# Global Prevalence and Incidence of Tinnitus

JAMA Neurology | Original Investigation

# Global Prevalence and Incidence of Tinnitus
## A Systematic Review and Meta-analysis

Carlotta M. Jarach, MSc; Alessandra Lugo, PhD; Marco Scala, MSc; Piet A. van den Brandt, PhD; Christopher R. Cederroth, PhD; Anna Odone, PhD; Werner Garavello, MD; Winfried Schlee, PhD; Berthold Langguth, MD; Silvano Gallus, PhD

**IMPORTANCE** To date, no systematic review has taken a meta-analytic approach to estimating the prevalence and incidence of tinnitus in the general population.

**OBJECTIVE** To provide frequency estimates of tinnitus worldwide.

**DATA SOURCES** An umbrella review followed by a traditional systematic review was performed by searching PubMed-MEDLINE and Embase from inception through November 19, 2021.

**STUDY SELECTION** Research data from the general population were selected, and studies based on patients or on subgroups of the population with selected lifestyle habits were excluded. No restrictions were applied according to date, age, sex, and country.

**DATA EXTRACTION AND SYNTHESIS** Relevant extracted information included type of study, time and location, end point, population characteristics, and tinnitus definition. The study followed the Meta-analysis of Observational Studies in Epidemiology (MOOSE) reporting guideline.

**MAIN OUTCOMES AND MEASURES** Pooled prevalence estimates of any tinnitus, severe tinnitus, chronic tinnitus, and diagnosed tinnitus as well as incidence of tinnitus were obtained using random-effects meta-analytic models; heterogeneity between studies was controlled using the $\chi^2$ test, and inconsistency was measured using the $I^2$ statistic.

**RESULTS** Among 767 publications, 113 eligible articles published between 1972 and 2021 were identified, and prevalence estimates from 83 articles and incidence estimates from 12 articles were extracted. The pooled prevalence of any tinnitus among adults was 14.4% (95% CI, 12.6%-16.5%) and ranged from 4.1% (95% CI, 3.7%-4.4%) to 37.2% (95% CI, 34.6%-39.9%). Prevalence estimates did not significantly differ by sex (14.1% [95% CI, 11.6%-17.0%] among male individuals; 13.1% [95% CI, 10.5%-16.2%] among female individuals), but increased prevalence was associated with age (9.7% [95% CI, 7.4%-12.5%] among adults aged 18-44 years; 13.7% [95% CI, 11.0%-17.0%] among those aged 45-64 years; and 23.6% [95% CI, 19.4%-28.5%] among those aged ≥65 years; $P < .001$ among age groups). The pooled prevalence of severe tinnitus was 2.3% (95% CI, 1.7%-3.1%), ranging from 0.5% (95% CI, 0.3%-0.7%) to 12.6% (95% CI, 11.1%-14.1%). The pooled prevalence of chronic tinnitus was 9.8% (95% CI, 4.7%-19.3%) and the pooled prevalence of diagnosed tinnitus was 3.4% (95% CI, 2.1%-5.5%). The pooled incidence rate of any tinnitus was 1164 per 100 000 person-years (95% CI, 479-2828 per 100 000 person-years).

**CONCLUSIONS AND RELEVANCE** Despite the substantial heterogeneity among studies, this comprehensive systematic review on the prevalence and incidence of tinnitus suggests that tinnitus affects more than 740 million adults globally and is perceived as a major problem by more than 120 million people, mostly aged 65 years or older. Health policy makers should consider the global burden of tinnitus, and greater effort should be devoted to boost research on tinnitus.

*JAMA Neurol*. doi:10.1001/jamaneurol.2022.2189
Published online August 8, 2022.

Supplemental content

**Author Affiliations:** Author affiliations are listed at the end of this article.

**Corresponding Author:** Silvano Gallus, PhD, Department of Environmental Health Sciences, Istituto di Ricerche Farmacologiche Mario Negri IRCCS, Via Mario Negri 2, 20156 Milan, Italy (silvano.gallus@marionegri.it).

The term *tinnitus* comes from the Latin word *tinnire*, which means "to ring." Individuals experiencing tinnitus report an unspecified acoustic sound like ringing, but also buzzing, clicking, pulsations, and other noises.[1] Tinnitus is considered a symptom of an underlying condition, rather than a disease, and it refers to the perception of sounds in the head or ears when no corresponding external sounds are present.[2,3] A severe form of tinnitus is associated with hearing loss, thus impairing quality of life.[4,5]

Today there is no globally accepted categorization of tinnitus, although different attempts have been made.[6] Moreover, evidence on the frequency (ie, prevalence and incidence) of tinnitus among the general population is still scant. The difficulties in obtaining adequate data are due to the multifactorial etiology of tinnitus, its associated disorders, the various characteristics of the symptoms, and the subjective nature of any assessment of tinnitus.[7]

The very few longitudinal studies on tinnitus hamper any accurate estimate of its incidence. Moreover, the prevalence of tinnitus, which is estimated as either point prevalence, period prevalence, or lifetime prevalence,[8] ranges widely, partly because of the lack of standardization in its assessment, illustrated in a systematic review in which McCormack et al[3] attempted to identify and collect data on the global prevalence of tinnitus.

Since that last review on the prevalence of tinnitus, the literature on tinnitus has increased by at least 30%. An update of the evidence, which also includes pediatric tinnitus, is now necessary. We conducted a systematic review to identify the relevant publications in the scientific literature on the frequency of tinnitus at a global level, using an original search method.[9]

### Key Points

**Question** What is the global prevalence and incidence of tinnitus?

**Findings** This systematic review and meta-analysis estimated that the annual incidence of tinnitus is approximately 1%, with 14% of adults experiencing any tinnitus and 2% experiencing a severe form of it. The prevalence of tinnitus did not differ by sex, but increased prevalence was associated with increasing age, with any tinnitus being present in 10% of young adults, 14% of middle-aged adults, and 24% of older adults.

**Meaning** This study suggests that the global burden of tinnitus is large, similar to migraine and pain, and the lack of effective treatment options justifies a major investment in research in this area.

## Methods

This systematic review and meta-analysis is based on 2 subsequent literature searches on the prevalence and incidence of tinnitus. The first search was an umbrella review: a systematic review to identify published meta-analyses, pooled analyses, and systematic reviews providing data on the prevalence or incidence of tinnitus. The second search was a traditional review of original publications: a systematic review of all original articles on the prevalence or incidence of tinnitus to update the results identified in the umbrella review. A review protocol was registered in advance on PROSPERO (registration number: CRD42021283684). The study followed the Meta-analysis of Observational Studies in Epidemiology (MOOSE) reporting guideline.

### Umbrella Review

We conducted an umbrella review to systematically collect existing evidence on the prevalence and incidence of tinnitus. We searched in PubMed-MEDLINE and Embase for all systematic reviews or meta-analyses published from inception through November 19, 2021, that had the word *tinnitus* in the title (eTable 1 in the Supplement). We retrieved 310 reviews from PubMed and 346 from Embase. After checking for duplicates using EndNote, version X7 (Clarivate), we excluded protocols, scoping reviews, case studies or animal model studies, and articles that were not in English. After applying our inclusion criteria (ie, reporting data on the prevalence or incidence of tinnitus), we excluded 369 reviews as not relevant, ending up with 15 publications. We added 1 study that we were aware of that followed our eligibility criteria but was not identified by our search string because it was not classified as a review. From each of these 16 relevant systematic reviews, we extracted the citations of all the original articles providing data on the prevalence and incidence of tinnitus, collecting 284 original studies in total.

We included only articles in English, based on samples representative of the general population, and with estimates specifically of tinnitus. Reports, letters to the editor, book chapters, conference proceedings, dissertations, and theses were not considered. We excluded studies based on patients or on subgroups of the population with selected lifestyle habits or other characteristics (eg, musicians or people regularly exposed to noise). No restrictions were applied regarding the date of publication, age, sex, and country. Two researchers (C.M.J. and M.S.) independently checked for eligibility. Any disagreement was resolved by discussion; in case of disagreement, a third reviewer (A.L.) helped to reach consensus. The umbrella review yielded 93 eligible original articles.

### Traditional Review

We then conducted a traditional review to check any relevant articles in the literature that might not have been identified through the umbrella review. We searched articles in PubMed-MEDLINE and Embase published from inception through November 19, 2021, using a string that included a combination of the words *tinnitus*, *prevalence*, and *incidence* in the title. From 245 publications, we checked for duplicates and retrieved 154 unique references. After excluding articles identified in the umbrella review (n = 45), other duplicates (n = 15), and noneligible articles (n = 78), we obtained 16 new records. To these, we added 2 other references retrieved from other sources that we knew followed our eligibility criteria. All the articles excluded from both the umbrella and the traditional review, as well as the reasons for exclusion, are listed in eTable 2 in the Supplement.

### Data Extraction and Management

We used a standardized form in Excel 2016 (Microsoft Corp) to extract data from each article identified. Relevant information included first author, year of publication, journal, type of study, time and location, end point (prevalence and/or incidence), other information (country and sample size), population characteristics (sex and age group), and tinnitus definition. Data were blindly extracted by 2 independent reviewers (C.M.J. and M.S.). Any disagreement was resolved by discussion, or with the help of a third reviewer (A.L.). Each prevalence estimate was extracted and classified by age group: children (≥17 years), young adults (18-44 years), middle-aged adults (45-64 years), older adults (≥65 years), and all adults (≥18 years).

If, while extracting, we came across summary tables that gave additional relevant citations, these were evaluated using the same inclusion and exclusion criteria. This evaluation led to 2 additional eligible articles, yielding a final total of 113 eligible articles. Among these, 24 articles were not included in the extraction for meta-analysis because their results were already included in other more complete or more recent articles (eTable 3 in the Supplement). We extracted prevalence or incidence estimates from 89 articles.

### Statistical Analysis

The pooled prevalence and incidence of any tinnitus and severe tinnitus were calculated overall for children, adolescents, and adults and separately by tinnitus definition (eTable 4 in the Supplement). For any tinnitus in adults, we identified 6 possible classes of definitions (A1-A6), and for severe tinnitus, we identified 5 possible classes (S1-S5). For children and adolescents, classes either had the word *tinnitus* in the question asked (any tinnitus or severe tinnitus) or had a phrase, such as "noises in your ears" (any noises or severe noises). Other possible definitions were chronic tinnitus or diagnosed tinnitus.

