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RESEARCH ARTICLE

# Associated Tinnitus Risk Factors in Patients with Type 2 Diabetes Mellitus

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## Abstract

Tinnitus risk factors for type 2 diabetes mellitus (T2DM) are still under debate. Our study objective was to find tinnitus prevalence and principal risk factors in community-dwelling T2DM subjects. It was an analytical observational cross-sectional design study conducted from August to October 2023 at a public health center in West Jakarta. The consecutive non-random sampling method included 140 ambulatory T2DM study subjects. Tinnitus Screener and Tinnitus Handicap Inventory assessed tinnitus presence and severity. Age, sex, T2DM duration, fasting and 2-hour post-prandial blood glucose concentrations, lipid profile, blood pressure, and severity of hypertension were extracted from medical records. Data analysis was by chi-squared or Fisher exact tests, followed by multiple logistic regression analysis, with statistical significance set at $p<0.05$. The subjects' mean age was 54.71±5.33 years, and T2DM duration was 8.75±2.55 years. Tinnitus prevalence was 92 (65.17%), with 44 subjects (47.83%) having moderate tinnitus. Multivariable logistic regression findings: age (p=0.576), T2DM duration (p=0.116), total cholesterol (p=0.053), HDL-cholesterol (p=0.425), hypertension (p=0.046). Hypertension increased the risk of tinnitus by 2.289 times in T2DM subjects after adjusting for age, T2DM duration, and total and HDL cholesterol. Hypertension is the main tinnitus risk factor. The high tinnitus prevalence in our T2DM subjects requires regular screening for auditory function and control of blood pressure to minimize tinnitus risk in T2DM subjects.

**Keywords:** Community, diabetes mellitus, hypertension, risk factor, tinnitus

## Introduction

Diabetes mellitus (DM) is a serious chronic condition with characteristic hyperglycemia resulting from low blood insulin concentrations due to reduced insulin synthesis or ineffective insulin utilization.[1] Globally, over 90% of DM cases are of type 2 (T2DM).[1] According to the International Diabetes Federation (IDF) 2021 report, Indonesia occupied fifth rank, with the current 19.5 million diabetes mellitus cases being projected to increase to 28.6 million in 2045.[1] In T2DM, the hyperglycemia may result in microangiopathy causing the basement membrane of the capillaries to thicken. Microvascular changes might also occur in the inner ear, disrupting the circulation flow and resulting in the narrowing of capillaries and the loss of the outer hair cells, which are responsible for the amplification of sound entering the cochlea.[2] This may lead to degeneration of nerve cells, observable in both cochlea and the eighth cranial nerve, and atrophy of the outer hair cells in the organs of Corti, such that patients with T2DM frequently have hearing disorders, including tinnitus.[2]

Tinnitus is the uni- or bilateral occurrence of abnormal aural sounds without external sounds.[3] Little has been understood of the relationship between diabetes and tinnitus.[2] The metabolism of the inner ear depends on the oxygen and glucose supply from the blood circulation. Alterations in the glucose metabolism as a result of microangiopathy can disturb the function of the brain cells and the inner ear, which may lead to tinnitus.[2] Tinnitus prevalence in T2DM cases varies between countries from 9.2% to 26.4%.[3,4]

Several studies that have been conducted to



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determine the relationship between risk factors and the occurrence of tinnitus have shown inconsistent results. Panahi et al.,[5] Biswas et al.,[6] and Jarach et al.[7] confirmed that aging increases tinnitus prevalence. However, Oosterloo et al.[8] found that tinnitus may not be age-dependent. Mousavi et al.[3] and Dhulipalla et al.[9] showed a relationship between T2DM duration and tinnitus severity. Musleh et al.[10] reported that T2DM cases with high lipid profile showed a 2.2-fold significantly greater risk for tinnitus, whereas Lee et al.[11] determined that in the hypertriglyceridemia group, there was a 1.27-fold significant risk for tinnitus than in the non-hypertriglyceridemia group, after adjusting for other factors. Ramatsoma and Patrick[12] reported hearing loss and tinnitus were more frequently found in hypertensive than non-hypertensive adults. However, Huang et al.[13] showed that the odds of prior hypertension were similar between the groups with and without tinnitus.

