Systematic review on metabolic and cardiovascular factors and their relationship to hearing loss

Revisión sistemática sobre los factores metabólicos y cardiovasculares y su relación con la pérdida de audición

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Abstract

Introduction: Hearing loss is a multifactorial condition affecting millions of people worldwide, studies suggest a link between dyslipidaemia and hearing function. Hypotheses have proposed the influence of elevated triglyceride levels which may contribute to vascular changes in the inner ear, affecting hearing. **Methodology:** A systematic review was conducted under the PRISMA guidelines, searching databases such as PubMed, Scopus, ScienceDirect and SpringerLink. We included studies published within a window of no more than seven years that analysed the relationship between triglycerides and hearing loss. **Results:** Seventeen studies were selected that indicated a significant association between dyslipidaemia and hearing loss, especially in cases of sudden hearing loss. In these studies, elevated triglyceride levels and a high triglyceride-glucose ratio (TG) were found to increase the risk of hearing loss, while elevated HDL levels appear to have a protective effect. The influence of metabolic syndrome and hypertension were also identified as being associated with an increased risk of hearing impairment. **Discussion:** The findings suggest that dyslipidaemia and metabolic factor negatively influence the inner ear microcirculation process. However, despite the methodological limitations of each study, they suggest monitoring lipid levels in the auditory relationship. **Conclusions:** Control of metabolic factors such as triglycerides and hypertension could play a key role in the prevention of hearing impairment.

Keywords: triglycerides, hearing loss, inner ear.

Resumen

Introducción: La pérdida auditiva es una condición multifactorial que afecta a millones de personas en el mundo, estudios sugieren una relación entre la dislipidemia y la función auditiva. Se han propuesto hipótesis que plantean la influencia de niveles elevados de triglicéridos lo cuales podrían contribuir a cambios vasculares en el oído interno, afectando la audición. **Metodología:** Para ello, se elaboró una revisión sistemática bajo las directrices PRISMA, con búsqueda en bases de datos como PubMed, Scopus, ScienceDirect y SpringerLink. Se incluyeron estudios publicados en una ventana no mayor a siete años de antigüedad que analizaran la relación entre triglicéridos y pérdida auditiva. **Resultados:** Se seleccionaron 17 estudios que indicaron una asociación significativa entre dislipidemia y pérdida auditiva, especialmente en casos de hipoacusia súbita. En dichos estudios, se detectó que niveles elevados de triglicéridos y un alto índice triglicéridos-glucosa (TyG) aumentan el riesgo de pérdidas en la función auditiva, mientras que niveles elevados de HDL parecen tener un efecto protector. Asimismo, también se identificó que la influencia de síndrome metabólico y la hipertensión asocian con mayor riesgo de deterioro auditivo. **Discusión:** Los hallazgos indican que la dislipidemia y el factor metabólico influyen negativamente el proceso de microcirculación del oído interno. No obstante, a pesar de las limitaciones metodológicas de cada estudio, estos apuntan llevar a cabo un monitoreo de los niveles de lípidos en la relación auditiva. **Conclusiones:** El control de factores metabólicos como los triglicéridos y la hipertensión pueden prevenir el deterioro auditivo.

Palabras clave: triglicéridos, pérdida auditiva, oído interno.

Introduction

Hearing loss is a prevalent medical condition affecting millions of people worldwide, with a multifactorial aetiology involving both genetic and environmental factors. It is estimated that in 2019, there were 1.570 billion people globally with hearing loss, equating to one in five individuals (20.3%). Of this total, 403 million had moderate or greater hearing loss, even after accounting for the use of hearing aids[1].Traditionally, hearing loss has been associated with ageing, hereditary factors, exposure to loud noises, and certain infectious diseases[2]. Additionally, other research suggests that noise-induced occupational hearing loss (ONIHL) is the most prevalent occupational disease worldwide[3]. The effects of noise exposure vary among individuals due to a complex interaction between environmental and host factors, including genetic predispositions. Similarly, it has been found that a high dietary glycaemic load (GL) and increased consumption of carbohydrates and sugars are linked to a higher risk of acute hearing loss. Furthermore, participants in the highest quartile of average glycaemic intake were found to have a 76% greater likelihood of developing hearing loss compared to those in the lowest quartile[4]. However, in recent years, various studies have begun to explore the relationship between metabolic health and auditory function, revealing associations between conditions such as dyslipidaemia and hearing loss[5]. In the same vein, an analysis of 237,028 workers found that conditions like hypertension and diabetes were associated with higher degrees of sensorineural hearing loss[6].

On the other hand, triglycerides, a type of fat found in the blood, have emerged as a particular factor of interest in relation to hearing loss. High triglyceride levels are often associated with cardiovascular diseases, diabetes, and metabolic syndrome[7]. This association is based on the hypothesis that elevated triglycerides may contribute to vascular and microvascular changes in the inner ear, affecting auditory function. Additionally, high triglycerides may be a marker of other metabolic and systemic processes that influence auditory health[8].

Therefore, it is important to understand how elevated triglycerides impact the physiology of the inner ear, a complex and delicate structure that relies on adequate blood supply to maintain its function[8]. Another aspect to consider is the microcirculation in the inner ear, which may be compromised by lipid accumulation, resulting in reduced perfusion and, ultimately, cellular damage[9].

Recent studies have indicated that dyslipidaemia and high triglyceride levels can lead to structural and functional changes in the blood vessels supplying the inner ear[10]. These changes may contribute to cochlear deterioration and subsequently cause hearing loss. Moreover, the relationship between high triglycerides and hearing loss may be associated with a state of chronic inflammation, which negatively impacts auditory health by damaging sensory and neural cells in the inner ear. This could explain the connection between dyslipidaemia and hearing loss. In this context, inflammation could be considered a critical link between lipid metabolism and auditory function[10].

It is also important to consider the intersection of hearing loss with other health conditions influenced by triglycerides. For example, diabetes and hypertension, both associated with elevated triglyceride levels, are linked to a higher risk of hearing loss. This suggests that high triglycerides may be an indicator of an adverse metabolic profile that collectively affects auditory health[11].

Finally, the importance of this review lies in investigating the relationship between high triglyceride levels and hearing loss, as this connection is not only relevant for the prevention and treatment of hearing loss but also has broader implications for public health. Early identification and management of high triglyceride levels could offer a promising avenue for preventing or mitigating hearing loss in vulnerable populations[12]. The exploration of the relationship between elevated triglycerides and hearing loss represents an emerging field of study with significant potential to improve the quality of life for individuals affected by these interrelated conditions[13].

