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Original Article

Knowledge Mapping of Benign Paroxysmal Positional Vertigo from 2002 to 2021: A Bibliometric Analysis

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BACKGROUND: This article evaluated the current status and focus areas in benign paroxysmal positional vertigo (BPPV) research in the world and to predict the direction of future research.

METHODS: Web of Science Core Collection were searched from January 1, 2002, to December 31, 2021. Bibliometric and statistical analysis were conducted to generate the basic information of the publications.

RESULTS: A total of 1255 publications were identified, with an increasing trend in the number of annual number of publications from 2019 to 2021. *Otology & Neurotology* was the most productive journal. Kim J, Kim C, and Lee J from South Korea were the top 3 productive authors. Seoul National University is the most influential institution. The top 5 cited burst keywords include recurrence, osteoporosis, bone mineral density, vitamin D deficiency, and BPPV.

CONCLUSION: The annual number of publications would continue to grow. The future research of BPPV will concentrate on osteoporosis and recurrence.

KEYWORDS: Benign paroxysmal positional vertigo, hotspot, research trends, visualization analysis, bibliometric analysis

INTRODUCTION

Benign paroxysmal positional vertigo (BPPV) is an inner ear disorder, which is characterized by repeated episodes of positional vertigo.[1] Benign paroxysmal positional vertigo is a common vestibular vertigo disease, accounting for 20%-30%. The annual incidence rate is (10.7-600.0)/100 000, the annual prevalence rate is 1.6%, and the lifelong prevalence rate is 2.4%.[2] Although BPPV can occur at all ages, it is relatively rare among children. Benign paroxysmal positional vertigo has a stable and significant growth after the age of 40, with a 7 times higher prevalence in patients aged >60 years compared to patients aged 18-39 years.[2] *The* incidence of idiopathic BPPV is higher in females, with a female-to-male ratio of 2 : 1 to 3 : 1.[2,3] BPPV is a kind of positional vertigo, not caused by any serious central nervous system (CNS) disorder, and the overall prognosis is good.[3] About 20% of patients diagnosed with BPPV can recover spontaneously within 1 month of a follow-up visit and up to 50% at 3 months follow-up, which may contribute to the disease being considered benign.[4] However, the vestibular damage and dysfunction that have been caused cannot be completely eliminated, and may even accompanied by emotional disorders such as anxiety and depression, affecting the quality of life, especially for the elderly and frail, who may be more vulnerable to serious injury from falls.[5,6]

Considering the significant prevalence of BPPV, its health and social implications are enormous. The cost of diagnosing BPPV for 1 patient is estimated to be about $2000.[7] As the increasing elderly population in the global world, the incidence and prevalence of BPPV are also likely to increase.[8,9] Therefore, it is essential to enhance the accuracy of diagnosis and the effectiveness of treatment to avoid unnecessary tests and medication, while also significantly improving healthcare quality and reducing medical and societal costs. Understanding the frontiers and focus areas of BPPV research is an important basis for achieving the above goals.

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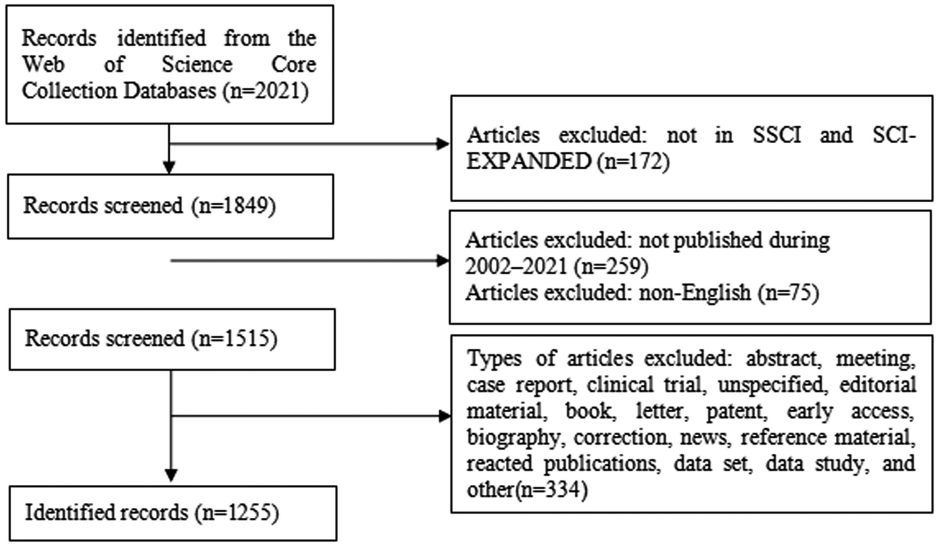

Figure 1. Flowchart of the included and excluded publications.