Up to the present, information on prevalence and tinnitus risk factors in community-dwelling T2DM cases still needs to be improved. It is urgently required to plan essential T2DM policies to prevent tinnitus. In T2DM with chronic tinnitus, psychological or emotional effects, sleep disturbance, auditory dysfunction, and other health issues reduce the quality of life.[14] The present study aimed to determine the prevalence of tinnitus and the associated risk factors that may predict tinnitus occurrence in community-dwelling T2DM cases.

## Methods

This analytical observational cross-sectional study was conducted on ambulatory T2DM cases at a public health center in Grogol Petamburan, West Jakarta, from August to October 2023. A total of 140 patients with diabetes mellitus were collected by consecutive non-random sampling. The inclusion criteria for prospective subjects were: T2DM cases between 45–60 years old, T2DM duration >5 years, capable of good communication, and agreeing to become study subjects by giving written informed consent. The exclusion criteria were: consumption of ototoxic medications in the recent past, having neurological disorders, or having been diagnosed with inner or outer ear disease, acoustic trauma, head trauma, or chronic otitis media.

The sample size was computed using (1) the formula for an infinite (unknown) population and (2) the formula for a finite (known) population:

$$n_o = \frac{(Z\alpha^2) \times p \times q}{d^2} \quad .....(1)$$

Where $n_o$: required optimal sample size; Zα: 1.96; p: prevalence of tinnitus in diabetes mellitus = 0.09 (8); q: (1–p) = 0.91; determined degree of confidence or accuracy of measurement = 0.01; resulting in $n_o = 126$.

$$n = n_o/(1+(n_o/N)) \quad .....(2)$$

Because the number of persons with T2DM (N) at the data collection site was 568, using formula (2) and adding 15 percent of anticipated dropouts, the required sample size was 121. The final sample size was 140.

This study was approved for ethical clearance by the Research Ethics Committee of the Faculty of Medicine, Universitas Trisakti (148/KER-FK/VII/2023). Data on age, sex, T2DM duration, history of hypertension, current blood pressure, lipid profile (total cholesterol, triglycerides, HDL cholesterol, LDL cholesterol), and fasting and 2-hour post-prandial blood glucose were obtained from medical records. To differentiate between tinnitus and the normal auditory phenomenon of "transient ear noise," the Tinnitus Screener was used.[15] Tinnitus Screener results of constant or intermittent tinnitus indicate chronic tinnitus. Subsequently, the tinnitus status was determined with the Tinnitus Handicap Inventory questionnaire (Indonesian version),[16] consisting of 26 items on tinnitus status. Initially, the subject was asked to answer each item with a three-level score (yes: four scores, occasionally: two scores, and no: 0 scores). Next, all scores were summed to obtain the total score. The range of obtainable scores was 0–100. The severity of tinnitus based on the total score was categorized into slight, mild, moderate, severe, and catastrophic, corresponding to score ranges of 0–16, 18–36, 38–56, 58–76, and 78–100, respectively.

Age was categorized into <50 years and ≥50 years, sex was categorized into male and female, and T2DM duration was categorized into <8 years and ≥8 years. Lipid profile (total cholesterol, triglycerides, HDL cholesterol, and LDL cholesterol) was categorized based on the

criteria of the Third Report of the Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III, or ATP III).[17] Total cholesterol was categorized into <200 mg/dl and ≥200 mg/dl, triglyceride concentration into <150 mg/dl and ≥150 mg/dl, HDL cholesterol into <60 mg/dl and ≥60 mg/dl, and LDL cholesterol into <160 mg/dl and ≥160 mg/dl. Blood glucose categories were determined based on the criteria of the American Diabetes Association,[18] where fasting blood glucose was categorized into <120 mg/dl and ≥120 mg/dl. In contrast, 2-hour post-prandial blood glucose was categorized into <200 mg/dl and ≥200 mg/dl. The presence of hypertension was categorized into hypertension if the blood pressure was <140/90 mmHg and hypertension if the blood pressure was ≥140/90 mmHg.