Methodology

Overview

This systematic review was conducted using a qualitative, explanatory-analytical methodology, employing the PRISMA tool and the PICO strategy to formulate the research question. This approach allowed for a rigorous structuring of the selection and analysis of relevant scientific literature. Systematic reviews synthesise current knowledge on a topic, consolidating previous findings and identifying areas requiring further study[14]. Furthermore, they represent the highest level of evidence within the scientific hierarchy[15].

Review Process

Explicit methods were applied to locate, select, and critically evaluate relevant studies. The PRISMA tool guided the process, ensuring transparency and rigour in the planning and execution of the review[16].

Research Question

The research question was formulated using the PICO (Patient/Intervention/Comparison/Outcome) framework, a tool widely used in evidence-based medicine. This framework allowed for the definition of the study's inclusion and exclusion criteria. The PICO question focused on three components: Patient, Intervention, and Outcomes, omitting the comparison due to the nature of the study. The question is detailed in Table 1.

Table 1. PIO Question

P	Patient, Population, or Problem	Patients with metabolic and cardiovascular factors
I	Intervention	Hearing loss
C	Comparison	Not applicable
O	Outcomes	Relationship and/or association between triglycerides and hearing loss

Review Question: What is the relationship and/or association between metabolic and cardiovascular factors and hearing loss?

INCLUSION CRITERIA

To ensure the relevance and quality of the literature included in the review, the following inclusion criteria were established:

a) Articles published within the last seven years, ensuring the timeliness of the knowledge.

b) Studies that included “metabolic and cardiovascular factors” and “hearing loss” as the main variables of analysis.

c) Publications in Spanish, English, and Portuguese, ensuring access to widely disseminated literature in the scientific field.

d) Articles with free access to facilitate the replicability of the study.

e) Empirical research presenting quantifiable and verifiable results.

EXCLUSION CRITERIA

The following types of publications were excluded from the review:

a) Articles that did not address the relationship between metabolic and cardiovascular factors and hearing loss.

b) Studies published outside the seven-year timeframe.

c) Narrative reviews, previous systematic reviews, and theoretical studies without empirical data.

d) Publications not available in open access.

SEARCH STRATEGY

A systematic search strategy was implemented using keywords in Spanish, English, and Portuguese, selected from the Health Sciences Descriptors (DeCS), developed by BIREME/PAHO/WHO, derived from the Medical Subject Headings (MeSH) thesaurus used by the U.S. National Library of Medicine, ensuring a standardised classification of terms. Subsequently, search equations were constructed using Boolean operators ‘AND’ and ‘OR’, optimising the identification of relevant literature (see Table 2).

Table 2. DeCS and MeSH Descriptors

Term	DeCS	MeSH
Audiology	**Spanish:** Audiología **English:** Audiology **Portuguese**: Audiologia	Health Care Category Health Care Economics and Organizations Organizations Societies American Speech-Language-Hearing Association
Triglycerides	**Spanish:**Triglicéridos **English:** Triglycerides **Portuguese:** Triglicerídeos	Chemicals and Drugs Category Lipids Glycerides Triglycerides
Hearing	**Spanish:** Audición **English:** Hearing **Portuguese:** Audição	Psychiatry and Psychology Category Psychological Phenomena Psychophysiology Sensation Hearing
Hearing loss	**Spanish**: Pérdida auditiva **English**: hearing loss **Portuguese:** Perda de audição	Otorhinolaryngologic Diseases Ear Diseases Hearing Disorders Hearing Loss
Inner ear	**Spanish:** Inner ear **English:** Inner ear **Portuguese:** Orelha Interna	Anatomy Category Sense Organs Ear Ear, Inner

SOURCES OF INFORMATION

The searches were conducted in highly relevant databases in the biomedical and health fields, including PubMed, Scopus, Science Direct, and SpringerLink. These databases were prioritised due to their extensive coverage and methodological rigour in indexing scientific publications. Search equations were adjusted according to the criteria and structure of each database, ensuring efficient and accurate retrieval of relevant articles (see Table 3).

Table 3. Search Algorithms

N	Search Algorithms
1	(«Audiology» OR «Triglycerides» OR «Hearing» OR «Hearing Loss» OR «Inner ear») AND («Health» OR «Lipids» OR «Ear Diseases» OR «Psychological Phenomena» OR «Psychophysiology» OR «Sensation» OR «Otorhinolaryngologic Diseases» OR «Hearing Disorders») AND («Health Care Category» OR «Chemicals and Drugs Category» OR «Psychiatry and Psychology Category» OR «Anatomy Category» OR «Sense Organs» OR «Ear» OR «Glycerides» OR «Organizations» OR «Societies» OR «American Speech-Language-Hearing Association»)
2	(«Pérdida auditiva» OR «Hearing Loss» OR «Perda de audição») AND («Triglicéridos» OR «Triglycerides» OR «Triglicerídeos») AND («Salud» OR «Health» OR «Saúde»)

In this context, Table 4 presents the equation used in each selected database. This is because the designed algorithms did not yield the same amount of scientific literature across all search engines but rather varied according to the parameters and structure of each database.

Table 4. Search equations by database

Database	Equation
PubMed	(«Audiology» OR «Triglycerides» OR «Hearing» OR «Hearing Loss» OR «Inner ear») AND («Health» OR «Lipids» OR «Ear Diseases» OR «Psychological Phenomena» OR «Psychophysiology» OR «Sensation» OR «Otorhinolaryngologic Diseases» OR «Hearing Disorders») AND («Health Care Category» OR «Chemicals and Drugs Category» OR «Psychiatry and Psychology Category» OR «Anatomy Category» OR «Sense Organs» OR «Ear» OR «Glycerides» OR «Organizations» OR «Societies» OR «American Speech-Language-Hearing Association»)
Scopus	(«Audiology» OR «Triglycerides» OR «Hearing» OR «Hearing Loss» OR «Inner ear») AND («Health» OR «Lipids» OR «Ear Diseases» OR «Psychological Phenomena» OR «Psychophysiology» OR «Sensation» OR «Otorhinolaryngologic Diseases» OR «Hearing Disorders») AND («Health Care Category» OR «Chemicals and Drugs Category» OR «Psychiatry and Psychology Category» OR «Anatomy Category» OR «Sense Organs» OR «Ear» OR «Glycerides» OR «Organizations» OR «Societies» OR «American Speech-Language-Hearing Association»)
Science Direct	(«Pérdida auditiva» OR «Hearing Loss» OR «Perda de audição») AND («Triglicéridos» OR «Triglycerides» OR «Triglicerídeos») AND («Salud» OR «Health» OR «Saúde»)
SpringerLink	(«Audiology» OR «Triglycerides» OR «Hearing» OR «Hearing Loss» OR «Inner ear») AND («Health» OR «Lipids» OR «Ear Diseases» OR «Psychological Phenomena» OR «Psychophysiology» OR «Sensation» OR «Otorhinolaryngologic Diseases» OR «Hearing Disorders») AND («Health Care Category» OR «Chemicals and Drugs Category» OR «Psychiatry and Psychology Category» OR «Anatomy Category» OR «Sense Organs» OR «Ear» OR «Glycerides» OR «Organizations» OR «Societies» OR «American Speech-Language-Hearing Association»)

