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Top 100-Cited Articles in Tinnitus: A Bibliometric Analysis

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BACKGROUND/AIMS
This study aimed to identify and analyze the top 100 cited articles about tinnitus research.

MATERIAL and METHODS
Using the Web of Science database, we searched the term "tinnitus" from 1900 to date and ordered the articles sequentially based on the highest to the lowest total number of citation. Then, we listed the top 100 cited articles and further analyzed them in terms of author, publication year, research category, journal, institution, and country. All data are reported as tabulated values, bar graph, and percentage. No statistical analysis was performed.

RESULTS
The most cited article received 726 citations. With 12 articles, the Hearing research journal published the highest number of articles. Moreover, 51 out of 100 articles originated from the USA. Southern Illinois University with 18 articles ranked the first in the list, followed by the University of Antwerp with 10 articles. Furthermore, 45% and 42% of these articles were categorized under the fields of neuroscience and otorhinolaryngology, respectively.

CONCLUSION
This bibliometric analysis identified the top 100 cited research articles about tinnitus and provided a track record of the historical development and trends in tinnitus research.

Keywords: Article, bibliometric analysis, the most cited, tinnitus

INTRODUCTION

Tinnitus is the phantom sensation of hearing sound without any external acoustic stimulation (1, 2). It is classified as objective tinnitus (observer/doctor can hear the sound during the examination) and subjective tinnitus (only patient can hear the sound) (3). In adult population, the most common type of tinnitus is idiopathic subjective tinnitus (3). While 10% to 15% of the adult population experiences tinnitus, only one in five patients seeks professional treatment (4-6).

The experimental and clinical studies on tinnitus contribute significantly to understanding the pathology and developing an effective strategy for the treatment. However, most of these studies and their impacts are inadequately known by clinicians. In fact, clinical decision to the treatment relies mostly on evidences from high-quality studies. The most important methodological factors to determine a high-quality study are the number of citations received and the impact factor of a journal where the article is published (7-9). In recent years, several articles aiming to analyze the top cited articles in breast cancer (10), septicemia (11), melanoma (12), pancreatitis (13), pulmonary diseases (14), and psychology (15) have been published. For clinicians, such articles involving bibliometric analysis are important to easily access the literature on a specific research field, thereby tracking easily the historical progression of the field. Therefore, identifying the top cited studies on tinnitus would be useful. Accordingly, this study aimed to identify and analyze the top 100 cited articles about tinnitus.

MATERIAL and METHODS

On April 6, 2018, we obtained the data used in this study from the Science Citation Index Expanded (SCI-Expanded) database of Web of Science (WOS) (Clarivate Analytics, USA) without using any restriction on time (1900 to date) and on journals (8500 major journals were included). Using the term "tinnitus," we searched the articles pub-

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lished from 1900 to date. Any article that is irrelevant to tinnitus was excluded from the study. A total of 4126 articles published from 1980 to date (April 6, 2018) were found. We then arranged these 4126 articles in a descending order by the number of citation and identified the top 100 cited articles. We analyzed the top 100 cited articles by publication year, country, institution, authors, journals, and research field through the WOS analysis tool. The total number of citation of the identified articles was also cross-checked using the Scopus database. We did not request for an approval from the ethics committee because this study was a retrospective evaluation of publicly available data. Nevertheless, the study was conducted in accordance with the Declaration of Helsinki. No statistical analysis was performed, considering that the results were reported as tables.

RESULTS

When the top 100 cited articles were listed in a descending order according to the number of citation, the most frequently cited article received 726 citations, whereas the least frequently cited article received 105 citations (Table 1). These most cited articles were published between 1980 and 2014 in 25 high-impact journals, and 77 out of these 100 articles were published within 15 years between 1999 and 2014. In 2011, the number of most cited articles peaked with 10 publications (Figure 1). With 12 publications, the *Hearing Research* was the most frequently chosen journal by the authors to publish their articles (Table 2); in particular, 51% of the articles originated in the USA, followed by Germany and then England (Table 3). When analyzing the centers where the articles were published, Southern Illinois University ranked the first, with 18% of all articles, followed by the University of Antwerp with 10% (Table 4). Furthermore, 45% and 42% of these articles were categorized under the fields of neuroscience and otorhinolaryngology, respectively (Table 5). Among the authors who published these articles, de Ridder D. was the most cited author, with 10 articles, followed by Langguth B. with 8 articles (Table 6).

TABLE 1. The top 100 cited articles in tinnitus research

Rank	Articles	Citation density	No. of Citations WOS	No. of Citations Scopus
1	Jastreboff PJ. Phantom auditory perception (tinnitus): mechanisms of generation and perception. Neurosci Res. 1990; 8 (4): 221-54.	25,03	726	880
2	Newman CW, Jacobson, GP, Spitzer JB. Development of the tinnitus handicap inventory. Archives of Otolaryngology-Head&Neck Surgery. 1996; 122(2): 143-148	27,65	636	788
3	Jos J. Eggermont, Larry E. Roberts. The neuroscience of tinnitus. Trends in Neurosciences. 2004; 27 (11): 666-682	41,27	619	701
4	Muhlnickel W, Elbert T, Taub E, Flor H. Reorganization of auditory cortex in tinnitus. Proc. Natl. Acad Sci. USA. 1998; 95 (11): 10340–10343	20,33	427	503
5	Lockwood AH, Salvi RJ, Coad ML, Towsley ML, Wack, DS, Murphy BW. The functional neuroanatomy of tinnitus - Evidence for limbic system links and neural plasticity. Neurology. 1998; 50 (1): 114-12	18,38	386	454
6	Jastreboff, PJ; Hazell, JWP. A Neurophysiological Approach to Tinnitus - Clinical Implications. British Journal of Odiology. 1993; 27 (1): 7-17	13,15	342	444
7	Shargorodsky, J; Curhan, GC; Farwell, WR. Prevalence and Characteristics of Tinnitus among US Adults. American Journal of Medicine. 2010; 123 (8): 711-718	36,88	332	365
8	Schaette, R; McAlpine, D. Tinnitus with a Normal Audiogram: Physiological Evidence for Hidden Hearing Loss and Computational Model. Journal of Neuroscience. 2011; 31 (38): 13452-13457	36,5	292	332
9	Lockwood, AH; Salvi, RJ; Burkard, RF. Current concepts: Tinnitus. New England Journal of Medicine. 2002; 347 (12): 904-910	17,11	291	348

Main Points:

- Bibliometric analysis of the top cited articles about tinnitus can provide a platform that allows the researchers to access such articles easily and analyze the studies.
- When analyzing the article list, a significant number (n=52) of paper is about the underlying mechanism of tinnitus.
- The effects of technological developments have been crucial in the advancement of tinnitus research. For example. neuroimaging by functional magnetic resonance imaging and positron emission tomography provides important data for pathophysiology-oriented studies.
- In tinnitus research, the top cited treatment-oriented articles are about repetitive transcranial magnetic stimulation.

