

How Common Are Auditory Manifestations in Vestibular Migraine? A Systematic Review and Meta-Analysis

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Abstract

Objective

To estimate the prevalence and characterise the clinical significance of auditory manifestations in adults with definite or probable vestibular migraine.

Methods

PubMed, Scopus and the Cochrane Library were systematically searched. Patient-level prevalence data were pooled using random-effects models with logit-transformed proportions. Hearing loss and hyperacusis were synthesised narratively when quantitative pooling was inappropriate.

Results

Fifteen studies were included. Twelve studies ($n = 1,967$) contributed to the aural-fullness meta-analysis and 13 ($n = 1,887$) to the tinnitus meta-analysis. Pooled prevalence was 28.8% for aural fullness (95% CI, 19.8–40.0%; $I^2 = 95.3\%$) and 40.7% for tinnitus (95% CI, 30.3–52.0%; $I^2 = 94.7\%$). Hearing-loss definitions were too heterogeneous for pooling, and evidence for hyperacusis remained limited.

Conclusion

Aural fullness and tinnitus are common in vestibular migraine, but substantial heterogeneity limits precise prevalence estimation. Standardised auditory assessment is needed to improve phenotyping and differential diagnosis.

Introduction

Vestibular migraine (VM) is one of the most common causes of recurrent episodic vertigo and is increasingly recognised as a major clinical entity at the interface between neurology and otology. Population-based estimates of VM prevalence vary according to diagnostic criteria and study design, with earlier epidemiological studies reporting estimates around 1% and more recent population-based analyses suggesting higher prevalence. The disorder predominantly affects women and is frequently associated with considerable functional impairment and reduced quality of life.^{1–3}

The diagnostic criteria established by the Bárány Society and the International Headache Society define VM primarily on the basis of recurrent vestibular symptoms associated with a current or previous history of migraine and characteristic migrainous features.⁴ Although auditory symptoms are not included among the core diagnostic criteria, tinnitus, aural fullness, hearing impairment and sound intolerance are frequently reported by patients with VM.^{5–8} Their presence may complicate diagnosis because similar manifestations occur in several peripheral vestibulocochlear disorders.

The overlap between vestibular migraine and Ménière's disease remains one of the major diagnostic challenges in neuro-otology. Both conditions may present with episodic vertigo, tinnitus and aural fullness, whereas audiometrically documented low- to medium-frequency sensorineural hearing loss is a defining diagnostic feature of definite Ménière's disease. Previous investigations have highlighted the clinical similarities and potential pathophysiological interactions between these disorders, emphasising the need for a more comprehensive understanding of cochlear manifestations in patients with VM.^{6,7,22}

Despite increasing interest in the auditory phenotype of VM, the reported prevalence of individual symptoms varies considerably across studies. Differences in diagnostic criteria, patient selection, symptom ascertainment, timing of assessment and definitions of hearing impairment limit direct comparisons between cohorts. In particular, hearing loss has been variably defined as subjective hearing difficulty, fluctuating auditory symptoms or objectively measured audiometric impairment, making a single pooled estimate potentially misleading.

The present systematic review and meta-analysis therefore aimed to characterise the auditory manifestations associated with definite or probable VM. The primary objective was to estimate the pooled prevalence of aural fullness and tinnitus when compatible patient-level data were available. Hearing-loss and audiometric findings were evaluated separately according to their clinical definitions, while hyperacusis and altered sound tolerance were explored narratively because of the limited and heterogeneous evidence. A secondary objective was to examine the implications of these auditory manifestations for the differential diagnosis between VM and other vestibulocochlear disorders, particularly Ménière's disease.

Materials and methods

Reporting guidelines and review methods

This systematic review and meta-analysis was conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) statement. Eligibility criteria, search procedures, data extraction, risk-of-bias assessment and statistical methods were established before the final quantitative synthesis to ensure methodological consistency and transparency. This systematic review was not prospectively registered, and a formal review protocol was not published or made publicly available.

Information sources and search strategy

A comprehensive literature search was performed in PubMed, Scopus and the Cochrane Library to identify studies reporting auditory manifestations in patients with vestibular migraine. Searches combined the term “vestibular migraine” with terms related to auditory and cochlear manifestations, including “aural fullness”, “tinnitus”, “hearing loss”, “auditory symptoms” and “cochlear symptoms”. In PubMed, searches were restricted to the Title/Abstract fields, whereas in Scopus the corresponding Article title, Abstract and Keywords fields were searched. The Cochrane Library targeted search was performed in Title, Abstract and Keyword fields. Reference lists of relevant publications were additionally screened manually.

The primary PubMed and Scopus search/export identified 176 and 348 records, respectively, giving 524 records before deduplication. After removal of 166 duplicate records, 358 unique PubMed/Scopus records were available for title and abstract screening. Supplementary Cochrane searches were performed separately: the targeted search identified three CENTRAL trial records, while a broader sensitivity search using “vestibular migraine” alone identified four Cochrane Reviews, 80 CENTRAL trial records and two Clinical Answers. These Cochrane results were used as supplementary sensitivity searches and were not added to the primary 358-record PubMed/Scopus screening count. The complete database-specific search strategies are provided in Supplementary Appendix S1. The initial search/export was documented on 17 June 2026 and the final search update was completed on 10 July 2026.

Eligibility criteria

Studies were eligible if they: (1) included adult patients diagnosed with definite or probable vestibular migraine according to recognised diagnostic criteria established by the Bárány Society and/or the International Headache Society; (2)

reported one or more auditory manifestations, including aural fullness, tinnitus, hearing loss, hyperacusis or related cochlear symptoms; and (3) provided original clinical data. Reviews, editorials, case reports and publications without vestibular migraine-specific auditory information were excluded. Conference abstracts or reports with insufficient information for quantitative extraction were not included in the primary meta-analyses but could be retained for narrative synthesis when clinically relevant information was available.

For quantitative synthesis, studies were required to provide extractable patient-level event counts and denominators for the outcome under consideration. Studies reporting auditory manifestations only at the level of individual vestibular attacks rather than individual patients were not pooled. Studies involving mixed vestibular migraine-spectrum populations were excluded from the primary meta-analyses unless data for eligible patients with vestibular migraine could be extracted separately. Cohorts selected specifically on the basis of the auditory outcome under investigation and overlapping or duplicate cohorts were also excluded from the corresponding primary prevalence analysis to reduce selection bias and double counting.