DATA COLLECTION

The selection process was carried out in several stages. Initially, two independent review teams conducted a critical assessment of titles and abstracts to identify studies that met the inclusion criteria. Subsequently, the selected articles were reviewed in full, extracting key information on methodology, study population, main results, and significant findings. For data systematisation, a data collection matrix was created in Microsoft Excel, which included the following fields: a) Study title, b) Author(s), c) Year of publication, d) Methodological design, e) Variables analysed, and f) Main results. This matrix allowed for the organisation of information, comparison of studies, assessment of methodological quality, and identification of gaps in literature. Additionally, meetings were held between the review teams to consolidate the information and resolve any discrepancies in the selection and analysis of the studies.

Results

This section presents the study selection carried out under pre-established and rigorous criteria. To ensure a systematic and transparent approach, specific search equations were used (see Table 4), which facilitated the identification and selection of relevant studies from scientific databases. The selection process followed the PRISMA flow diagram (Figure 1), covering the phases of identification, screening, preliminary selection, and final inclusion. Table 6 shows the main characteristics of the studies included in the review.

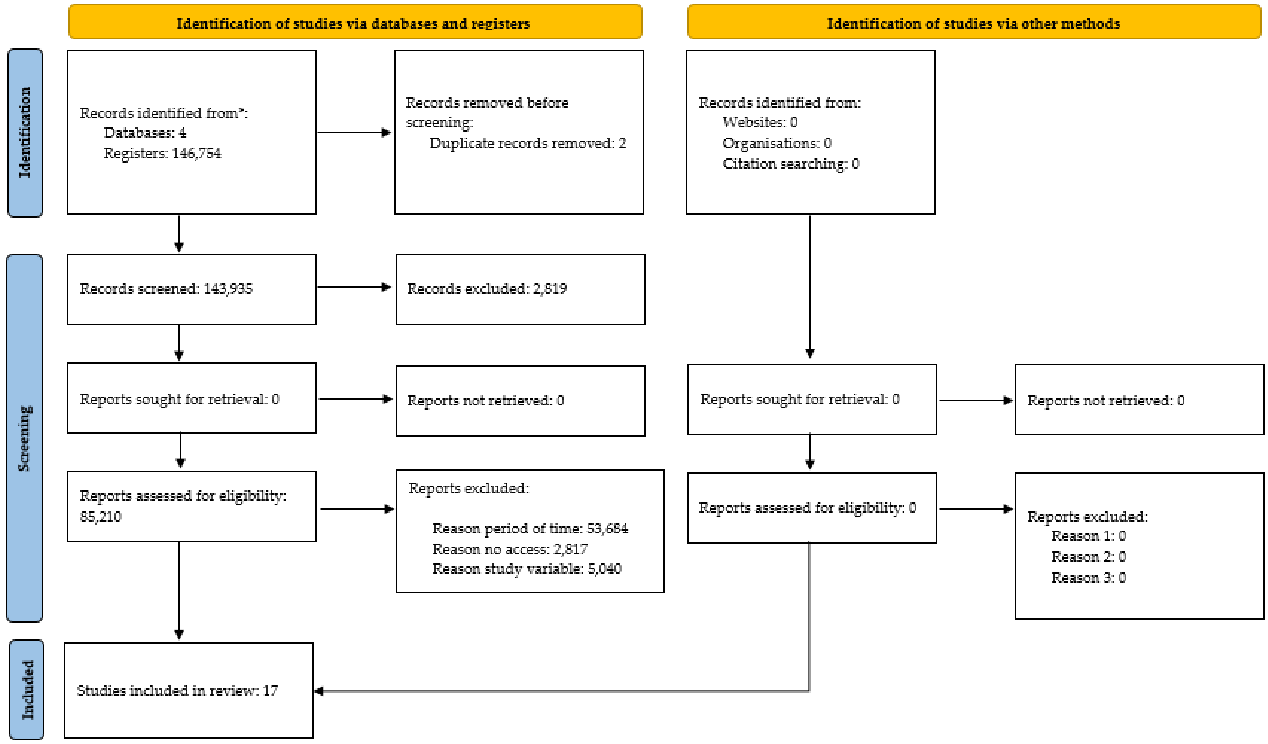
Study Selection

The document search yielded a total of 146,754 records. Of these, 71,139 met the initial selection criteria, while 53,684 were excluded due to document type, time period, or other reasons. In PubMed, 17,487 records were identified, of which 15,685 were considered valid. However, 1,236 were discarded for not meeting the established time period, 195 due to lack of access, 2 for being reviews, incomplete texts, or duplicates, and 357 for not meeting variable criteria. Ultimately, only 12 documents were selected for the sample. In Science Direct, 1,508 records were found, of which 1,196 were considered valid. A total of 121 were excluded due to document type, 110 for lack of access, and 77 for not meeting variable criteria, resulting in the selection of 4 documents. Scopus was the database with the highest number of records, reaching 40,348. However, only 6,475 were valid, while 27,649 were discarded due to document type, 2,512 for time period, and 3,712 for not meeting variable criteria. After applying the filters, no documents were selected for the final sample. On the other hand, SpringerLink presented the largest volume of records, with 87,411 in total. Of these, 47,783 met the initial selection criteria. However, 24,678 were excluded due to document type and 894 for not meeting variable criteria. In the end, only 1 document was included in the sample. During the identification phase, a total of 146,754 records were retrieved from various databases. After applying the exclusion criteria, a final sample of 17 studies was obtained. Firstly, 61,543 records were removed due to reasons such as incomplete or duplicate texts, lack of access to the full document, non-compliance with variable selection criteria, and other methodological or quality issues (see Table 5).

Table 5. Summary of Identified and Selected Documents

Database	Total Found	Document Type	Time Period	No Access	Reviews/Incomplete Texts/ Duplicates	Non-compliance with Variable Criteria	Total Sample
PubMed	17,487	15,685	1,236	195	2	357	12
Science Direct	1,508	1,196	121	110	0	77	4
Scopus	40,348	6,475	27,649	2,512	0	3,712	0
SpringerLink	87,411	47,783	24,678	0	0	894	1
Total	146,754	71,139	53,684	2,817	2	5,04	17

Figure 1. Flow Diagram



Source: [17]

The study selection process is represented in the PRISMA flow diagram (Figure 1), which shows each stage of the procedure, from the identification of records in databases to the final selection of studies included in the review.