Before data analysis, data cleaning was performed using consistency, range, and logical checks. The Kolmogorov-Smirnov test for all numerical variables determined the normality of data distribution. Numerical data of normal distribution were presented as mean±SD, whereas numerical data of non-normal distribution were presented as median. Categorical data were reported as number of respondents (n), percentage (%), odds ratio (OR), and 95% confidence interval (95%CI). The t-test and Mann-Whitney test were used to find differences in numerical data between the tinnitus and non-tinnitus groups. Chi-squared test and Fisher's exact test were used to determine the relationship of the categorical data of age, sex, T2DM duration, lipid profile (total cholesterol, triglycerides, HDL cholesterol, and LDL cholesterol), blood glucose (fasting and 2-hour post-prandial), and presence of hypertension accompanied by tinnitus in T2DM cases. Risk factors with a p-value of <0.2 in the Mann-Whitney U-test and independent t-test were deemed candidate variables for analysis with the multivariable logistic regression test, with the statistical significance set at $p<0.05$. Data processing was done using the SPSS statistical program version 25.

## Results

This study involved 140 T2DN cases, with a mean age of 54.71±5.33 years. The majority of subjects (78 or 55.7%) were female, with a mean T2DM duration of 8.75±2.55 years.

**Table 1 Subject Characteristics**

| Variables | Tinnitus | | p* |
|---|---|---|---|
| | Present n=92 | Absent n=48 | |
| Age (years), median (min–max) | 56 (38–70) | 52.5 (41–68) | 0.005* |
| Duration of type 2 diabetes mellitus (years) | 10 (5–15) | 7.5 (5–14) | 0.004* |
| Blood lipids (mg/dl) | | | |
| Total cholesterol | 197.5 (110–291) | 202.5 (113–303) | 0.740 |
| Triglycerides | 146.59±60.16 | 154.88±77.93 | 0.138# |
| High-density lipoprotein cholesterol | 43 (25–76) | 43 (28–80) | 0.616 |
| Low-density lipoprotein cholesterol | 110.5 (40–181) | 89.5 (39–180) | 0.121 |
| Blood glucose (mg/dl) | | | |
| Fasting | 145.5 (77–379) | 144.5 (90–458) | 0.711 |
| 2-hour post-prandial | 198 (100–437) | 187 (98–487) | 0.970 |
| Blood pressure, mean±SD (mmHg) | | | |
| Systolic | 129 (100–169) | 120 (100–160) | 0.053 |
| Diastolic | 90 (70–100) | 80 (70–100) | 0.510 |
| Severity of tinnitus, n (%) | | | |
| Slight | 7 (7.6) | | |
| Mild | 28 (30.4) | | |
| Moderate | 44 (47.8) | | |
| Severe | 13 (14.1) | | |
| Catastrophic | 0 (0) | | |

Note: *Mann-Whitney U test, #independent t-test, *significance $p<0.05$. Hypertension categories: no hypertension = blood pressure <140 mmHg/80 mmHg, hypertension = blood pressure ≥140/80 mmHg. Severity of tinnitus was measured with the Tinnitus Handicap Inventory questionnaire and categorized into slight (score ≤16), mild (18–36), moderate (38–56), severe (58–76), catastrophic (78–100)

The subjects with and without hypertension were equal, namely 70 subjects (50%) in each group. Tinnitus was found in 92 subjects (65.17%), among whom 44 subjects (47.8%) had moderate tinnitus (Table 1).

The group of respondents with tinnitus had a significantly higher median age (p<0.005) and a substantially longer duration of T2DM (p<0.004) in comparison with the group of respondents without tinnitus. No differences were found in blood lipid (total cholesterol, triglycerides, HDL cholesterol, LDL cholesterol) and blood glucose levels (fasting and 2-hour post-prandial), as well as in blood pressure (systolic and diastolic) in the tinnitus and non-tinnitus groups (Table 1).

We used the chi-squared and Fisher's exact tests to determine the risk factors meeting the conditions for inclusion in the multivariate test (Table 2). We found five variables meeting the conditions for inclusion in the multivariate test, namely age (OR=0.364, 95% CI=0.153–0.869, p=0.020), T2DM duration (OR=0.373, 95% CI=0.180–0.773, p=0.007), total cholesterol (OR=0.619, 95% CI=0.306–1.250, p=0.180), HDL cholesterol (OR=0.528, 95% CI=0.199–1.405, p=0.196), and presence of hypertension (OR=2.167, 95% CI=1.060–4.430, p=0.033).