Bibliometric analysis was used as a statistical method to analyze all knowledge carriers about a topic. After searching the database, we found almost no bibliometric analysis of BPPV. To fill this gap, we conducted bibliometrics on BPPV-related studies published from 2002 to 2021. This bibliometric analysis is to point out the research hotspots, and trends in BPPV, including authors, journals, countries, keywords, references, and the complex relationships among them.

MATERIAL AND METHODS

Data Collection

Relevant literature was searched by 2 authors independently searching the WoSCC, during the course of a single day (on July 3, 2022). The search strategy was as follows: TS = ("benign position* vertigo" OR "benign paroxysmal position* vertigo" OR BPPV). The literature search and selection process is shown in Figure 1. Additionally, journal information comes from the 2022 journal citation report (Clarivate Analytics, Philadelphia, Pa, USA), including journal impact factor (JIF) and quartile in category (Q1, Q2, Q3, and Q4).

This study was approved by Ethics committee of Beijing Rehabilitation Hospital (Approval No: 2021-065; Date: October 30, 2021).

MAIN POINTS

- Considering the significant prevalence of BPPV, its health and social implications are enormous.
- It is very important to improve the accuracy of BPPV diagnosis and the effectiveness of treatment to avoid unnecessary tests and medication, while also significantly improving health care quality and reducing medical and societal costs. Understanding the frontiers and focus areas of BPPV research is an important basis for achieving the above goals.
- This study showed the annual number of publications has grown rapidly in the past two decades and will continue to grow. The relationship between the incidence of BPPV and osteoporosis, recurrence rate, and risk factors of BPPV may continue to be the focus of research now and in the future.

Bibliometric and Statistical analysis

CiteSpace (Drexel University, Philadelphia, Pa, USA) was conducted to a net map of institutions, a cooperation network map of authors, journal analysis, clusters and timeline of the co-cited references, and the strongest citation bursts. The VOSviewer (Centre for Science and Technology Studies, Leiden University, Leiden, The Netherlands) was applied to conduct visualization networks of keywords co-occurrence network map. Scimago Graphica (SCImago Lab, Madrid, Spain) and Microsoft Excel 2019 (Microsoft, Redmond, WA, USA) were conducted to generate the basic information of the publications in order to know the geographical and annual distribution for predicting trends in the future.

RESULTS

Analysis of the Global Publication

In total, 1255 publications with 12 269 citations were published from 2002 to 2021. The annual publications of BPPV research are shown in Figure 2. In this study, Excel software is used for correlation fitting, and the correlation coefficient is 0.8615. The closer the correlation coefficient is to 1, the closer the relationship between the 2 variables is to the proportional relationship. In general, the number of literatures has shown an overall growth trend in the past 20 years. Although there were 3 troughs in 2007, 2011, and 2016, it did not affect the overall trend of increase at the rate of 3-5 articles per year. From 2002 to 2019, especially in the past 2 years, namely 2020 and 2021, the growth rate has increased significantly.

Analysis of the Most Prolific Countries/Regions

Figure 3 displays the visualization map of research collaboration between the countries/regions. The size of the circle represents the publication volume. For example, the circle of the United States is the largest in the world, followed by China, South Korea, Japan, and Italy. Betweenness centrality (BC) can show the importance of the institutions, BC 0.1 is usually indicated connecting more links. The contribution and BC value of each country were shown in Table 1. It can be seen that the United States is the most central, indicating that it has the most prominent position in the field of BPPV related research. The United States has strong ties with Germany,