Pooled estimates were obtained using random-effects meta-analytic models to take account of the heterogeneity of the estimates. Heterogeneity among studies was controlled using the $\chi^2$ test, and inconsistency was measured using the $I^2$ statistic, which represents the proportion of total variation associated with between-study variance, with higher values denoting a greater degree of heterogeneity. Stratified analyses by selected individual-level characteristics (eg, sex and age) and country-specific characteristics (eg, continent, gross domestic product [GDP], and latitude of the main city) were performed to detect possible sources of heterogeneity. The quality of the studies was not assessed because it was beyond the scope of meta-analyses on disease frequency. Because most prevalence and incidence estimates were provided without 95% CIs, we recalculated all the 95% CIs from the raw data given in the original articles. All *P* values were from 2-sided tests and results were deemed statistically significant at $P < .05$.

All statistical analyses were performed using the R Studio software, version 1.4.1717 (R Group for Statistical Computing), particularly the "meta" and "metaphor" packages. To assess publication bias, we examined the funnel plots visually and applied the Egger test for funnel plot asymmetry.

## Results

Among 767 publications (384 reviews, 284 identified original publications, 94 articles from the traditional review, and 5 articles known by the authors), 113 eligible articles published between 1972 and 2021 were identified. We extracted prevalence estimates from 83 articles and incidence estimates from 12 articles. eFigure 1 in the Supplement shows the flowchart of study selection. Details on country, age group, and tinnitus definition in the 89 eligible articles included in meta-analyses are summarized in eTable 5 in the Supplement.

The pooled prevalence estimate of any tinnitus among adults (**Figure 1**)[4,7,10-49] was 14.4% (95% CI, 12.6%-16.5%; 55 studies; $I^2 = 100\%$). Among all studies, the estimates ranged from 4.1% (95% CI, 3.7%-4.4%) to 37.2% (95% CI, 34.6%-39.9%). The prevalence of any tinnitus did not differ according to the definitions (test for subgroup differences, $\chi^2_5 = 8.60$; $P = .13$ among strata): the prevalence of those who were asked "Have you experienced tinnitus?" (A1) was 17.5% (95% CI, 14.0%-21.8%; 12 studies; $I^2 = 100\%$); for those who were asked if they had experienced tinnitus "for more than 5 minutes?" (A2), it was 13.7% (95% CI, 10.7%-17.4%; 9 studies; $I^2 = 100\%$); for those who were asked "Have you experienced tinnitus during the last months?" (A3), it was 14.2% (95% CI, 10.0%-19.8%; 7 studies; $I^2 = 100\%$); for those who were asked "During the last months, have you experienced tinnitus which lasts for more than 5 minutes?" (A4), it was 16.0% (95% CI, 13.1%-19.4%; 18 studies; $I^2 = 99\%$); for those assessing tinnitus through a specific scale (A5), it was 9.3% (95% CI, 3.2%-24.1%; 3 studies; $I^2 = 100\%$); and for those who were asked about other tinnitus definitions (A6), it was 9.6% (95% CI, 6.3%-14.3%; 6 studies; $I^2 = 100\%$).

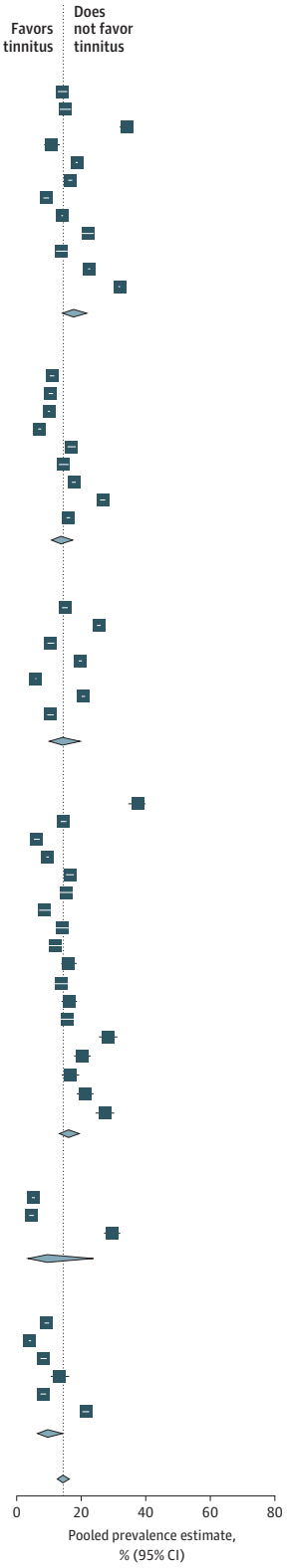
The pooled prevalence of any tinnitus among children and adolescents (eFigure 2 in the Supplement) was 13.6% (95% CI, 8.5%-21.0%; 27 studies; $I^2 = 100\%$). Among all studies, this prevalence ranged from 0.7% (95% CI, 0.6%-0.8%) to 66.9% (95% CI, 62.6%-71.0%). The prevalence of any tinnitus among children and adolescents was heterogeneous in strata of tinnitus definition classes ($P = .01$ among strata); for those who were in a study in which the word "tinnitus" was not present in the question (any noises), the prevalence was 20.4% (95% CI, 14.4%-28.0%; 18 studies; $I^2 = 99\%$), and for those who were in a study in which it was present (any tinnitus), it was 5.6% (95% CI, 2.0%-14.8%; 9 studies; $I^2 = 100\%$).

The pooled prevalence of any tinnitus was 9.7% (95% CI, 7.4%-12.5%; 22 studies; $I^2 = 100\%$) among young adults, 13.7% (95% CI, 11.0%-17.0%; 30 studies; $I^2 = 100\%$) among middle-aged adults, and 23.6% (95% CI, 19.4%-28.5%; 31 studies; $I^2 = 99\%$) among older adults (eFigure 3 in the Supplement). For adults, the pooled prevalence for any tinnitus was 14.1% (95% CI, 11.6%-17.0%; 32 studies; $I^2 = 100\%$) among male individuals and 13.1% (95% CI, 10.5%-16.2%; 30 studies; $I^2 = 100\%$) among female individuals ($P = .62$ between strata; **Table 1**).

Any tinnitus in adults significantly differed by continents, ranging from 5.2% (95% CI, 4.7%-5.7%; 1 study) in Africa to 21.9% (95% CI, 20.2%-23.8%; 1 study) in South America

Figure 1. Forest Plot of Any Tinnitus Prevalence Among Adults, by Different Definition Classes of Any Tinnitus

| Source | Adults with tinnitus, No. | Sample size, No. | % (95% CI) |
|---|---|---|---|
| **A1** | | | |
| Axelsson and Ringdahl,[17] 1989 | 337 | 2378 | 14.2 (12.8-15.6) |
| Kuttila et al,[18] 2005 | 259 | 1721 | 15.0 (13.4-16.8) |
| Sugiura et al,[19] 2008 | 743 | 2193 | 33.9 (31.9-35.9) |
| Dorner et al,[20] 2010 | 74 | 686 | 10.8 (8.6-13.4) |
| Krog et al,[21] 2010 | 9579 | 51574 | 18.6 (18.2-18.9) |
| Baigi et al,[22] 2011 | 2024 | 12166 | 16.6 (16.0-17.3) |
| Bernhardt et al,[23] 2011 | 393 | 4308 | 9.1 (8.3-10.0) |
| Engdahl et al,[24] 2012 | 7049 | 49948 | 14.1 (13.8-14.4) |
| Oiticica and Bittar,[25] 2015 | 430 | 1960 | 21.9 (20.1-23.8) |
| Herr et al,[26] 2016 | 207 | 1489 | 13.9 (12.2-15.8) |
| Lugo et al,[4] 2019 | 16066 | 71542 | 22.5 (22.2-22.8) |
| Schubert et al,[27] 2021 | 39625 | 124651 | 31.8 (31.5-32.0) |
| **Pooled estimate** | | **324616** | **17.5 (14.0-21.8)** |
| Heterogeneity: $I^2$ = 100%; $P$ < .001 | | | |
| **A2** | | | |
| Coles,[28] 1984 | 888 | 8069 | 11.0 (10.3-11.7) |
| Coles,[28] 1984b[a] | 810 | 7645 | 10.6 (9.9-11.3) |
| Davis,[29] 1989 | 3533 | 35330 | 10.0 (9.7-10.3) |
| Davis,[29] 1989b[a] | 765 | 10778 | 7.1 (6.6-7.6) |
| Parving et al,[30] 1993 | 576 | 3387 | 17.0 (15.8-18.3) |
| Quaranta et al,[31] 1996 | 315 | 2170 | 14.5 (13.1-16.1) |
| Hannaford et al,[32] 2005 | 2684 | 15140 | 17.7 (17.1-18.3) |
| Hasson et al,[16] 2010 | 2989 | 11213 | 26.7 (25.8-27.5) |
| Fujii et al,[33] 2001 | 2312 | 14423 | 16.0 (15.4-16.6) |
| **Pooled estimate** | | **108155** | **13.7 (10.7-17.4)** |
| Heterogeneity: $I^2$ = 100%; $P$ < .001 | | | |
| **A3** | | | |
| Cooper,[34] 1994 | 945 | 6342 | 14.9 (14.0-15.8) |
| Shargorodsky et al,[35] 2010 | 3587 | 14178 | 25.3 (24.6-26.0) |
| Nondahl et al,[36] 2011 | 345 | 3267 | 10.6 (9.5-11.7) |
| Park et al,[11] 2014 | 4950 | 25100 | 19.7 (19.2-20.2) |
| Wu et al,[38] 2015 | 4771 | 79976 | 6.0 (5.8-6.1) |
| Kim et al,[37] 2015 | 4234 | 20500 | 20.7 (20.1-21.2) |
| Yang et al,[39] 2018 | 387 | 3705 | 10.4 (9.5-11.5) |
| **Pooled estimate** | | **153068** | **14.2 (10.0-19.8)** |
| Heterogeneity: $I^2$ = 100%; $P$ < .001 | | | |
| **A4** | | | |
| Gopinath et al,[14] 2010 | 481 | 1292 | 37.2 (34.6-39.9) |
| Xu et al,[40] 2011 | 918 | 6333 | 14.5 (13.6-15.4) |
| Gallus et al,[7] 2015 | 183 | 2952 | 6.2 (5.4-7.1) |
| Masterson et al,[41] 2016 | 2243 | 23393 | 9.6 (9.2-10.0) |
| Choi et al,[13] 2020 | 605 | 3669 | 16.5 (15.3-17.7) |
| Biswas et al,[12] 2021 (UK) | 154 | 1007 | 15.3 (13.1-17.7) |
| Biswas et al,[12] 2021 (IE) | 82 | 941 | 8.7 (7.0-10.7) |
| Biswas et al,[12] 2021 (FR) | 137 | 971 | 14.1 (12.0-16.5) |
| Biswas et al,[12] 2021 (DE) | 108 | 911 | 11.9 (9.8-14.1) |
| Biswas et al,[12] 2021 (GR) | 152 | 945 | 16.1 (13.8-18.6) |
| Biswas et al,[12] 2021 (IT) | 134 | 979 | 13.7 (11.6-16.0) |
| Biswas et al,[12] 2021 (PT) | 155 | 958 | 16.2 (13.9-18.7) |
| Biswas et al,[12] 2021 (ES) | 155 | 1000 | 15.5 (13.3-17.9) |
| Biswas et al,[12] 2021 (BG) | 285 | 1007 | 28.3 (25.5-31.2) |
| Biswas et al,[12] 2021 (LV) | 194 | 957 | 20.3 (17.8-23.0) |
| Biswas et al,[12] 2021 (PL) | 126 | 762 | 16.5 (14.0-19.4) |
| Biswas et al,[12] 2021 (RO) | 208 | 984 | 21.1 (18.6-23.8) |
| Rademaker et al,[42] 2021 | 254 | 932 | 27.3 (24.4-30.2) |
| **Pooled estimate** | | **49993** | **16.0 (13.1-19.4)** |
| Heterogeneity: $I^2$ = 99%; $P$ < .01 | | | |
| **A5** | | | |
| Khedr et al,[43] 2010 (TSCHQ) | 439 | 8484 | 5.2 (4.7-5.7) |
| Jalessi et al,[10] 2013 (TQ) | 146 | 3194 | 4.6 (3.9-5.4) |
| House et al,[44] 2018 (THI) | 388 | 1314 | 29.5 (27.1-32.1) |
| **Pooled estimate** | | **12992** | **9.3 (3.2-24.1)** |
| Heterogeneity: $I^2$ = 100%; $P$ < .01 | | | |
| **A6** | | | |
| Weiss,[45] 1972 | 622 | 6672 | 9.3 (8.6-10.0) |
| Palmer et al,[47] 2002 | 527 | 12907 | 4.1 (3.7-4.4) |
| Nondahl et al,[46] 2002 | 308 | 3737 | 8.2 (7.4-9.2) |
| Johansson and Arlinger,[48] 2003 | 76 | 575 | 13.2 (10.6-16.3) |
| Nondahl et al,[15] 2010 | 308 | 3737 | 8.2 (7.4-9.2) |
| Oosterloo et al,[49] 2021 | 1304 | 6098 | 21.4 (20.4-22.4) |
| **Pooled estimate** | | **33726** | **9.6 (6.3-14.3)** |
| Heterogeneity: $I^2$ = 100%; $P$ < .01 | | | |
| **Pooled estimate** | | **682550** | **14.4 (12.6-16.5)** |
| Heterogeneity: $I^2$ = 100%; $P$ < .001 | | | |
| Test for subgroup differences: $\chi^2_5$ = 8.60; $P$ = .13 | | | |




