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Original Article

A Bibliometric Analysis of Publications on Tinnitus: A Study Based on Web of Science Data From 1980 to 2020

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BACKGROUND: The incidence of tinnitus has been increasing together with its patient impact and societal costs. Much research has been conducted in the field of tinnitus, especially on treatment modalities because there still is no cure. This study aims to analyze the evolutions and developments in the scientific output relating to tinnitus.

METHODS: We analyzed the Science Citation Index Expanded featured articles in the Web of Science Core Collection relating to tinnitus from 1980 to 2020. The publications were analyzed by characteristics such as the countries and institutions, journals, the most cited articles and references, and the most frequently used words in the abstracts and keywords.

RESULTS: In total, 8282 articles relating to tinnitus were identified in the Web of Science. The number of publications has been significantly increasing after the 1990s. Of the 8282 articles, a major part originated from the American and European institutions. Most articles originated from high-impact journals, which consequently also covered the most cited papers. A major interest was seen in areas about treatment and pathogenic mechanisms.

CONCLUSION: This bibliometric analysis here indicated an increasing trend in tinnitus research from 1980 to 2020, particularly with the increase in tinnitus burden and the societal costs by it. Specific interest has been seen in the specific tinnitus pathophysiological mechanisms and treatment. Individual researchers and institutions will gain a new perspective on their future studies based on the bibliometric data in our paper.

KEYWORDS: Tinnitus, Web of Science, bibliometric analysis, publication

INTRODUCTION

By differences in handled definitions, reported prevalence numbers of tinnitus vary widely, ranging between 5% and 43%.[1-3] Recently, to differentiate more especially between the perception of the sound and the efficacy, a multidisciplinary proposal has been made distinguishing tinnitus ("the conscious awareness of a tonal or composite noise for which there is no identifiable corresponding external acoustic source") from having a tinnitus disorder ("when tinnitus is associated with emotional distress, cognitive dysfunction, and/or autonomic arousal, leading to behavioral changes and functional disability").[4] The experienced impact on the daily life of people with tinnitus disorder is diverse and complex and associated with impaired quality of life, social withdrawal, and impaired work performance.[5-7] This not only has a social impact but also develops an economic burden on society.[8,9] This makes tinnitus an interesting subject in the research field. Clinical and experimental studies are gradually increasing to develop an effective treatment by providing a better understanding of the pathology.[10] However, to date, the true etiology of tinnitus remains unclear, and the number of evidence-based treatments is limited. Also, it is difficult for clinicians to have a comprehensive and general perspective for treatment due to the rapidly increasing number of articles. A relative ranking of these studies can provide precious information for patients, practitioners, and decision-makers. Recently, the European Union granted the "Unification of Treatments and Interventions for Tinnitus Patients (UNITI)" project to uniform the treatment for patients with tinnitus.[4] The UNITI will be doing this, inter alia, by analyzing the results of existing clinical studies to identify subgroups of patients with specific treatment responses and identify systematic differences between the patient groups at the participating clinical centers.

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Bibliometric analysis, which has been increasing in popularity recently, is another statistical method of bibliographic counting that can assess and quantify the literature growth of a particular research content.[11,12] Bibliometric methods examine the many features of publications to provide development trends or future research orientations of an area of interest.[13,14] In recent years, bibliometric analysis is being used in many fields of medicine worldwide to evaluate research efficiency.[12-18] Also, in the field of otology, bibliometric analysis has been an upcoming phenomenon. In 2020, the first earlier bibliometric study concerning tinnitus was performed by Ceylan.[18] However, this analysis only identified the top 100 cited papers about the tinnitus from 1900 to 2020. Then, a bibliometric analysis of studies on tinnitus over the last 20 years has been published recently by Zhou et al.[19] On the other hand, our study is the most comprehensive bibliometric study on tinnitus in the literature to the best of our knowledge.

Here, we present the bibliometric analysis of Science Citation Index Expanded (SCI-E) featured articles in the Web of Science Core Collection (WoS) about tinnitus published from 1980 to 2020. The rise in the number of papers confirms the academic understanding of the necessity for studies on tinnitus and most likely also correlates with the increasing knowledge about physiopathology. Our results also determine hotspots for tinnitus centers and research trends in this research field.

METHODS

An advanced search was conducted in the WoS for SCI-E featured articles on 27 March 2021. (The data in this research come from public databases and do not require ethical approval.) All publications with the word "tinnitus" in the title of the articles published in SCI-E indexed journals between 1980 and 2020 were determined. A search query containing the term "tinnitus" was performed. In the present study, only articles and review papers were included. Proceedings papers, early access, meeting abstracts, book chapters, and reprints were excluded from the analysis. There were no restrictions on language or data category.

We used the VOSviewer software version 1.6.17 for this bibliometric analysis.[20] The articles were analyzed by publication characteristics, including the number of publications by year, article type and research domain; the countries and institutions with the most publications; journals with the most publications and the development in years; the most cited articles and references; the most frequently used references in the publications, and the most frequent words in the abstracts and the keywords. The obtained data were added to the Marked List in the WoS database. The data were exported as Tab-delimited (Win) with Export Records to File. Visual network maps were generated for the analyzed characteristics.

MAIN POINTS

- A major interest was seen in areas about treatment and pathogenic mechanisms.
- Bibliometric analysis can help researchers gain information on the research trends and develop a future perspective for particular studies.
- Our analysis indicated an increasing trend in tinnitus research in the last 30 years, particularly with the increase in tinnitus burden and of the societal costs by it.