CHARACTERISTICS OF THE STUDIES

Table 6 presents the selected studies that explore the relationship between various metabolic and cardiovascular factors and hearing loss, particularly sudden sensorineural hearing loss (SSNHL) and age-related hearing loss.

Table 6. Selected Studies

n	Title	Authors	Year	Findings
1	Identification of dyslipidemia as a risk factor for sudden sensorineural hearing loss: A multicentre case-control study	Li X, Chen B, Zhou X, Ye F, Wang Y, Hu W.	2021	The study found an association between blood lipid levels and the incidence and prognosis of sudden sensorineural hearing loss (SSNHL).
2	Correlation between hearing impairment and the Triglyceride Glucose Index: based on a national cross-sectional study	Liu L, Qin M, Ji J, Wang W.	2023	The study identified a positive correlation between the Triglyceride Glucose Index (TyG) and the prevalence of hearing impairment (HI). Additionally, it was found that participants with a higher TyG index have a greater risk of hearing loss, particularly at high frequencies.
3	Serum lipid metabolism characteristics and potential biomarkers in patients with unilateral sudden sensorineural hearing loss	Chen X, Zheng Z, Xie D, Xia L, Chen Y, Dong H, Feng Y.	2021	The study found that patients with sudden sensorineural hearing loss across all frequencies exhibited elevated levels of glycerolipids, glycerophospholipids, and sphingolipids, along with pronounced metabolic abnormalities in glycerophospholipids, which may have contributed to the pathogenesis. Furthermore, sphingolipids and plasmalogens were associated with the level of hearing improvement.
4	Association Between Metabolic Syndrome and Hearing Impairment: a Study on 200 Subjects	Sahni H, Bhagat S, Bhatia Q, Singh P, Chawla S, Kaur A.	2023	The study demonstrated that individuals with a higher number of metabolic syndrome components (e.g., 4 or 5) were more likely to have hearing loss. Additionally, hearing impairment was significantly associated with higher triglycerides, elevated fasting glucose, and higher blood pressure.
5	Lipid Profile in Patients with Sensorineural Hearing Loss - One Year Observational Study in a Tertiary Care Centre	Mudhol RS, Patwegar A.	2019	Serum levels of low-density lipoprotein were directly correlated with the severity of sensorineural hearing loss, while serum levels of high-density lipoprotein were negatively correlated with the severity of sensorineural hearing loss in both sexes, but not significantly.
6	Traditional and non-traditional lipid parameters as risk factors for sudden sensorineural hearing loss	Chen X, Zheng Z, Liu X, Huang J, Xie D, Feng Y.	2018	The study found that patients with sensorineural hearing loss exhibited markedly dysregulated lipid metabolism. Additionally, it indicated that elevated serum lipid levels may be a causal factor in hearing impairment and could influence the degree of hearing loss. It is also suggested that rapid improvement in cochlear microcirculation may benefit patients with elevated total cholesterol levels.
7	Association between Serum Lipid Levels and Sensorineural Hearing Loss in Korean Adult Population	Jung W, Kim J, Cho IY, Jeon KH, Song YM.	2022	The study found that higher levels of HDL-C (high-density lipoprotein cholesterol) are associated with a lower risk of high-frequency hearing loss in the Korean adult population, supporting the idea that impaired microcirculation in the inner ear could be an underlying mechanism for high-frequency hearing loss (HF-HL).
8	Lipids and sudden sensorineural hearing loss: A bidirectional two-sample Mendelian randomisation analysis	Pu K, Li L, Qiu Y, Song H.	2024	The study indicated that reduced serum HDL-C (cholesterol) levels are an independent risk factor for the onset of sudden sensorineural hearing loss (SSNHL). Additionally, it suggested that monitoring and focusing on lipid levels could be valuable for the prevention and treatment of SSNHL.
9	L–shaped association of triglyceride glucose index and sensorineural hearing loss: results from a cross-sectional study and Mendelian randomisation analysis	Rey Y, Liu H, Nie X, Lu N, Yan S, Wang X, Zhao Y.	2024	The study provided evidence of a non-linear relationship between the TyG index, fasting glucose, and SNHL, suggesting that controlling glucose and triglyceride levels could be crucial for preventing sensorineural hearing loss.
10	Association Between Triglyceride-Glucose Index and Hearing Threshold Shifts of Adults in the United States: National Health and Nutrition Examination Survey, 2015–2016	Pan JY, Chen Y, Lin ZH, Lv B, Chen L, Feng SY.	2024	The study found that the Triglyceride Glucose Index (TyG) has a U-shaped relationship with hearing thresholds at speech frequencies. This suggests that both very low and very high TyG indices may be associated with an increased risk of hearing loss. It concludes that maintaining a balanced TyG index is important for effective hearing health management.
11	Association of metabolic syndrome and its components with hearing loss in low-income women: A population-based cross-sectional study	Xu Y, Wang G, Wang M, Guo S, Tu J, Wang J, Ning X, Li D, Yang D.	2024	The study found that factors such as hypertension, hyperglycaemia, age, education level, BMI, smoking, and alcohol consumption may influence hearing loss in low-income women.

12	Cochleovestibular dysfunction in patients with diabetes mellitus, systemic arterial hypertension, and dyslipidaemia	Chávez-Delgado ME, Vázquez-Granados I, Rosales-Cortés M, Velasco-Rodríguez V.	2019	The study identified that factors such as age, duration of chronic complex health conditions (CCHC), number of comorbidities, and certain lifestyles may significantly influence cochleovestibular dysfunction (simultaneous impairment of auditory (cochlea) and vestibular (balance) functions of the inner ear) in patients with complex chronic diseases.
13	Relationship Between Hypertension and Hearing Loss: Analysis of the Related Factors	Hou Y, Liu B.	2024	The study found a correlation between hypertension and hearing loss. It identified that vascular damage contributes to hypertension-related hearing loss. Therefore, it recommends paying greater attention to the impact of hypertension on auditory function in clinical practice.
14	Hearing loss, tinnitus, and hypertension: analysis of the baseline data from the Brazilian Longitudinal Study of Adult Health (ELSA-Brasil)	Samelli AG, Santos IS, Miguel FYO, Padilha M, Gomes RF, Moreira R, Bensenor IM, Lotufo PA.	2021	The study detected those participants with hypertension initially showed worse hearing thresholds and a higher prevalence of tinnitus. However, the results were not significant after adjusting for factors such as age, sex, and the presence of diabetes. Additionally, it suggested that hearing loss and tinnitus in individuals with hypertension may be more related to age and other risk factors than to hypertension itself.
15	The potential relationship between uric acid and the recovery in sudden sensorineural hearing loss	Zhou Y, Wen J, Yang Z, Zeng R, Gong W, Jing Q.	2023	The study indicated that hyperuricaemia could be an independent risk factor for hearing recovery in patients with sudden sensorineural hearing loss. Additionally, it mentioned that serum uric acid and initial hearing thresholds possibly affected auditory outcomes in men and women with sensorineural hearing loss.
16	ELSA-Brasil: a 4-year incidence of hearing loss in adults with and without hypertension	Padilha FYO, Oenning NSX, Santos IS, Rabelo CM, Moreira RR, Bensenor IM, Lotufo PA, Samelli AG.	2022	The study found no significant association between hypertension and hearing loss after adjusting for multiple risk factors. However, it observed that adults over 60 years of age have a higher relative risk of hearing loss.
17	Association Between Hypertension and Hearing Loss	Nawaz MU, Vinayak S, Rivera E, Elahi K, Tahir H, Ahuja V, Jogezai S, Maher W, Naz S.	2021	The study found that hypertension (HTN) is positively correlated with hearing loss. Additionally, it mentioned that long-term hypertensive patients should be regularly assessed to determine the status of their hearing abilities.