In some articles, the number of cases and/or sample sizes might not coincide with those provided in the original study owing to the R package, which recalculates the percentage. We were interested in keeping the estimate provided; therefore, we modified numbers accordingly. A1 indicates the question "Have you experienced tinnitus?"; A2, "Have you experienced tinnitus for more than 5 minutes?"; A3, "Have you experienced tinnitus during the last months"?; A4, "During the last months, have you experienced tinnitus which lasts for more than 5 minutes?"; A5, assessment of tinnitus through a specific scale; A6, assessment of tinnitus via other tinnitus definitions; BG, Bulgaria; DE, Germany; ES, Spain; FR, France; GR, Greece; IE, Ireland; IT, Italy; LV, Latvia; PL, Polonia; PT, Portugal; RO, Romania; THI, Tinnitus Handicap Inventory; TQ, Tinnitus Questionnaire; and TSCHQ, Tinnitus Sample Case History Questionnaire.

[a] This study had 2 populations; the second population is indicated by "b."

($P$ < .001 among strata; Table 1). The presence of tinnitus did not differ among per-capita GDP tertiles (<$4100, 14.3% [95% CI, 11.2%-18.0%]; $4100-$5200, 13.8% [95% CI, 11.0%-17.1%]; and >$5200, 15.6% [95% CI, 12.3%-19.5%]; $P$ = .74

Table 1. Pooled Prevalence of Any Tinnitus in Adults, Overall and in Strata of Selected Individual-Level or Country-Specific Characteristics

| Stratum[a] | Any tinnitus | | | |
|---|---|---|---|---|
| | Studies, No. | Pooled % (95% CI) | $I^2$, % | *P* value for heterogeneity among strata |
| Total | 55 | 14.4 (12.6-16.5) | 100 | NA |
| Individual-level characteristics | | | | |
| Sex | | | | |
| Male | 32 | 14.1 (11.6-17.0) | 100 | .62 |
| Female | 30 | 13.1 (10.5-16.2) | 100 | |
| Age group, y | | | | |
| Children and adolescents (5-17) | 27 | 13.6 (8.5-21.0) | 100 | <.001 |
| Young adults (18-44) | 22 | 9.7 (7.4-12.5) | 100 | |
| Middle-aged adults (45-64) | 30 | 13.7 (11.0-17.0) | 100 | |
| Older adults (≥65) | 31 | 23.6 (19.4-28.5) | 99 | |
| Tinnitus definition | | | | |
| Have you experienced tinnitus? (A1) | 12 | 17.5 (14.0-21.8) | 100 | .13 |
| For more than 5 min? (A2) | 9 | 13.7 (10.7-17.4) | 100 | |
| During the last months? (A3) | 7 | 14.2 (10.0-19.8) | 100 | |
| For more than 5 min during the last months? (A4) | 18 | 16.0 (13.1-19.4) | 99 | |
| Tinnitus identified with a validated questionnaire (A5) | 3 | 9.3 (3.2-24.1) | 100 | |
| Other definitions of any tinnitus (A6) | 6 | 9.6 (6.3-14.3) | 100 | |
| Country-specific characteristics | | | | |
| Continent | | | | |
| Africa | 1 | 5.2 (4.7-5.7) | NA | <.001 |
| Asia | 7 | 15.2 (9.8-22.9) | 99 | |
| Europe | 35 | 14.7 (12.7-16.9) | 100 | |
| North America | 9 | 13.4 (9.8-18.1) | 100 | |
| Oceania | 2 | 16.2 (4.0-47.7) | 100 | |
| South America | 1 | 21.9 (20.2-23.8) | NA | |
| Gross domestic product per capita (tertiles), $[b] | | | | |
| <4100 | 17 | 14.3 (11.2-18.0) | 99 | .74 |
| 4100-5200 | 22 | 13.8 (11.0-17.1) | 100 | |
| >5200 | 16 | 15.6 (12.3-19.5) | 100 | |
| Latitude of the main city (tertiles) | | | | |
| <40° | 19 | 15.0 (11.5-19.4) | 100 | .03 |
| 40°-51° | 18 | 11.7 (9.4-14.5) | 100 | |
| ≥52° | 18 | 17.0 (14.4-19.9) | 99 | |

Abbreviation: NA, not applicable.

[a] All estimates were for adults, but studies based on specific age groups, such as children and adolescents or older adults only, or on 1 specific sex were not included unless in the age group stratum or sex stratum.

[b] Gross domestic product per capita was based on official World Bank national data. Taiwan data were not available; therefore, we used China data in that case. Latitude was reported using approximated GeoHack coordinates.

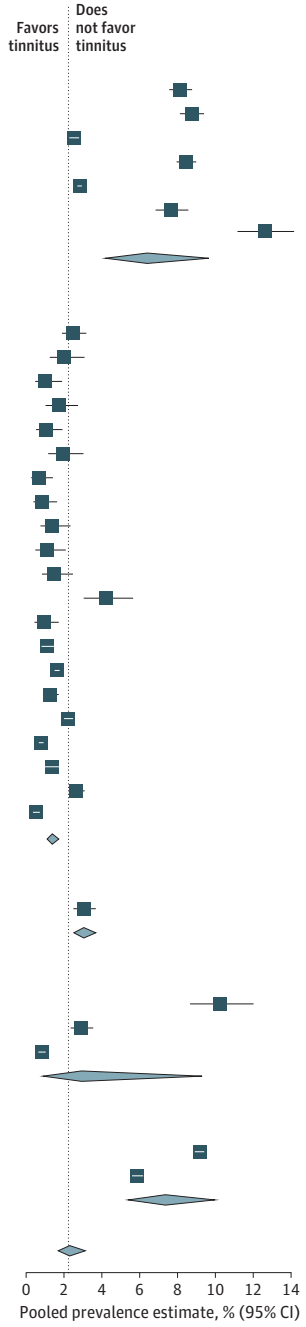
among strata), but it differed according to latitude of the main city (<40°, 15.0% [95% CI, 11.5%-19.4%]; 40°-51°, 11.7% [95% CI, 9.4%-14.5%]; and ≥52°, 17.0% [95% CI, 14.4%-19.9%]; *P* = .03 among strata).

The pooled prevalence of severe tinnitus among adults was 2.3% (95% CI, 1.7%-3.1%; 34 studies; $I^2$ = 99%) (**Figure 2**).[4,7,10-13,16,17,21,25,28-30,32,33,36,37,40,43,44,46,49] Among all studies, the pooled prevelance ranged from 0.5% (95% CI, 0.3%-0.7%) to 12.6% (95% CI, 11.1%-14.1%). Severity of tinnitus among adults differed with the tinnitus definition classes (*P* < .001 among strata). For those who were asked "Are you bothered by your tinnitus?" (S1), the pooled prevalence of severe tinnitus was 6.4% (95% CI, 4.2%-9.6%; 7 studies; $I^2$ = 100%); for those who were asked "How much are you bothered by your tinnitus?" (S2), it was 1.3% (95% CI, 1.1%-1.7%; 21 studies; $I^2$ = 93%); for those who were asked "Does your tinnitus interfere with sleep and concentration?" (S3), the only study identified a prevalence of 3.0% (95% CI, 2.5%-3.6%); for those asked about tinnitus severity assessed on a validated scale (S4), the pooled prevalence was 2.9% (95% CI, 0.9%-9.2%; 3 studies; $I^2$ = 99%); and for those asked about other tinnitus severity definitions (S5), it was 7.3% (95% CI, 5.4%-9.9%; 2 studies; $I^2$ = 100%).