RESULTS

Between 1980 and 2020, 9036 articles were extracted from the SCI-E databases of the WoS. After exclusion for article type, 8282 articles were eligible for analysis. It was found that a total of 168 730 citations were made to these 8282 articles, and the average citation was 20.37. The first 25 articles with the most citations are shown in Table 1. A total of 127 003 different references were cited in these articles. The top 10 most cited references are shown in Table 2.

The number of articles in the WoS relating to tinnitus gradually expanded starting from 1980 to 2020: from 23 publications to 575 publications (Figure 1). With significant increases in publications occurring in 1991 and 2010, this period can be divided into 3 periods—1980-1990: 23-68 publications; 1991-2009: 80-243 publications, and 2010-2020: 343-575 publications. Since 2010, there is an ongoing increase in the number of publications. Most publications occurred in 2019: 623.

The top 5 institutions with the highest number of publications are, respectively, Regensburg University with 189 publications, Nottingham University with 167 publications, Antwerp University with 123 publications, Karolinska Institutet with 119 publications, and Oregon Health & Science University with 113 publications. The top 20 institutions with the most publications are shown in Figure 2. The articles originated from 110 different countries. Figure 3 shows the first 20 countries where the most publications originated. Most of these countries are located in Europe: 10 (50%). However, most articles originated from the USA: 2247 (27.1%) of 8282 articles. The second and third most publications occurred in Germany with 1089 (13.1%) and 696 (8.4%) articles from the UK. The top 5 are completed by countries from Asia: China and South Korea with 508 (6.1%) and 375 (4.5%) publications, respectively.

Figure 4 shows the first 10 journals with the highest publication rate about tinnitus. The first 5 journals in which the most articles have been published are, respectively, *Otology & Neurotology* with 359 articles, *Hearing Research* with 301 articles, *HNO* with 252 articles, *Journal of Laryngology and Otology* with 247 articles, and *Acta Oto-Laryngologica* with 195 articles. When the distribution of the number of articles published in these journals by years was analyzed with the VOSviewer software, it was determined that a significant change was observed between 2004 and 2014 (Figure 5).

In the abstracts of the examined articles, 100 419 different tinnitus-related terms were found. The most frequently used 25 of these terms are shown in Figure 6. Tinnitus was the most occurring term in the abstract, followed by patient and study. Generating a keyword network map resulted in 10 678 different keywords. The most frequently used 25 keywords are shown in Figure 7.

DISCUSSION

This bibliometric analysis of tinnitus between 1980 and 2020 shows an increase in the number of publications over the 30-year analysis period; especially, a significant increase in the last 10 years has been seen. An interesting development has been seen in the study subject, whereby there is a development from research in pathogenesis

Table 1. The 25 Most Cited Articles

Title	Authors	Source Title	Year	DOI	Citation
Adding Insult to Injury: Cochlear Nerve Degeneration after Temporary Noise-Induced Hearing Loss		*Journal of Neuroscience*	2009	10.1523/JNEUROSCI.2845-09.2009	1215
Intraperitoneal Cisplatin Plus Intravenous Cyclophosphamide Versus Intravenous Cisplatin Plus Intravenous Cyclophosphamide for Stage III Ovarian Cancer		*New England Journal of Medicine*	1996	10.1056/NEJM199612263352603	923
Evidence-Based Guidelines on the Therapeutic Use of Repetitive Transcranial Magnetic Stimulation (rTMS)		*Clinical Neurophysiology*	2014	10.1016/j.clinph.2014.05.021	904
Development of the Tinnitus Handicap Inventory		*Archives of Otolaryngology—Head & Neck Surgery*	1996		864
Phantom Auditory-Perception (Tinnitus) —Mechanisms of Generation and Perception		*Neuroscience Research*	1990	10.1016/0168-0102(90)90031-9	828
Thalamocortical Dysrhythmia: A Neurological and Neuropsychiatric Syndrome Characterized by Magnetoencephalography		*Proceedings of the National Academy of Sciences of The United States of America*	1999	10.1073/pnas.96.26.15222	818
The Neuroscience of Tinnitus		*Trends in Neurosciences*	2004	10.1016/j.tins.2004.08.010	740
Safety Aspects of Transcranial Direct Current Stimulation Concerning Healthy Subjects and Patients		*Brain Research Bulletin*	2007	10.1016/j.brainresbull.2007.01.004	645
Fatal Microcystin Intoxication in Haemodialysis Unit in Caruaru, Brazil		*Lancet*	1998	10.1016/S0140-6736(97)12285-1	539
Evidence-Based Guidelines on the Therapeutic Use of Transcranial Direct Current Stimulation (tDCS)		*Clinical Neurophysiology*	2017	10.1016/j.clinph.2016.10.087	487
Guided Internet-Based vs. Face-to-Face Cognitive Behavior Therapy for Psychiatric and Somatic Disorders: A Systematic Review and Meta-analysis		*World Psychiatry*	2014	10.1002/wps.20151	484
Reorganization of Auditory Cortex in Tinnitus		*Proceedings of the National Academy of Sciences of the United States of America*	1998	10.1073/pnas.95.17.10340	471
A Clinical Study of Type-2 Neurofibromatosis		*Quarterly Journal of Medicine*	1992		456
Prevalence and Characteristics of Tinnitus Among US Adults		*American Journal of Medicine*	2010	10.1016/j.amjmed.2010.02.015	452
Tinnitus with a Normal Audiogram: Physiological Evidence for Hidden Hearing Loss and Computational Model		*Journal of Neuroscience*	2011	10.1523/JNEUROSCI.2156-11.2011	446
The Functional Neuroanatomy of Tinnitus—Evidence for Limbic System Links and Neural Plasticity		*Neurology*	1998	10.1212/WNL.50.1.114	418
Diagnostic Criteria for Meniere's Disease		*Journal of Vestibular Research—Equilibrium & Orientation*	2015	10.3233/VES-150549	391
A Neurophysiological Approach To Tinnitus—Clinical Implications		*British Journal of Audiology*	1993	10.3109/03005369309077884	386
Tinnitus		*Lancet*	2013	10.1016/S0140-6736(13)60142-7	371
Tuning Out the Noise: Limbic-Auditory Interactions in Tinnitus		*Neuron*	2010	10.1016/j.neuron.2010.04.032	350
Reversing Pathological Neural Activity Using Targeted Plasticity		*Nature*	2011	10.1038/nature09656	348
Phantom Percepts: Tinnitus and Pain as Persisting Aversive Memory Networks		*Proceedings of the National Academy of Sciences of the United States of America*	2011	10.1073/pnas.1018466108	344
Management of 1000 Vestibular Schwannomas (Acoustic Neuromas): Hearing Function in 1000 Tumor Resections		*Neurosurgery*	1997	10.1097/00006123-199702000-00005	335
Ringing Ears: The Neuroscience of Tinnitus		*Journal of Neuroscience*	2010	10.1523/JNEUROSCI.4028-10.2010	327
Classification and Epidemiology of Tinnitus		*Otolaryngologic Clinics of North America*	2003	10.1016/S0030-6665(02)00160-3	327