Study selection

Two reviewers (A.-M.P. and R.C.) independently screened titles and abstracts and subsequently assessed potentially eligible full-text reports against the predefined eligibility criteria. Disagreements regarding study eligibility were resolved through discussion and consensus. Reasons for exclusion at the full-text stage were recorded and are summarised in the PRISMA flow diagram, with **key study-level eligibility decisions** provided in Supplementary Table S1. Studies that fulfilled the general eligibility criteria but did not provide quantitatively compatible patient-level prevalence data were retained for narrative synthesis when clinically relevant.

Data extraction

Data were independently extracted by two reviewers (A.-M.P. and R.C.) using a standardised data-extraction framework. Discrepancies between reviewers were resolved through discussion and consensus. Extracted variables included first author, year of publication, country, study design, study population and sample size, diagnostic criteria for vestibular migraine, comparator groups when applicable, definitions and methods of ascertainment of auditory outcomes, and reported auditory manifestations.

For each quantitatively eligible outcome, patient-level event counts and corresponding denominators were extracted whenever available. Aural fullness, tinnitus, hearing loss and hyperacusis were extracted separately rather than combined into a composite auditory outcome. When multiple auditory manifestations were reported within the same study, each outcome was extracted independently. Studies providing only qualitative descriptions, attack-level data or otherwise non-extractable patient-level outcomes were retained exclusively for narrative synthesis when appropriate. Study characteristics and outcome-specific quantitative data are presented in Supplementary Tables S1 and S2.

Outcomes

The primary quantitative outcomes were the prevalence of aural fullness and tinnitus among patients with definite or probable vestibular migraine. Hearing loss, audiometric abnormalities and hyperacusis were synthesised narratively because the available studies used clinically heterogeneous definitions, populations, denominators or assessment methods that did not support a clinically interpretable pooled prevalence estimate.

For quantitative synthesis, outcome-specific patient-level event counts and denominators were required. When outcome-specific auditory data were reported separately for patients with vestibular migraine alone and patients with overlapping

vestibular migraine and Ménière's disease, data from the vestibular migraine-only subgroup were preferentially extracted. When separate auditory outcome counts were unavailable, the full cohort was retained provided that all participants met diagnostic criteria for definite or probable vestibular migraine.

Risk of bias assessment

Methodological quality was assessed using the Joanna Briggs Institute (JBI) critical appraisal tools appropriate to the design of the included studies. Risk-of-bias assessment was performed independently by two reviewers (A.-M.P. and R.C.), with disagreements resolved through discussion and consensus. Appraisal focused on domains relevant to the individual study design, including sampling and participant selection, validity of the vestibular migraine diagnosis, reliability of auditory outcome ascertainment, completeness of reporting and appropriateness of statistical analysis. Overall judgements were expressed qualitatively as low concern or some concerns; population-related applicability limitations were reported separately and were not treated as methodological risk of bias.

Statistical analysis

Meta-analyses were performed using R software (R Foundation for Statistical Computing, Vienna, Austria) with the *meta* and *metafor* packages. Separate prevalence meta-analyses were conducted for aural fullness and tinnitus. Studies could contribute to more than one outcome-specific synthesis when compatible patient-level data were available.

Because substantial clinical and methodological heterogeneity was anticipated, random-effects models were used. Study-specific proportions were transformed using the logit transformation before pooling and subsequently back-transformed for interpretation. Between-study variance was estimated using the DerSimonian–Laird method. Pooled prevalence estimates are reported with 95 per cent confidence intervals. Statistical heterogeneity was assessed using Cochran's Q statistic and quantified using the I^2 statistic, with I^2 values greater than 75 per cent considered indicative of considerable heterogeneity. Forest plots were generated for each quantitative outcome.

Formal tests for publication bias were not performed because the number of studies available for each meta-analysis was limited and substantial clinical and statistical heterogeneity was present, conditions under which funnel-plot asymmetry tests may be unreliable.

Results and analysis

Study selection

The primary PubMed and Scopus searches identified 524 records (PubMed, $n = 176$; Scopus, $n = 348$). After removal of 166 duplicate records, 358 unique records underwent title and abstract screening. Supplementary Cochrane searches were conducted separately and were not added to the primary screening denominator. Of the 358 screened records, 275 were excluded at the title and abstract stage, leaving 83 reports sought for retrieval. One report could not be retrieved, and 82 reports were assessed for full-text eligibility.

Following full-text assessment, 67 reports were excluded because of an ineligible population or study design, absence of a relevant auditory outcome, lack of separately extractable vestibular migraine data, insufficient data, overlapping or duplicate cohorts, or other eligibility reasons. Fifteen unique studies were retained in the systematic review. Twelve studies contributed to the aural-fullness meta-analysis and 13 to the tinnitus meta-analysis; individual studies could contribute to more than one outcome. Hearing-loss and audiometric findings were synthesised narratively. Hyperacusis and altered sound-tolerance findings were evaluated in an exploratory narrative synthesis because the available studies

differed substantially in outcome definition and ascertainment. The study-selection process is shown in Fig. 1, and key study-level eligibility decisions are provided in Supplementary Table S1.

Characteristics of included studies

The 15 studies included in the systematic review were published between 2016 and 2026 and originated from Europe, Asia and South America. Study designs were predominantly observational and included multicentre cross-sectional studies, retrospective clinical cohorts, comparative cohorts and clinical series. Sample sizes varied substantially, contributing to the clinical and methodological heterogeneity of the evidence base.

Twelve studies provided compatible patient-level data for aural fullness and 13 for tinnitus, with several studies contributing to both quantitative outcomes. Two studies provided clinically relevant information on hyperacusis or altered sound tolerance and were retained for exploratory narrative synthesis. Additional clinically relevant findings were retained for narrative interpretation of hearing loss, audiometric abnormalities and the differential diagnosis with Ménière's disease. Studies with outcome-selected populations, non-separable composite outcomes, incompatible historical diagnostic definitions, mixed populations without separately extractable vestibular migraine data, or duplicate or overlapping cohorts were not pooled.

The principal characteristics of the included studies are summarised in Table 1, while detailed extraction and key eligibility decisions are provided in the Supplementary Materials.