The pooled prevalence of severe tinnitus among children and adolescents was 2.7% (95% CI, 0.8%-8.4%; 10 studies; $I^2$ = 99%) (**Table 2**). The pooled prevalence of severe tinnitus was 0.4% (95% CI, 0.3%-0.7%; 2 studies; $I^2$ = 0%) for young adults, 2.7% (95% CI, 1.6%-4.7%; 3 studies; $I^2$ = 97%) for middle-aged adults, and 6.9% (95% CI, 2.6%-17.4%; 4 studies; $I^2$ = 99%) for the older adults. The pooled prevalence of

Figure 2. Forest Plot of Pooled Prevalence, by Different Definitions of Severe Tinnitus in Adults

| Source | Adults with tinnitus, No. | Sample size, No. | % (95% CI) |
|---|---|---|---|
| **S1** | | | |
| Coles,[28] 1984 | 654 | 8069 | 8.1 (7.5-8.7) |
| Coles,[28] 1984b[a] | 665 | 7645 | 8.7 (8.1-9.4) |
| Fujii et al,[33] 2011 | 360 | 14423 | 2.5 (2.2-2.8) |
| Hasson et al,[16] 2010 | 943 | 11213 | 8.4 (7.9-8.9) |
| Lugo et al,[4] 2019 | 1995 | 71542 | 2.8 (2.7-2.9) |
| Nondahl et al,[46] 2002 | 285 | 3737 | 7.6 (6.8-8.5) |
| Oiticica and Bittar,[25] 2015 | 246 | 1960 | 12.6 (11.1-14.1) |
| **Pooled estimate** | | **118589** | **6.4 (4.2-9.6)** |
| Heterogeneity: $I^2$ = 100%; $P$ < .001 | | | |
| **S2** | | | |
| Axelsson and Ringdahl,[17] 1989 | 58 | 2378 | 2.4 (1.9-3.1) |
| Biswas et al,[12] 2021 (BG) | 20 | 1007 | 2.0 (1.2-3.1) |
| Biswas et al,[12] 2021 (DE) | 9 | 912 | 1.0 (0.5-1.9) |
| Biswas et al,[12] 2021 (ES) | 17 | 1000 | 1.7 (1.0-2.7) |
| Biswas et al,[12] 2021 (FR) | 10 | 971 | 1.0 (0.5-1.9) |
| Biswas et al,[12] 2021 (GR) | 18 | 945 | 1.9 (1.1-3.0) |
| Biswas et al,[12] 2021 (IE) | 6 | 941 | 0.6 (0.2-1.4) |
| Biswas et al,[12] 2021 (IT) | 8 | 979 | 0.8 (0.4-1.6) |
| Biswas et al,[12] 2021 (LV) | 13 | 957 | 1.4 (0.7-2.3) |
| Biswas et al,[12] 2021 (PL) | 8 | 761 | 1.1 (0.5-2.1) |
| Biswas et al,[12] 2021 (PT) | 14 | 958 | 1.5 (0.8-2.4) |
| Biswas et al,[12] 2021 (RO) | 41 | 984 | 4.2 (3.0-5.6) |
| Biswas et al,[12] 2021 (UK) | 9 | 1007 | 0.9 (0.4-1.7) |
| Choi et al,[13] 2020 | 40 | 3669 | 1.1 (0.8-1.5) |
| Davis,[29] 1989 | 565 | 35330 | 1.6 (1.5-1.7) |
| Gallus et al,[7] 2015 | 36 | 2952 | 1.2 (0.9-1.7) |
| Hannaford et al,[32] 2005 | 333 | 15140 | 2.2 (2.0-2.4) |
| Kim et al,[37] 2015 | 146 | 19290 | 0.8 (0.6-0.9) |
| Nondahl et al,[36] 2011 | 43 | 3267 | 1.3 (1.0-1.8) |
| Oosterloo et al,[49] 2021 | 160 | 6098 | 2.6 (2.2-3.1) |
| Xu et al,[40] 2011 | 31 | 6333 | 0.5 (0.3-0.7) |
| **Pooled estimate** | | **105879** | **1.3 (1.1-1.7)** |
| Heterogeneity: $I^2$ = 93%; $P$ < .01 | | | |
| **S3** | | | |
| Parving et al,[30] 1993 | 102 | 3387 | 3.0 (2.5-3.6) |
| **Pooled estimate** | | **3387** | **3.0 (2.5-3.6)** |
| Heterogeneity: not applicable | | | |
| **S4** | | | |
| House et al,[44] 2018 (THI) | 134 | 1314 | 10.2 (8.6-12.0) |
| Jalessi et al,[10] 2013 (TQ) | 92 | 3207 | 2.9 (2.3-3.5) |
| Khedr et al,[43] 2010 (THI) | 67 | 8484 | 0.8 (0.6-1.0) |
| **Pooled estimate** | | **13005** | **2.9 (0.9-9.2)** |
| Heterogeneity: $I^2$ = 99%; $P$ < .01 | | | |
| **S5** | | | |
| Krog et al,[21] 2010 | 4699 | 51574 | 9.1 (8.9-9.4) |
| Park et al,[11] 2014 | 1466 | 25100 | 5.8 (5.6-6.1) |
| **Pooled estimate** | | **76674** | **7.3 (5.4-9.9)** |
| Heterogeneity: $I^2$ = 100%; $P$ < .01 | | | |
| **Pooled estimate** | | **317534** | **2.3 (1.7-3.1)** |
| Heterogeneity: $I^2$ = 99%; $P$ < .001 | | | |
| Test for subgroup differences: $\chi^2_4$ = 90.24; $P$ < .01 | | | |




In some articles, the number of cases and/or sample sizes might not coincide with those provided in the original study owing to the R package, which recalculates the percentage. We were interested in keeping the estimate provided; therefore, we modified numbers accordingly. BG indicates Bulgaria; DE, Germany; ES, Spain; FR, France; GR, Greece; IE, Ireland; IT, Italy; LV, Latvia; PL, Polonia; PT, Portugal; RO, Romania; S1, "Are you bothered by your tinnitus?"; S2, "How much are you bothered by your tinnitus?"; S3, "Does your tinnitus interfere with sleep and concentration?"; S4, assessment of tinnitus severity through a specific scale; S5, assessment of tinnitus severity via other definitions of tinnitus severity; THI, Tinnitus Handicap Inventory; and TQ, Tinnitus Questionnaire.

[a] This study had 2 populations; the second population is indicated by "b."

severe tinnitus was 2.3% (95% CI, 1.1%-4.6%; 8 studies; $I^2$ = 100%) for male individuals and 2.7% (95% CI, 1.7%-4.3%; 7 studies; $I^2$ = 99%) for female individuals ($P$ = .66 among strata).

Severity among adults significantly differed by continent, ranging from 0.8% (95% CI, 0.6%-1.0%; 1 study) in Africa to 3.3% (95% CI, 1.2%-8.8%; 4 studies; $I^2$ = 99%) in North America ($P$ < .001 among strata) (Table 2). The prevalence of severe tinnitus did not differ significantly by per capita GDP tertile (1.7% [95% CI, 1.1%-2.7%] for <$4100; 2.7% [95% CI, 1.6%-4.3%] for $4100-$5200; and 3.0% [95% CI, 1.5%-5.9%] for >$5200; $P$ = .29 among strata) or by latitude (2.6% [95% CI, 1.5%-4.6%] for <40°; 1.9% [95% CI, 1.1%-3.1%] for 40°-51°; and 2.4% [95% CI, 1.4%-4.0%] for ≥52°; $P$ = .65 among strata). Pooled prevalence estimates of any tinnitus and severe tinnitus per continent are listed in eTable 6 in the Supplement.

Converting our pooled prevalence estimates to absolute numbers, we found that there were 749 million adults (95% CI, 655-858 million adults) worldwide with any tinnitus and 120 million adults (95% CI, 88-177 million adults) with severe

Table 2. Pooled Prevalence of Severe Tinnitus Among Adults, Overall and in Strata of Selected Individual-Level or Country-Specific Characteristics

| Stratum[a] | Severe tinnitus | | | |
|---|---|---|---|---|
| | Studies, No. | Pooled % (95% CI) | $I^2$, % | *P* value for heterogeneity among strata |
| Total | 34 | 2.3 (1.7-3.4) | 99 | NA |
| Individual-level characteristics | | | | |
| Sex | | | | |
| Male | 8 | 2.3 (1.1-4.6) | 100 | .66 |
| Female | 7 | 2.7 (1.7-4.3) | 99 | |
| Age group, y | | | | |
| Children and adolescents (5-17) | 10 | 2.7 (0.8-8.4) | 99 | <.001 |
| Young adults (18-44) | 2 | 0.4 (0.3-0.7) | 0 | |
| Middle-aged adults (45-64) | 3 | 2.7 (1.6-4.7) | 97 | |
| Older adults (≥65) | 4 | 6.9 (2.6-17.4) | 99 | |
| Tinnitus severity definition | | | | |
| Are you bothered by your tinnitus? (S1) | 7 | 6.4 (4.2-9.6) | 100 | <.001 |
| How much are you bothered by your tinnitus? (S2) | 21 | 1.3 (1.1-1.7) | 93 | |
| Does your tinnitus interfere with sleep and concentration? (S3) | 1 | 3.0 (2.5-3.6) | NA | |
| Tinnitus severity measured with a scale (S4) | 3 | 2.9 (0.9-9.2) | 99 | |
| Other definitions of severe tinnitus (S5) | 2 | 7.3 (5.4-9.9) | 100 | |
| Country-specific characteristics | | | | |
| Continent | | | | |
| Africa | 1 | 0.8 (0.6-1.0) | NA | <.001 |
| Asia | 5 | 1.8 (0.8-3.9) | 100 | |
| Europe | 23 | 2.2 (1.6-3.1) | 99 | |
| North America | 4 | 3.3 (1.2-8.8) | 99 | |
| Oceania | NA | NA | NA | |
| South America | 1 | 12.6 (11.1-14.1) | NA | |
| Gross domestic product per capita (tertiles), $[b] | | | | |
| <4100 | 15 | 1.7 (1.1-2.7) | 99 | .29 |
| 4100-5200 | 11 | 2.7 (1.6-4.3) | 100 | |
| ≥5200 | 8 | 3.0 (1.5-5.9) | 99 | |
| Latitude of the main city (tertiles) | | | | |
| <40° | 12 | 2.6 (1.5-4.6) | 99 | .65 |
| 40-51° | 12 | 1.9 (1.1-3.1) | 99 | |
| ≥52° | 10 | 2.4 (1.4-4.0) | 100 | |

Abbreviation: NA, not applicable.

[a] All estimates were for adults, but studies based on specific age groups, such as children and adolescents or older adults only, or on 1 specific sex were not included unless in the age group stratum or sex stratum.

[b] Gross domestic product per capita was based on the official World Bank national data. Taiwan data were not available; therefore, we used China data in that case. Latitude was reported using approximated GeoHack coordinates.

tinnitus. Using continent-specific estimates, we found that the resulting numbers would not change substantially (any tinnitus: 746 million people [95% CI, 537-1039 million people]; severe tinnitus: 140 million people [95% CI, 92-237 million people]).