Table 3 shows the results of the multivariable

**Table 2 Relationship of Several Risk Factors with Tinnitus in T2DM Subjects**

| Variables | Tinnitus | | p[b] | OR (95% CI) |
|---|---|---|---|---|
| | Yes n=92 (%) | No n=48 (%) | | |
| Age (years) | | | | |
| <50 | 12 (46.2) | 14 (53.8) | 0.020[@] | 0.364 (0.153–0.869) |
| ≥50 | 80 (70.2) | 34 (29.8) | | |
| Gender | | | | |
| Male | 42 (67.7) | 20 (32.3) | 0.652 | 1.176 (0.581–2.381) |
| Female | 50 (64.1) | 28 (35.9) | | |
| Type 2 diabetes mellitus duration (years) | | | 0.007[@] | 0.373 (0.180–0.773) |
| <8 | 25 (51.0) | 24 (49.0) | | |
| ≥8 | 67 (73.6) | 24 (26.4) | | |
| Total cholesterol level (mg/dl) | | | | |
| <200 | 55 (70.5) | 23 (29.5) | 0.180[@] | 0.619 (0.306–1.250) |
| ≥200 | 37 (59.7) | 25 (40.3) | | |
| Triglycerides level (mg/dl) | | | | |
| <150 | 49 (85.3) | 26 (34.7) | 0.919 | 1.037 (0.515–2.089) |
| ≥150 | 43 (66.2) | 22 (33.8) | | |
| High-density lipoprotein cholesterol level (mg/dl) | | | 0.196 | 0.528 (0.199–1.405) |
| <60 | 82 (67.8) | 39 (32.2) | | |
| ≥60 | 10 (52.6) | 9 (47.4) | | |
| Low-density lipoprotein cholesterol level (mg/dl) | | | 1.000 | 1.048 (0.299–3.673) |
| <160 | 84 (65.6) | 44 (34.4) | | |
| ≥160 | 8 (66.7) | 4 (33.3) | | |
| Fasting blood glucose level (mg/dl) | | | | |
| <126 | 26 (63.4) | 15 (36.9) | 0.712 | 1.154 (0.539–2.469) |
| ≥126 | 66 (66.7) | 33 (33.3) | | |
| 2-hour post-prandial blood glucose level (mg/dl) | | | 0.736 | 1.128 (0.559–2.277) |
| <200 | 49 (64.5) | 27 (35.5) | | |
| ≥200 | 43 (67.2) | 21 (32.8) | | |
| Hypertension | | | | |
| No hypertension | 40 (57.1) | 30 (42.9) | 0.033[@] | 2.167 (1.060–4.430) |
| Hypertension | 52 (74.3) | 18 (25.7) | | |

Note: [b]chi-squared test and Fischer's exact test; [@]p<0.2: meet conditions for inclusion in multivariable multiple logistic regression analysis, significance p<0.05

**Table 3 Results of Multivariable Logistic Regression Analysis**

| Variables | aOR | 95% CI | p |
|---|---|---|---|
| Age (years) | 1.358 | 0.465–3.971 | 0.576 |
| Type 2 diabetes mellitus duration (years) | 1.990 | 0.844–4.696 | 0.116 |
| Total cholesterol level (mg/dl) | 0.543 | 0.248–1.189 | 0.127 |
| High-density lipoprotein cholesterol level (mg/dl) | 0.652 | 0.229–1.862 | 0.425 |
| Hypertension | 2.289 | 1.015–5.163 | 0.046* |

Note: aOR: adjusted odds ratio, *significance p<0.05

multiple logistic regression analysis after adjusting for age, T2DM duration, total cholesterol, and HDL cholesterol. Hypertensive T2DM subjects had a significantly greater tinnitus risk of 2.289 times that of non-hypertensive T2DM subjects (aOR=2.289, 95% CI=1.015–5.163, p=0.046).