The analysed studies explore the association between blood lipid levels, the triglyceride-glucose index (TyG), hypertension, diabetes, and other metabolic factors with hearing loss. Several studies, such as those by Li et al.[18] and Chen et al.[19], identified that elevated levels of lipids, such as glycerolipids and sphingolipids, are associated with an increased risk of SSNHL (sudden sensorineural hearing loss) and may influence the prognosis of hearing recovery. Additionally, it was found that high-density lipoprotein cholesterol (HDL-C) levels are inversely related to the risk of hearing loss, which is associated with a protective role of HDL-C Jung et al.[9] Pu et al.[20].

The TyG index, which combines triglyceride and glucose levels, has also been linked to hearing loss. Studies such as those by Liu et al.[21] and Pan et al.[22] indicate that a high TyG index is associated with an increased risk of hearing loss, particularly at high frequencies. However, a U-shaped relationship has also been observed, where both very low and very high TyG levels may increase the risk of hearing loss Pan et al.[22].

Hypertension and other metabolic conditions, such as diabetes, have also been associated with hearing loss. Studies such as those by Hou and Liu[21] and Samelli et al.[23] indicate that vascular damage caused by hypertension may contribute to hearing loss, although some studies did not find a significant association after adjusting for factors such as age and sex Padilha et al.[24]. Additionally, hyperuricemia has been observed to be an independent risk factor for hearing recovery in patients with SSNHL Zhou et al.[25].

On the other hand, Table 7 presents the methodological information of the selected studies, which included the study design, sample size, measurement of triglyceride levels, glucose, hypertension, and other metabolic factors, sensorineural hearing loss, study limitations, and statistical treatment.

Table 7. Methodological details of the studies.

n	Title	Authors	Sample Size	Measurement of Metabolic Factors	Auditory Measurement	Correlation or Association Test	Result	Study Limitations
1	Identification of Dyslipidaemia as a Risk Factor for Sudden Sensorineural Hearing Loss: A Multicentre Case-Control Study	Li X, Chen B, Zhou X, Ye F, Wang Y, Hu W.	2,397 men and 2,179 women	Fasting Lipid Profile	Pure-Tone Audiometry	Chi-Square	Positive association between blood lipid levels and sensorineural hearing loss	No long-term evaluations were conducted to observe if dyslipidaemia affected hearing recovery over time
2	Correlation Between Hearing Impairment and the Triglyceride Glucose Index: Based on a National Cross-Sectional Study	Liu L, Qin M, Ji J, Wang W.	10,906 patients (5,313 men and 5,593 women)	Fasting Blood Glucose; Fasting Lipid Profile	Audiometry	Chi-Square	Positive association between triglyceride levels and sensorineural hearing loss	Cross-sectional design without follow-up
3	Serum Lipid Metabolism Characteristics and Potential Biomarkers in Patients with Unilateral Sudden Sensorineural Hearing Loss	Chen X, Zheng Z, Xie DY, Xia L, Chen Y, Dong H, Feng Y.	60 patients (31 men and 29 women)	Fasting Lipid Profile	Audiometry	Chi-Square	Positive association between triglyceride levels and sensorineural hearing loss	Small sample size
4	Association Between Metabolic Syndrome and Hearing Impairment: A Study on 200 Subjects	Sahni H, Bhagat S, Bhatia Q, Singh P, Chawla S, Kaur A.	200 patients (129 men and 71 women)	Fasting Lipid Profile	Pure-Tone Audiometry; Tympanometry; Otoacoustic Emissions	Spearman's Correlation	Positive correlation between triglyceride levels and sensorineural hearing loss	Cross-sectional design without follow-up
5	Lipid Profile in Patients with Sensorineural Hearing Loss - One Year Observational Study in a Tertiary Care Centre	Mudhol RS, Patwegar A.	58 patients (gender not specified)	Fasting Lipid Profile	Pure-Tone Audiometry	Pearson's Correlation	Negative correlation between triglyceride levels and hearing loss	Small sample size
6	Traditional and Non-Traditional Lipid Parameters as Risk Factors for Sudden Sensorineural Hearing Loss	Chen X, Zheng Z, Liu X, Huang J, Xie D, Feng Y.	452 patients (gender not specified)	Fasting Lipid Profile	Pure-Tone Audiometry	Spearman's Correlation and Chi-Square	Positive correlation between triglyceride levels and sensorineural hearing loss	No significant limitations
7	Association Between Serum Lipid Levels and Sensorineural Hearing Loss in Korean Adult Population	Jung W, Kim J, Cho IY, Jeon KH, Song YM.	10,356 patients (4,509 men and 5,874 women)	Fasting Lipid Profile	Pure-Tone Audiometry	Chi-Square	Negative (inverse) association between triglyceride levels and sensorineural hearing loss	Different methods used to measure LDL-C
8	Lipids and Sudden Sensorineural Hearing Loss: A Bidirectional Two-Sample Mendelian Randomisation Analysis	Pu K, Li L, Qiu Y, Song H.	1,491 cases of hearing loss and 196,593 controls	Blood Test Records	Medical Records	Spearman's Correlation	Negative (inverse) correlation between triglyceride levels and sensorineural hearing loss	Observational design
9	L–Shaped Association of Triglyceride Glucose Index and Sensorineural Hearing Loss: Results from a Cross-Sectional Study and Mendelian Randomisation Analysis	Rey Y, Liu H, Nie X, Lu N, Yan S, Wang X, Zhao Y.	1,851 patients (891 men and 960 women)	Enzymatic Assays	Pure-Tone Audiometry	Chi-Square	Positive association between triglyceride and glucose levels with sensorineural hearing loss	Cross-sectional design without follow-up
10	Association Between Triglyceride-Glucose Index and Hearing Threshold Shifts of Adults in the United States: National Health and Nutrition Examination Survey, 2015–2016	Pan JY, Chen Y, Lin ZH, Lv B, Chen L, Feng SY.	1,226 cases of hearing loss (549 men and 677 women)	Enzymatic Assay Records	Medical Records	Spearman's Correlation	Positive correlation between triglyceride and glucose levels with sensorineural hearing loss	Limitations in the database used
11	Association of Metabolic Syndrome and Its Components with Hearing Loss in Low-Income Women: A Population-Based Cross-Sectional Study	Xu Y, Wang G, Wang M, Guo S, Tu J, Wang J, Ning X, Li X, Yang D.	1,448 women	Fasting Lipid Profile	Pure-Tone Audiometry and Otoscopy	Chi-Square	No association between triglyceride levels and sensorineural hearing loss	Cross-sectional design without follow-up