Table 1. Characteristics of studies contributing to the quantitative and narrative syntheses

Study	Country	Design	VM population	Auditory data used	Role in synthesis	Key note
Kirkim et al., 2017 [9]	Turkey	Comparative audiological	44 VM	Tinnitus 16/44	Tinnitus meta-analysis	No aural-fullness prevalence
Teggi et al., 2018 [10]	Multicentre Europe	Multicentre cross-sectional	252 definite VM	AF 22/252; T 27/252	AF and T meta-analyses	Symptoms recorded as attack accompaniments
Zhang et al., 2016 [11]	China	Clinical field-testing cohort	67 VM	AF 3/67; T 7/67	AF and T meta-analyses	ICHD-3 beta-based cohort
Martínez et al., 2017 [12]	Spain	Clinical series	41 VM	AF 8/41; T 12/41	AF and T meta-analyses	Headache-unit cohort
Çelebisoy et al., 2022 [13]	Turkey	Multicentre clinical cohort	379 pure VM; 36 additional VM/MD overlap	AF 104/379; T 134/379	AF and T meta-analyses	VM/MD subgroup excluded from primary prevalence pooling because pure-VM outcome data were available
Li et al., 2022 [14]	China	Clinical cohort	62 definite VM	AF 10/62; T 16/62	AF and T meta-analyses	Bárány/IHS definite VM subgroup
Morganti et al., 2016 [15]	Brazil	Retrospective descriptive	78 with symptom data	AF 23/78; T 41/78	AF and T meta-analyses	Audiometry used a different denominator
Shi et al., 2022 [6]	China	Retrospective clinical cohort	166 VM	AF 68/166; T 86/166	AF and T meta-analyses	Hearing loss analysed narratively
Liu et al., 2025 [16]	Taiwan	Retrospective tertiary cohort	393 definite/probable VM	AF 169/393; T 214/393	AF and T meta-analyses	Full VM cohort used because outcome-specific counts were not separately reported by MD-overlap status; chronic/fluctuating otological symptoms
Haritha et al., 2025 [17]	India	Retrospective observational	45 VM	AF 5/45; T 22/45	AF and T meta-analyses	PTA findings synthesised narratively
Zhang et al., 2025 [18]	China	Retrospective diagnostic cohort	141 VM	AF 115/141; T 108/141	AF and T meta-analyses	VM versus non-VM diagnostic cohort
Haro-Hernandez et al., 2025 [19]	Spain/Italy	Multicentre cross-sectional	51 enrolled; tinnitus denominator 50	T 38/50; hyperacusis reported narratively	Tinnitus meta-analysis; hyperacusis narrative synthesis	Published hyperacusis reporting not sufficiently compatible for prevalence pooling
Kwak et al., 2026 [20]	South Korea	Retrospective cohort	169 VM	AF 81/169; T 68/169	AF and T meta-analyses	Full VM cohort used because AF/T outcome

Study	Country	Design	VM population	Auditory data used	Role in synthesis	Key note
						counts were not separately reported for the VM-only subgroup; hearing fluctuations not pooled as hearing loss
Jiang et al., 2025 [21]	China	Retrospective comparative	174 VM	AF 75/174	AF meta-analysis	AF versus non-AF VM subgroups
Turğut et al., 2026 [23]	Turkey	Comparative audiological study	VM group within a three-group study; total study N = 69	Hyperacusis, sound tolerance and auditory-processing measures	Exploratory narrative synthesis	Hyperacusis reported in 47.73% of the VM group; not included in prevalence pooling

Abbreviations: AF, aural fullness; T, tinnitus; VM, vestibular migraine; MD, Ménière's disease; PTA, pure-tone audiometry.

Meta-analysis of aural fullness

Twelve studies comprising 1,967 patients provided compatible patient-level data on aural fullness and were included in the quantitative synthesis. Using a random-effects model with logit transformation, the pooled prevalence of aural fullness was 28.8 per cent (95 per cent confidence interval, 19.8–40.0 per cent). Considerable heterogeneity was observed among studies ($I^2 = 95.3$ per cent), indicating substantial variability in study populations, symptom ascertainment and the temporal definition of aural fullness.

Individual study estimates varied widely, ranging from approximately 4 per cent to more than 80 per cent. This dispersion indicates that aural fullness is a clinically relevant but non-uniform manifestation of vestibular migraine. Individual study estimates and the pooled prevalence are presented in Figure 2.

Study-specific prevalence estimates are presented with 95% confidence intervals. The pooled prevalence was 28.8% (95% CI, 19.8–40.0%) using a random-effects model. Substantial heterogeneity was observed ($I^2 = 95.3\%$).

Meta-analysis of tinnitus

Thirteen studies comprising 1,887 patients provided compatible patient-level data on tinnitus. Using a random-effects model with logit transformation, the pooled prevalence was 40.7 per cent (95 per cent confidence interval, 30.3–52.0 per cent), with considerable between-study heterogeneity ($I^2 = 94.7$ per cent).

Individual estimates showed marked variation across cohorts, reflecting differences in recruitment setting, diagnostic era, symptom definition and whether tinnitus was recorded as an ictal, intermittent or persistent manifestation. Individual study estimates and the pooled prevalence are presented in Figure 3.

Study-specific prevalence estimates are presented with 95% confidence intervals. The pooled prevalence was 40.7% (95% CI, 30.3–52.0%) using a random-effects model. Substantial heterogeneity was observed ($I^2 = 94.7\%$).

Hearing loss and audiometric abnormalities

Hearing impairment could not be appropriately summarised using a single pooled prevalence because the included studies measured clinically different outcomes. Some studies reported subjective or fluctuating hearing loss during vestibular episodes, whereas others defined hearing impairment using pure-tone audiometry, with non-uniform frequency ranges and threshold criteria. Combining these estimates would therefore have introduced substantial outcome-definition heterogeneity in addition to between-study clinical heterogeneity.

Across the available studies, audiometrically defined abnormalities ranged from relatively uncommon hearing loss in large clinical cohorts to higher prevalences in studies using different audiometric thresholds or testing protocols.^{6,13,17} Subjective or fluctuating hearing symptoms were also reported in several cohorts,^{16,20} but were not treated as equivalent to persistent sensorineural hearing loss. Hearing-loss findings were therefore retained for narrative synthesis and differential-diagnostic interpretation rather than pooled into a single prevalence estimate.