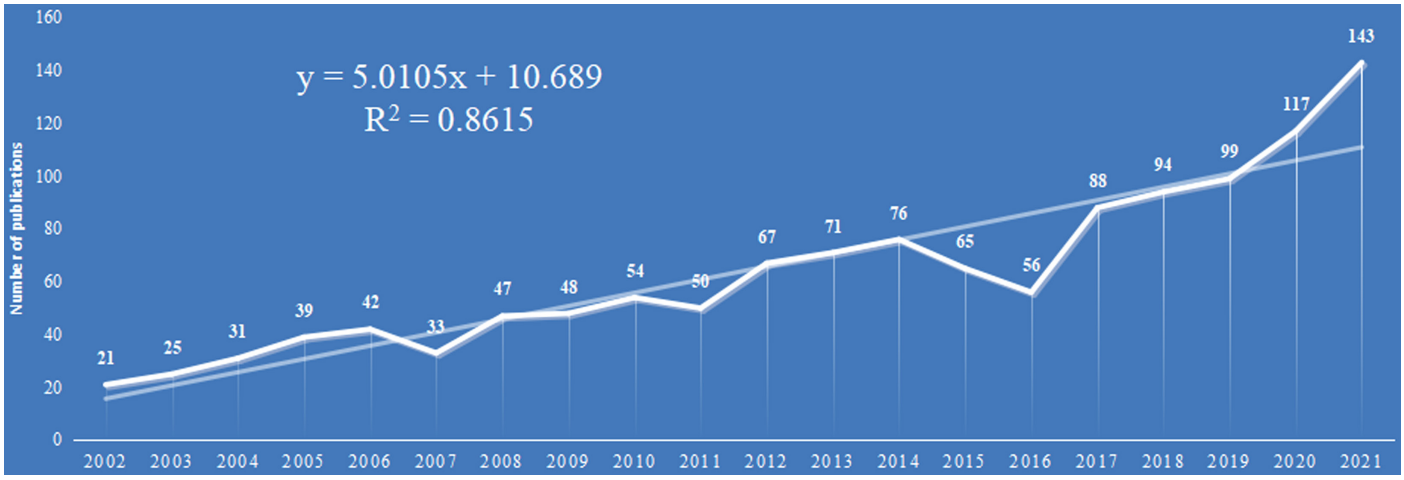

Figure 2. Annual number of globally published publications in the field of benign paroxysmal positional vertigo research from 2002 to 2021.

Switzerland, Italy, Sweden, and France. The overall strength of Western Europe is very strong, which is the region with the most intensive research on BPPV and the most closely connected region. East Asia, represented by China, Japan, and South Korea, is also relatively active. Germany, France, and the United States made outstanding contributions in the early stage of the BPPV research field. Meanwhile, Germany, France, and the United States, which were coded with red, made outstanding contributions in the early stage of the BPPV research field. China, Australia, Denmark, and Norway, which were coded with blue, is the new rising countries in this field in the last 3 years.

Analysis of the Most Prolific Institutions

The collaboration network map of institutions was conducted by CiteSpace (Figure 4). The size of the node reflects the quantity of publications of that country, and the connecting line between nodes indicates link strength of a co-authorship relationship which can be weighted by total link strength (TLS). Total link strength is an important parameter that could quantitatively measure the strength of links. Seoul National University, Osaka University, Hallym University Korea, Konkuk University, and Johns Hopkins University ranked in the top 5. Seoul National University, Osaka University, and Johns Hopkins University were the top 3 with the largest TLS. Seoul National University, Hallym University Korea, and Johns Hopkins University occupied the central position of the collaboration network. However, Seoul National University was the only 1 whose BC value greater than 0.1, that means the cooperation with other institutions (except for the above institutions) needs to be strengthened. Organizations from South Korea, Japan, the USA, Israel, and China occupied the top 5 positions of contributors to BPPV research.

Figure 3. International collaboration analysis among different countries in the field of benign paroxysmal positional vertigo research from 2002 to 2021.

Table 1. Top 20 Countries with the Most Publications Related to Benign Paroxysmal Positional Vertigo

Rank	Country	Contribution	Centrality
1	USA	244	0.46
2	China	158	0.05
3	South Korea	125	0.06
4	Japan	108	0.11
5	Italy	107	0.05
6	Germany	80	0.43
7	Türkiye	76	0
8	Spain	46	0
9	United Kingdom	44	0.01
10	Canada	37	0.11
11	Switzerland	34	0.42
12	India	29	0.27
13	Australia	28	0.16
14	Israel	28	0
15	Greece	28	0.05
16	Brazil	27	0.07
17	Sweden	18	0.29
18	Netherlands	22	0
19	France	21	0.47
20	Egypt	19	0.05