12	Cochleovestibular Dysfunction in Patients with Diabetes Mellitus, Systemic Arterial Hypertension, and Dyslipidaemia	Chávez-Delgado ME, Vázquez-Granados I, Rosales-Cortés M, Velasco-Rodríguez V.	385 patients (216 women and 169 men)	Fasting Lipid Profile and Enzymatic Assays	Pure-Tone Audiometry and Otoscopy	Chi-Square	Positive association between triglyceride and glucose levels with sensorineural hearing loss	Cross-sectional design without follow-up
13	Relationship Between Hypertension and Hearing Loss: Analysis of the Related Factors	Hou Y, Liu B.	517 patients (303 men and 214 women)	Fasting Lipid Profile	Pure-Tone Audiometry and Otoscopy	Chi-Square	Positive association between triglyceride and glucose levels with sensorineural hearing loss	Observational design
14	Hearing Loss, Tinnitus, and Hypertension: Analysis of the Baseline Data from the Brazilian Longitudinal Study of Adult Health (ELSA-Brasil)	Samelli AG, Santos IS, Miguel FYO, Padilha M, Gomes RF, Moreira R, et al.	900 patients (425 men and 475 women)	Fasting Lipid Profile	Pure-Tone Audiometry; Acoustic Immittance Measurements	Chi-Square	No association between hypertension and hearing loss	Cross-sectional design without follow-up
15	The Potential Relationship Between Uric Acid and the Recovery in Sudden Sensorineural Hearing Loss	Zhou Y, Wen J, Yang Z, Zeng R, Gong W, Jing Q.	520 patients (294 men and 226 women)	Fasting Lipid Profile	Pure-Tone Audiometry	Pearson's and Spearman's Correlation	Positive correlation between dyslipidaemia and sensorineural hearing loss	Data based on previous records
16	ELSA-Brasil: A 4-Year Incidence of Hearing Loss in Adults With and Without Hypertension	Padilha FYOM, Oenning NSX, Santos IS, Rabelo CM, Moreira RR, Bensenor IM, et al.	595 patients (297 men and 379 women)	Fasting Lipid Profile	Pure-Tone Audiometry; Verbal Audiometry; Audiological Anamnesis; Acoustic Immittance Measurements	Chi-Square	No association between hypertension and sensorineural hearing loss	Limitations in hypertension measurement
17	Association Between Hypertension and Hearing Loss	Nawaz MU, Vinayak S, Rivera E, Elahi K, Tahir H, Ahuja V, et al.	600 individuals (359 men and 241 women)	Systolic and Diastolic Blood Pressure Examination	Pure-Tone Audiometry	Chi-Square	Positive association between hypertension and sensorineural hearing loss	Cross-sectional design without follow-up

Regarding design and sample, most studies present a cross-sectional approach, meaning they do not include long-term follow-up to assess changes in the analysed variables. Sample sizes vary widely, ranging from 58 to 10,906 participants, with differences in gender distribution, which in some cases is specified and in others is not. For example, Liu et al.[21] included a sample of 10,906 patients, while the study by Mudhol and Patwegar[26] had only 58 participants.

Concerning the measurement of triglyceride and glucose levels, most studies used a fasting lipid profile test. Additionally, some studies relied on enzymatic assays or medical records to obtain these values. For instance, the study by Pu et al.[20] used medical records as a source of information to determine triglyceride levels.

For auditory assessment, pure-tone audiometry is the most used test to determine the presence of hearing loss. However, some studies complement this assessment with tympanometry, otoacoustic emissions, and acoustic immittance measurements. An example of this methodological combination is the study by Sahni et al.[27], which employed pure-tone audiometry, tympanometry, and otoacoustic emissions.

Among the most used statistical tests to evaluate the association between variables are the Chi-square test, Spearman's correlation, and Pearson's correlation. For example, the study by Mudhol and Patwegar[26] used Pearson's correlation, while that of Sahni et al.[27] used Spearman's correlation.

Regarding the correlation and association between triglyceride levels and sensorineural hearing loss, most studies report a positive relationship. However, some studies, such as that of Jung et al.[9], identified a negative association, while others, such as that of Xu et al.[28], found no statistically significant relationship.

Finally, among the main limitations of the analysed studies is the cross-sectional design, which does not allow for the establishment of causal relationships or the assessment of changes over time. Similarly, the small sample size in some studies hinders the generalisation of the results. A representative case is the study by Chen et al.[19], which included only 60 participants, limiting the extrapolation of its findings.

Dyslipidaemia and Hearing Loss

Dyslipidaemia, characterised by elevated levels of LDL cholesterol, triglycerides, and total cholesterol, has been identified as a significant risk factor for hearing loss[29]. Li et al.[18] demonstrated that patients with dyslipidaemia had a 2.5 times higher risk of developing SSNHL (sudden sensorineural hearing loss) compared to those without dyslipidaemia (OR: 2.5; 95% CI: 1.8–3.4). Furthermore, LDL cholesterol and triglyceride levels were significantly higher in patients with SSNHL (147.3 mg/dL and 178.6 mg/dL, respectively) compared to controls (112.4 mg/dL and 123.7 mg/dL). These findings align with the results of Chen et al.[19], who reported elevated levels of total cholesterol (5.23 ± 0.98 mmol/L) and triglycerides (1.89 ± 0.54 mmol/L) in patients with SSNHL, in contrast to controls (4.12 ± 0.76 mmol/L and 1.12 ± 0.41 mmol/L, respectively).

Additionally, Mudhol and Patwegar[26] observed that 65% of patients with hyperlipidaemia presented with moderate to severe hearing loss, compared to only 30% in patients with normal lipid profiles. These findings highlight that hyperlipidaemia not only increases the risk of hearing loss but is also associated with greater severity of hearing impairment. The relationship between elevated lipid levels and hearing loss appears to be independent of other risk factors, such as age and gender[30]. Although patients over 50 years of age and men showed a higher prevalence of lipid abnormalities associated with hearing loss Mudhol & Patwegar[26].