Table 2. The Top 10 Most Cited References

1	Newman CW. *Arch Otolaryngol*, 1996;122:143	653
2	Jastreboff PJ. *Neuroscı Res*. 1990;8:221. doı:10.1016/0168-0102(90)90031-9	615
3	Eggermont JJ. *Trends Neuroscı*. 2004;27:676. doi:10.1016/j.tins.2004.08.010	553
4	Shargorodsky J. *Am J Med*. 2010;123:711. doi:10.1016/j.amjmed.2010.02.015	369
5	Axelsson A. *British Journal of Audiology*. 1989;23:53. doi:10.3109/03005368909077819	359
6	Lockwood AH. *Neurology*. 1998;50:114. doi:10.1212/wnl.50.1.114	312
7	Muhlnickel W. *P Natl Acad Scı Usa*, 1998;95:10340. doi:10.1073/pnas.95.17.10340	301
8	Baguley D. *Lancet*, 2013;382:1600. doi:10.1016/s0140-6736(13)60142-7	290
9	Rauschecker JP. *Neuron*, 2010;66:819. doi:10.1016/j.neuron.2010.04.032	282
10	Henry JA. *J Speech Lang Hear R*, 2005;48:1204. doi:10.1044/1092-4388(2005/084)	278

to treatment of tinnitus, as seen in the most recurring keywords and terms in the abstract of the studies.

Although tinnitus is gaining popularity in the modern times, it has been present from the ancient times. The first records of tinnitus are mentioned in the Ebers Papyrus from the ancient Egyptian period (1550 BC) where people with tinnitus were seen as bewitched and were offered a cure for the "bewitched ear."[21,22] Hippocrates took in his Corpus Hipporcratum in fifth century BC a more scientific approach, describing tinnitus in association with the pulsating headache and hearing loss. In the modern times, there has been a significant interest in tinnitus and his research.[23] This can be seen in the number of publications and citations from journals with high-impact factors, like *Hearing Research*, *Ear & Hearing*, *Plos One*, *The Laryngoscope*, and *Otology and Neurotology* (see Figure 4 and 5). One reason for this interest can be on one hand assigned to the development of how modern (medical) science is done in the 21st century, with the uprising number of publications and journals. On the other hand, people are living in a noisier environment and are having a higher life expectancy, which may give the impression that the prevalence of tinnitus is rising. However, the prevalence of tinnitus is not significantly changed in the last 50 years.[24] A clearer explanation could be that over the years different definitions have been used for tinnitus, and no clear difference has been made in the symptomatic disease and the impact it has on the lives of patients. More recently, UNITI made the difference in the definition by the sound and the impact: tinnitus and tinnitus disorder.[4] Because this clear difference had not been given earlier, no clear development in the prevalence of tinnitus disorder can be given. With the given fact that modern medicine is more accessible for patients and the high social costs made by tinnitus worldwide (e.g., societal costs of €6.8 billion and health care costs of €1.9 billion in the Netherlands),[25] one can make the assumption that the number of patients with tinnitus disorder is rising.

In the development of tinnitus research, there has been an emphasis on the pathogenesis and treatment of tinnitus. This can be seen in the most frequently used keywords and words in the abstract (e.g., sensorineural hearing loss, transcranial magnetic stimulation, plasticity, and treatment) (Figures 6 and 7). Similarly, Zhou et al[19] reported that the most transcranial magnetic stimulation keywords were found in the articles published in the last 20 years related to tinnitus. Despite this emphasis on the pathogenesis and treatment, still no clear cause and (curative) treatment have been found. One of the major turning points in the understanding of tinnitus and its management was when Pawel Jastebroff took a different view on tinnitus. Jastebroff proposed in 1990 a neurophysiological model, which relegates the cochlea to a minor role in tinnitus distress and gives much greater importance to the role of the brain and the autonomic nervous system.[26] This model suggests that in tinnitus the links between elements of the central nervous system are governed by classical conditioning or associative learning. It highlights emotional processing as the significant factor in generating tinnitus distress and promotes habituation to reduce that distress. A proof for this turning point in our analysis can be seen in Table 2, where Jastebroff is the second and another (neuro)scientist Jos J.