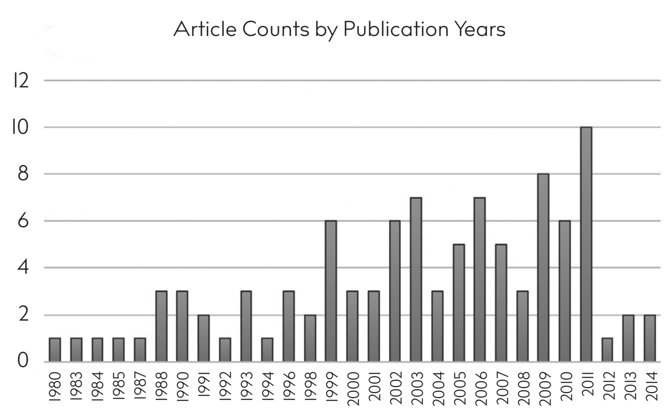

FIGURE 1. Distribution of articles by years of publication

TABLE 1. The top 100 cited articles in tinnitus research (continued)

Rank	Articles	Citation density	No. of Citations WOS	No. of Citations Scopus
10	Henry, JA; Dennis, KC; Schechter, MA. General review of tinnitus: Prevalence, mechanisms, effects, and management. Journal of Speech Language and Hearing Research. 2005; 48 (5): 1204-1235	20,64	289	320
11	Norena, AJ; Eggermont, JJ. Changes in spontaneous neural activity immediately after an acoustic trauma: implications for neural correlates of tinnitus. Hearing Research. 2003; 183 (1-2): 137-153	17	272	294
12	Heller, AJ. Classification and epidemiology of tinnitus. Otolaryngologic Clinics of North America. 2003; 36 (2): 239-+	16,87	270	317
13	Rauschecker, JP; Leaver, AM; Muhlau, M. Tuning Out the Noise: Limbic-Auditory Interactions in Tinnitus. Neuron. 2010; 66 (6): 819-826	29,88	269	304
14	De Ridder, D; Elgoyhen, AB; Romo, R; Langguth, B. Phantom percepts: Tinnitus and pain as persisting aversive memory networks. Proceedings of The National Academy of Sciences of The United States of America. 2011; 108 (20): 8075-8080	33,37	267	301
15	Brozoski, TJ; Bauer, CA; Caspary, DM. Elevated fusiform cell activity in the dorsal cochlear nucleus of chinchillas with psychophysical evidence of tinnitus. Journal of Neuroscience. 2002; 22 (6): 2383-2390	29,33	264	277
16	Roberts, LE; Eggermont, JJ; Caspary, DM; Shore, SE; Melcher, JR; Kaltenbach, JA. Ringing Ears: The Neuroscience of Tinnitus. Journal of Neuroscience. 2010; 30 (45): 14972-14979	28,44	256	302
17	Tyler, RS; Baker, LJ. Difficulties Experienced by Tinnitus Sufferers. Journal of Speech and Hearing Disorders. 1983; 48 (2): 150-154	6,5	234	284
18	Wilson, JP. Evidence For a Cochlear Origin For Acoustic Re-Emissions, Threshold Fine-Structure and Tonal Tinnitus. Hearing Research. 1980; 2 (3-4): 233-252	5,97	233	227
19	Kuk, FK; Tyler, RS; Russell, D; Jordan, H. The Psychometric Properties of A Tinnitus Handicap Questionnaire. Ear and Hearing. 1990; 11 (6): 434-445	7,90	229	283
20	Hallam, RS; Jakes, SC; Hinchcliffe, R. Cognitive Variables In Tinnitus Annoyance. British Journal of Clinical Psychology. 1988; 27 (3): 213-222	7,26	225	256
21	Norena, A; Micheyl, C; Chery-Croze, S; Collet, L. Psychoacoustic characterization of the tinnitus spectrum: Implications for the underlying mechanisms of tinnitus. Audiology and Neuro-Otology. 2002; 7 (6): 358-369	12,59	214	236
22	Muhlau, M; Rauschecker, JP; Oestreicher, E; Gaser, C; Rottinger, M; Wohlschlager, AM; Simon, F; Etgen, T; Conrad, B; Sander, D. Structural brain changes in tinnitus. Cerebral Cortex. 2006; 16(9): 1283-1288	16,31	212	240
23	Goebel, G; Hiller, W. The Tinnitus Questionnaire (TQ) - A Standardized Instrument For Grading The Severity of Tinnitus - Results of A Multicenter Study Using The TQ. HNO. 1994; 42 (3): 166-172	8,48	212	222
24	Wilson, PH; Henry, J; Bowen, M; Haralambous, G. Tinnitus Reaction Questionnaire - Psychometric Properties of A Measure of Distress Associated With Tinnitus. Journal of Speech and Hearing Research. 1991; 34 (1): 197-201	7,54	211	273
25	Baguley, D; McFerran, D; Hall, D. Tinnitus. Lancet. 2013; 382 (9904): 1600-1607	34,66	208	226
26	Dobie, RA. A review of randomized clinical trials in tinnitus. Laryngoscope. 1999; 109 (8): 1202-1211	10,2	204	251
27	Weisz, N; Moratti, S; Meinzer, M; Dohrmann, K; Elbert, T. Tinnitus perception and distress is related to abnormal spontaneous brain activity as measured by magnetoencephalography. Plos Medicine. 2005; 2 (6): 546-553	13,79	193	239
28	Vanneste, S; Plazier, M; van der Loo, E; Van de Heyning, P; Congedo, M; De Ridder, D. The neural correlates of tinnitus-related distress. Neuroimage. 2010; 52 (2): 470-480	21	189	207
29	Turner, JG; Brozoski, TJ; Bauer, CA; Parrish, JL; Myers, K. Gap detection deficits in rats with tinnitus: A potential novel screening tool. Behavioral Neuroscience. 2006; 120 (1): 188-195	14,54	189	198
30	Leaver, AM; Renier, L; Chevillet, MA; Morgan, S; Kim, HJ; Rauschecker, JP. Dysregulation of Limbic and Auditory Networks in Tinnitus. Neuron. 2011; 69 (1): 33-43	23,25	186	191
31	Melcher, JR; Sigalovsky, IS; Guinan, JJ; Levine, RA. Lateralized tinnitus studied with functional magnetic resonance imaging: Abnormal inferior colliculus activation. Journal of Neurophysiology. 2000; 83 (2): 1058-1072	9,79	186	214
32	Meikle, MB; Henry, JA; Griest, SE; Stewart, BJ; Abrams, HB; McArdle, R; et al. The Tinnitus Functional Index: Development of a New Clinical Measure for Chronic, Intrusive Tinnitus. Ear and Hearing. 2012; 33 (2): 153-176	26,29	184	198
33	Guitton, MJ; Caston, J; Ruel, J; Johnson, RM; Pujol, R; Puel, JL. Salicylate induces tinnitus through activation of cochlear NMDA receptors. Journal of Neuroscience. 2003; 23 (9): 3944-3952	11,5	184	204
34	Jastreboff, PJ; Brennan, JF; Coleman, JK; Sasaki, CT. Phantom Auditory Sensation in Rats - An Animal-Model For Tinnitus. Behavioral Neuroscience. 1988; 102 (6): 811-822	5,90	183	209
35	Kleinjung, T; Eichhammer, P; Langguth, B; Jacob, P; Marienhagen, J; Hajak, G; Wolf, SR; Strutz, J. Long-term effects of repetitive transcranial magnetic stimulation (rTMS) in patients with chronic tinnitus. Otolaryngology-Head and Neck Surgery. 2005; 132 (4): 566-569	13	182	205
36	Moller, AR. Pathophysiology of tinnitus. Otolaryngologic Clinics of North America. 2003; 36 (2): 249-+	11	176	208