Insulin Resistance and Hearing Loss

Insulin resistance, measured using the triglyceride-glucose (TyG) index, has emerged as an important risk factor for hearing loss[31]. Liu et al.[21] found that participants with a higher TyG index (≥ 9.0) had a hearing loss prevalence of 22.5%, compared to only 14.3% in those with a lower TyG index (< 8.5). Moreover, the risk of moderate or severe hearing loss was 1.8 times higher in individuals with an elevated TyG index. This finding was supported by Pan et al.[22], who reported that a one-unit increase in the TyG index was associated with a 15% increase in the risk of hearing loss.

A recent study[32] also identified an L-shaped association between the TyG index and hearing loss, where the risk increased significantly when the TyG index exceeded a specific threshold. Participants in the 75th percentile or higher of the TyG index had a 40% higher risk of developing hearing loss compared to those in the 25th percentile or lower, indicating that insulin resistance and metabolic dysfunction play a significant role in the pathogenesis of hearing loss, particularly in individuals with obesity or metabolic syndrome[13].

Metabolic Syndrome and Hearing Loss

Metabolic syndrome, which includes components such as obesity, hypertension, dyslipidaemia, and insulin resistance, has been strongly associated with hearing loss. Sahni et al.[27] found that 62% of patients with metabolic syndrome presented with some degree of hearing loss, compared to a much lower prevalence in those without metabolic syndrome. Furthermore, individual components of metabolic syndrome, such as abdominal obesity and hypertension, showed a particularly strong association with hearing loss. For example, abdominal obesity increased the risk of hearing loss by 45% (OR: 1.45, 95% CI: 1.20–1.75), while hypertension increased it by 38% (OR: 1.38, 95% CI: 1.15–1.65) (Xu et al., 2024). In women with metabolic syndrome, the prevalence of hearing loss was 32.5%, compared to 18.7% in women without metabolic syndrome. Additionally, advanced age and low socioeconomic status exacerbated this association, with a prevalence of 42.3% in women over 50 years of age with metabolic syndrome[28].

Hypertension and Hearing Loss

Hypertension has been consistently associated with a higher risk of hearing loss. Hou and Liu (2024) found that patients with hypertension had a hearing loss prevalence of 42.5%, compared to only 28.3% in individuals without hypertension. Moreover, the duration of hypertension was a critical factor in hearing impairment, with an incidence of 58.7% in patients who had hypertension for more than 10 years, compared to 35.2% in those with less than 5 years of diagnosis. Blood pressure control also played an important role. Patients with poorly controlled hypertension (systolic blood pressure > 140 mmHg) had a 2.3 times higher risk of developing hearing loss compared to those with well-controlled blood pressure[33].

Clinical Implications

The findings of these studies have significant clinical benefits. First, they suggest that managing metabolic risk factors such as dyslipidaemia, insulin resistance, and hypertension may be important for preventing hearing loss. For example, controlling LDL cholesterol and triglyceride levels, as well as reducing the TyG index, could be effective strategies for reducing the risk of hearing loss[34].

Second, these findings highlight the need for regular monitoring and check-ups in patients with metabolic disease, particularly in those with metabolic syndrome or uncontrolled hypertension. For instance, the prevalence of hearing loss in patients with metabolic syndrome is 62%, which justifies the implementation of early screening in this population.

Finally, these findings could influence the development of preventive and therapeutic interventions to improve metabolic and auditory health. For example, a comprehensive management programme for metabolic syndrome, including lifestyle changes, blood pressure control, and lipid management, could have a significant impact on preventing hearing loss.

Limitations and Future Research

Although this review provides valuable evidence, it is important to acknowledge its limitations. Many of these studies are cross-sectional, which limits our ability to establish causal relationships. Additionally, most studies were conducted in specific populations, which may limit the generalisability of the results. Future research should include longitudinal and clinical studies to establish causal relationships and evaluate the effectiveness of interventions aimed at improving metabolic and auditory health.

Conclusions

Patients with high LDL cholesterol and triglyceride levels have a 2.5 times higher risk of developing hearing loss. Furthermore, 65% of patients with hyperlipidaemia present with moderate to severe hearing loss, compared to 30% in individuals with normal lipid levels.

Individuals with a high TyG index (≥ 9.0) have a hearing loss prevalence of 22.5%, compared to 14.3% in those with a low TyG index (< 8.5). Each one-unit increase in the TyG index increases the risk of hearing loss by 15%.

62% of patients with metabolic syndrome present with hearing loss, compared to a much lower prevalence in those without metabolic syndrome. In women with metabolic syndrome, the prevalence is 32.5%, rising to 42.3% in those over 50 years of age.

Patients with hypertension have a hearing loss prevalence of 42.5%, compared to 28.3% in individuals without hypertension. Those with poorly controlled hypertension have a 2.3 times higher risk of developing hearing loss.

Controlling metabolic risk factors can prevent hearing loss. Measures such as lipid management, reducing insulin resistance, blood pressure control, and a comprehensive approach to metabolic syndrome are key strategies for reducing the risk of hearing loss, particularly in older populations and those with chronic conditions.

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References

1. Haile LM, Kamenov K, Briant PS, Orji AU, Steinmetz JD, Abdoli A, et al. Hearing loss prevalence and years lived with disability, 1990-2019: Findings from the Global Burden of Disease Study 2019. Lancet. 2021;397(10278):996–1009.

2. Chen KH, Su S Bin, Chen KT. An overview of occupational noise-induced hearing loss among workers: epidemiology, pathogenesis, and preventive measures. Environ Health Prev Med. 2020;25(1):1–10.

3. Sheffield AM, Smith RJH. The epidemiology of deafness. Cold Spring Harb Perspect Med. 2019;9(9):1–15.

4. Gopinath B, Flood VM, McMahon CM, Burlutsky G, Brand-Miller J, Mitchell P. Dietary glycemic load is a predictor of age-related hearing loss in older adults. J Nutr [Internet]. 2010;140(12):2207–12. Available from: https://doi.org/10.3945/jn.110.128462

5. Barcelos FVL, Paiva KM de, Machado MJ, Haas P. Auditory Changes in Occupational Health Associated With Metabolic Diseases in Adult Workers. Am J Lifestyle Med. 2024;0(0):1–15.

6. Kim KS, Choi SH. Cardiometabolic diseases according to the type and degree of hearing loss in noise-exposed workers. Ann Occup Environ Med. 2024;36(1):1–11.