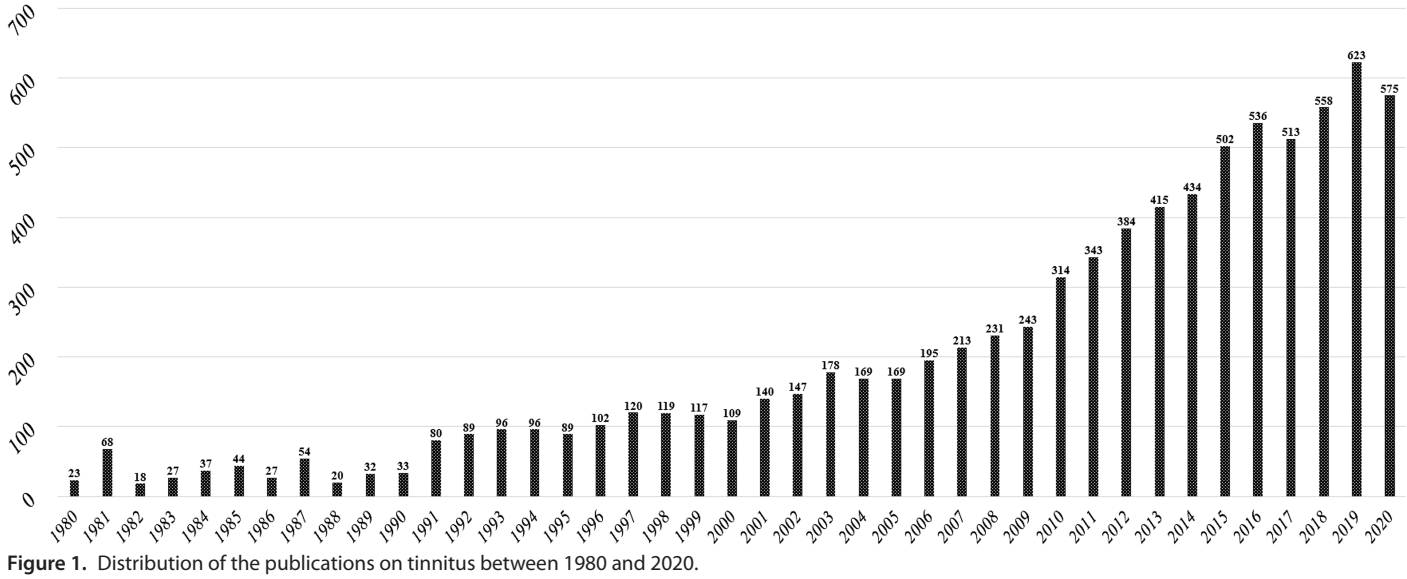

Figure 1. Distribution of the publications on tinnitus between 1980 and 2020.

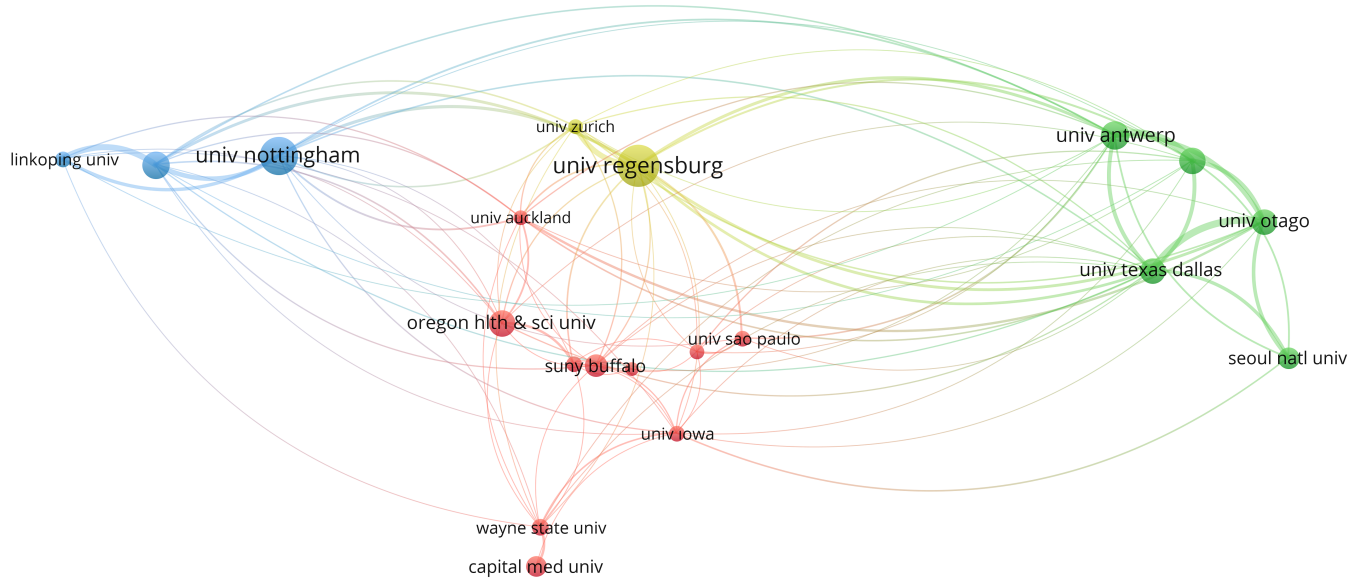

Figure 2. Collaboration map of the 20 organizations with the most publications on tinnitus between 1980 and 2020.