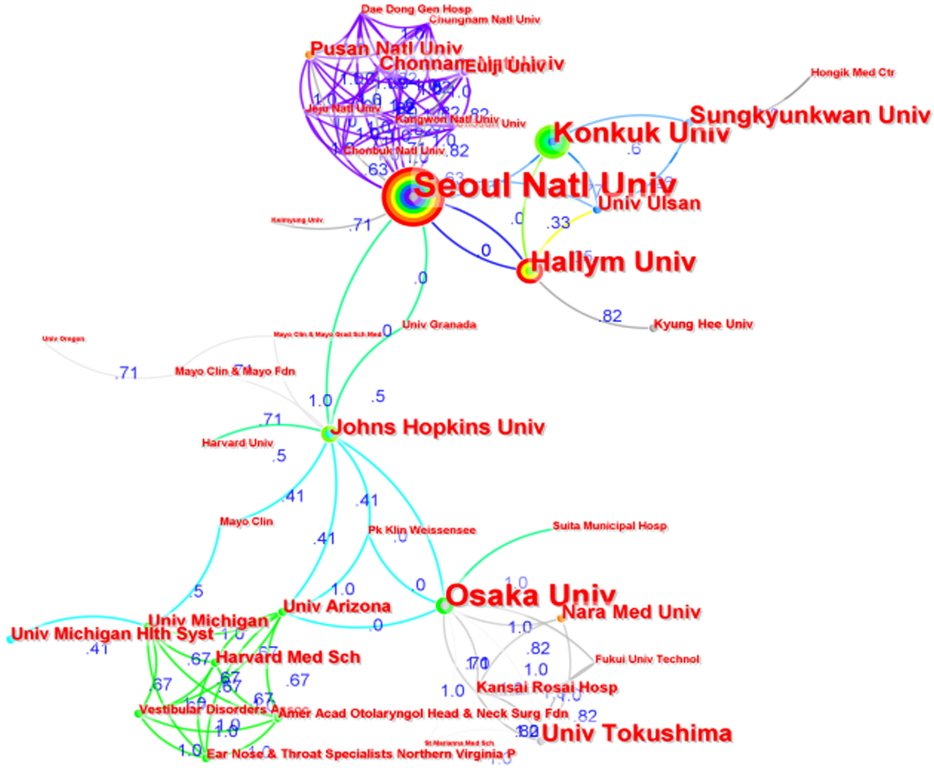

Figure 4. Overlay visualization map of institution co-authorship analysis in the field of benign paroxysmal positional vertigo from 2002 to 2021 generated by CiteSpace software.

Analysis of the Most Influential Authors

More than 1200 authors contributed to the publication of 1255 documents. The number of publications represents the degree of research activity and contribution of that author in the field. In the network map, shown as Figure 5, Kim J, KIM C, LEE J, KIM S, and KIM H from South Korea were the top 5 authors. It is particularly worth mentioning that 13 of the 20 authors with the largest number of publications are from South Korea, additionally, these authors had the highest collaboration and BC value, which suggests that the authors from South Korea have the most influence in this subject area. It is easy to note that the authors are mainly divided into 3 groups based on collaboration, which were distributed in East Asia, Europe, and North America. The collaboration within the groups was relatively strong, but the collaboration between the groups was found to be weak. The East Asia group centered on Kim C and Kim J in this field. Kim J had the largest BC value (0.17) and ranked first, followed by Imai T (0.16) and Lee J (0.09). It is believed that the frequently cited authors have greater influence, and authors who are jointly cited seem to have similar research content.

Analysis of Core Journals and Subject Categories

The publication related to BPPV research has been published by more than 269 journals. Table 2 listed the top 20 most prolific journals. *Otology & Neurotology* (42 publications, IF: 2.619, Q2) published the most papers on BPPV, followed by *Acta Oto-Laryngologica, Laryngoscope,* and *Neurology. Neurology* (59.935) has the highest JIF, followed by *Journal of Neurology, Neurosurgery and Psychiatry* (13.654), and *Journal of Neurology* (6.682). It also can be seen that 30% of journals belong to Q1, 40% belong to Q2. The rest belong to Q3 (25%), Q4 (5%).[6]

Publications were mainly divided into 6 subject categories: (1) Otorhinolaryngology, (2) Neurosciences Neurology, (3) Geriatrics Gerontology, (4) Ophthalmology, (5) Physiology, (6) Research Experimental Medicine. *Otolaryngology-head and Neck Surgery, Laryngoscope, Acta Oto-Laryngologica, Neurology, Otology & Neurotology,* and *Journal of Neurology, Neurosurgery and Psychiatry* ranked in the top 5 co-citation journals. Among them, *Otolaryngology-head and Neck Surgery, Laryngoscope, Acta Oto-Laryngologica,* and *Neurology* occupy the most dominant position. Apart from that, Otorhinolaryngology and Neurosciences Neurology were 2 main subject categories.

