 85 dB for more than eight hours caused SNHI.<sup>20,21</sup>

## Data Quality Control

To guarantee the quality of data, data collectors underwent three days of training. To determine the validity of the questionnaire, Cronbach's alpha was examined, and the result was 76.54%. Additionally, 5% of the total sample size of T2DM patients at Bahir Dar General Hospital participated in the questionnaire pretesting. The main investigator closely monitored the data collectors each day. Before entry, the data underwent a thorough check for both consistency and completeness.

## Data Processing and Analysis

Once the data was collected, it was exported into STATA version 14.0 for analysis. Descriptive statistics, including frequency, median, mean, interquartile range, and percentage, were utilized to provide a comprehensive summary of the participants. The normality of the data was examined using the Shapiro–Wilk test, revealing a p-value of 0.001. Furthermore, the goodness-of-fit for the model was assessed through the Hosmer–Lemeshow test, with a calculated value of 0.2654. Variables with a p-value of  $\leq 0.2$  in bivariable regression were included in multivariable logistics regression. To assess the strength of the association between the independent variables and outcome variables, odds ratios (OR) at a 95% confidence interval (CI) were calculated. In the multivariable regression, variables with a p-value of  $\leq 0.05$  were regarded as significantly associated.

## Results

### Demographic and Social Attributes of Participants

A total of 846 participants were recruited with a 99.65% response rate. Among these, 58.8% were men. The participants' age span ranged from 24 to 70 years, with a mean age of  $51.6 \pm 10.10$ . In terms of religious affiliation, 74% identified as Christians. Regarding educational attainment, 36.19% reported not having formal education. Additionally, 59% of participants indicated residing in urban areas, while 28.57% identified as civil servants. The median monthly income among respondents was 3000 ETB. Institutional sound levels of DMCRH, TGRH, and DTCRH were 61.5, 65.3, and 51.2 dB, respectively (Table 1).

### Behavioral Characteristics of Study Participants

In this study, 17.14% of participants did regular physical exercise, 6.43% had a history of cigarette smoking, 19.5% were heavy alcohol drinkers, and 89.52% were earphone utilizers (Table 2).

### Clinical Characteristics of Participants

The average duration of T2DM was 5 years, with an interquartile range of 8.25 years. Out of all the study participants, 91.19% started antidiabetic medication. From those, 41.90% took oral antidiabetics. A history of hypertension, hyperlipidemia, thyroid, and cardiovascular disease was present in 28.33%, 10.24%, 5.95%, and 6.19% of the individuals, respectively. Among participants, 61.67% had poor glycemic control, 8.33% had a history of ear infection, and 41.43% used ototoxic medications. The average BMI of the participants was  $24 \pm 4$  kg/m<sup>2</sup> (Table 3).

**Table 1** Socio-demographic characteristics of T2DM patients and Chi-square test in Amhara region, CSRH, Northwest Ethiopia, 2022

Variable	Categories	Frequency/Mean	Percentage	p-value
Sex	Female	347	41.19	0.391
	Male	496	58.81	
Age in year	–	51.6 ± 10.10	–	0.000*
Residence	Rural	371	44.05	0.903
	Urban	472	55.95	
Religion	Orthodox	689	81.67	0.734
	Muslim	94	11.19	
	Other	60	7.14	
Occupation	Unemployed	172	20.48	0.291
	Civil servant	241	28.57	
	Farmer	224	26.43	
	Other	206	24.52	
Occupational sound	Not-noisy	761	90.24	0.668
	Noisy	82	9.76	
Monthly Income	< 2250	343	40.71	0.300
	2250–8900	450	53.33	
	>8900	50	5.95	
Educational status	Diploma and above	166	19.76	0.894
	Secondary	175	20.71	
	Primary	197	23.33	
	No formal	305	36.19	
Noise area	No	759	90.00	0.424
	Yes	84	10.00	
Getting sudden loud noise	No	684	81.19	0.975
	Yes	159	18.81	

Note: \*P value ≤ 0.05.

**Table 2** Behavioral characteristics of T2DM patients and Chi-square test in Amhara region, CSRH, Northwest Ethiopia, 2022 (n=843)

Variable	Categories	Frequency	Percentage	P-value
Regular physical exercise	No	699	82.86	0.000*
	< 2 hrs	32	3.81	
	≥2hrs/wk	112	13.33	
Alcohol drinking status	Never-drinker	84	10.00	0.683
	Light-drinker	594	70.48	
	Heavy- drinker	165	19.52	
Smoking status	No smoker	789	93.57	0.003*
	Smoker	54	6.43	
Earphone used	No	755	89.52	0.306
	Yes	88	10.48	

Note: \*P value ≤ 0.05.