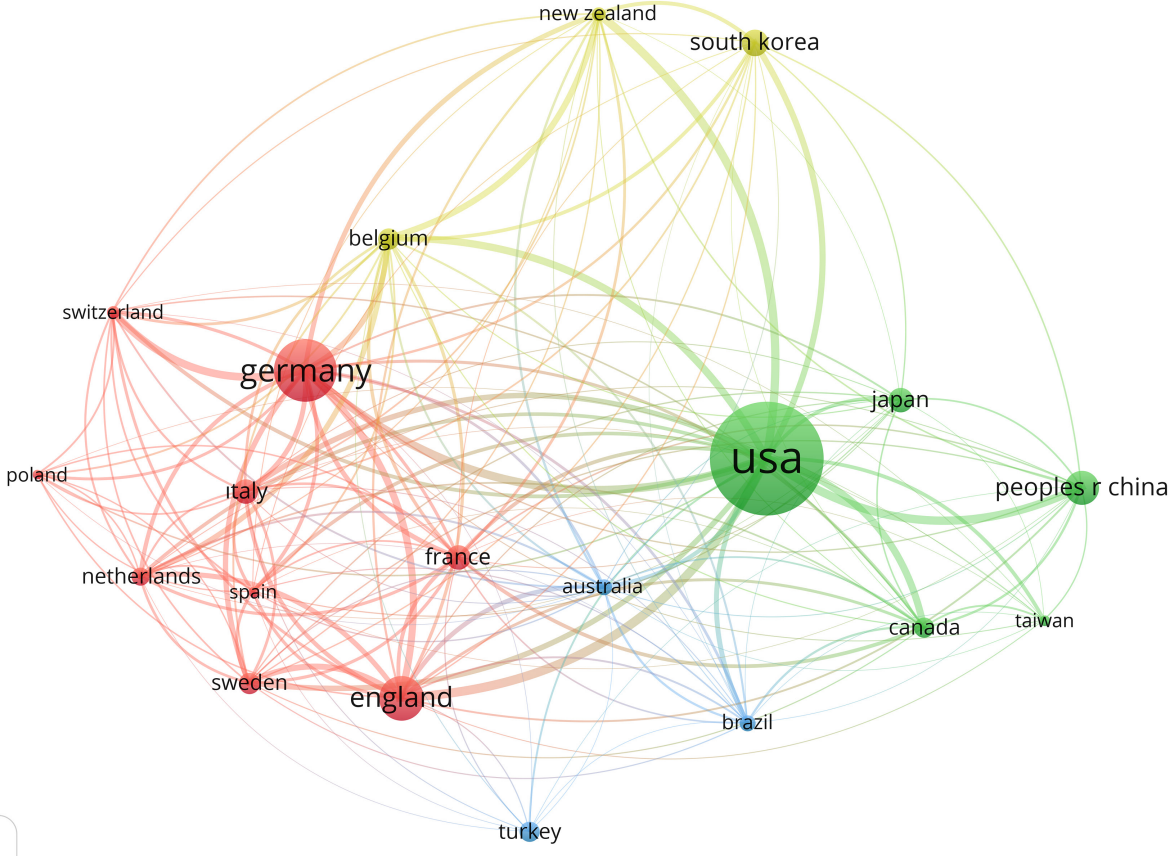

Figure 3. Collaboration map of the 20 countries with the most publications on tinnitus between 1980 and 2020.