TABLE 1. The top 100 cited articles in tinnitus research (continued)

Rank	Articles	Citation density	No. of Citations WOS	No. of Citations Scopus
37	Lanting, CP; de Kleine, E; van Dijk, P. Neural activity underlying tinnitus generation: Results from PET and fMRI. Hearing Research. 2009; 255 (1-2): 1-13	17,5	175	181
38	Kaltenbach, JA; Afman, CE. Hyperactivity in the dorsal cochlear nucleus after intense sound exposure and its resemblance to tone-evoked activity: a physiological model for tinnitus. Hearing Research. 2000; 140 (1-2): 165-172	9,16	174	189
39	Arnold, W; Bartenstein, P; Oestreicher, E; Romer, W; Schwaiger, M. Focal metabolic activation in the predominant left auditory cortex in patients suffering from tinnitus: A PET study with [F-18]deoxyglucose. ORL-Journal For Oto-Rhino-Laryngology and Its Related Specialties. 1996; 58 (4): 195-199	7,43	171	203
40	Stouffer, JL; Tyler, RS. Characterization of Tinnitus by Tinnitus Patients. Journal of Speech and Hearing Disorders. 1990; 55 (3): 439-453	5,76	167	203
41	Langguth, B; Kreuzer, PM; Kleinjung, T; De Ridder, D. Tinnitus: causes and clinical management. Lancet Neurology. 2013; 12 (9): 920-930	26,66	160	183
42	Schlee, W; Hartmann, T; Langguth, B; Weisz, N. Abnormal resting-state cortical coupling in chronic tinnitus. BMC Neuroscience. 2009; 10 (11): 1-11	16	160	172
43	Kaltenbach, JA; Zacharek, MA; Zhang, JS; Frederick, S. Activity in the dorsal cochlear nucleus of hamsters previously tested for tinnitus following intense tone exposure. Neuroscience Letters. 2004; 355 (1-2): 121-125	10,66	160	167
44	Norena, AJ. An integrative model of tinnitus based on a central gain controlling neural sensitivity. Neuroscience and Biobehavioral Reviews. 2011; 35 (5): 1089-1109	19,75	158	173
45	Weisz, N; Hartmann, T; Dohrmann, K; Schlee, W; Norena, A. High-frequency tinnitus without hearing loss does not mean absence of deafferentation. Hearing Research. 2006; 222 (1-2): 108-114	12,15	158	171
46	Andersson, G; Stromgren, T; Strom, L; Lyttkens, L. Randomized controlled trial of Internet-based cognitive behavior therapy for distress associated with tinnitus. Psychosomatic Medicine. 2002; 64 (5): 810-816	9,29	158	191
47	Arndt, S; Aschendorff, A; Laszig, R; Beck, R; Schild, C; Kroeger, S; Ihorst, G; Wesarg, T. Comparison of Pseudobinaural Hearing to Real Binaural Hearing Rehabilitation After Cochlear Implantation in Patients With Unilateral Deafness and Tinnitus. Otology & Neurotology. 2011; 32 (1): 39-47	19,62	157	200
48	Levine, RA. Somatic (Craniocervical) tinnitus and the dorsal cochlear nucleus hypothesis. American Journal of Otolaryngology. 1999; 20 (6): 351-362	7,85	157	188
49	Yang, G; Lobarinas, E; Zhang, LY; Turner, J; Stolzberg, D; Salvi, R; Sun, W. Salicylate induced tinnitus: Behavioral measures and neural activity in auditory cortex of awake rats. Hearing Research. 2007; 226 (1-2): 244-253	12,92	155	163
50	De Ridder, D; Verstraeten, E; Van der Kelen, K; De Mulder, G; Sunaert, S; Verlooy, J; Van de Heyning, P; Moller, A. Transcranial magnetic stimulation for tinnitus: Influence of tinnitus duration on stimulation parameter choice and maximal tinnitus suppression. Otology & Neurotology. 2005; 26 (4): 616-619	11	154	170
51	Landgrebe, M; Langguth, B; Rosengarth, K; Braun, S; Koch, A; Kleinjung, T; May, A; de Ridder, D; Hajak, G. Structural brain changes in tinnitus: Grey matter decrease in auditory and non-auditory brain areas. Neuroimage. 2009; 46 (1): 213-218	15,3	153	166
52	Coles RRA; Baskill JL; Sheldrake JB. Measurement and management of tinnitus Part II. Management. The Journal of Laryngology and Otology. 1985; 99 (1): 1-10	4,5	153	11
53	McCombe, A; Baguley, D; Coles, R; McKenna, L; McKinney, C; Windle-Taylor, P. Guidelines for the grading of tinnitus severity: the results of a working group commissioned by the British Association of Otolaryngologists, Head and Neck Surgeons, 1999. Clinical Otolaryngology. 2001; 26 (5): 388-393.	7,55	151	165
54	Langguth, B; Goodey, R; Azevedo, A; Bjorne, A; Cacace, A; Crocetti, A; et al. Consensus for tinnitus patient assessment and treatment outcome measurement: Tinnitus Research Initiative meeting, Regensburg, July 2006. Tinnitus: Pathophisiology and Treatment.Book Series: Progress in Brain Research. 2007; 166: 525-536	12,42	149	156
55	Mirz, F; Pedersen, CB; Ishizu, K; Johannsen, P; Ovesen, T; Stodkilde-Jorgensen, H. Positron emission tomography of cortical centers of tinnitus. Hearing Research. 1999; 134 (1-2): 133-144	7,4	148	180
56	Jastreboff, PJ; Gray, WC; Gold, SL. Neurophysiological approach to tinnitus patients. American Journal of Otology. 1996; 17 (2): 236-240	6,30	145	202
57	Van der Loo, E; Gais, S; Congedo, M; Vanneste, S; Plazier, M; Menovsky, T; Van de Heyning, P; De Ridder, D. Tinnitus Intensity Dependent Gamma Oscillations of the Contralateral Auditory Cortex. Plos One. 2009; 10 (4): 1-5	14,2	142	152
58	Gu, JW; Halpin, CF; Nam, EC; Levine, RA; Melcher, JR. Tinnitus, Diminished Sound-Level Tolerance, and Elevated Auditory Activity in Humans With Clinically Normal Hearing Sensitivity. Journal of Neurophysiology. 2010; 104 (6): 3361-3370	15,55	140	151
59	Giraud, AL; Chery-Croze, S; Fischer, G; Fischer, C; Vighetto, A; Gregoire, MC; Lavenne, F; Collet, L. A selective imaging of tinnitus. Neuroreport. 1999; 10 (1): 1-5	7	140	155
60	Plewnia, C; Reimold, M; Najib, A; Brehm, B; Reischl, G; Plontke, SK; Gerloff, C. Dose-dependent attenuation of auditory phantom perception (tinnitus) by PET-guided repetitive transcranial magnetic stimulation. Human Brain Mapping. 2007; 28 (3): 238-246	11,58	139	159

TABLE 1. The top 100 cited articles in tinnitus research (continued)