## Prevalence of Sensorineural Hearing Impairment

The study found that 50.5% of participants had SNHI (95% CI: 45.69%, 55.26%). Of those, a majority of the participants (75.46%) had a bilateral SNHI (Figure 1).

## Severity of Sensorineural Hearing Impairment

Among all patients with SNHI, 55.64, 26.08, 13.98, and 4.30% experienced mild, moderate, moderately-severe, and severe SNHI respectively. Notably, none of the patients exhibited profound HI (Figure 2).

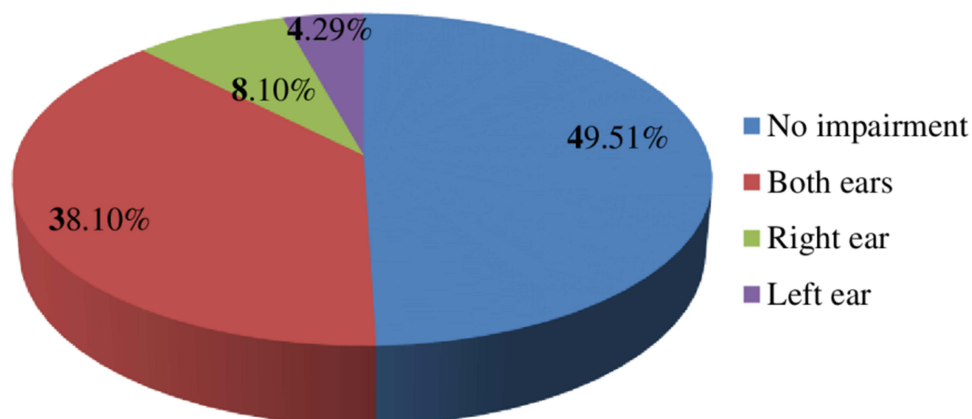
**Table 3** Clinical characteristics of T2DM patients and Chi-square test in Amhara region, CSRH, Northwest Ethiopia, 2022 (n=843)

Variable	Categories	Frequency	Percentage	p-value
Family history of HI	No	769	91.19	0.911
	Yes	74	8.81	
Ear infection trauma/ surgery	No	773	91.67	0.003*
	Yes	70	8.33	
Duration of T2DM	<10 year	590	70.00	0.000*
	≥10 year	253	30.00	
Antidiabetics drugs	No started	68	8.10	0.000*
	Insulin only	266	31.43	
	Insulin and oral	156	18.57	
	Oral only	353	41.90	
Hyperlipidemia	No	757	89.76	0.000*
	Yes	86	10.24	
Hypertension	No	604	71.67	0.000*
	Yes	239	28.33	
Cardiovascular disease	No	791	93.81	0.116
	Yes	52	6.19	
Thyroid disorder	No	793	94.05	0.071
	Yes	50	5.95	
Ototoxic drugs	Not used	494	58.57	0.027*
	Used	349	41.43	
Glycemic control	Good	323	38.33	0.014*
	Poor	520	61.67	
BMI	Normal weight	441	52.38	0.000*
	Overweight	276	32.62	
	Obese	88	10.48	
	Underweight	38	4.52	

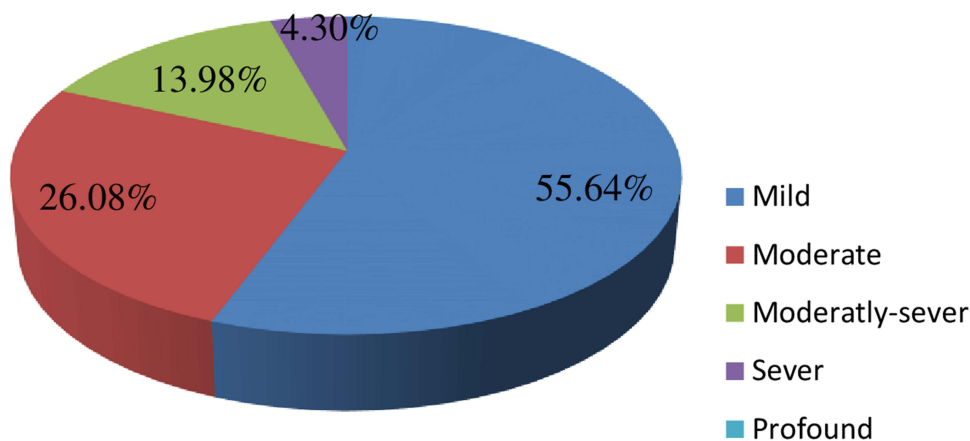
Note: \*P value ≤ 0.05.