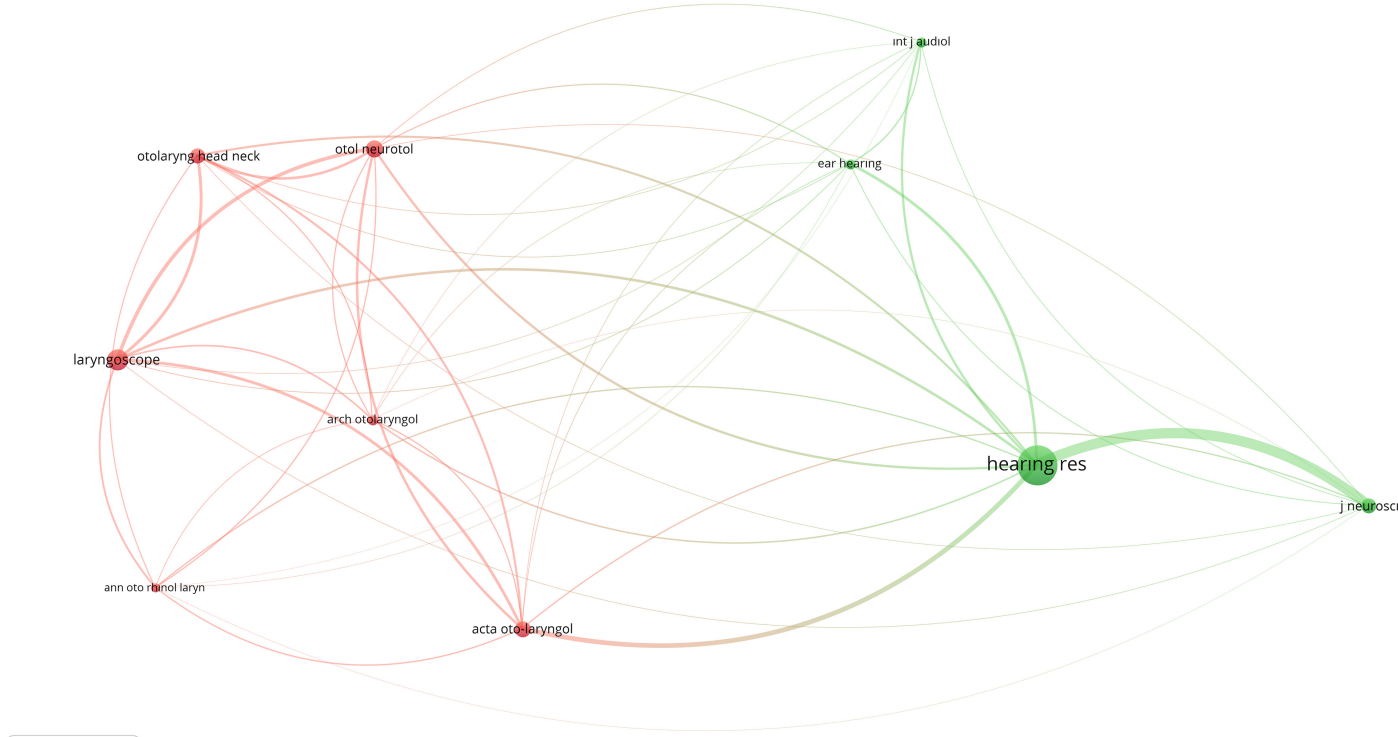

Figure 4. Top 10 journals with the most cited publications on tinnitus between 1980 and 2020.

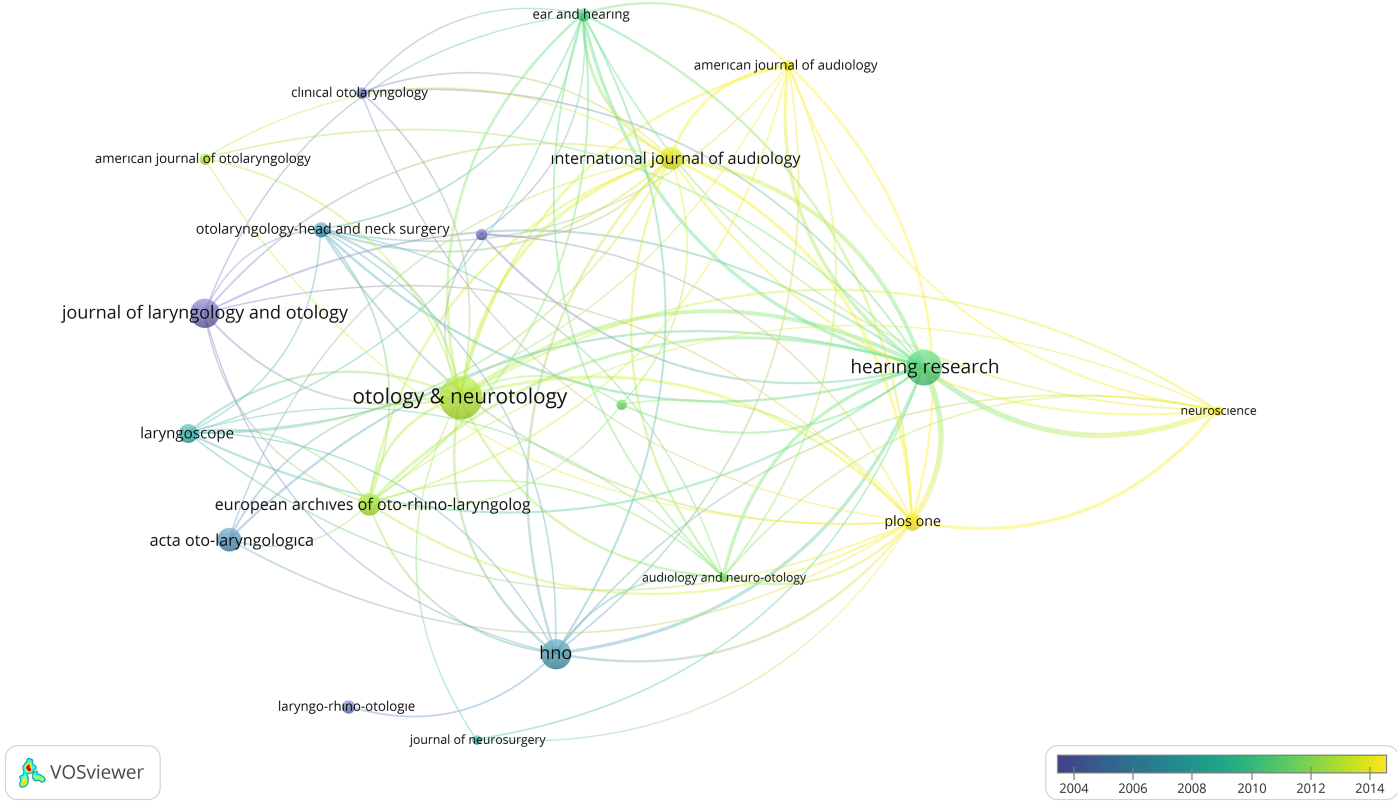

Figure 5. Change map over time of the journals in which studies on tinnitus were published between 2004 and 2014.