Rank	Articles	Citation density	No. of Citations WOS	No. of Citations Scopus
61	Fregni, F; Marcondes, R; Boggio, PS; Marcolin, MA; Rigonatti, SP; Sanchez, TG; Nitsche, MA; Pascual-Leone, A. Transient tinnitus suppression induced by repetitive transcranial magnetic stimulation and transcranial direct current stimulation. European Journal of Neurology. 2006; 13 (9): 996-1001	10,69	139	154
62	Bauer, CA; Turner, JG; Caspary, DM; Myers, KS; Brozoski, TJ. Tinnitus and inferior colliculus activity in chinchillas related to three distinct patterns of cochlear trauma. Journal of Neuroscience Research. 2008; 86 (11): 2564-2578	12,54	138	146
63	Mirz, F; Gjedde, A; Ishizu, K; Pedersen CB. Cortical networks subserving the perception of tinnitus - a PET study. Acta Oto-Laryngologica Supplement. 2000; 543: 241-243	8,56	137	144
64	Plewnia, C; Bartels, M; Gerloff, C. Transient suppression of tinnitus by transcranial magnetic stimulation. Annals of Neurology. 2003; 53 (2): 263-266	8,19	131	153
65	Moller, AR; Moller, MB; Yokota, M. Some Forms of Tinnitus May Involve The Extralemniscal Auditory Pathway. Laryngoscope. 1992; 102 (10): 1165-1171	4,85	131	157
66	Moller, AR. Pathophysiology of Tinnitus. Annals of Otology Rhinology and Laryngology. 1984; 93 (1): 39-44	3,71	130	157
67	Schlee, W; Mueller, N; Hartmann, T; Keil, J; Lorenz, I; Weisz, N. Mapping cortical hubs in tinnitus. BMC Biology. 2009; 7 (80):-	12,9	129	131
68	Vermeire, K; de Heyning, PV. Binaural Hearing after Cochlear Implantation in Subjects with Unilateral Sensorineural Deafness and Tinnitus. Audiology and Neuro-Otology. 2009; 14 (3): 163-171	12,9	129	147
69	Dobie, RA. Depression and tinnitus. Otolaryngologic Clinics of North America. 2003; 26 (2): 383-+	8	128	153
70	Tonndorf, J. The Analogy Between Tinnitus And Pain - A Suggestion For A Physiological-Basis of Chronic Tinnitus. Hearing Research. 1987; 28 (2-3): 271-275	4	128	144
71	Kaltenbach, JA; Zhang, JS; Finlayson, P. Tinnitus as a plastic phenomenon and its possible neural underpinnings in the dorsal cochlear nucleus. Hearing Research. 2005; 206 (1-2): 200-226.	9	126	141
72	Plewnia, C; Reimold, M; Najib, A; Reischl, G; Plontke, SK; Gerloff, C. Moderate therapeutic efficacy of positron emission tomography-navigated repetitive transcranial magnetic stimulation for chronic tinnitus: a randomised, controlled pilot study. Journal of Neurology Neurosurgery And Psychiatry. 2007; 78 (2): 152-156.	10,33	124	138
73	Schaette, R; Kempter, R. Development of tinnitus-related neuronal hyperactivity through homeostatic plasticity after hearing loss: a computational model. European Journal of Neuroscience. 2006; 23 (11): 3124-3138	9,54	124	147
74	Andersson, G. Psychological aspects of tinnitus and the application of cognitive-behavioral therapy. Clinical Psychology Review. 2002; 22 (7): 977-990	7,29	124	145
75	Yang, S; Weiner, BD; Zhang, LS; Cho, SJ; Bao, SW. Homeostatic plasticity drives tinnitus perception in an animal model. Proceedings of The National Academy of Sciences of The United States of America. 2011; 108 (36): 14974-14979	15,37	123	139
76	Sullivan, MD; Katon, W; Dobie, R; Sakai, C; Russo, J; Harropgriffiths, J. Disabling Tinnitus - Association With Affective-Disorder. General Hospital Psyhiatry. 1988; 10 (4): 285-291	3,93	122	134
77	Kaltenbach, JA. Tinnitus: Models and mechanisms. Hearing Research. 2011; 276 (1-2): 52-60	15	120	131
78	Wang, H; Brozoski, TJ; Turner, JG; Ling, L; Parrish, JL; Hughes, LF; Caspary, DM. Plasticity at Glycinergic Synapses in Dorsal Cchlear Nucleus of Rats With Behavioral Evidence of Tinnitus. Neuroscience. 2009; 164 (2): 747-759	12	120	120
79	Tunkel DE; Bauer CA; Sun GH, at al. Clinical Practice Guideline: Tinnitus. Otolaryngol Head Neck Surg. 2014; 151 (2 Suppl): 1-40	23,8	119	129
80	Smits, M; Kovacs, S; de Ridder, D; Peeters, RR; Van Hecke, P; Sunaert, S. Lateralization of functional magnetic resonance imaging (fMRI) activation in the auditory pathway of patients with lateralized tinnitus. Neuroradiology. 2007; 49 (8): 669-679	9,83	118	134