## Associated Factors of Hearing Impairment

In the bivariable logistic regression analysis, age, regular physical exercise, smoking history, hypertension, ear infections or trauma, duration of T2DM, antidiabetic medication, BMI, hyperlipidemia, use of ototoxic drugs, and glycemic control were identified as factors significantly associated with the SNHI. However, in the multivariable logistic regression analysis, age, duration of T2DM, hypertension, hyperlipidemia, and regular physical exercise exhibited significant associations with the SNHI.



**Figure 1** Prevalence of SNHI among T2DM patients in Amhara region, Northwest Ethiopia, 2022.



**Figure 2** Severity of sensorineural hearing impairment among type 2 diabetes mellitus patients in Amhara region, Northwest Ethiopia, 2022.

As age increased by one-unit, the likelihood of developing SNHI increased by 1.1 times, as indicated by an adjusted odds ratio (AOR) of 1.10, with a 95% confidence interval ranging from 1.07 to 1.14. Also, the odds of developing SNHI among participants with a diabetic duration of  $\geq 10$  years were 2.26 times higher than those with a diabetic duration of  $< 10$  years (AOR = 2.26, 95% CI: 1.26, 4.06). Moreover, the odds of developing SNHI in hypertensive patients were 1.94 times higher than in non-hypertensive individuals, as evidenced by an AOR of 1.94 with a 95% CI ranging from 1.02 to 3.69. In addition, the odds of developing SNHI in hyperlipidemic respondents were 2.86 times higher than in respondents with normal lipid levels (AOR = 2.86, 95% CI: 1.05, 7.82). However, Individuals engaging in regular physical exercise for two or more hours were 75% less likely to develop SNHI compared to those who did not engage in regular physical exercise (Table 4).

**Table 4** Significantly associated variables in bivariable and multivariable logistic regression analysis among T2DM patients in Amhara region, CSRH, Northwest Ethiopia, 2022

Variable	Categories	SNHI in Frequency		COR (95% CI)	AOR (95% CI)
		Yes	No		
Age	–	56.61 ± 8.70	46.50 ± 8.81	1.14 (1.11, 1.17)	1.10 (1.07, 1.14)
Regular exercise per week	<2 hrs	6	26	0.17 (0.05, 1.59)	0.04 (0.08, 1.45)
	$\geq 2$ hrs	14	98	0.10 (0.15, 0.23)	0.25 (0.09, 0.68)
Smoking status	No	406	293	1.00	1.00
	Smoker	38	16	2.47 (1.05, 5.75)	1.52 (0.45, 5.12)
Ear Trauma/infection/	Non-smoker	387	402	1.00	1.00
	Yes	52	18	3.09 (1.41, 6.77)	1.66 (0.59, 4.66)
Duration of diabetes mellitus	No	373	400	1.00	1.00
	$\geq 10$	183	70	3.73 (2.36, 5.85)	2.26 (1.26, 4.06)
Antidiabetics drugs	<10	243	347	1.00	1.00
	Insulin only	85	181	0.86 (0.39, 1.89)	0.87 (0.33, 2.26)
	Insulin and oral	90	66	2.50 (1.09, 5.76)	1.19 (0.45, 3.16)
	Oral	227	126	3.29 (1.52, 7.09)	1.38 (0.49, 3.88)
Hyperlipidemia	Not used	24	44	1.00	1.00
	Yes	72	14	5.88 (2.55, 13.53)	2.86 (1.05, 7.82)
Hypertension	No	353	404	1.00	1.00
	Yes	179	60	4.31 (2.67, 6.89)	1.94 (1.02, 3.69)
Cardiovascular disease	No	247	357	1.00	1.00
	Yes	34	18	1.93 (0.84, 4.43)	0.90 (0.26, 3.13)
	No	391	400	1.00	1.00

(Continued)

Table 4 (Continued).