As shown in Figure 6, the left side of the map refers to the citing journals, and the right refers to the cited journals. There were seven core citation paths as follows. The grey paths indicate that documents published in Dentistry/Dermatology/Surgery journals usually cited documents published in journals belonging to Molecular/Biology/Genetics, Dentistry/Dermatology/Surgery, and Health/Nursing/Medicine. The green paths imply that the majority of papers published in the journals of Medicine/Medical/Clinical are likely to be biased to cite papers published in journals within Molecular/Biology/Genetics and Dentistry/Dermatology/Surgery. The green paths display that the reported thesis in journals referring to Neurology/Sports/Ophthalmology are based on Dentistry/Dermatology/Surgery and Health/Nursing/Medicine.

Analysis of Highly Cited and Co-citation References

The top 20 most cited references on BPPV were listed in Table 3. The highest JIF (170.076) paper was "Clinical Practice Guideline: Benign Paroxysmal Positional Vertigo (Update)" which has been cited 115 times and was published in *New England.* According to CiteSpace,

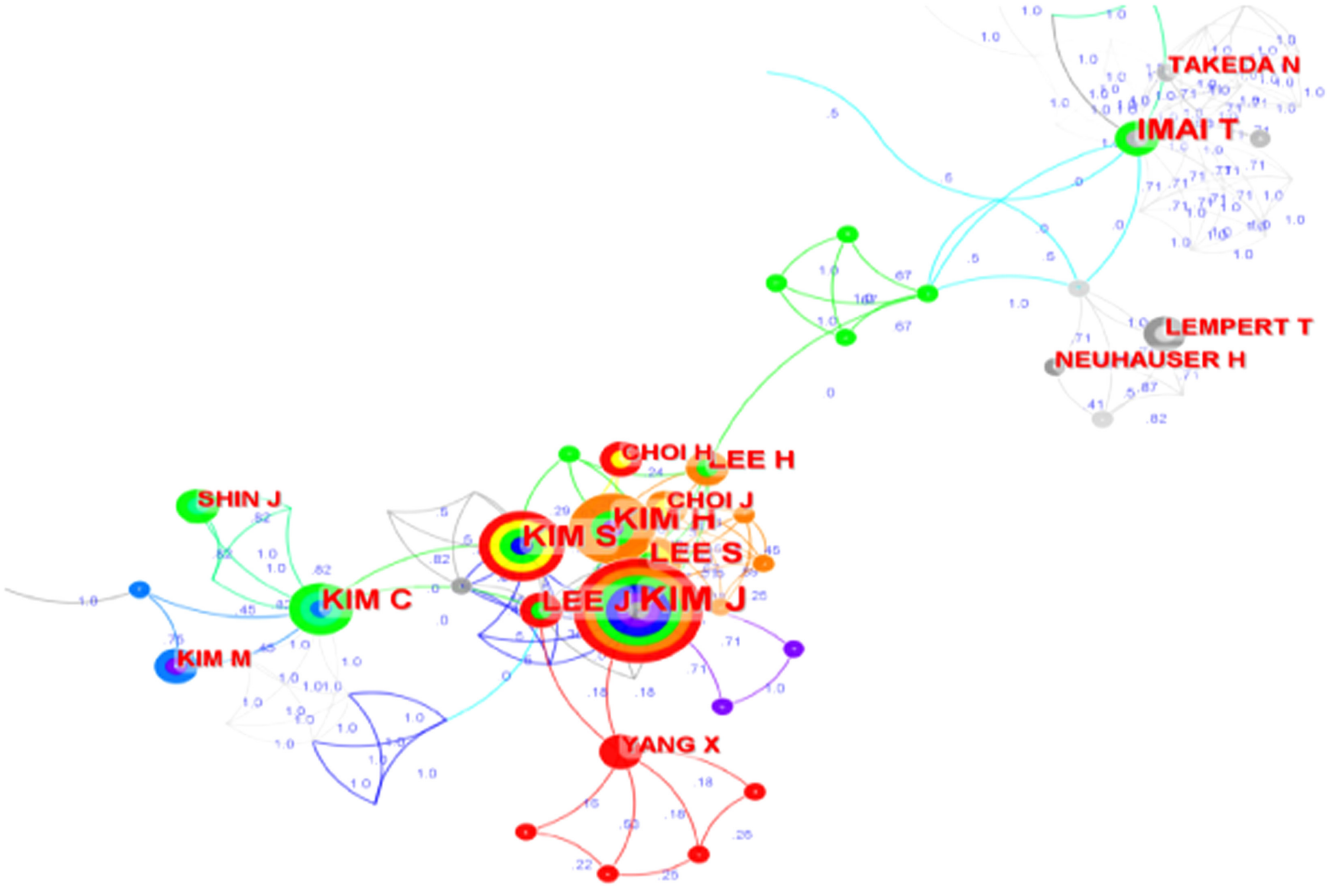

Figure 5. The most influential authors in the field of benign paroxysmal positional vertigo from 2002 to 2021 generated by CiteSpace software.