81	Middleton, JW; Kiritani, T; Pedersen, C; Turner, JG; Shepherd, GMG; Tzounopoulos, T. Mice with behavioral evidence of tinnitus exhibit dorsal cochlear nucleus hyperactivity because of decreased GABAergic inhibition. Proceedings of The National Academy of Sciences of The United States of America. 2011; 108 (18): 7601-7606	14,62	117	131
82	Folmer, RL; Griest, SE; Meikle, MB; Martin, WH. Tinnitus severity, loudness, and depression. Otolaryngology-Head and Neck Surgery. 1999; 121 (1): 48-51	5,85	117	142
83	Hickox, AE.; Liberman MC. Is noise-induced cochlear neuropathy key to the generation of hyperacusis or tinnitus? Journal of Neurophysiology. 2014; 11 (3): 552-564	23,2	116	122
84	Van de Heyning, P; Vermeire, K; Diebl M; et al. Incapacitating unilateral tinnitus in single-sided deafness treated by cochlear implantation. Annals of Otology Rhinology and Laryngology. 2008; 117 (9): 645-652.	10,45	115	195
85	Norena, AJ; Eggermont, JJ. Enriched acoustic environment after noise trauma abolishes neural signs of tinnitus. Neuroreport. 2006; 17 (6): 559-563	8,85	115	126
86	Bauer, CA; Brozoski, TJ. Assessing tinnitus and prospective tinnitus therapeutics using a psychophysical animal model. JARO 2001; 2 (1): 54-64	6,39	115	131

TABLE 1. The top 100 cited articles in tinnitus research (continued)

Rank	Articles	Citation density	No. of Citations WOS	No. of Citations Scopus
87	Hesser, H; Weise, C; Westin, VZ; et al. A systematic review and meta-analysis of randomized controlled trials of cognitive-behavioral therapy for tinnitus distress. Clinical Psychology Review. 2011; 31 (4): 545-553	14,25	114	125
88	Lockwood, AH; Wack, DS; Burkard, RF; Goad, ML; Reyes, SA; Arnold, SA; Salvi, RJ. The functional anatomy of gaze-evoked tinnitus and sustained lateral gaze. Neurology. 2001; 56 (4): 472-480	6,33	114	132
89	Sullivan, M; Katon, W; Russo, J; Dobie, R; Sakai, C. A Randomized Trial of Nortriptyline For Severe Chronic Tinnitus - Effects on Depression, Disability, And Tinnitus Symptoms. Archives of Internal Medicine. 1993; 153 (19): 2251-2259	4,38	114	124
90	Halford, JBS; Anderson, SD. Anxiety And Depression In Tinnitus Sufferers. Journal of Psychosomatic Research. 1991; 35 (4-5): 383-390	4,07	114	143
91	Langguth, B; Landgrebe, M; Kleinjung, T; Sand, GP; Hajak, G. Tinnitus and depression. World Journal of Biological Psychiatry. 2011; 12 (7): 489-500	13,87	111	129
92	De Ridder, D; De Mulder, G; Walsh, V; Muggleton, N; Sunaert, S; Moller, A. Magnetic and electrical stimulation of the auditory cortex for intractable tinnitus - Case report. Journal of Neurosurgery. 2004; 100 (3): 560-564	7,33	110	126
93	Andersson, G; Lyttkens, L. A meta-analytic review of psychological treatments for tinnitus. British Journal of Audiology. 1999; 33 (4): 201-210	5,5	110	137
94	Moller, MB; Moller, AR; Jannetta, PJ; Jho, HD. Vascular Decompression Surgery For Severe Tinnitus - Selection Criteria And Results. Laryngoscope. 1993; 103 (4): 421-427	4,23	110	131
95	Haller, Sven; Birbaumer, Niels; Veit, Ralf . Real-time fMRI feedback training may improve chronic tinnitus. European Rdiology. 2010; 20 (3): 696-703	12	108	114
96	Adjamian, P; Sereda, M; Hall, DA. The mechanisms of tinnitus: Perspectives from human functional neuroimaging. Hearing Research. 2009; 253 (1-2): 15-31	10,8	108	119
97	Koenig, O; Schaette, R; Kempter, R; Gross, M. Course of hearing loss and occurrence of tinnitus. Hearing Research. 2006; 221 (1-2): 59-64	8,31	108	133
98	Baguley, DM. Mechanisms of tinnitus. British Medical Bulletin. 2002; 63: 195-212	6,29	107	124
99	Eichhammer, P; Langguth, B; Marienhagen, J; Kleinjung, T; Hajak, G. Neuronavigated repetitive transcranial magnetic stimulation in patients with tinnitus: A short case series. Biological Psychiatry. 2003; 54 (8): 862-865.	6,62	106	115
100	Roberts, LE; Moffat, G; Baumann, M; Ward, LM; Bosnyak, DJ. Residual Inhibition Functions Overlap Tinnitus Spectra and the Region of Auditory Threshold Shift. JARO-Journal of The Association For Research In Otolaryngology. 2008; 9 (4): 417-435	9,54	105	112