A possible publication bias emerged for the prevalence of any tinnitus and for the prevalence of severe tinnitus ($P < .001$ for the Egger test; eFigure 4 in the Supplement). For adults, the pooled prevalence of diagnosed tinnitus was 3.4% (95% CI, 2.1%-5.5%; 3 studies; $I^2 = 99\%$), and the pooled prevalence of chronic tinnitus, defined as tinnitus occurring most or all of the time or persisting for months, was 9.8% (95% CI, 4.7%-19.3%; 3 studies; $I^2 = 99\%$).

Of 89 studies, 12 provided information on incidence estimates (**Table 3**).[14,15,23,46,50-57] These longitudinal studies came from 7 countries (ie, Australia, Germany, Sweden, Switzerland, Taiwan, UK, and US) and were published from 2002 to 2019. Annual incidence rates ranged substantially from 54 to 3914 per 100 000 person-years. The pooled annual incidence rate of any tinnitus, based on the crude estimate of the 6 studies among adults (with both sexes combined), is 1164 per 100 000 person-years (95% CI, 479-2828 per 100 000 person-years) (eFigure 5 in the Supplement).

## Discussion

To our knowledge, this systematic review provides the most comprehensive and up-to-date evidence on the prevalence and incidence of tinnitus worldwide among adults and children or adolescents, summarizing estimates from 89 original studies. For the first time, we provide pooled estimates of

Table 3. Incidence of Any Tinnitus Among Adults in the 12 Studies Included

| Source | Type of study and sample size | Incidence estimates | Notes |
|---|---|---|---|
| Bernhardt et al,[23] 2011 (Germany) | Cross-sectional analysis from the Study of Health in Pomerania, which is a 5-y follow-up study in West Pomerania of German adults aged 20-79 y (N = 212 157) | In >5 y of follow-up, 161 (75 female, 86 male) of 2970 participants without any tinnitus at baseline (5.4%) reported any new tinnitus; derived annual incidence rate, 1080 per 100 000 person-years.<br>A total of 166 (76 female, 90 male) of 3134 participants without diagnosed tinnitus at baseline (5.3%) reported new diagnosed tinnitus; derived annual incidence rate 1040 per 100 000 person-years. | Any tinnitus was defined as ear noises, while diagnosed tinnitus was defined after a diagnosis by an otolaryngologist. Prevalence of any tinnitus was 9.1% (95% CI, 8.3%-10.0%; we calculated CI) and of diagnosed tinnitus was 3.3% (95% CI, 2.8%-3.8%; we calculated CI). We calculated estimates between sexes: for those without any tinnitus at baseline it was 6.0% (95% CI, 4.8%-7.7%) among male participants and 4.7% (95% CI, 3.7%-5.7%) among female participants. For those without diagnosed tinnitus at baseline, prevalence was 6.1% (95% CI, 4.9%-7.3%) for male participants and 4.8% (95% CI, 3.7%-5.8%) for female participants. Estimates by age group were not reported. |
| Bogo et al,[50] 2017 (Sweden) | Cohort study of male twins (N = 500) aged 50 y, without tinnitus at baseline, with a follow-up after 18 y | In >18 y of follow-up, 139 new cases of tinnitus were observed. Overall incidence proportion: 27.8% (95% CI, 24.1%-31.9%). Derived annual incidence rate: 1544 per 100 000 person-years. | Estimates by age group were not reported. Overall prevalence of tinnitus was 13.5% at baseline (n = 146) and 34.4% (n = 191) at follow-up. |
| Frei et al,[51] 2012 (Switzerland) | Prospective cohort study (n = 1375) with follow-up after 1 y (n = 1124) for randomly selected residents from Basel, Switzerland, aged between 30 and 60 y | A total of 44 new cases of tinnitus were observed in 1 y. Derived annual incidence rate: 3914 per 100 000 person-years. | Tinnitus was present in 128 participants (9.3%) and in 131 participants (11.7%) at follow-up. No indications were provided on sex or age. |
| Glicksman et al,[52] 2014 (US) | Female cohort in the Nurses' Health Study II (N = 65 085) aged 30-44 y and without tinnitus at baseline in 1991, with a follow-up after 18 y | In >18 y of follow-up, 5289 new cases of tinnitus were found. Reported annual incidence rate: 475 per 100 000 person-years. | A significant inverse association between caffeine intake and incidence of tinnitus was observed. There was no association with decaffeinated coffee intake. Age-specific tinnitus incidence rates were provided by age groups. They were as follows: 361 cases for those younger than 40 y (104 per 100 000 person-years), 2286 cases for those aged 40-49 y (419 per 100 000 person-years), and 2642 for those older than 50 y (1273 per 100 000 person-years). |
| Gopinath et al,[14] 2010 (Australia) | Population-based study (Blue Mountains Hearing Study) (N = 1214), which is part of a larger cohort of people aged 49 y or older, with follow-up after 5 y | In >5 y of follow-up, of 811 individuals without tinnitus at baseline, 156 new cases were found (19.2%). Derived annual incidence rate: 3847 per 100 000 person-years. | Tinnitus at baseline persisted in 81.6% of participants (n = 346 of 424). A significant trend ($P$ = .005) was observed for the 5-y incidence for age, with incidence of tinnitus decreasing with age. A significant age trend was observed for men only. There was no sex difference in the 5-y incidence of tinnitus. |
| Lee et al,[53] 2016 (Taiwan) | Retrospective population-based cohort study (N = 30 340) of people aged ≥20 y over 10 y | There were 530 incident cases of diagnosed tinnitus. Derived annual incidence rate: 302 per 100 000 person-years. | Tinnitus was identified with *ICD-9* code 388.3. Incidence rates were provided according to sex (271 per 100 000 person-years for men, 317 per 100 000 person-years for women) and age (195 per 100 000 person-years for those aged ≤49 y, 500 per 100 000 person-years for those aged 50-64 y, and 576 per 100 000 person-years for those aged ≥65 y). |
| Martinez et al,[54] 2015 (UK) | Observational study of adults at risk for developing clinically significant tinnitus (N = 4 703 226) aged <85 y, with an observation period of 10 y | There were 14 303 incident cases of clinically significant tinnitus, leading to an incidence rate of 5.4 new cases per 10 000 person-years (95% CI, 5.3-5.5 per 10 000 person-years). The 5-y cumulative incidence was 24.9 cases per 10 000 person-years (95% CI, 24.3-25.4 per 10 000 person-years) and the 10-y cumulative incidence was 58.4 cases per 10 000 person-years (95% CI, 57.4-59.4 per 10 000 person-years). Reported annual incidence rate: 54 per 100 000 person-years. | Clinically significant tinnitus was defined as discharge from hospital with a primary diagnosis of tinnitus, or a primary care recording of tinnitus with subsequent related medical follow-up within 28 d. The incidence rate did not depend on sex, but increased with age, peaking at 11.4 per 10 000 person-years in those aged 60-69 y. The study provided the annual incidence rate for every year from 2002 to 2010, and 5-y and 10-y cumulative incidence by age at start of observation. |
| Nondhal et al,[46] 2002 (US) | Population-based study (Beaver Dam Study) of adults (N = 2513) aged 48-92 y, without tinnitus at baseline, with a follow up after 5 y | In >5 y of follow-up, 144 new cases of tinnitus were observed (67 in men and 77 in women), leading to a 5-y cumulative incidence of tinnitus of 5.7% (95% CI, 4.8%-6.6%). Derived annual incidence rate of 1140 per 100 000 person-years. | Prevalence of tinnitus at baseline (N = 3753) was 8.2% (95% CI, 7.4%-9.1%), higher in men (8.8%; 95% CI, 7.4%-10.2%) than in women (7.8%; 95% CI, 6.7%-9.0%). Incidence was higher in men (6.5%; 95% CI, 5.0%-8.0%) than in women (5.2%; 95% CI, 4.1%-6.3%). Estimates for incidence by age seemed not to vary among age groups; they were 6.2% (95% CI 4.7%-7.6%) for those aged 48-59 y, 5.2% (95% CI, 3.6%-6.8%) for those aged 60-69 y, 6.2% (95% CI, 4.2%-8.2%) for those aged 70-79 y, and 3.9% (95% CI, 1.5%-8.3%) for those aged 80-92 y. |

(continued)

Table 3. Incidence of Any Tinnitus Among Adults in the 12 Studies Included (continued)

| Source | Type of study and sample size | Incidence estimates | Notes |
|---|---|---|---|
| Nondhal et al,[15] 2010 (US) | Population-based study (Beaver Dam Study) of adults (N = 2922) aged 48-92 y, without tinnitus at baseline, with follow up after 10 y | In >10 years of follow-up, the 10-y cumulative incidence of tinnitus was 12.7% (95% CI, 11.4%-14.0%). Derived annual incidence rate: 1270 per 100 000 person-years. | The incidence of tinnitus was higher for men (14.8%; 95% CI, 12.7%-16.9%) than for women (11.2%; 95% CI, 9.7%-12.7%). For women, the 10-y incidence seemed to decrease with increasing age. |
| Shih et al,[55] 2017 (Taiwan) | Population-based cohort study (Taiwan National Health Insurance Research Database) of adults (N = 741 720) aged ≥18 y, followed for 10 y | There were 1173 incident cases of diagnosed tinnitus (615 in men and 558 in women). Derived annual incidence rate was 78 per 100 000 person-years. | Tinnitus was identified with *ICD-9* code 388.3. Incidence rates were provided by sex. |
| Stohler et al,[56] 2019 (UK) | Two separate study populations: first, retrospective cohort study of adult patients from 2000 and 2016 (N = 109 783); second, case-control study. | Age-standardized incidence rates of first-time GP-recorded tinnitus was 25.0 per 10 000 person-years (95% CI, 24.6-25.5 per 10 000 person-years). Reported annual incidence rate 250 per 100 000 person-years. | The incidence rates increased with age and were highest in the group aged 60-69 y (41.2 per 10 000 person-years; 95% CI, 40.7-41.7 per 10 000 person-years). Rates were similar for men (25.7 per 10 000 person-years; 95% CI, 25.0-26.4 per 10 000 person-years) and women (24.7 per 10 000 person-years; 95% CI, 24.0-25.3 per 10 000 person-years). Rates were also given by year (2000-2016). |
| Whelan et al,[57] 2011 (US) | Multi-institutional collaborative retrospective study (Childhood Cancer Survivors) investigating long-term survivors (≥5 y) diagnosed and treated between 1970 and 1986 compared with a randomly selected sibling cohort (N = 18 381) | Derived annual incidence rate in siblings was 159 per 100 000 person-years. | Cases were provided among cancer survivors, but annual incidence rate and relative risks made possible to derive the corresponding rate in siblings. |

Abbreviations: GP, general practitioner; *ICD-9*, *International Classification of Diseases, Ninth Revision*.

tinnitus; based on our data, approximately 14% of the world population have experienced tinnitus, and more than 2% have severe tinnitus. The prevalence of tinnitus is similar for both sexes, and increases in prevalence are associated with increasing age. Heterogeneous estimates have been reported by the few studies that provide data on the incidence of tinnitus. The pooled annual incidence rate approaches 1%.