## Discussion

Studies on tinnitus prevalence in T2DM have previously been conducted in many countries, but only a few studies have determined tinnitus prevalence and risk factors in community-dwelling T2DM cases. More than half of o respondents (65.17%) had tinnitus (Table 1). In this study, both the prevalence and severity of tinnitus in T2DM subjects were more significant than in studies conducted in Iran and Malaysia, which found tinnitus prevalences of 26.4% and 9.1%, respectively.[3,4] The differences in prevalences between our study and those of the Iranian and Malaysian studies may have been caused by the different demographic and clinical characteristics of the study subjects.

Our study results show that younger subjects aged <50 years had a 0.364 times significantly lower risk for tinnitus than older subjects aged ≥50 years (Table 2). The mechanisms that may explain the relationship between older age and the occurrence of tinnitus are still unclear to the present. Several studies confirm that tinnitus prevalence significantly increases with increasing age.[5–7] Each increment in age by 10 years from the age of 45 years onwards raises the ORs to 1.58, 2.84, and 3.24, respectively.[5] In a general elderly population, 1 in 5 persons has tinnitus, in which participants with hearing impairment are twice as likely to have tinnitus.[8] Tinnitus is not age-dependent, even in conjunction with the age-dependent presence of hearing impairment.[8]

The National Health and Nutrition Examination Survey (NHANES) data show that an increment in hearing loss by one decibel increases the odds of tinnitus by 3% in younger persons but by 6% in older persons. NHANES indicated that aging could make individuals more vulnerable to developing tinnitus when hearing loss is present.[19] Therefore, for a specific rise in hearing loss, older persons will report more tinnitus than younger persons.[19] Because the underlying mechanisms remain unclear, it is suggested that hearing damage may accelerate brain aging, which may be the actual tinnitus factor.[20]

Unlike hearing impairment, tinnitus is probably not associated with aging processes. One possible explanation is that the pathophysiology of age-related hearing impairment is principally different from other types of hearing loss that are more likely to induce tinnitus.[21] It is certain that tinnitus and hearing impairment in older people co-occur. Still, the age-related effect of hearing impairment does not contribute to the association between hearing impairment and tinnitus.[8]

Our study results show that a T2DM duration of <8 years poses a 0.373 times significantly lower risk for tinnitus than a T2DM duration of ≥8 years (Table 2). A longer duration of suffering from T2DM is associated with an increased hazard ratio at risk of moderate or high hearing loss in comparison with non-T2DM cases (pooled multivariable-adjusted hazard ratio [HR] 1.24 [95% CI=1.10, 1.40]).[22] Other studies by Mousavi et al.[3] and Dhulipalla et al.[9] showed an association between T2DM duration of more than ten years and tinnitus.

Among the hypotheses explaining the relationship between the duration of T2DM and tinnitus, one hypothesis is that T2DM generally occurs in persons of advanced age. The longer a person has T2DM, the older that person becomes. In addition, the presence of chronic

hyperglycemia leads to a higher probability of microangiopathy as a complication of T2DM.[2] The metabolism of the inner ear depends on the oxygen and glucose supply from the blood circulation. Alterations in glucose metabolism as a result of microangiopathy in the inner ear can disturb the function of the brain cells and the inner ear, which may contribute to tinnitus.[2] Degraded hearing may exacerbate this due to neurosensory impairments that increase with age.[3] In one study, it was shown that tinnitus is not age dependent, but that aging may render a person more vulnerable to developing tinnitus when hearing loss is present.[8,19] The dependency between age and tinnitus may be due to T2DM duration because the longer the T2DM duration, the more severe the T2DM side effects.[3]

Our bivariate analysis determined that there was no significant relationship between lipid profiles in the groups with tinnitus and without tinnitus (Table 2). The development of tinnitus, hearing loss, and vertigo may be significantly influenced by high blood total cholesterol, LDL cholesterol, and triglyceride concentrations, causing blockage of the inner ear microcirculation by microthrombosis, increased blood viscosity, or altered vasomotion, ultimately resulting in reduced cochlear perfusion.[10,23] Our results differ from those of Musleh et al.[10] and Lee et al.[11] Musleh et al.[10] showed that subjects with a high lipid profile had a statistically significant two-fold risk for tinnitus (OR=2.2, p=0.024). Lee et al.[11] found that the OR of tinnitus in subjects with hypertriglyceridemia was 1.27-fold that in subjects without hypertriglyceridemia after adjusting for age, sex, hypertension, diabetes, dyslipidemia, anemia, current smoking, obesity, noise exposure, stress cognition, and depressive mood or anxiety (95% CI=1.04–1.56, p=0.022). The differences between our study and the studies of Musleh et al.[10] and Lee et al.[11] may have been caused by the respondents' dietary patterns and lifestyles, which were not investigated in the present study. However, our study did not find differences in lipid levels (total cholesterol, triglyceride, HDL cholesterol, and LDL cholesterol) between the tinnitus and non-tinnitus groups (Table 1).