Hyperacusis and sound intolerance

Haro-Hernandez et al. reported hyperacusis in 35 patients; however, the reported percentage did not correspond to a clearly identifiable cohort denominator, preventing unambiguous reconstruction of patient-level prevalence.¹⁹ Turğut et al. investigated auditory sound tolerance and processing in patients with vestibular migraine using the Khalfa Hyperacusis Questionnaire, loudness discomfort levels, spectral-resolution testing and transient-evoked otoacoustic-emission suppression; hyperacusis was reported in 47.73 per cent of the vestibular migraine group.²³

Because the available studies differed in methods of hyperacusis ascertainment and reporting of quantitative denominators, these data were retained as an exploratory narrative synthesis rather than combined into a pooled prevalence estimate. The available findings suggest that altered sound tolerance may occur in a subset of patients with vestibular migraine, but the evidence remains insufficient to estimate its prevalence reliably.

Risk of bias assessment

The methodological quality of included studies was evaluated using the Joanna Briggs Institute critical appraisal tools appropriate to study design. Most studies were judged to have low or some methodological concerns. The most frequent limitations related to sampling procedures, sample-size justification and incomplete methodological reporting. No study was excluded solely on the basis of risk of bias. The complete study-level assessment is presented in Supplementary Table S3.

Discussion

The present systematic review and meta-analysis synthesised evidence from 15 studies examining auditory manifestations in adults with definite or probable vestibular migraine. Aural fullness and tinnitus were sufficiently and consistently reported to support separate quantitative syntheses, whereas hearing loss, audiometric abnormalities, hyperacusis and altered sound tolerance required narrative interpretation because of substantial differences in definitions and assessment methods. The pooled prevalence was 28.8% for aural fullness and 40.7% for tinnitus, although both estimates were accompanied by considerable between-study heterogeneity. These findings support the clinical relevance of auditory symptoms within the vestibular migraine phenotype while also demonstrating that their frequency depends strongly on the population studied and the way in which symptoms are defined and ascertained.

Aural Fullness as a Frequent Manifestation of Vestibular Migraine

The present meta-analysis indicates that aural fullness is a common but highly variable auditory manifestation of vestibular migraine. Across 12 studies comprising 1,967 patients, the pooled prevalence was 28.8% (95% CI, 19.8–40.0%). Considerable heterogeneity was observed ($I^2 = 95.3\%$), indicating that the pooled estimate should be interpreted as a summary across clinically and methodologically diverse populations rather than as a fixed prevalence applicable to all patients with vestibular migraine.

Individual study estimates ranged from less than 5% to more than 80%. This wide dispersion probably reflects differences in recruitment setting, diagnostic era, patient selection and symptom ascertainment. Some studies recorded aural fullness specifically as an accompaniment of vestibular attacks, whereas others captured chronic, fluctuating or historically reported otological symptoms. Consequently, aural fullness occurring exclusively during attacks may represent a clinically different phenomenon from persistent or interictal ear pressure. Future studies should therefore specify the temporal relationship between aural fullness, vertigo and migraine manifestations.

The clinical setting may also influence the reported frequency of aural fullness. Patients recruited from otology or dizziness clinics may be more likely to present with prominent cochlear complaints than those evaluated primarily in headache or neurology settings. In addition, retrospective symptom collection may be particularly susceptible to recall bias, especially when patients are asked to report symptoms occurring during previous vestibular episodes. These differences in ascertainment probably contributed to the high statistical heterogeneity observed in the present analysis.

From a clinical perspective, aural fullness represents a challenging symptom in the differential diagnosis of vestibular disorders. Although it is commonly associated with Eustachian tube dysfunction and Ménière's disease, the present findings indicate that it is also a frequent component of the vestibular migraine phenotype. In definite Ménière's disease, audiometrically documented low- to medium-frequency sensorineural hearing loss constitutes an important diagnostic feature, whereas patients with vestibular migraine may report significant subjective ear pressure despite normal or minimally altered audiometric findings.^{6,7,22}

Several pathophysiological mechanisms have been proposed to explain aural fullness in vestibular migraine, including trigeminovascular activation, neurogenic inflammation, transient alterations in cochlear perfusion and central sensory dysregulation.^{5,8} These mechanisms could theoretically generate abnormal auditory sensations without persistent structural cochlear injury and may contribute to the discrepancy between subjective symptoms and objective audiological findings observed in some patients. However, the available evidence does not establish the relative contribution of peripheral and central mechanisms.

Collectively, these findings support the recognition of aural fullness as a clinically relevant manifestation of vestibular migraine. Vestibular migraine should therefore be considered in the differential diagnosis of recurrent ear pressure, particularly when significant middle-ear pathology and persistent audiometrically documented sensorineural hearing loss are absent. Nevertheless, aural fullness alone is nonspecific and should not be regarded as diagnostic of vestibular migraine.

Tinnitus and the Auditory Phenotype of Vestibular Migraine

Tinnitus was the most frequently reported auditory manifestation in the quantitative synthesis. Across 13 studies comprising 1,887 patients, the pooled prevalence was 40.7% (95% CI, 30.3–52.0%). As with aural fullness, heterogeneity was considerable ($I^2 = 94.7\%$), indicating substantial variability according to study population, recruitment setting, diagnostic criteria and the timing and definition of symptom ascertainment.

Individual study estimates ranged from approximately 10% to more than 75%. Some cohorts recorded tinnitus only when it accompanied vestibular attacks, whereas others included intermittent, chronic or historically reported tinnitus. These

approaches are not clinically equivalent and may account for a substantial proportion of the observed variation. Attack-associated tinnitus may reflect transient migraine-related sensory or vascular changes, whereas persistent tinnitus may involve additional cochlear, central auditory or psychological factors.

The high frequency of tinnitus across the included studies supports its relevance within the auditory phenotype of vestibular migraine. Nevertheless, the pooled estimate should not be interpreted as a uniform prevalence applicable to every clinical population. Instead, it represents an average across heterogeneous cohorts in which tinnitus was assessed using different definitions and at different stages of the disease course.