The various cross-sectional studies providing data on the frequency of tinnitus used a wide variety of assessment methods.[3,58,59] We therefore classified the questions about any tinnitus into 6 groups and about severe tinnitus into 5 groups. Despite the substantial heterogeneity of estimates in the classes of any tinnitus, we did not find statistically significant differences in its prevalence across classes. This finding suggests that, at least for any tinnitus, not all the variability is explained by different definitions, and other factors might explain the prevalence of any tinnitus better at the population level.

Concomitantly, our findings suggest that data on tinnitus among children or adolescents are more prone to different interpretations of the question used to assess tinnitus. One possible reason could be that children are more frequently asked about tinnitus without specifically mentioning the name of the symptom. Other researchers have suggested that children might report the presence of noise to please the interviewers.[60] Despite the increasing number of studies on the subject, tinnitus remains an unrecognized problem that is inadequately assessed in the pediatric population.[61]

We found differences in terms of any tinnitus and severe tinnitus in association with age, confirming the increasing prevalence of the symptom with age.[7,10,11] In particular, whereas the prevalence of any tinnitus among older adults was close to 2.5 times higher than among young adults, the prevalence of severe tinnitus among older adults was almost 20 times higher than among young adults. This finding suggests that tinnitus is a particular disorder of older people.[8]

The literature is not unanimous about whether there is any association between sex and tinnitus. McCormack and colleagues[3] generally reported a higher prevalence of any tinnitus among men than women, whereas Biswas and colleagues[12] found a higher prevalence of bothersome tinnitus among women than men. The latter is consistent with previous findings of an association between severe tinnitus and suicidal attempts among women but not among men.[4] In our comprehensive review, pooling findings from a vast scientific literature, we did not find any significant difference according to sex for either any tinnitus or severe tinnitus.

As previously noted,[8] information is scant on the differences in tinnitus prevalence among countries, and we were only partially able to fill the gap. In fact, Africa, Oceania, and South America are not well represented. We found only 2 studies on the prevalence of any tinnitus and 2 studies on the prevalence of severe tinnitus from Africa and South America combined, covering more than 1.7 billion people. This finding may, to some extent, be due to the fact that, by protocol, we did not include articles that were not in English. Pooled estimates for any tinnitus from the other continents were somehow similar—between 13% and 15%—whereas differences were larger for pooled estimates for severe tinnitus—between 1.8% and 3.3%.

In addition to country-specific population characteristics, including lifestyle and dietary habits,[7] mental health conditions,[1] or ethnicity,[13] variations in the prevalence of tinnitus between countries and continents could be explained by different exposures and etiologies. Recently, it has been evidenced by means of genetic epidemiology studies[50,62-64] and genomic studies[65,66] that tinnitus is hereditary. Although common variants have been associ-

ated with broad tinnitus definitions, such as "any" tinnitus, it appears that rare variants are more associated with severe tinnitus.[65,66] Thus, differences in population genetics could be associated with the large discrepancies in the prevalence of severe tinnitus, as for instance in South America. However, more efforts are needed to investigate the association of genetics with any tinnitus or severe tinnitus across different countries and continents. In a European survey, Biswas et al[12] found that the prevalence of tinnitus was greater in countries from the eastern European region than in western Europe, with Bulgaria reaching a prevalence for any tinnitus of 28.3% and Romania with a prevalence for severe tinnitus peaking at 4.2%. This finding is consistent with a greater prevalence of hearing loss among individuals in these countries, according to the Global Burden of Disease study.[67] It is possible that less active work-related preventive measures against occupational noise exposure or limited access to rehabilitation for hearing loss by means of hearing aids may cause such disparities across Europe. In contrast, the low frequency of acoustic neuromas and head injuries and traumas among individuals with tinnitus is unlikely to explain such variety across countries and continents.[68-70] Other risk factors could also underlie such differences in prevalence. However, only a handful of case-control and longitudinal studies have investigated the potential causal relationship to tinnitus, most of which focus on hearing-related conditions.[14,15] Thus, a comprehensive picture of the association of nonauditory etiologies with any tinnitus or severe tinnitus is required.

Our results do indicate that differences arise when using multiple definitions to assess tinnitus. For future research, therefore, we recommend using a standardized questionnaire for assessing the prevalence of tinnitus, to make better comparisons between different surveys, identifying more solid estimates of tinnitus in various countries worldwide. We acknowledge, however, that no single question can address the multidimensional properties of tinnitus that are critical for its assessment (duration [acute or chronic], temporality [intermittent or constant], and severity [negligible or impactful]). Thus, our suggestion is to systematically use the questions given by a consortium of experts available in multiple languages.[58]

For children specifically, a large difference was clear between questionnaires that mentioned the term *tinnitus* and those that did not; we conclude that future surveys addressing children and adolescents must state clearly the name of the disorder in their questions—with an explanation—as the high prevalence of tinnitus might be a result of the participants not recognizing the extraordinary nature of the symptom being investigated.

An association has been hypothesized between socioeconomic status and tinnitus.[16,54] Although with all the limitations of an ecological analysis,[71,72] we found no association between per-capita GDP and tinnitus prevalence.

Tinnitus has been reported to have a seasonal pattern, where it is worse in the winter than in the summer.[73] Thus, the hours of sunlight per day or certain temperatures might be associated with the onset or severity of tinnitus. Countries with their main city at an intermediate latitude (40°-51°) had the lowest prevalence and the lowest severity of tinnitus. Future analytical studies should investigate this issue in more detail.

In this meta-analysis, we defined as eligible only studies based on samples representative of the general population, excluding subgroups of the population exposed to selected risk factors, such as veterans and musicians. In these 2 particular populations, the prevalence of tinnitus was reported with a point estimate of 31% among veterans[74] and 26% among musicians,[75] much higher than among the general adult population. These 2 subpopulations might therefore be targeted for specific interventions to prevent or limit exposure to noise and, consequently, to reduce tinnitus and other hearing conditions.

There is a paucity of articles on the incidence of tinnitus: of 113 eligible articles, only 12 provided data on the incidence of tinnitus, although many cohorts were available with tinnitus assessed at follow-up. The incidence rates differed by up to 2 orders of magnitude in various studies. Although estimates stratified by sex are frequently provided, information is limited on incident cases by age group.

### Limitations and Strengths

This study has some limitations, including the classification of tinnitus into 6 groups of questions for any tinnitus (A1-A6) and 5 groups for severe tinnitus (S1-S5). Although inspired by the 8 different categories for tinnitus identified by McCormack et al,[3] our classification has not been validated and is therefore subject to the interpretation of the researchers who used it. Moreover, we cannot exclude a possible publication bias regarding the prevalence of both any tinnitus and severe tinnitus.

The strengths of the study include the original method used to identify relevant articles, which involves an umbrella review as well as a traditional review.[9] This method has already been shown to be both effective and efficient in the identification of relevant articles in other recent systematic reviews.[76-78] Thus, we were able to include almost twice the number of articles included in the most comprehensive review of the literature published before the present one,[3] including, in our opinion, at least 11 articles that could have been retrieved by McCormack and colleagues[3] but were not in that review. Thus, to our knowledge, this is the most comprehensive review conducted to date because it considers a larger publication period (between 1972 and 2021) and is not limited to adults but also includes children and adolescents.

## Conclusions

To our knowledge, this is the first meta-analysis on the frequency of tinnitus. Generalizing our estimates to the whole global population, one can infer that more than 740 million people experience tinnitus and more than 120 million people worldwide have a severe form of tinnitus. Such estimates place tinnitus at an order of magnitude similar to the leading causes of years lived with disability, namely, hearing loss, followed by migraine, low back pain, and neck pain.[67] Health authori-

ties and research institutions, such as the Global Burden of Disease, should consider this prevalence and play a leading role in funding, ultimately to boost research on tinnitus and improve the care and the lives of patients with tinnitus.

## ARTICLE INFORMATION

**Accepted for Publication:** June 13, 2022.

**Published Online:** August 8, 2022. doi:10.1001/jamaneurol.2022.2189

**Author Affiliations:** Department of Environmental Health Sciences, Istituto di Ricerche Farmacologiche Mario Negri IRCCS, Milan, Italy (Jarach, Lugo, Scala, Gallus); GROW-School for Oncology and Developmental Biology, Department of Epidemiology, Maastricht University Medical Centre, Maastricht, the Netherlands (van den Brandt); Care and Public Health Research Institute-School for Public Health and Primary Care, Department of Epidemiology, Maastricht University Medical Centre, Maastricht, the Netherlands (van den Brandt); Laboratory of Experimental Audiology, Department of Physiology and Pharmacology, Karolinska Institutet, Stockholm, Sweden (Cederroth); National Institute for Health Research Nottingham Biomedical Research Centre, Nottingham University Hospitals National Health Service Trust, Nottingham, United Kingdom (Cederroth); Division of Clinical Neuroscience, Hearing Sciences, School of Medicine, University of Nottingham, Nottingham, United Kingdom (Cederroth); School of Medicine, University Vita-Salute San Raffaele, Milan, Italy (Odone); Department of Public Health, Experimental and Forensic Medicine, University of Pavia, Pavia, Italy (Odone); School of Medicine and Surgery, Department of Otorhinolaryngology, University of Milan-Bicocca, Milan, Italy (Garavello); Department of Psychiatry and Psychotherapy, University Regensburg, Regensburg, Germany (Schlee, Langguth).

**Author Contributions:** Ms Jarach and Dr Galllus had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.
*Concept and design:* Jarach, Lugo, Cederroth, Odone, Garavello, Schlee, Gallus.
*Acquisition, analysis, or interpretation of data:* Jarach, Scala, van den Brandt, Odone, Schlee, Langguth, Gallus.
*Drafting of the manuscript:* Jarach, Scala, Schlee, Gallus.
*Critical revision of the manuscript for important intellectual content:* Jarach, Lugo, van den Brandt, Cederroth, Odone, Garavello, Schlee, Langguth, Gallus.
*Statistical analysis:* Jarach, Scala.
*Obtained funding:* Cederroth, Schlee, Gallus.
*Supervision:* van den Brandt, Odone, Garavello, Schlee, Gallus.