Eggermont, who also described the neuroscience of tinnitus,[27] is the third most cited reference in tinnitus research. With this change of view about a neurophysiological model of tinnitus, the therapy modalities gradually shifted from curative treatment for tinnitus to decreasing the tinnitus disorder. Based on his neurophysiological model, Jastebroff introduced in 2007 a specific clinical method,

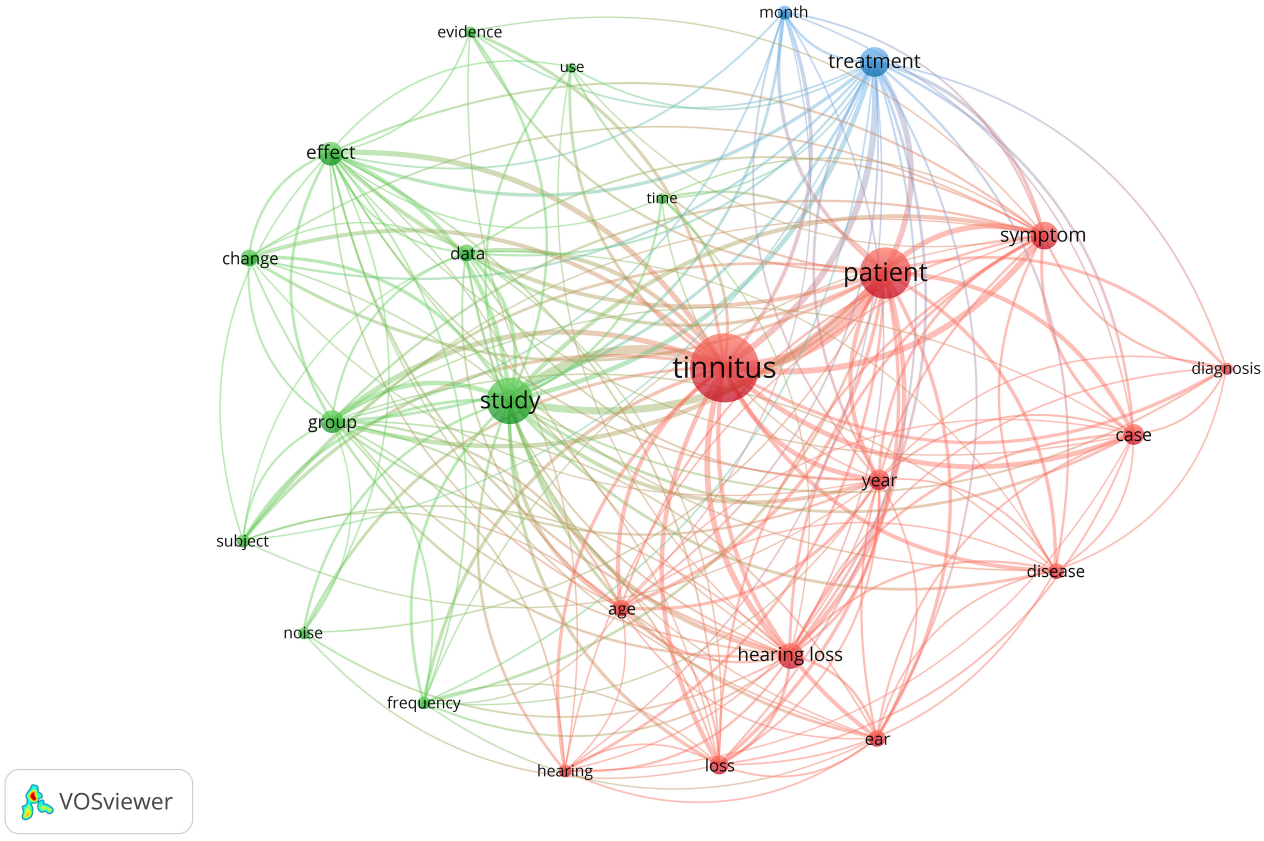

Figure 6. Word co-occurrence map of the words in the abstracts on these papers about the tinnitus between 1980 and 2020.