Proposed mechanisms of auditory manifestations in migraine include transient alterations in cochlear perfusion, trigeminovascular activation, neurogenic inflammation and abnormalities in central sensory processing.^{5,8} These mechanisms may contribute to tinnitus in some patients even in the absence of persistent cochlear injury or substantial audiometric abnormalities. However, direct mechanistic evidence remains limited, and the present review cannot determine whether tinnitus in vestibular migraine is primarily generated by peripheral cochlear dysfunction, central auditory processing abnormalities or an interaction between both.

From a clinical standpoint, tinnitus may complicate the differential diagnosis between vestibular migraine and Ménière's disease. Both disorders can present with episodic vertigo, tinnitus and aural fullness. The characterisation of hearing impairment is therefore particularly important. Auditory complaints in vestibular migraine may be transient or fluctuating, whereas audiometrically documented low- to medium-frequency sensorineural hearing loss forms part of the diagnostic framework for definite Ménière's disease.^{6,7,22}

Tinnitus should therefore be interpreted in the context of the complete clinical phenotype rather than used as an isolated diagnostic discriminator. Relevant factors include the temporal relationship between tinnitus and vestibular attacks, laterality, persistence, associated migraine features and serial audiometric findings. Standardised reporting of these characteristics would improve comparison between studies and may help identify clinically meaningful tinnitus phenotypes within vestibular migraine.

Hearing Loss and Differential Diagnosis with Ménière's Disease

Hearing loss was not sufficiently uniform across the available literature to justify a single pooled prevalence estimate. Across the included studies, the term encompassed subjective hearing difficulty, transient or fluctuating hearing symptoms during vestibular attacks and objectively documented abnormalities on pure-tone audiometry. Audiometric definitions also differed in terms of frequency ranges, threshold criteria and denominators. Pooling these clinically distinct outcomes would therefore have generated an estimate of uncertain clinical meaning.

This distinction is particularly relevant in vestibular migraine, in which subjective auditory complaints may occur without persistent deterioration of conventional audiometric thresholds.^{6,20} Conversely, measurable threshold abnormalities have been reported in selected cohorts, with their apparent prevalence varying according to the audiometric definition and testing protocol used.^{6,13,17} These findings should therefore be interpreted according to the method of ascertainment rather than reduced to a single overall prevalence.

Subjective hearing difficulty should not automatically be considered equivalent to sensorineural hearing loss. Patients may perceive reduced hearing during episodes of aural pressure, tinnitus, phonophobia or sensory overload despite normal or near-normal pure-tone thresholds. Conversely, a single abnormal audiogram does not establish a progressive cochlear disorder without consideration of age, previous noise exposure, otological history and longitudinal threshold evolution.

The overlap between vestibular migraine and Ménière's disease remains an important diagnostic challenge in neuro-otology because both conditions may present with episodic vertigo, tinnitus, aural fullness and hearing complaints.^{6,7,22} Audiometrically documented low- to medium-frequency sensorineural hearing loss is a defining diagnostic feature of definite Ménière's disease, whereas the auditory phenotype of vestibular migraine appears more heterogeneous and may include auditory symptoms without a corresponding persistent cochlear deficit.^{6,7,22}

Nevertheless, the distinction is not always straightforward. Hearing symptoms may fluctuate, early Ménière's disease may not initially demonstrate a stable audiometric pattern, and some patients may fulfil clinical features of both disorders. For this reason, the absence of hearing loss on a single audiogram does not definitively exclude Ménière's disease, just as the presence of nonspecific threshold abnormalities does not exclude vestibular migraine. Serial audiometry and longitudinal clinical assessment may be more informative than a single cross-sectional examination.

Transient cochlear perfusion changes, trigeminovascular activation and altered central sensory processing have been proposed as potential mechanisms of auditory dysfunction in vestibular migraine.^{5,6,8} However, the present review cannot establish whether these mechanisms account for the different audiometric phenotypes reported across studies. Future investigations should clearly separate subjective hearing symptoms from objectively documented hearing loss and explicitly report the frequencies, thresholds and criteria used to define impairment.

Comprehensive audiological evaluation therefore remains important in patients presenting with recurrent vertigo and auditory symptoms. Pure-tone audiometry may help distinguish subjective or transient auditory complaints from persistent cochlear impairment and contributes to the differential diagnosis between vestibular migraine, Ménière's disease and other inner-ear disorders. Longitudinal studies using standardised audiometric definitions are needed to determine the frequency, pattern and natural history of objective hearing impairment in vestibular migraine.

Hyperacusis and Altered Sound Tolerance

Hyperacusis and altered sound tolerance were less extensively investigated than tinnitus or aural fullness. Only two studies provided clinically relevant evidence, and their findings were unsuitable for quantitative pooling because of differences in outcome ascertainment, assessment instruments and reporting of quantitative denominators. The available evidence should therefore be considered exploratory.

Haro-Hernandez et al. reported hyperacusis in 35 patients, but the reported percentage did not correspond to a clearly identifiable cohort denominator, preventing unambiguous reconstruction of patient-level prevalence.¹⁹ Turğut et al. provided complementary psychoacoustic evidence by assessing patients with vestibular migraine using the Khalfa Hyperacusis Questionnaire, loudness discomfort levels, spectral-resolution testing and transient-evoked otoacoustic-emission suppression.²³ Hyperacusis was reported in 47.73% of the vestibular migraine group.

These findings suggest that altered sound tolerance may occur in a clinically relevant subset of patients with vestibular migraine. However, hyperacusis, phonophobia and nonspecific sound sensitivity should not be used interchangeably. Phonophobia is typically related to migraine attacks and may reflect aversion to sound, whereas hyperacusis generally refers to reduced tolerance of sounds of ordinary intensity. Studies that do not clearly distinguish these constructs may produce estimates that are difficult to compare or interpret.

The available observations are compatible with the broader concept of sensory hypersensitivity in migraine. Central sensitisation, altered thalamocortical processing and enhanced excitability within sensory pathways may contribute to reduced sound tolerance, although the relative contribution of peripheral and central auditory mechanisms remains uncertain.^{5,8}

Clinically, hyperacusis should be regarded as a potential associated manifestation rather than a diagnostic feature of vestibular migraine. The limited number of studies and non-uniform assessment methods preclude a reliable pooled prevalence estimate. Future prospective studies should use standardised definitions, validated questionnaires, psychoacoustic measurements and clearly defined vestibular migraine populations to determine the prevalence and diagnostic relevance of altered sound tolerance.