**Conflict of Interest Disclosures:** Dr Cederroth reported being a member of the British Tinnitus Association's Professional Advisers' Committee and the American Tinnitus Association's Scientific Advisory Board. Dr Schlee reported receiving grants from the European Union's Horizon 2020 Research and Innovation Programme grant agreement during the conduct of the study. Dr Langguth reported receiving grants from European Union Unification of Treatments and Interventions for Tinnitus Patients during the conduct of the study; receiving personal fees from Neuromod and Schwabe outside the submitted work; and serving as chair of the Tinnitus Research Initiative, a nonprofit organization. No other disclosures were reported.

**Funding/Support:** The work of Drs Lugo, Langguth, and Gallus and Mr Scala, is partially supported by Unification of Treatments and Interventions for Tinnitus Patients–UNITI project, which has received funding from the European Union's Horizon 2020 Research and Innovation Programme (grant agreement 848261). The work of Ms Jarach and Drs Cederroth and Gallus is partially supported by Tinnitus Genetic and Environmental Risks–TIGER project, which has received funding from the European Union's Horizon 2020 Research and Innovation Programme (grant agreement GNP-182). The study is also supported by AIT ONLUS Associazione Italiana Tinnitus.

**Role of the Funder/Sponsor:** The funders had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication.

**Additional Information:** Data and R scripts that support the findings of this study and materials are available from the corresponding author on request.

## REFERENCES

1. Langguth B, Kreuzer PM, Kleinjung T, De Ridder D. Tinnitus: causes and clinical management. *Lancet Neurol*. 2013;12(9):920-930. doi:10.1016/S1474-4422(13)70160-1

2. Baguley D, McFerran D, Hall D. Tinnitus. *Lancet*. 2013;382(9904):1600-1607. doi:10.1016/S0140-6736(13)60142-7

3. McCormack A, Edmondson-Jones M, Somerset S, Hall D. A systematic review of the reporting of tinnitus prevalence and severity. *Hear Res*. 2016;337:70-79. doi:10.1016/j.heares.2016.05.009

4. Lugo A, Trpchevska N, Liu X, et al. Sex-specific association of tinnitus with suicide attempts. *JAMA Otolaryngol Head Neck Surg*. 2019;145(7):685-687. doi:10.1001/jamaoto.2019.0566

5. Nondahl DM, Cruickshanks KJ, Dalton DS, et al. The impact of tinnitus on quality of life in older adults. *J Am Acad Audiol*. 2007;18(3):257-266. doi:10.3766/jaaa.18.3.7

6. Cianfrone G, Mazzei F, Salviati M, et al. Tinnitus Holistic Simplified Classification (THoSC): a new assessment for subjective tinnitus, with diagnostic and therapeutic implications. *Ann Otol Rhinol Laryngol*. 2015;124(7):550-560. doi:10.1177/0003489415570931

7. Gallus S, Lugo A, Garavello W, et al. Prevalence and determinants of tinnitus in the Italian adult population. *Neuroepidemiology*. 2015;45(1):12-19. doi:10.1159/000431376

8. Biswas R, Hall DA. Prevalence, incidence, and risk factors for tinnitus. *Curr Top Behav Neurosci*. 2021;51:3-28. doi:10.1007/7854_2020_154

9. Lugo A, Bosetti C, Peveri G, Rota M, Bagnardi V, Gallus S. Dose-response relationship between cigarette smoking and site-specific cancer risk: protocol for a systematic review with an original design combining umbrella and traditional reviews. *BMJ Open*. 2017;7(10):e018930.

10. Jalessi M, Farhadi M, Asghari A, et al. Tinnitus: an epidemiologic study in Iranian population. *Acta Med Iran*. 2013;51(12):886-891.

11. Park KH, Lee SH, Koo JW, et al. Prevalence and associated factors of tinnitus: data from the Korean National Health and Nutrition Examination Survey 2009-2011. *J Epidemiol*. 2014;24(5):417-426. doi:10.2188/jea.JE20140024

12. Biswas R, Lugo A, Akeroyd MA, Schlee W, Gallus S, Hall DA. Tinnitus prevalence in Europe: a multi-country cross-sectional population study. *Lancet Reg Health Eur*. 2021;12:100250. doi:10.1016/j.lanepe.2021.10025

13. Choi JS, Yu AJ, Voelker CCJ, Doherty JK, Oghalai JS, Fisher LM. Prevalence of tinnitus and associated factors among Asian Americans: results from a national sample. *Laryngoscope*. 2020;130(12):E933-E940. doi:10.1002/lary.28535

14. Gopinath B, McMahon CM, Rochtchina E, Karpa MJ, Mitchell P. Incidence, persistence, and progression of tinnitus symptoms in older adults: the Blue Mountains Hearing Study. *Ear Hear*. 2010;31(3):407-412. doi:10.1097/AUD.0b013e3181cdb2a2

15. Nondahl DM, Cruickshanks KJ, Wiley TL, et al. The ten-year incidence of tinnitus among older adults. *Int J Audiol*. 2010;49(8):580-585. doi:10.3109/14992021003753508

16. Hasson D, Theorell T, Westerlund H, Canlon B. Prevalence and characteristics of hearing problems in a working and non-working Swedish population. *J Epidemiol Community Health*. 2010;64(5):453-460. doi:10.1136/jech.2009.095430

17. Axelsson A, Ringdahl A. Tinnitus—a study of its prevalence and characteristics. *Br J Audiol*. 1989;23(1):53-62. doi:10.3109/03005368909077819

18. Kuttila S, Kuttila M, Le Bell Y, Alanen P, Suonpää J. Recurrent tinnitus and associated ear symptoms in adults. *Int J Audiol*. 2005;44(3):164-170. doi:10.1080/14992020500057608

19. Sugiura S, Uchida Y, Nakashima T, Yoshioka M, Ando F, Shimokata H. Tinnitus and brain MRI findings in Japanese elderly. *Acta Otolaryngol*. 2008;128(5):525-529. doi:10.1080/00016480701558930

20. Dorner TE, Stronegger WJ, Rebhandl E, Rieder A, Freidl W. The relationship between various psychosocial factors and physical symptoms reported during primary-care health examinations. *Wien Klin Wochenschr*. 2010;122(3-4):103-109. doi:10.1007/s00508-010-1312-6

21. Krog NH, Engdahl B, Tambs K. The association between tinnitus and mental health in a general population sample: results from the HUNT Study. *J Psychosom Res*. 2010;69(3):289-298. doi:10.1016/j.jpsychores.2010.03.008

22. Baigi A, Oden A, Almlid-Larsen V, Barrenäs ML, Holgers KM. Tinnitus in the general population with a focus on noise and stress: a public health study. *Ear Hear*. 2011;32(6):787-789. doi:10.1097/AUD.0b013e31822229bd

23. Bernhardt O, Mundt T, Welk A, et al. Signs and symptoms of temporomandibular disorders and the

incidence of tinnitus. *J Oral Rehabil*. 2011;38(12):891-901. doi:10.1111/j.1365-2842.2011.02224.x

**24**. Engdahl B, Krog NH, Kvestad E, Hoffman HJ, Tambs K. Occupation and the risk of bothersome tinnitus: results from a prospective cohort study (HUNT). *BMJ Open*. 2012;2(1):e000512. doi:10.1136/bmjopen-2011-000512

**25**. Oiticica J, Bittar RS. Tinnitus prevalence in the city of São Paulo. *Braz J Otorhinolaryngol*. 2015;81(2):167-176. doi:10.1016/j.bjorl.2014.12.004

**26**. Herr RM, Loerbroks A, Bosch JA, Seegel M, Schneider M, Schmidt B. Associations of organizational justice with tinnitus and the mediating role of depressive symptoms and burnout-findings from a cross-sectional study. *Int J Behav Med*. 2016;23(2):190-197. doi:10.1007/s12529-015-9505-z

**27**. Schubert NMA, Rosmalen JGM, van Dijk P, Pyott SJ. A retrospective cross-sectional study on tinnitus prevalence and disease associations in the Dutch population-based cohort Lifelines. *Hear Res*. 2021;411:108355. doi:10.1016/j.heares.2021.108355

**28**. Coles RR. Epidemiology of tinnitus: (1) prevalence. *J Laryngol Otol Suppl*. 1984;9:7-15. doi:10.1017/S1755146300090041

**29**. Davis AC. The prevalence of hearing impairment and reported hearing disability among adults in Great Britain. *Int J Epidemiol*. 1989;18(4):911-917. doi:10.1093/ije/18.4.911

**30**. Parving A, Hein HO, Suadicani P, Ostri B, Gyntelberg F. Epidemiology of hearing disorders: some factors affecting hearing: the Copenhagen Male Study. *Scand Audiol*. 1993;22(2):101-107. doi:10.3109/01050399309046025

**31**. Quaranta A, Assennato G, Sallustio V. Epidemiology of hearing problems among adults in Italy. *Scand Audiol Suppl*. 1996;42:9-13.

**32**. Hannaford PC, Simpson JA, Bisset AF, Davis A, McKerrow W, Mills R. The prevalence of ear, nose and throat problems in the community: results from a national cross-sectional postal survey in Scotland. *Fam Pract*. 2005;22(3):227-233. doi:10.1093/fampra/cmi004

**33**. Fujii K, Nagata C, Nakamura K, et al. Prevalence of tinnitus in community-dwelling Japanese adults. *J Epidemiol*. 2011;21(4):299-304. doi:10.2188/jea.JE20100124

**34**. Cooper JC Jr. Health and Nutrition Examination Survey of 1971-75, part II: tinnitus, subjective hearing loss, and well-being. *J Am Acad Audiol*. 1994;5(1):37-43.