Table 2. Top 20 Journals with the Most Publications in the Field of Benign Paroxysmal Positional Vertigo

Rank	Sources Title	Output	JIF (2022)	Quartile in Category (2022)
1	*Otology & Neurotology*	42	2.619	Q2
2	*Acta Oto-Laryngologica*	41	1.698	Q4
3	*Laryngoscope*	41	2.970	Q2
4	*Neurology*	41	59.935	Q1
5	*American Journal of Otolaryngology*	40	2.873	Q2
6	*European Archives of Oto-Rhino-Laryngology*	40	3.236	Q2
7	*Journal of Vestibular Research-Equilibrium & Orientation*	40	2.354	Q3
8	*Otolaryngology-Head and Neck Surgery*	40	5.591	Q1
9	*Annals of Otology Rhinology and Laryngology*	39	1.973	Q3
10	*Journal of Neurology*	39	6.682	Q1
11	*Auris Nasus Larynx*	38	2.119	Q3
12	*Journal of Neurology, Neurosurgery and Psychiatry*	38	13.654	Q1
13	*Frontiers in Neurology*	37	4.086	Q2
14	*International Journal of Audiology*	36	2.437	Q2
15	*Journal of Laryngology And Otology*	35	2.187	Q3
16	*Acta Otorhinolaryngologica Italica*	29	2.618	Q2
17	*Brazilian Journal of Otorhinolaryngology*	29	2.474	Q2
18	*Journal of Otolaryngology-Head & Neck Surgery*	29	4.856	Q1
19	*Journal of International Advanced Otology*	28	1.316	Q1
20	*Audiology and Neuro-Otology*	27	2.213	Q3

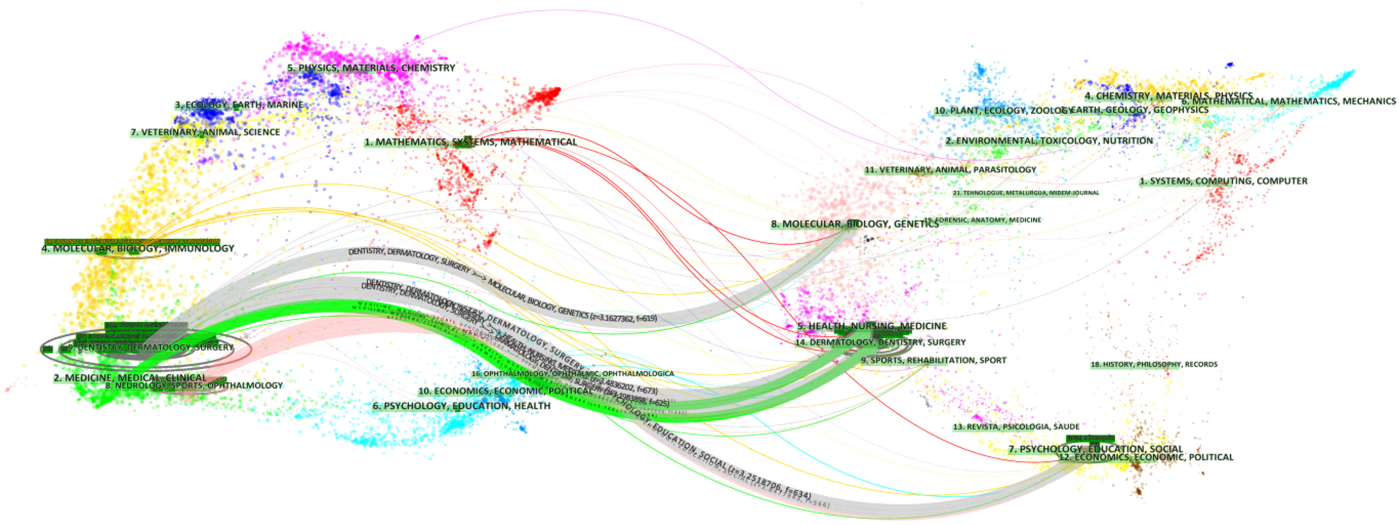

Figure 6. Dual-map overlays of discipline and journal analysis related to benign paroxysmal positional vertigo generated by CiteSpace software.

the cited references could be divided into different clusters with different colors, see Figure 7. The largest cluster (#0) was "sudden sensorineural hearing loss", followed by "repositioning Maneuver" (#1), and "epidemiological evidence" (#2). The software also produced the timeline view in Figure 8, the timeline revealed a shift in this area from "benign paroxysmal positional vertigo" (#0), and "dizziness" (#2), "off-vertical axis rotation" (#3), and "lying-down nystagmus" (#5) to "dix-hallpike maneuver" (#1), and "vestibular neuritis" (#7).