TABLE 2. Journals in which the top 100 cited articles were published

Field: Source Titles	Record Count	% of 100	Bar Chart
HEARING RESEARCH	12	12.000	
JOURNAL OF NEUROSCIENCE	4	4.000	
PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES OF THE UNITED STATES OF AMERICA	4	4.000	
JOURNAL OF NEUROPHYSIOLOGY	3	3.000	
LARYNGOSCOPE	3	3.000	
OTOLARYNGOLOGIC CLINICS OF NORTH AMERICA	3	3.000	
OTOLARYNGOLOGY HEAD AND NECK SURGERY	3	3.000	
ANNALS OF OTOLOGY RHINOLOGY AND LARYNGOLOGY	2	2.000	
AUDIOLOGY AND NEURO OTOLOGY	2	2.000	
BEHAVIORAL NEUROSCIENCE	2	2.000	
BRITISH JOURNAL OF AUDIOLOGY	2	2.000	
CLINICAL PSYCHOLOGY REVIEW	2	2.000	
EAR AND HEARING	2	2.000	
JARO JOURNAL OF THE ASSOCIATION FOR RESEARCH IN OTOLARYNGOLOGY	2	2.000	
JOURNAL OF SPEECH AND HEARING DISORDERS	2	2.000	
NEUROIMAGE	2	2.000	
NEUROLOGY	2	2.000	

TABLE 2. Journals in which the top 100 cited articles were published (continued)

Field: Source Titles	Record Count	% of 100	Bar Chart
NEURON	2	2.000	
NEUROREPORT	2	2.000	
OTOLOGY NEUROTOLOGY	2	2.000	
ACTA OTO LARYNGOLOGICA	1	1.000	
AMERICAN JOURNAL OF MEDICINE	1	1.000	
AMERICAN JOURNAL OF OTOLARYNGOLOGY	1	1.000	
AMERICAN JOURNAL OF OTOLOGY	1	1.000	
ANNALS OF NEUROLOGY	1	1.000	

TABLE 3. Countries of origin of the top 100 cited articles

Field: Source Titles	Record Count	% of 100	Bar Chart
USA	51	51.000	
GERMANY	24	24.000	
ENGLAND	14	14.000	
BELGIUM	11	11.000	
CANADA	8	8.000	
FRANCE	8	8.000	
SWEDEN	5	5.000	
NETHERLANDS	3	3.000	
NEW ZEALAND	3	3.000	
SWITZERLAND	3	3.000	
AUSTRIA	2	2.000	
BRAZIL	2	2.000	
DENMARK	2	2.000	
ITALY	2	2.000	
ARGENTINA	1	1.000	
AUSTRALIA	1	1.000	
COLOMBIA	1	1.000	
MEXICO	1	1.000	
PEOPLES R CHINA	1	1.000	
SOUTH KOREA	1	1.000	
SPAIN	1	1.000	

TABLE 4. Institutions of origin

Field: Source Titles	Record Count	% of 100	Bar Chart
UNIVERSITY OF ANTWERP	10	10.000	
SOUTHERN ILLINOIS UNIVERSITY	9	9.000	
SOUTHERN ILLINOIS UNIVERSITY SYSTEM	9	9.000	
HARVARD UNIVERSITY	8	8.000	
UNIVERSITY OF REGENSBURG	8	8.000	
MASSACHUSETTS EYE EAR INFIRMARY	7	7.000	
VA BOSTON HEALTHCARE SYSTEM	7	7.000	
CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS	6	6.000	

TABLE 4. Institutions of origin (continued)

Field: Source Titles	Record Count	% of 100	Bar Chart
UNIVERSITY OF KONSTANZ	6	6.000	
STATE UNIVERSITY OF NEW YORK SUNY SYSTEM	5	5.000	
UNIVERSITY COLLEGE LONDON	5	5.000	
UNIVERSITY OF CALGARY	5	5.000	
UNIVERSITY OF LONDON	5	5.000	
UNIVERSITY OF TEXAS SYSTEM	5	5.000	
VETERANS HEALTH ADMINISTRATION VHA	5	5.000	
CLEVELAND CLINIC FOUNDATION	4	4.000	
EBERHARD KARLS UNIVERSITY OF TUBINGEN	4	4.000	
GEORGETOWN UNIVERSITY	4	4.000	
PENNSYLVANIA COMMONWEALTH SYSTEM OF HIGHER EDUCATION PCSHE	4	4.000	
STATE UNIVERSITY OF NEW YORK SUNY BUFFALO	4	4.000	
UNIVERSITY OF CALIFORNIA SYSTEM	4	4.000	
UNIVERSITY OF PITTSBURGH	4	4.000	
HUMBOLDT UNIVERSITY OF BERLIN	3	3.000	
MCMASTER UNIVERSITY	3	3.000	
OREGON HEALTH SCIENCE UNIVERSITY	3	3.000	