Clinical Implications

The findings of the present systematic review and meta-analysis have several implications for clinical practice. Auditory symptoms appear to constitute a relevant component of the vestibular migraine phenotype. Tinnitus affected approximately two in five patients in the pooled analysis, while aural fullness affected approximately three in ten. However, both estimates showed substantial between-study variability and should not be interpreted as precise prevalence values for every clinical population.

Vestibular migraine should be considered in patients with recurrent vestibular episodes accompanied by auditory complaints, particularly when the clinical pattern is not fully explained by middle-ear disease or a persistent cochlear disorder. Nevertheless, tinnitus and aural fullness are nonspecific symptoms and should not independently establish the diagnosis. Their interpretation requires integration with the characteristics of the vestibular episodes, migraine history, associated migrainous features and exclusion of alternative vestibular disorders.

Differentiation between vestibular migraine and Ménière's disease remains particularly relevant in otorhinolaryngology and neuro-otology. Although both disorders may present with episodic vertigo, tinnitus, aural fullness and hearing complaints, hearing-loss terminology and measurement were too heterogeneous across the vestibular migraine literature to support a single pooled prevalence estimate. Comprehensive audiological assessment, particularly pure-tone audiometry, therefore remains important for characterising the presence, pattern and persistence of cochlear involvement.^{6,7,22}

The occurrence of subjective auditory symptoms in patients with normal or minimally altered audiometric findings also raises the possibility of an important contribution from central sensory mechanisms. Clinicians should recognise that ear pressure, tinnitus or sound sensitivity may occur without clearly identifiable middle-ear pathology or persistent cochlear impairment. Incorporating migraine history, associated sensory symptoms and the temporal relationship between vestibular and auditory manifestations may improve diagnostic characterisation.^{4–6}

Greater standardisation in the reporting of auditory outcomes is warranted. Future clinical studies should distinguish transient from persistent symptoms, specify whether manifestations occur during attacks or during interictal periods, report laterality and duration, distinguish subjective hearing complaints from objectively measured impairment and employ validated assessment tools whenever possible.

A multidisciplinary approach involving otorhinolaryngologists, neurologists, neuro-otologists and audiologists may provide an appropriate framework for evaluating patients with vestibular migraine and associated auditory manifestations, particularly in diagnostically ambiguous cases. Improved characterisation of these symptoms may help reduce diagnostic delay and misclassification with other vestibulocochlear disorders.

Strengths and Limitations

The present study provides a focused systematic synthesis of the auditory manifestations associated with vestibular migraine and incorporates patient-level prevalence data for two clinically important symptoms, aural fullness and

tinnitus. The review was conducted in accordance with PRISMA 2020 recommendations, employed predefined eligibility criteria and incorporated formal risk-of-bias assessment using Joanna Briggs Institute critical appraisal tools. Quantitative syntheses used random-effects models because clinical and methodological heterogeneity was anticipated.

An additional strength is the separate consideration of clinically distinct auditory outcomes rather than their aggregation into a composite measure. In particular, subjective hearing complaints, fluctuating auditory symptoms and audiometrically defined hearing impairment were not treated as interchangeable outcomes. This distinction improves the clinical interpretability of the findings and is particularly relevant to the differential diagnosis between vestibular migraine and Ménière's disease.

The primary prevalence analyses were restricted to studies providing extractable patient-level event counts and denominators. Studies reporting only attack-level data, outcome-selected cohorts, non-separable mixed populations or overlapping cohorts were excluded from the corresponding quantitative synthesis when their inclusion could have introduced selection bias or double counting. Clinically relevant studies that could not be pooled were retained for narrative interpretation rather than excluded entirely.

Several limitations should nevertheless be acknowledged. First, considerable heterogeneity was observed for both aural fullness and tinnitus. This probably reflects differences in study design, diagnostic era, recruitment setting, patient populations, symptom definitions and whether auditory manifestations were recorded during attacks, between attacks or across the overall disease course. The pooled prevalences should therefore be interpreted as summary estimates across heterogeneous clinical contexts rather than precise population parameters.

Second, the evidence base was dominated by retrospective, cross-sectional and specialist-clinic studies. These designs are susceptible to recall bias and selection bias and may overrepresent patients with more complex, persistent or otologically prominent symptoms. The generalisability of the findings to unselected or community-based vestibular migraine populations is therefore uncertain.

Third, auditory outcome ascertainment differed substantially between studies. This limitation was particularly important for hearing loss, for which subjective complaints, fluctuating symptoms and audiometrically defined impairment were not considered interchangeable and were therefore synthesised narratively. Differences in audiometric frequency ranges, threshold definitions and reporting denominators further limited direct comparison.

Fourth, evidence regarding hyperacusis and altered sound tolerance was limited to only two clinically heterogeneous studies. Differences in assessment instruments, psychoacoustic methods and reporting of quantitative denominators precluded a reliable prevalence meta-analysis. These findings should therefore be regarded as exploratory.

Fifth, the substantial heterogeneity and limited number of studies per outcome restricted the feasibility and interpretability of subgroup analyses and meta-regression. It was consequently not possible to determine reliably whether prevalence differed according to diagnostic criteria, geographical region, recruitment setting, attack-related versus persistent symptom assessment or other study-level characteristics.

Formal publication-bias and small-study-effect testing was not performed because the number of studies available for each quantitative outcome was limited and heterogeneity was considerable. Under these conditions, funnel-plot asymmetry and related statistical tests may be unreliable. Publication bias and language-related selection effects nevertheless cannot be completely excluded.

Finally, the review was not prospectively registered, and a formal protocol was not published or made publicly available. Although eligibility criteria, data-extraction procedures, risk-of-bias assessment and statistical methods were established

before the final quantitative synthesis, the absence of prospective registration represents a limitation in methodological transparency. No formal certainty-of-evidence framework was applied.

Despite these limitations, the findings consistently demonstrate that tinnitus and aural fullness are common components of the auditory phenotype of vestibular migraine. Future multicentre prospective studies using uniform diagnostic criteria, standardised symptom definitions, validated auditory assessment instruments and longitudinal audiometric protocols are required to clarify the temporal pattern, mechanisms and diagnostic relevance of auditory manifestations in vestibular migraine.