**35**. Shargorodsky J, Curhan GC, Farwell WR. Prevalence and characteristics of tinnitus among US adults. *Am J Med*. 2010;123(8):711-718. doi:10.1016/j.amjmed.2010.02.015

**36**. Nondahl DM, Cruickshanks KJ, Huang GH, et al. Tinnitus and its risk factors in the Beaver Dam Offspring Study. *Int J Audiol*. 2011;50(5):313-320. doi:10.3109/14992027.2010.551220

**37**. Kim HJ, Lee HJ, An SY, et al. Analysis of the prevalence and associated risk factors of tinnitus in adults. *PLoS One*. 2015;10(5):e0127578. doi:10.1371/journal.pone.0127578

**38**. Wu BP, Searchfield G, Exeter DJ, Lee A. Tinnitus prevalence in New Zealand. *N Z Med J*. 2015;128(1423):24-34.

**39**. Yang H, Cai Y, Guo H, et al. Prevalence and factors associated with tinnitus: data from adult residents in Guangdong province, South of China. *Int J Audiol*. 2018;57(12):892-899. doi:10.1080/14992027.2018.1506169

**40**. Xu X, Bu X, Zhou L, Xing G, Liu C, Wang D. An epidemiologic study of tinnitus in a population in Jiangsu Province, China. *J Am Acad Audiol*. 2011;22(9):578-585. doi:10.3766/jaaa.22.9.3

**41**. Masterson EA, Themann CL, Luckhaupt SE, Li J, Calvert GM. Hearing difficulty and tinnitus among U.S. workers and non-workers in 2007. *Am J Ind Med*. 2016;59(4):290-300. doi:10.1002/ajim.22565

**42**. Rademaker MM, Smit AL, Brabers AEM, de Jong JD, Stokroos RJ, Stegeman I. Using different cutoffs to define tinnitus and assess its prevalence—a survey in the Dutch general population. *Front Neurol*. 2021;12:690192. doi:10.3389/fneur.2021.690192

**43**. Khedr EM, Ahmed MA, Shawky OA, Mohamed ES, El Attar GS, Mohammad KA. Epidemiological study of chronic tinnitus in Assiut, Egypt. *Neuroepidemiology*. 2010;35(1):45-52. doi:10.1159/000306630

**44**. House L, Bishop CE, Spankovich C, Su D, Valle K, Schweinfurth J. Tinnitus and its risk factors in African Americans: the Jackson Heart Study. *Laryngoscope*. 2018;128(7):1668-1675. doi:10.1002/lary.26964

**45**. Weiss NS. Relation of high blood pressure to headache, epistaxis, and selected other symptoms—the United States Health Examination Survey of Adults. *N Engl J Med*. 1972;287(13):631-633. doi:10.1056/NEJM197209282871303

**46**. Nondahl DM, Cruickshanks KJ, Wiley TL, Klein R, Klein BE, Tweed TS. Prevalence and 5-year incidence of tinnitus among older adults: the Epidemiology of Hearing Loss Study. *J Am Acad Audiol*. 2002;13(6):323-331. doi:10.1055/s-0040-1715975

**47**. Palmer KT, Griffin MJ, Syddall HE, Davis A, Pannett B, Coggon D. Occupational exposure to noise and the attributable burden of hearing difficulties in Great Britain. *Occup Environ Med*. 2002;59(9):634-639. doi:10.1136/oem.59.9.634

**48**. Johansson MS, Arlinger SD. Prevalence of hearing impairment in a population in Sweden. *Int J Audiol*. 2003;42(1):18-28. doi:10.3109/14992020309056081

**49**. Oosterloo BC, Croll PH, Baatenburg de Jong RJ, Ikram MK, Goedegebure A. Prevalence of tinnitus in an aging population and its relation to age and hearing loss. *Otolaryngol Head Neck Surg*. 2021;164(4):859-868. doi:10.1177/0194599820957296

**50**. Bogo R, Farah A, Karlsson KK, Pedersen NL, Svartengren M, Skjönsberg Å. Prevalence, incidence proportion, and heritability for tinnitus: a longitudinal twin study. *Ear Hear*. 2017;38(3):292-300. doi:10.1097/AUD.0000000000000397

**51**. Frei P, Mohler E, Braun-Fahrländer C, Fröhlich J, Neubauer G, Röösli M; QUALIFEX-team. Cohort study on the effects of everyday life radio frequency electromagnetic field exposure on non-specific symptoms and tinnitus. *Environ Int*. 2012;38(1):29-36. doi:10.1016/j.envint.2011.08.002

**52**. Glicksman JT, Curhan SG, Curhan GC. A prospective study of caffeine intake and risk of incident tinnitus. *Am J Med*. 2014;127(8):739-743. doi:10.1016/j.amjmed.2014.02.033

**53**. Lee CF, Lin MC, Lin HT, Lin CL, Wang TC, Kao CH. Increased risk of tinnitus in patients with temporomandibular disorder: a retrospective population-based cohort study. *Eur Arch Otorhinolaryngol*. 2016;273(1):203-208. doi:10.1007/s00405-015-3491-2

**54**. Martinez C, Wallenhorst C, McFerran D, Hall DA. Incidence rates of clinically significant tinnitus: 10-year trend from a cohort study in England. *Ear Hear*. 2015;36(3):e69-e75. doi:10.1097/AUD.0000000000000121

**55**. Shih CP, Lin HC, Chung CH, et al. Increased risk of tinnitus in patients with chronic kidney disease: a nationwide, population-based cohort study. *PLoS One*. 2017;12(8):e0183192. doi:10.1371/journal.pone.0183192

**56**. Stohler NA, Reinau D, Jick SS, Bodmer D, Meier CR. A study on the epidemiology of tinnitus in the United Kingdom. *Clin Epidemiol*. 2019;11:855-871. doi:10.2147/CLEP.S213136

**57**. Whelan K, Stratton K, Kawashima T, et al. Auditory complications in childhood cancer survivors: a report from the Childhood Cancer Survivor Study. *Pediatr Blood Cancer*. 2011;57(1):126-134. doi:10.1002/pbc.23025

**58**. Biswas R, Lugo A, Gallus S, Akeroyd MA, Hall DA. Standardized questions in English for estimating tinnitus prevalence and severity, hearing difficulty and usage of healthcare resources, and their translation into 11 European languages. *Hear Res*. 2019;377:330-338. doi:10.1016/j.heares.2019.02.008

**59**. Biswas R, Lugo A, Genitsaridi E, et al. Modifiable lifestyle-related risk factors for tinnitus in the general population: an overview of smoking, alcohol, body mass index and caffeine intake. *Prog Brain Res*. 2021;263:1-24. doi:10.1016/bs.pbr.2021.04.005

**60**. Baguley DM, McFerran DJ. Tinnitus in childhood. *Int J Pediatr Otorhinolaryngol*. 1999;49(2):99-105. doi:10.1016/S0165-5876(99)00111-1

**61**. Savastano M, Marioni G, de Filippis C. Tinnitus in children without hearing impairment. *Int J Pediatr Otorhinolaryngol*. 2009;73(suppl 1):S13-S15. doi:10.1016/S0165-5876(09)70003-5

**62**. Maas IL, Brüggemann P, Requena T, et al. Genetic susceptibility to bilateral tinnitus in a Swedish twin cohort. *Genet Med*. 2017;19(9):1007-1012. doi:10.1038/gim.2017.4

**63**. Cederroth CR, PirouziFard M, Trpchevska N, et al. Association of genetic vs environmental factors in Swedish adoptees with clinically significant tinnitus. *JAMA Otolaryngol Head Neck Surg*. 2019;145(3):222-229. doi:10.1001/jamaoto.2018.3852

**64**. Trpchevska N, Bulla J, Prada Hellberg M, et al. Sex-dependent aggregation of tinnitus in Swedish families. *J Clin Med*. 2020;9(12):3812. doi:10.3390/jcm9123812

**65**. Clifford RE, Maihofer AX, Stein MB, Ryan AF, Nievergelt CM. Novel risk loci in tinnitus and causal inference with neuropsychiatric disorders among adults of European ancestry. *JAMA Otolaryngol Head Neck Surg*. 2020;146(11):1015-1025. doi:10.1001/jamaoto.2020.2920

**66**. Amanat S, Gallego-Martinez A, Sollini J, et al. Burden of rare variants in synaptic genes in patients with severe tinnitus: an exome based extreme phenotype study. *EBioMedicine*. 2021;66:103309. doi:10.1016/j.ebiom.2021.103309

**67**. GBD 2016 Disease and Injury Incidence and Prevalence Collaborators. Global, regional, and

national incidence, prevalence, and years lived with disability for 328 diseases and injuries for 195 countries, 1990-2016: a systematic analysis for the Global Burden of Disease Study 2016. *Lancet*. 2017;390(10100):1211-1259. doi:10.1016/S0140-6736(17)32154-2

**68**. Edvall NK, Gunan E, Genitsaridi E, et al. Impact of temporomandibular joint complaints on tinnitus-related distress. *Front Neurosci*. 2019;13:879. doi:10.3389/fnins.2019.00879

**69**. Lugo A, Edvall NK, Lazar A, et al. Relationship between headaches and tinnitus in a Swedish study. *Sci Rep*. 2020;10(1):8494. doi:10.1038/s41598-020-65395-1

**70**. Cederroth CR, Lugo A, Edvall NK, et al. Association between hyperacusis and tinnitus. *J Clin Med*. 2020;9(8):2412. doi:10.3390/jcm9082412

**71**. Morgenstern H. Uses of ecologic analysis in epidemiologic research. *Am J Public Health*. 1982;72(12):1336-1344. doi:10.2105/AJPH.72.12.1336

**72**. Neumark Y. What can ecological studies tell us about death? *Isr J Health Policy Res*. 2017;6(1):52. doi:10.1186/s13584-017-0176-x

**73**. Plante DT, Ingram DG. Seasonal trends in tinnitus symptomatology: evidence from internet search engine query data. *Eur Arch Otorhinolaryngol*. 2015;272(10):2807-2813. doi:10.1007/s00405-014-3287-9

**74**. Theodoroff SM, Lewis MS, Folmer RL, Henry JA, Carlson KF. Hearing impairment and tinnitus: prevalence, risk factors, and outcomes in US service members and veterans deployed to the Iraq and Afghanistan wars. *Epidemiol Rev*. 2015;37:71-85. doi:10.1093/epirev/mxu005

**75**. Di Stadio A, Dipietro L, Ricci G, et al. Hearing loss, tinnitus, hyperacusis, and diplacusis in professional musicians: a systematic review. *Int J Environ Res Public Health*. 2018;15(10):E2120. doi:10.3390/ijerph15102120

**76**. Botteri E, Borroni E, Sloan EK, et al. Smoking and colorectal cancer risk, overall and by molecular subtypes: a meta-analysis. *Am J Gastroenterol*. 2020;115(12):1940-1949. doi:10.14309/ajg.0000000000000803

**77**. Lugo A, Peveri G, Bosetti C, et al. Strong excess risk of pancreatic cancer for low frequency and duration of cigarette smoking: a comprehensive review and meta-analysis. *Eur J Cancer*. 2018;104:117-126. doi:10.1016/j.ejca.2018.09.007

**78**. Lugo A, Peveri G, Gallus S. Should we consider gallbladder cancer a new smoking-related cancer? a comprehensive meta-analysis focused on dose-response relationships. *Int J Cancer*. 2020;146(12):3304-3311. doi:10.1002/ijc.32681