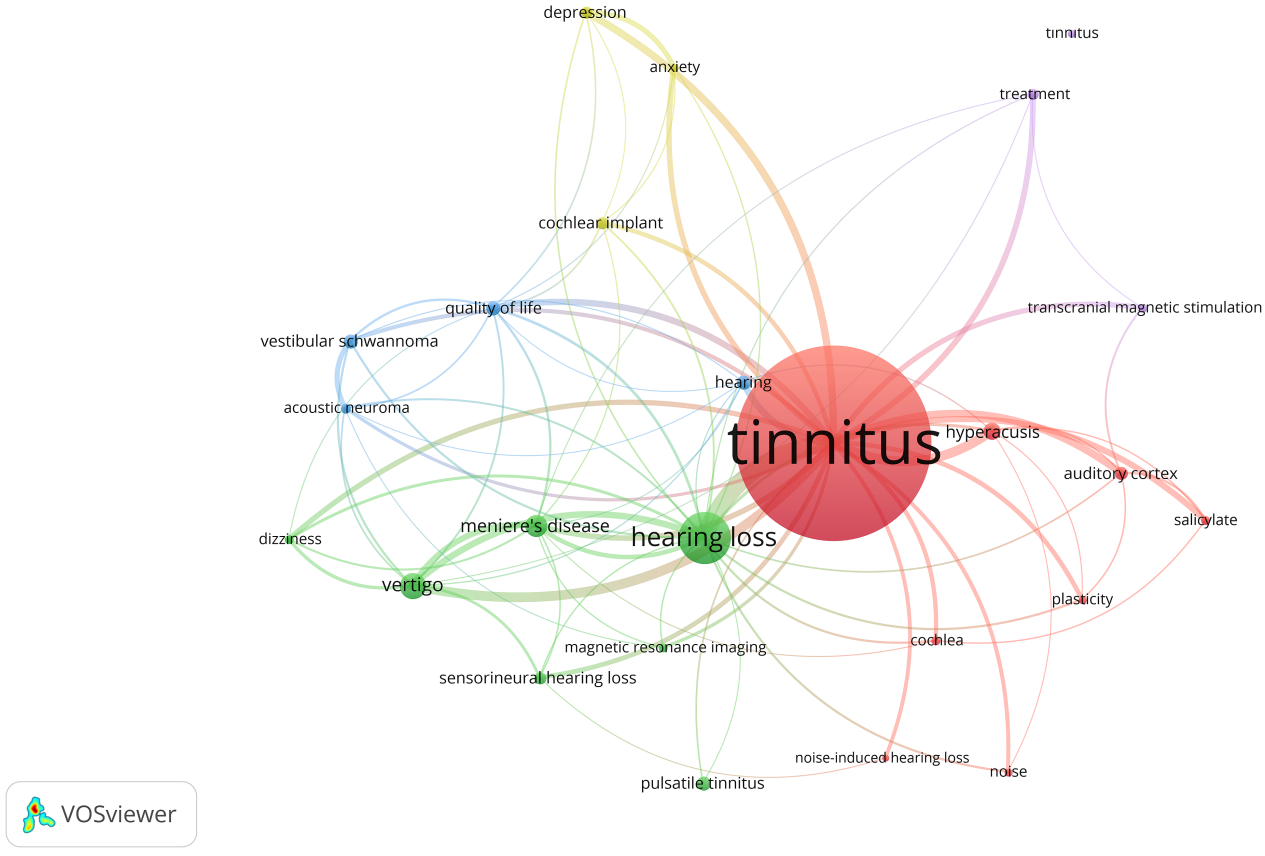

Figure 7. Word co-occurrence map of the keywords on these papers about the tinnitus between 1980 and 2020.

aimed at habituation of reactions evoked by tinnitus and subsequently habituation of the tinnitus perception.[28] Since then, these different treatment modalities based on this principle have been developed and used in clinical practice. The introduction of this clinical method can also explain the significant increase in publication on tinnitus from 2009 on Figure 1.

Besides the shift in treatment modalities, the importance and changing the aim to decrease tinnitus disorder instead of curing tinnitus can also be seen in the development of different methods to objectify tinnitus disorder. A big development derived from this is the development of tinnitus questionnaires to objectify the impact of tinnitus on patients with tinnitus disorder. Important examples of these questionnaires are the Tinnitus Handicap Inventory (THI),[29] Tinnitus Questionnaire,[30] and Tinnitus Functional Index.[31] These questionnaires are widely used in treatment and tinnitus research to assess the effect of the treatment. The importance of these questionnaires can be seen on the fact that Newman, who developed the THI,[29] is the number one cited reference in tinnitus research (Table 2).

Figures 2 and 3 show a particular interest of Europe and the USA in tinnitus research. Also, the most influential researchers on tinnitus like Pawel Jastebroff and David Baguley originate from these areas. This gives the impression that tinnitus research is more centered in developed countries. This is similar to the bibliometric study of tinnitus by Zhou et al.[19] Looking at the prevalence rate of tinnitus, there is no difference between developed countries and developing countries.[1,2,24,32] A particular explanation for the epicenter function of the developed countries in tinnitus research is the accessibility of the general health care in these developed countries and the high societal costs made by tinnitus disorder.[25] This makes tinnitus a highly interesting research topic for these geographical areas.

Recently, the first bibliometric analysis on tinnitus was performed by Ceylan in 2020.[18] However, he narrowed his search to the top 100 cited articles. As seen in his analysis, these 100 most cited articles were particularly from the last two decades, which shows the rise of tinnitus research in the last couple of years. Also, in this article most of these articles originating from the USA and the European countries. In his article, Jastebroff's article[26] about the introduction of the neurophysiological model on tinnitus was the most cited article, given the importance of the introduction of this model.

Bibliometric analyses are frequently applied as a quantitative method[33] for evaluating not only published scientific achievements but also international collaborations, the historical development of a research field, and research trends. Therefore, a bibliometric analysis can help researchers gain information on the research trends and develop a future perspective for particular studies. The WoS is the most widely used citation database for the bibliometric analysis.

This study has several limitations, mainly due to its bibliometric methodology. Popular medical databases including the WoS, PubMed, Google Scholar, and Scopus are used for scientific research. Due to the nature of the analyzed studies, the WoS could not be used in combination with other databases. In addition, the main language of the WoS database is English, and a few articles related to the subject written in other languages may have been missed. Secondly, our analysis was performed on articles published from 1980, which may discard earlier published articles on tinnitus. However, the trend on publications on tinnitus rises after the 1990s of the previous century. The top 100 cited articles on tinnitus from 1900 to 2020 by Ceylan[18] are published after 1980, which indicates no important amount of articles have been discarded hereby.

CONCLUSION

In this study, we performed a bibliometric analysis to demonstrate the historical development and trend in tinnitus research. Our analysis indicated an increasing trend in tinnitus research in the last 30 years, particularly with the increase in tinnitus burden and of the societal costs by it. A specific interest has been seen in the specific tinnitus pathophysiological mechanisms and treatment. This increase is predicted to continue without a definitive cure. Individual researchers and institutions will gain a new perspective on their future studies based on the bibliometric data in our paper. They could also benefit for the publication of their articles by being aware of possible collaborations and active journals publishing on tinnitus.

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