TABLE 5. Distribution of the articles according to the Web of Science Categories

Field: Web of Science Categories	Record Count	% of 100	Bar Chart
NEUROSCIENCES	45	45.000	
OTORHINOLARYNGOLOGY	42	42.000	
AUDIOLOGY SPEECH LANGUAGE PATHOLOGY	17	17.000	
CLINICAL NEUROLOGY	10	10.000	
MEDICINE GENERAL INTERNAL	6	6.000	
PSYCHIATRY	6	6.000	
SURGERY	6	6.000	
MULTIDISCIPLINARY SCIENCES	5	5.000	
RADIOLOGY NUCLEAR MEDICINE MEDICAL IMAGING	5	5.000	
NEUROIMAGING	4	4.000	
BEHAVIORAL SCIENCES	3	3.000	
LINGUISTICS	3	3.000	
MEDICINE RESEARCH EXPERIMENTAL	3	3.000	
PHYSIOLOGY	3	3.000	
PSYCHOLOGY CLINICAL	3	3.000	
REHABILITATION	2	2.000	
BIOLOGY	1	1.000	
LANGUAGE LINGUISTICS	1	1.000	
PSYCHOLOGY	1	1.000	
PSYCHOLOGY MULTIDISCIPLINARY	1	1.000	

DISCUSSION

Bibliometric analysis is a frequently applied quantitative method in many areas for different purposes; for instance, it can help track the historical development of a research field and research trends (16). Therefore, bibliometric analysis of the top cited articles about tinnitus can provide a platform that allows the researchers to access such articles easily and analyze the studies. Furthermore, it can provide an opportunity to observe

TABLE 6. Authors who contributed three or more of the top 100 cited tinnitus research articles

Field: Authors	Record Count	% of 100	Bar Chart
DE RIDDER D	10	10.000	
LANGGUTH B	8	8.000	
KLEINJUNG T	6	6.000	
BAUER CA	5	5.000	
BROZOSKI TJ	5	5.000	
HAJAK G	5	5.000	
KALTENBACH JA	5	5.000	
ANDERSSON G	4	4.000	
CASPARY DM	4	4.000	
EGGERMONT JJ	4	4.000	
JASTREBOFF PJ	4	4.000	
MOLLER AR	4	4.000	
RAUSCHECKER JP	4	4.000	
TURNER JG	4	4.000	
TYLER RS	4	4.000	
VAN DE HEYNING P	4	4.000	
WEISZ N	4	4.000	
EICHHAMMER P	3	3.000	
ELBERT T	3	3.000	
GERLOFF C	3	3.000	
HARTMANN T	3	3.000	
HENRY JA	3	3.000	
LANDGREBE M	3	3.000	
LEVINE RA	3	3.000	
LOCKWOOD AH	3	3.000	

the research trend and can give the researchers a clue for future studies.

Our bibliometric analysis showed that 80% of the top 100 cited articles about tinnitus were published within the past 2 decades. The reason may be that published articles have increased overall and have a widespread internet access for literature search within the past 20 years (12, 17). Given the fact that the number of citation is closely proportional to the publishing date (18-21), such as the snowball phenomenon (22), the more recent articles most likely received less citation than the earlier articles. Not surprisingly then, articles published since 2014 could not be part of the list, highlighting the effect of publishing year on receiving more citation. The article entitled "Phantom Auditory Perception (Tinnitus): Mechanism of Generation and Perception," published in 1990 by Jastreboff P.J. is the most cited article in our list. Interestingly, only eight articles published in the 1980s appeared in the list. Among them, the most cited article received 284 citations but only ranked 17th in the list. Two reasons why the earlier studies in the 1980s received less citation are as follows. First, obliteration by incorporation might happen during the development of the field, and certain contents of the earlier studies might become well accepted and commonly used; consequently, their authors were no longer cited (7). Second, parallel to the rapid technological development, the field of tinnitus research may be ever developing.

The articles are not generally cited within 2 years of publication, but they receive more citation 3–10 years after publication (23). After this time period, they still receive citation, but less frequently (23). To overcome this intrinsic problem, we further calculated the average yearly citation for each article in our list. Subsequently, the ranking of the articles slightly changed. For example, Jos J. Eggermont's article entitled "The Neuroscience of Tinnitus," published in 2004 ranked third in the original list, but it ranked first in the list according to the average yearly citation.

The citation number of articles was not analyzed solely by WOS. Google Scholar and Scopus are the other most widely used citation databases (24). However, WOS is the most commonly used citation database for bibliometric analysis, and it provides a user-friendly analyzing tool. In this study, we primarily used WOS and then cross-checked with Scopus. Our findings showed that when analyzing the top 100 cited articles in Scopus, 12 out of 100 articles in the original list generated by WOS did not enter the list generated by Scopus.

To consider an article as a "classic article," it must have at least 100 citations (25). Hence, the articles in our list can be considered as classic articles because all of them reached at least 100 citations. However, the total citation number of these classic articles about tinnitus remains far below than that of the classic papers identified by other bibliometric analyses in different research fields (10-15). The possible reason for this situation could be that tinnitus is an extremely specific research field that only 4419 articles have been published to date, and this number is dramatically lesser than the article numbers in other bibliometric analyses in various research fields (10, 11).

Except for one article published in German, all articles were published in English. As can also be seen in other bibliometric analyses in various research fields (10-15), most of these articles (N=51) originated from universities or institutions in the USA. As discussed in other bibliometric analyses (26), this situation can be associated with the fact that USA dominates the research on medical science because of a higher federal budget and a higher number of researchers than any country. Furthermore, authors from the USA generally tend to cite articles originated from the USA (17), resulting in a higher citation for USA-based articles.