The multivariate analysis of our study showed that subjects with T2DM and hypertension have a 2.289 times greater risk for tinnitus than do subjects with T2DM without hypertension (aOR=2.289, 95% CI=1.015–5.163, p=0.046). Tinnitus may more frequently occur concurrently with auditory or systemic disorders such as T2DM and hypertension.[3] The action of hypertension and T2DM on the auditory system may be explained by the assumption that high blood pressure and hyperglycemia increase blood viscosity, thereby increasing resistance to blood flow, thus depriving the tissues of oxygen.[2,4] The interference with inner ear functions may ultimately be caused by diabetes mellitus or hypertension manifesting as hyperviscosity or microangiopathy syndrome.[25]

The reported relationships of hypertension and diabetes with tinnitus have been controversial. In patients with hypertension, the probability of tinnitus increases (OR=1.46, 95%CI=1.25–1.70),[26] and the probability of hearing loss compared to patients without hypertension.[12] T2DM subjects with one and ≥2 comorbidities had significant two-fold and three-fold greater odds of tinnitus (OR=2.03, 95% CI=1.70–2.43 and OR=3.24, 95% CI=2.62–4.01, respectively) as compared with T2DM subjects without comorbidities.[5] These results are consistent with our study results; however, differing results were shown by NHANES and the Korea National Health and Nutrition Examination Survey (KNHANES),[26,27] showing that hypertension and diabetes mellitus did not increase the odds of frequent tinnitus. KNHANES analysis instead found that a history of hyperlipidemia was associated with tinnitus.[27] These contradictory study results indicate the need for prospective studies to investigate the abovementioned relationships.

In our study, the greater tinnitus prevalence in T2DM cases merits consideration because chronic tinnitus negatively impacts the quality of life of T2DM cases due to psychological or emotional effects, sleep disturbance, and auditory and health effects.[14] Tinnitus should be considered a public health problem and should be included in the planning design at all levels of care, including primary care in the community setting. Auditory function disorders must be diagnosed much earlier so that timely intervention strategies may be instituted. Screening for hearing in T2DM is essential for successful prevention. It should be performed at least every 2 years or sooner if high-risk conditions exist, such as tinnitus perception and poor speech understanding.[28] Our study results confirm that in T2DM, there is a need not only for glycemic control to prevent

complications[29] but also for screening of auditory functions because patients with T2DM are susceptible to tinnitus and hearing disorders. Impaired glucose metabolism and hypertension in patients with T2DM may cause microvascular complications in the inner ear, causing them to have more chances of hearing loss, tinnitus, and dizziness.[2,5,30]

Our study has several limitations such as (i) the cross-sectional study design that prevents the establishment of a cause-and-effect relationship between various factors and tinnitus; (ii) the Tinnitus Screener questionnaire that has not been validated for Indonesian patients and the fact that supporting examinations are still needed to confirm the diagnosis; (iii) the data on lipid and blood glucose levels that in the present study were obtained from medical records and are known to be affected by time-dependent variable dietary intakes.

Future large-scale prospective and longitudinal studies should clarify the link between lipid profiles, Hba1c, and tinnitus. The multi-causal contributing factors of tinnitus must still be studied in elderly people, presumably comprising otologic, metabolic, neurologic, psychological, and cardiovascular conditions, as well as medications.

## Conclusions

Hypertension is the most influential risk factor for tinnitus in patients with T2DM. The high prevalence of tinnitus in T2DM shows the need for routine hearing screening to detect tinnitus as early as possible. Simultaneous blood pressure and glycemic control are necessary to minimize the risk of tinnitus, particularly in patients with T2DM and comorbid hypertension.

## Conflict of Interest

The authors do not have any conflict of interest to declare.

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