Analysis of Co-Occurring Keywords

The keywords based on VOSviewer could be divided into 8 clusters as follows: i) refers to basic research, with red nodes; ii) epidemiology and risk factors, green nodes; iii) repositioning therapy, blue nodes; iv) vestibular rehabilitation, yellow nodes; v) vestibular function examination, purple nodes; vi) association with osteoporosis, pink nodes; vii) association with neuroscience, orange nodes; viii) other treatment, gray nodes; see Figure 9.

Table 3. The Top 10 Most Cited Papers on Benign Paroxysmal Positional Vertigo

Title	Journal	First Author	Year	Citations
Clinical practice guideline: benign paroxysmal positional vertigo (update)	*Otolaryngology-Head and Neck Surgery*	BhattacharyyaN	2017	115
Epidemiology of benign paroxysmal positional vertigo: a population based study	*Journal of Vestibular Research-Equilibrium & Orientation*	Von Breverna	2015	86
Benign paroxysmal positional vertigo	*New England Journal of Medicine*	Kim J	2014	67
Clinical practice guideline: Benign paroxysmal positional vertigo	*Otolaryngology-Head and Neck Surgery*	Bhattacharyya N	2008	50
Benign paroxysmal positional vertigo: diagnostic criteria	*Journal of Neurology, Neurosurgery and Psychiatry*	Von Breverna	2007	44
Practice parameter: therapies for benign paroxysmal positional vertigo (an evidence-based review)	*Neurology*	Fife TD	2008	34
Low bone mineral density and vitamin D deficiency in patients with benign positional paroxysmal vertigo	*European Archives of Oto-Rhino-Laryngology*	Talaat HS	2015	33
Reduction of recurrence rate of benign paroxysmal positional vertigo by treatment of severe vitamin D deficiency	*Auris Nasus Larynx*	Talaat HS	2016	29
Decreased serum vitamin D in idiopathic benign paroxysmal positional vertigo	*Journal of Neurology*	Jeong S	2013	29
Prospective clinical investigation of the relationship between idiopathic benign paroxysmal positional vertigo and bone	*Laryngoscope*	Parham K	2013	27
The Epley (canalith repositioning) maneuver for benign paroxysmal positional vertigo (review)	*Cochrane Database of Systematic Reviews*	Hilton MP	2014	27
A multicenter observational study on the role of comorbidities in the recurrent episodes of benign paroxysmal positional vertigo	*Auris Nasus Larynx*	De Stefano A	2014	27
Benign paroxysmal positional vertigo	*Journal of Clinical Neurology*	Lee S	2010	23