Variable	Categories	SNHI in Frequency		COR (95% CI)	AOR (95% CI)
		Yes	No		
Hyperthyroidism	Yes	34	16	2.18 (0.92, 5.17)	1.70 (0.51, 5.64)
	No	391	402	1.00	1.00
Ototoxic drugs	Used	199	150	1.56 (1.05, 2.29)	1.10 (0.66, 1.86)
	Not used	227	267	1.00	1.00
Glycemic control	Poor	287	233	1.65 (1.11, 2.44)	1.16 (0.69, 1.95)
	Good	138	185	1.00	1.00
Body mass index	Overweight	165	110	2.20 (1.42, 3.39)	1.20 (0.67, 2.13)
	Obese	62	26	3.51 (1.74, 7.08)	1.85 (0.78, 4.40)
	Underweight	20	18	1.63 (0.64, 4.19)	1.47 (0.45, 4.86)
	Normal	179	263	1.00	1.00

## Discussion

The objective of the current study was to evaluate the prevalence of sensorineural hearing impairment and factors associated with it among patients with type 2 diabetes mellitus in Ethiopia.

In the current study, the overall magnitude of SNHI among the participants was 50.49% (95% CI; 45.69%, 55.26%). It was consistent with studies conducted in Australia 50%,<sup>22</sup> Pakistan 46.1%,<sup>23</sup> Switzerland 46.9%,<sup>11</sup> Taiwan 47%,<sup>24</sup> Saudi Arabia 49%,<sup>25</sup> South Africa 55%,<sup>26</sup> and Egypt 51.3%.<sup>27</sup> The consistency in study design and participant characteristics may account for the observed trend. However, the findings from this study revealed lower values compared to similar research conducted in Japan (60.2%),<sup>28</sup> Iran (85%),<sup>29</sup> Nepal (72.5%),<sup>1</sup> India (58%),<sup>30</sup> North India (81%),<sup>31</sup> and Nigeria (71.8%).<sup>32</sup> This possible discrepancy might be due to natural disasters such as volcanic eruptions, flooding, and tsunamis that regularly affect Asian countries.<sup>33</sup> Another possible reason might be due to environmental factors; Southeast Asia is region where barotraumas frequently occur that causes HI.<sup>34</sup> In contrast, this result was higher than the results reported in the USA (43.6%),<sup>3</sup> Mexico (21.7%),<sup>35</sup> UK (7.5%),<sup>36</sup> China (45.1%),<sup>37</sup> Canada (44%-69.7%),<sup>10</sup> and Kenya (39.7%).<sup>38</sup> This might be due to differences in economic and public health institutions coverage. In Ethiopia, there is limited access to health institutions, early screening, sufficient immunization, and a high prevalence of inner ear infections.<sup>39,40</sup> This factor could potentially contribute to the high prevalence of SNHI in this research. This study showed that the magnitude of bilateral SNHI (38.10%) was higher than unilateral SNHI (12.39%). This observation finds support in studies conducted in Saudi Arabia,<sup>25</sup> China 45.1%,<sup>37</sup> and USA.<sup>3</sup> This might be due to the nature of hyperglycemia, which distributes equally in both ears and leads to progressive, bilateral, and irreversible SNHI.<sup>3</sup> Factors significantly associated with predictor variables in multivariable logistic regression were age, duration of T2DM, hypertension, hyperlipidemia, and regular physical exercise. Age, duration of diabetes mellitus, hypertension, and hyperlipidemia were positively associated with SNHI. However, regular physical exercise was negatively associated with the occurrence of SNHI. The current study revealed that as age increased, the opportunity of developing SNHI also increased. This was substantiated by research conducted in Pakistan,<sup>23</sup> the USA,<sup>41</sup> Korea,<sup>42</sup> Iran,<sup>43</sup> Japan,<sup>44</sup> China,<sup>45</sup> Jammu,<sup>46</sup> India,<sup>30</sup> and North India.<sup>31</sup> This may be the result of vascular insufficiency, decreased mitochondrial activity, and increased ROS generation with aging.<sup>4,19</sup> ROS disrupts mitochondrial DNA, which results in decreased oxygen and energy supply in the inner ear.<sup>47</sup> The results of the current study suggested that individuals with a long duration of T2DM had a higher chance of developing SNHI than those with a short-term duration. This was in line with studies done in Mexico,<sup>35</sup> Indonesia,<sup>48</sup> Turkey,<sup>49</sup> Nepal,<sup>1</sup> Iran,<sup>29</sup> China,<sup>37</sup> Jammu,<sup>46</sup> India,<sup>50</sup> Saudi Arabia,<sup>25</sup> and South Africa.<sup>26</sup> The possible reason might be that chronic hyperglycemia affects the inner ear nerve tracts and blood vessels by increased reactive oxygen species.<sup>51</sup> Excess production of oxygen-free radicals in the body caused a potentially toxic effect on the inner ear, which eventually caused neuronal degeneration in the auditory system and led to SNHI.<sup>52</sup> In addition, persistent hyperglycemia causes diabetic microangiopathy in the ear. In hyperglycemia, there was a notable thickening of the vascular wall of the basilar membrane and stria vascularis, accompanied by the loss of outer hair cells. This caused SNHI.<sup>53</sup> According to the current study, hypertension was significantly associated with SNHI in T2DM patients. This was supported by studies in Mexico,<sup>35</sup> Turkey,<sup>49</sup>