Conclusion

Auditory manifestations are a clinically relevant component of the vestibular migraine phenotype. In the present review, aural fullness had a pooled prevalence of 28.8% (95% CI, 19.8–40.0%) across 12 studies comprising 1,967 patients, while tinnitus had a pooled prevalence of 40.7% (95% CI, 30.3–52.0%) across 13 studies comprising 1,887 patients. Both outcomes showed considerable between-study heterogeneity, indicating substantial variation in symptom frequency according to clinical population, recruitment setting, temporal definition and method of ascertainment.

Hearing impairment should not be treated as a single uniform outcome in vestibular migraine research. The available literature combines subjective hearing difficulty, attack-related fluctuations and audiometrically documented abnormalities assessed using different frequency ranges and threshold criteria. These findings are therefore more appropriately interpreted according to their method of ascertainment than summarised using a single pooled prevalence estimate. Hyperacusis and altered sound tolerance may represent additional components of the auditory phenotype, but the current evidence is limited to a small number of clinically heterogeneous studies and does not support a reliable quantitative prevalence estimate.

Overall, the findings support systematic assessment of auditory symptoms in patients with vestibular migraine and careful audiological evaluation when differentiating vestibular migraine from Ménière's disease and other vestibulocochlear disorders. Future prospective studies should use standardised vestibular migraine diagnostic criteria, explicitly distinguish ictal from interictal and persistent manifestations, separate subjective hearing complaints from objectively documented hearing loss and apply uniform audiometric and sound-tolerance assessment protocols to improve auditory phenotyping and the comparability of prevalence estimates.

Declarations

Supplementary Materials: Table S1, detailed characteristics and eligibility decisions for included and narrative studies; Table S2, study-level patient counts used in the aural-fullness and tinnitus meta-analyses; Table S3, Joanna Briggs Institute risk-of-bias assessments; Appendix S1, complete database search strategies; PRISMA 2020 checklist.

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files are available from the corresponding author on reasonable request.

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Figures

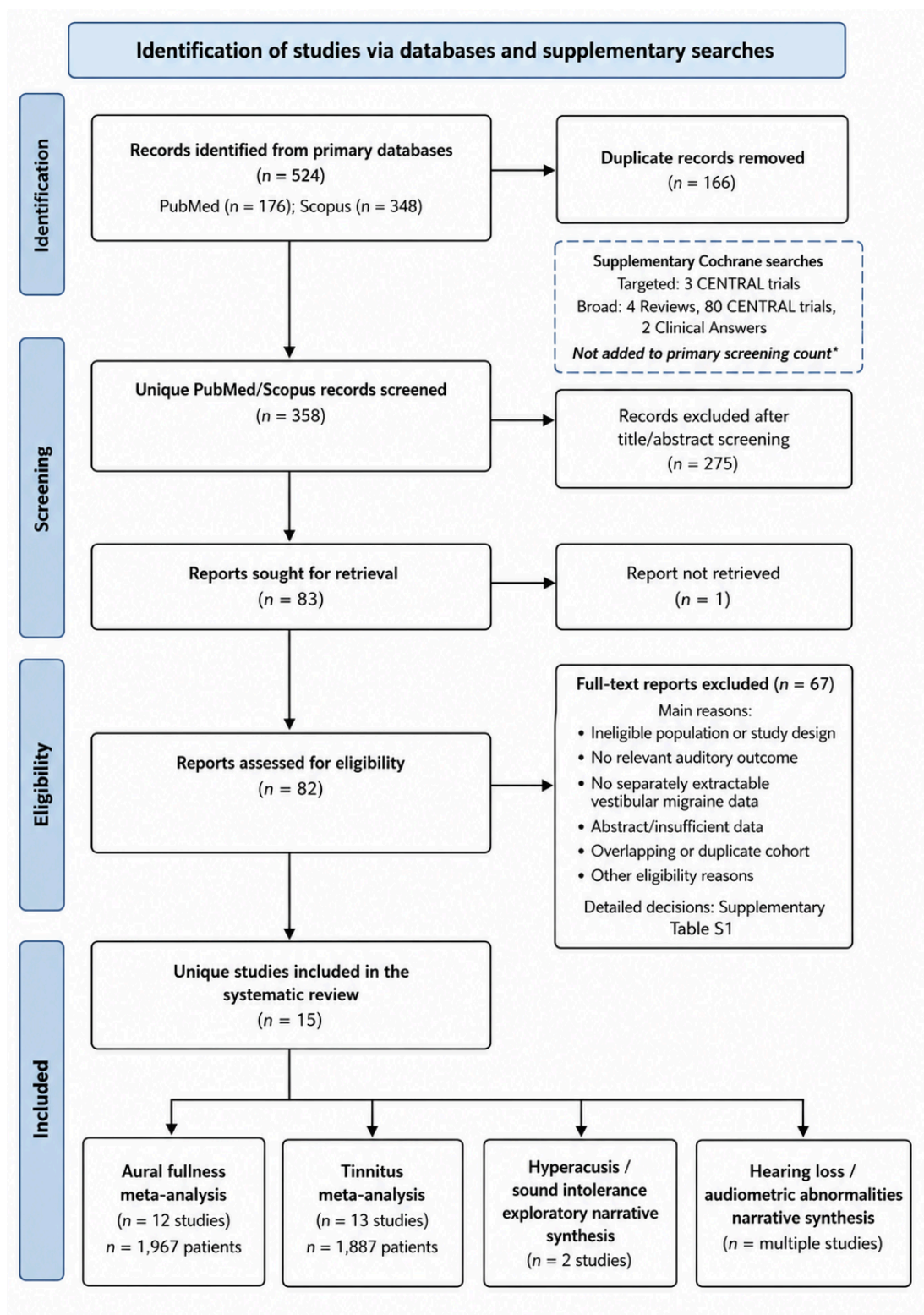


Figure 1

PRISMA 2020 flow diagram. Fifteen unique studies were retained in the systematic review; outcome-specific syntheses overlap because individual studies could contribute to more than one auditory outcome.