The top 100 cited articles about tinnitus were published in first-quartile journals (high-impact journals). The journal *Hearing research* (the latest impact factor: 2906; Journal Citation Reports, Clarivate Analytics, 2018) with 12 published articles is the top preferred journal, followed by the *Journal of Neuroscience* (impact factor in 2018: 5988; Journal Citation Reports, Clarivate Analytics, 2018). Most authors thought that publishing in high-impact journals provides more of an advantage to receive higher citations; hence, they tend to publish their articles in these journals, eventually resulting in maintaining the impact factor of these high-impact journals (19). Therefore, following the Bradford's law (27, 28), most of the top cited articles were published in a limited number of selective high-impact journals.

Our bibliometric analysis in tinnitus research also provided the opportunity to identify the authors and their studies. For example, as being the first among three authors, de Ridder D. ranked first in our list, with 10 articles, followed by Langguth B. with 8 articles. Meanwhile, Jastreboff P.J., who is the author of the top cited article in our list, published four articles in which he was regarded as the first author, and two of these articles appeared in the top 10. In addition, Jastreboff and Hazell (5) et al.'s article on the study of the first emotional test on an animal model using rats 30 years ago ranked 34th in the list.

When analyzing each article in our list, a significant number (n=52) of them is about the underlying mechanism of tinnitus. This finding can be associated with the fact that the pathology of tinnitus remains poorly known, and the research is heterogeneous. Hence, an effective classification of the underlying pathophysiological mechanisms of tinnitus symptoms could be an innovative approach toward personalized rehabilitation (29). Therefore, more research on humans and animals that investigates tinnitus pathology is clinically important.

Eleven out of 100 articles in our list are questionnaire studies. *Tinnitus handicap inventory* and *tinnitus functional index* are the two common questionnaires used to evaluate the effects of tinnitus. Considering that the second top cited article in the list was about a commonly used questionnaire, that is, tinnitus handicap inventory, not surprisingly, it received high citations (n=636). Similar to the articles involving commonly used questionnaires, review articles also receive typically high citations because such articles are generally the primary source when writing up a new article to track the past studies in the literature (7). Our findings also support this idea in a way that 16 out of 100 articles in the list are review articles. Moreover, the third top cited article, which also ranks first in the list based on average yearly citation number, is a review article.

The effects of technological developments have been crucial in the advancement of tinnitus research. For example, neuroimaging by functional magnetic resonance imaging (fMRI) and positron emission tomography (PET) provides important data for pathophysiology-oriented studies. For instance, the fMRI study on lateralized tinnitus by Melcher, J.R. et al. showed an abnormally low percent signal change in the inferior colliculus contralateral to the tinnitus percept compared with that in control subjects (30). This study ranked 31st in our list. In addition to this study, four more articles involve the use of fMRI. Meanwhile, PET is another commonly used imaging modality, and nine articles in our list mention the use of PET. Showing the cortical abnormalities except the auditory system, PET using the voxel-based morphometry and magnetoencephalography methods showed changes in cortical activities on subcallosal region including the frontal cortex, parietal lob, mesial posterior regions, and nucleus accumbens. With the roles of central auditory pathway and limbic system on tinnitus pathophysiology revealed tangibly, these studies are among the classic articles about tinnitus.

Another interesting finding of this bibliometric analysis is that most of the classic articles about tinnitus (n=15) involve animal studies/models. Animal models are used, mainly because tinnitus is a subjective phenomenon and its diagnosis in humans relies on self-report. Therefore, animal models have been developed to overcome this problem and to provide a more objective evaluation. However, the common problem with animal tinnitus models is its reliability and validity.

In tinnitus research, the top cited treatment-oriented articles are about repetitive transcranial magnetic stimulation (rTMS). This noninvasive method was first developed in 2003, involving a repetitive short-period ~2 Tesla magnetic stimulus modulated by neuronal activity transcutaneously (31). Considering that this method is expensive, time consuming and used with neuronavigation, it is used limitedly to research, and it is not viable as a routine procedure in clinics. The articles that involved rTMS receive high citations, probably because it is a relatively new technology and its effect mechanism is not still well understood.

Meanwhile, this study has several limitations. First, we did not consider the effect of incomplete station, that is, analyzing the results from systematic reviews, instead of analyzing each article separately. Other intrinsic limitations include self-citation, journal and author bias, in-house bias toward friends or colleagues, language bias toward English, and omission bias toward not purposely referencing competitors (12), which all eventually affect the listing of the top 100 cited articles. Second, we used the WOS database where only major journal article citations are accounted for calculating the total citation number of an article. However, in Google Scholar, other citations in books and an online platform are also accounted for calculating the total citation number. Therefore, our reported citation numbers can be different from those calculated by Google Scholar (26). Furthermore, the WOS only includes articles published after 1975, whereas earlier studies before 1975 can be found in Scopus database. For example, the earliest study found in Scopus database was published in 1841. Nevertheless, none of the articles published before 1975 appeared in the top 100 list generated by Scopus. Lastly, the time for collecting citation data is another important factor that can also affect the ranking of articles in the list because the total number of citation changes continuously. Especially, the citation numbers of the articles located at the bottom of the list are extremely close to each other. Thus, the ranking of these articles can change swiftly, and/or some of these articles can be out of the list soon after. Moreover, the articles having a higher yearly average citation can claim immediately the top of the list. Thus, our list of top 100 cited articles about tinnitus can change soon afterward when considering tinnitus research as an ever-developing field.

In this study, we identified and analyzed the top 100 cited research articles about tinnitus, with the aim of providing researchers a source to track the historical development and trends of the field. Our analysis indicated that the current tinnitus research trends include finding the objective evolution of tinnitus, revealing specific pathophysiological mechanisms of tinnitus etiology, and developing new treatment methods accordingly. Meanwhile, technological innovations support these efforts critically to provide an opportunity for diagnosing tinnitus objectively.

Ethics Committee Approval: Authors declared that the research was conducted according to the principles of the World Medical Association Declaration of Helsinki "Ethical Principles for Medical Research Involving Human Subjects". (amended in October 2013).

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