7. Fernández-Travieso JC. Síndrome Metabólico y Riesgo Cardiovascular. Postpy Chir. 2016;

8. Martín Villares C, San Román Carbajo J, Domínguez Calvo J, Fernández Pello ME, Pomar Blanco P, Tapia Risueño M. Perfil lipídico de la sordera ligada al envejecimiento. Nutr Hosp. 2005;20(1):52–7.

9. Jung W, Kim J, Cho IY, Jeon KH, Song YM. Association between Serum Lipid Levels and Sensorineural Hearing Loss in Korean Adult Population. Korean J Fam Med. 2022;43(5):334–43.

10. Trune DR, Nguyen-Huynh A. Vascular pathophysiology in hearing disorders. Semin Hear. 2012;33(3):242–50.

11. Ding S, Liu Y, Duan T, Fang P, Tong Q, Li H, et al. Mendelian Randomization Reveals: Triglycerides and Sensorineural Hearing Loss. Bioengineering. 2024;11(5):1–12.

12. Silky S, Singh V, Gupta DK, Chaudhary AK, Yadav R, Kumar R, et al. A Study of Relationship Between Serum Lipids and Sensorineural Hearing Loss. Indian J Otolaryngol Head Neck Surg [Internet]. 2023;75(s1):578–83. Available from: https://doi.org/10.1007/s12070-023-03657-w

13. Díaz M, Díaz S. Relación entre síndrome metabólico, enfermedades metabólicas e hipoacusia: una revisión sistemática con metaanálisis. 2023;1125–42.

14. Manterola C, Astudillo P, Arias E, Claros N. Revisiones sistemáticas de la literatura. Qué se debe saber acerca de ellas. Cir Esp. 2013;91(3):149–55.

15. Moreno B, Muñoz M, Cuellar J, Domancic S, Villanueva J. Revisiones Sistemáticas: definición y nociones básicas. Rev clínica period-

oncia, Implantol y Rehabil oral. 2018;11(3):184–6.

16. Barquero Morales WG. Analisis De Prisma Como Metodología Para Revisión Sistemática: Una Aproximación General. Saúde em Redes. 2022;8(sup1):339–60.

17. Moher D, Liberati A, Tetzlaff J AD. PRISMA 2020 Diagrama de Flujo. Gr Prism. 2020;

18. Li X, Chen B, Zhou X, Ye F, Wang Y, Hu W. Identification of dyslipidemia as a risk factor for sudden sensorineural hearing loss: A multicenter case-control study. J Clin Lab Anal. 2021;35(12):1–6.

19. Chen X, Zheng Z, Liu X, Huang J, Xie D, Feng Y. Traditional and nontraditional lipid parameters as risk factors for sudden sensorineural hearing loss. Braz J Otorhinolaryngol [Internet]. 2024;90(4):101435. Available from: https://doi.org/10.1016/j.bjorl.2024.101435

20. Pu K, Li L, Qiu Y, Song H. Lipids and sudden sensorineural hearing loss: A bidirectional two-sample Mendelian randomization analysis. Auris Nasus Larynx. 2024;51(2):365–70.

21. Liu L, Qin M, Ji J, Wang W. Correlation between hearing impairment and the Triglyceride Glucose Index: based on a national cross-sectional study. Front Endocrinol (Lausanne). 2023;14(June):1–12.

22. Pan JY, Chen Y, Lin ZH, Lv B, Chen L, Feng SY. Association Between Triglyceride-Glucose Index and Hearing Threshold Shifts of Adults in the United States: National Health and Nutrition Examination Survey, 2015–2016. J Multidiscip Healthc. 2024;17(April):1791–801.

23. Samelli AG, Santos IS, Maestri Miguel Padilha FYO, Gomes RF, Moreira RR, Rabelo CM, et al. Hearing loss, tinnitus, and hypertension: Analysis of the baseline data from the Brazilian longitudinal study of adult health (elsa-brasil). Clinics. 2021;76:1–7.

24. Padilha FYOMM, Oenning NSX, de Souza Santos I, Rabelo CM, Moreira RR, Bensenor IM, et al. ELSA-Brasil: a 4-year incidence of hearing loss in adults with and without hypertension. Rev Saude Publica. 2022;56:1–9.

25. Zhou Y, Wen J, Yang Z, Zeng R, Gong W, Jing Q. The potential relationship between uric acid and the recovery in sudden sensorineural hearing loss. Braz J Otorhinolaryngol [Internet]. 2024;90(1):101368. Available from: https://doi.org/10.1016/j.bjorl.2023.101368

26. Mudhol R, Patwegar A. Lipid Profile in Patients with Sensorineural Hearing Loss - One Year Observational Study in a Tertiary Care Centre. Madridge J Otorhinolaryngol. 2019;4(1):77–80.

27. Sahni D, Bhagat S, Bhatia L, Singh P, Chawla S, Kaur A. Association Between Metabolic Syndrome and Hearing Impairment: a Study on 200 Subjects. Indian J Otolaryngol Head Neck Surg [Internet]. 2024;76(1):262–7. Available from: https://doi.org/10.1007/s12070-023-04138-w

28. Xu Y, Wang G, Wang M, Guo S, Tu J, Wang J, et al. Association of metabolic syndrome and its components with hearing loss in low-income women: A population-based cross-sectional study. Clin Epidemiol Glob Heal. 2024;27(April).

29. Hsu LC, Tsui KH, Wei JCC, Yip HT, Hung YM, Chang R. Female human papillomavirus infection associated with increased risk of infertility: A nationwide population-based cohort study. Int J Environ Res Public Health. 2020;17(18):1–9.

30. Fallah E, Strimbu CE, Olson ES. Nonlinearity of intracochlear motion and local cochlear microphonic: Comparison between guinea pig and gerbil. Hear Res [Internet]. 2021;405:108234. Available from: https://doi.org/10.1016/j.heares.2021.108234

31. Imarai C, Aracena K, Contreras D, Caro J, Resumen L 1. Relación entre hipoacusia y diabetes mellitus tipo 2 Relationship between hearing loss and type 2 diabetes mellitus. Rev Otorrinolaringol Cir Cabeza Cuello. 2013;73:157–63.

32. Wang Y, Liu H, Nie X, Lu N, Yan S, Wang X, et al. L–shaped association of triglyceride glucose index and sensorineural hearing loss: results from a cross-sectional study and Mendelian randomization analysis. Front Endocrinol (Lausanne). 2024;15(February):1–10.

33. Nawaz MU, Vinayak S, Rivera E, Elahi K, Tahir H, Ahuja V, et al. Association Between Hypertension and Hearing Loss. Cureus. 2021;13(9):16–9.

34. Li J, Zhu YM, Wang YQ, Gu XC. Associations of Blood Lipids with the Risk and Prognosis of Sudden Sensorineural Hearing Loss: A Meta-analysis. J Int Adv Otol. 2024;20(5):431–8.