Qatar,<sup>54</sup> Saudi Arabia,<sup>25</sup> and Nigeria.<sup>55</sup> This might be due to reduced blood flow and oxygen transport in the stria vascularis secondary to hypertension.<sup>56</sup> In addition to this, hypertension caused hypertension-induced vascular injury in the blood-labyrinth barrier (BLB) of the cochlea. This has the potential to disrupt the ionic balance within the endolymph, potentially resulting in SNHI.<sup>56</sup> Furthermore, participants who had hyperlipidemia were more likely to develop SNHI than their counterparts. This was supported by studies conducted in Korea<sup>57</sup> and Mexico.<sup>35</sup> The possible explanation might be the deterioration of inner ear perfusion due to atherosclerosis and increased blood viscosity secondary to hyperlipidemia.<sup>58–60</sup> Finally, the current study demonstrated that engaging in regular physical exercise had a protective effect against SNHI, with an AOR of 0.25 and a 95% CI ranging from 0.09 to 0.68. This finding is consistent with research conducted in the United States.<sup>41</sup> The possible reason might be that regular physical exercise reduces glucose ototoxicity by elevating glucose uptake by hepatic and skeletal muscle tissues.<sup>61</sup> Also, regular physical exercise increases oxygen-rich blood flow to the inner ear by increasing cardiac output.<sup>61</sup> Generally, regular physical exercise protects the inner ear from glucose toxicity.

## Strengths and Limitations of the Study

This research was carried out in multiple centers and encompassed a diverse population, thereby enhancing its generalizability. In addition to this, primary data was employed to enhance the credibility of the evidence. However, due to its cross-sectional study design, the research did not demonstrate a cause-and-effect relationship. In addition, the dose of ototoxic drugs was not accurately determined because of recall bias and the utilization of unrecorded drugs by the patients. Overall, the study serves as a foundation for future investigators to conduct more robust study designs, such as experimental and cohort in this setting to yield enhanced conclusions.

## Conclusion and Recommendations

The magnitude of sensorineural hearing impairment in type 2 diabetes mellitus participants in the Amhara region was notably high. This study revealed that factors such as age, duration of diabetes mellitus, hypertension, and hyperlipidemia are associated with increased odds of experiencing sensorineural hearing impairment in type 2 diabetes mellitus participants. Therefore, health policymakers should develop a policy for routine hearing screening for all type 2 diabetic patients. To mitigate the impact of sensorineural hearing impairment, it is recommended that medical staff and stakeholders in each referral hospital prioritize early management of diabetes mellitus, hypertension, and cholesterol. Additionally, individuals with type 2 diabetes mellitus should actively participate in regular physical activity to minimize the potential effects.

## Abbreviations

CSRH, Comprehensive and Specialized Referral Hospitals; dB, Decibel; KHz, Kilo Hertz; SNHI, Sensorineural Hearing Impairment, T2DM, Type Two Diabetes Mellitus.

## Data Sharing Statement

The dataset are available upon request from the corresponding author.

## Ethical Consideration

The research received scrutiny and approval from the University of Gondar, School of Medicine, College of Medicine and Health Science Institutional Review Board (IRB No. SOM/1482/2022). An official letter of permission was acquired from the University of Gondar. The study adhered to the ethical principles outlined in the Helsinki Declaration for Medical Research involving Human Subjects.<sup>62</sup> Prior to the commencement of actual data collection, formal authorization was obtained from the medical directorates of each hospital. Additionally, written informed consent was obtained from every study participant after a thorough explanation of the study's significance.

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## Author Contributions

Each author played a substantial role in the undertaken work, contributing to various aspects such as conception, study design, execution, data acquisition, analysis, and interpretation. They actively participated in drafting, revising, or critically reviewing the article and provided final approval for the version intended for publication. All authors reached a consensus on the journal to which the article was submitted and willingly commit to being accountable for all aspects of the work.

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The authors report no conflicts of interest in this work.

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