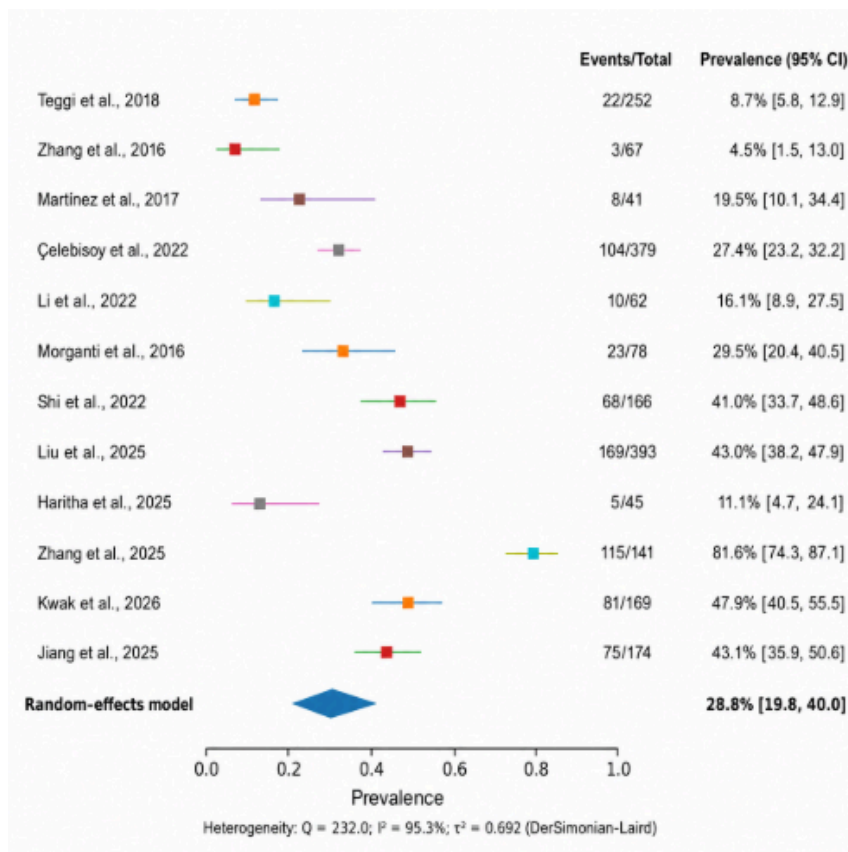


Figure 2

Forest plot of the prevalence of aural fullness in patients with vestibular migraine.

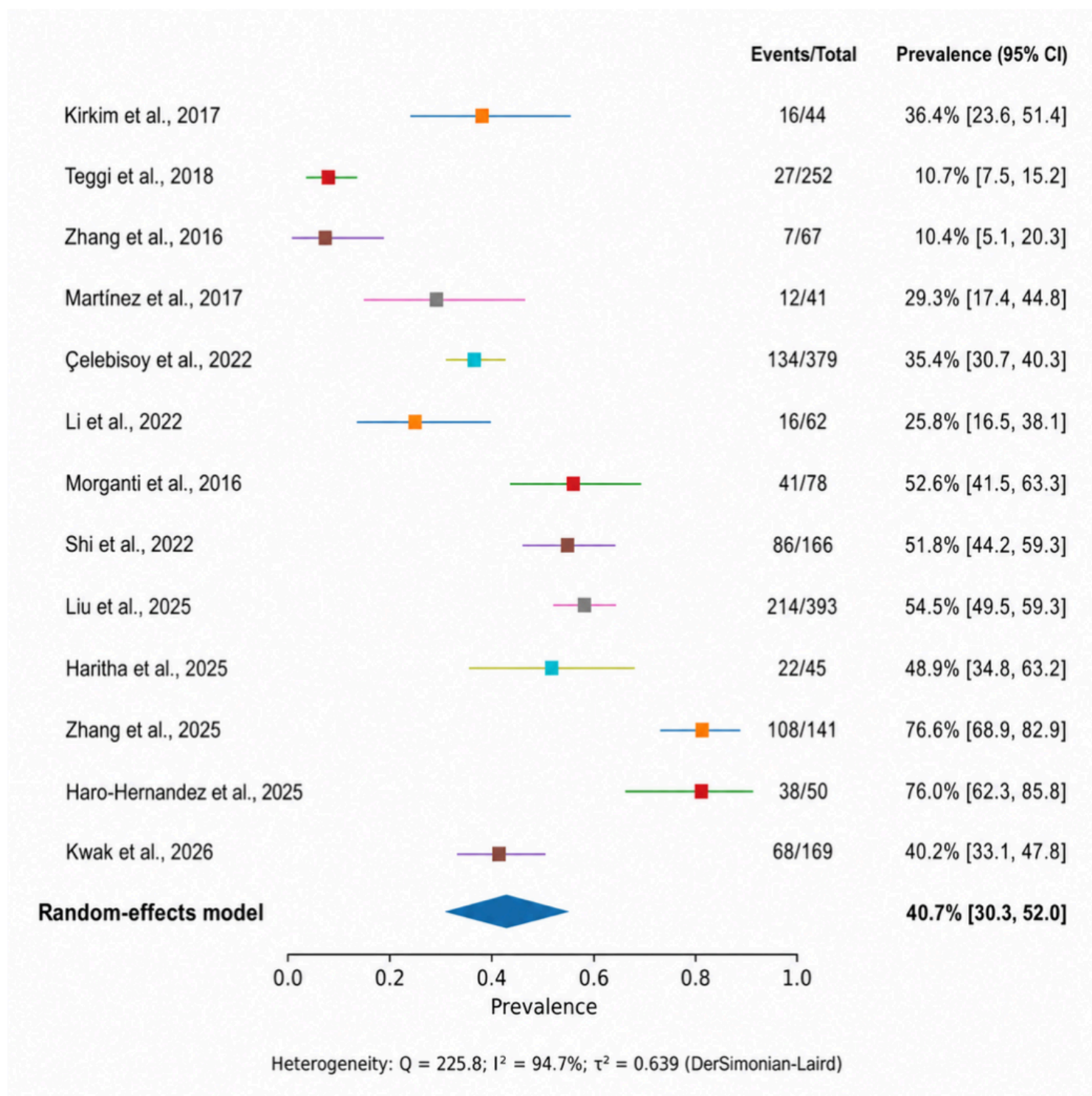


Figure 3

Forest plot of the prevalence of tinnitus in patients with vestibular migraine.

Supplementary Files

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- [PRISMA2020Checklist.docx](#)
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