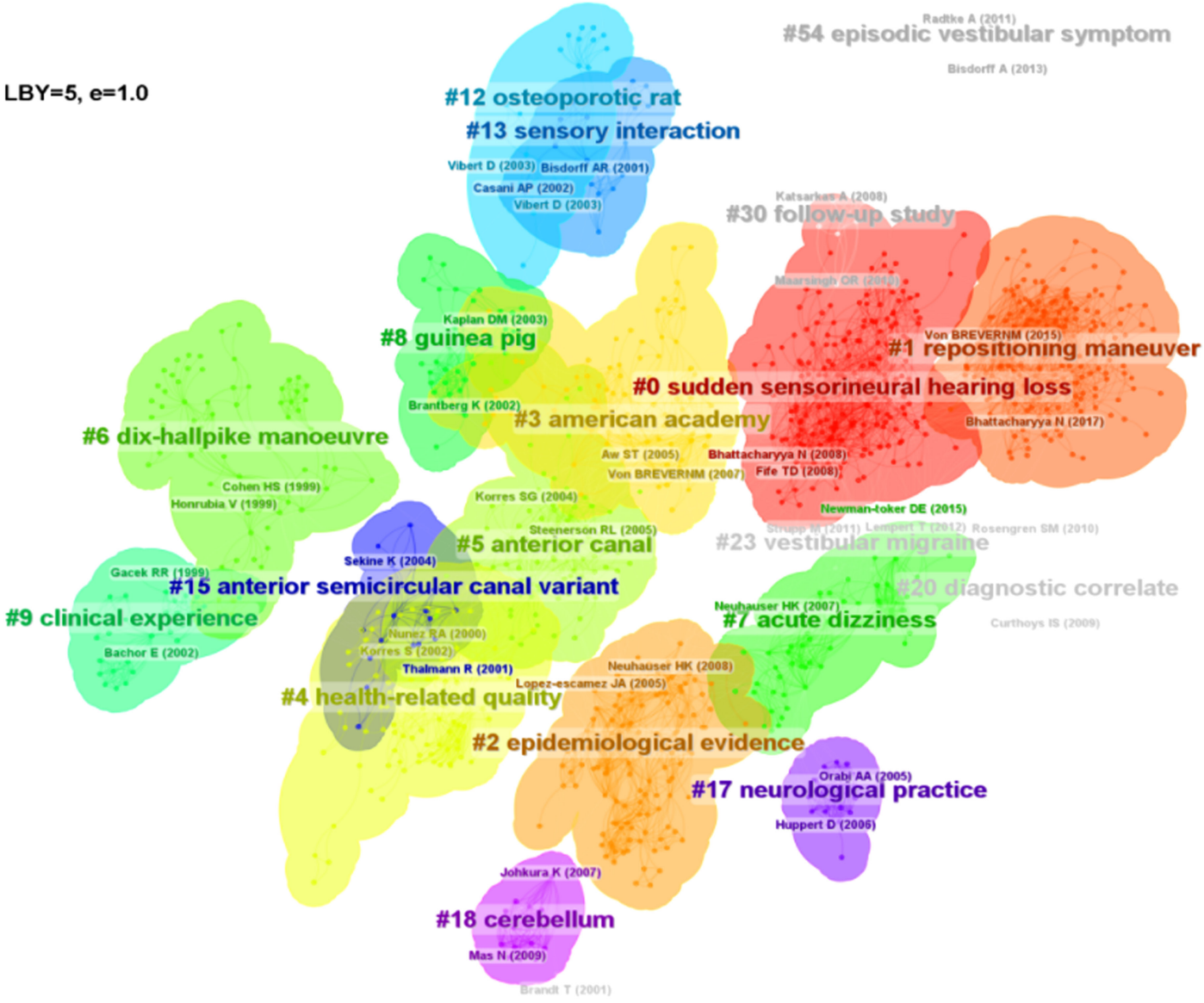

Figure 7. The clusters of the co-cited references related to benign paroxysmal positional vertigo generated by CiteSpace software.

Analysis of Burst Keywords

As shown in Figure 10, there was the top 30 keywords with the strongest citation bursts from 2002 to 2021. The most recent burst keyword was "recurrence" (2017-2021). From 2015, the burst words began to relate to orthopedics has continued to 2021, including "association" (2015-2021), "osteoporosis" (2016-2021), "bone mineral density" (2016-2021), "vitamin d deficiency" (2016-2021), "vitamin d" (2018-2021), and the bursts are still ongoing. Simultaneously, "evoked myogenic potentials," "residual dizziness," "positional nystagmus," "epidemiology," "epley maneuver," "classification," "vestibular migraine" "vestibular disorder," "prevalence," and "balance" were also lasting to 2021.

DISCUSSION

Main Findings

This study shows the knowledge framework, research hotspots, and trends of BPPV through bibliometric analysis. More than 1200 authors contributed to the publication of these 1255 documents. The number of reports has shown an overall growth trend in the past 20 years. Although there were 3 troughs in 2007, 2011, and 2016, it did not affect the overall trend of increasing at the rate of 3-5 articles per year. From 2002 to 2021, especially in the past 2 years, namely 2020 and 2021, the growth rate has increased significantly (Figure 2), which means that the research on BPPV will still be a hotspot in the future. Benign paroxysmal positional vertigo is the most common vestibular disorder that can cause dizziness.[10,11] According to previous research, the prevalence of BPPV was 10.7 to 140 per 100 000 people.[12-14] With the increase in the world population and the aggravation of aging, the number of BPPV patients will continue to increase.

Productive Countries, Institutions, Authors, and Journals

The United States occupies the most prominent position as it had the largest number of publications (244, ranked first), high centrality (rank second), and high degree of international collaboration with European countries, such as Germany, Switzerland, and Italy. East Asia, represented by China, South Korea, and Japan, is also relatively active in research. As China has been the main contributor in the field

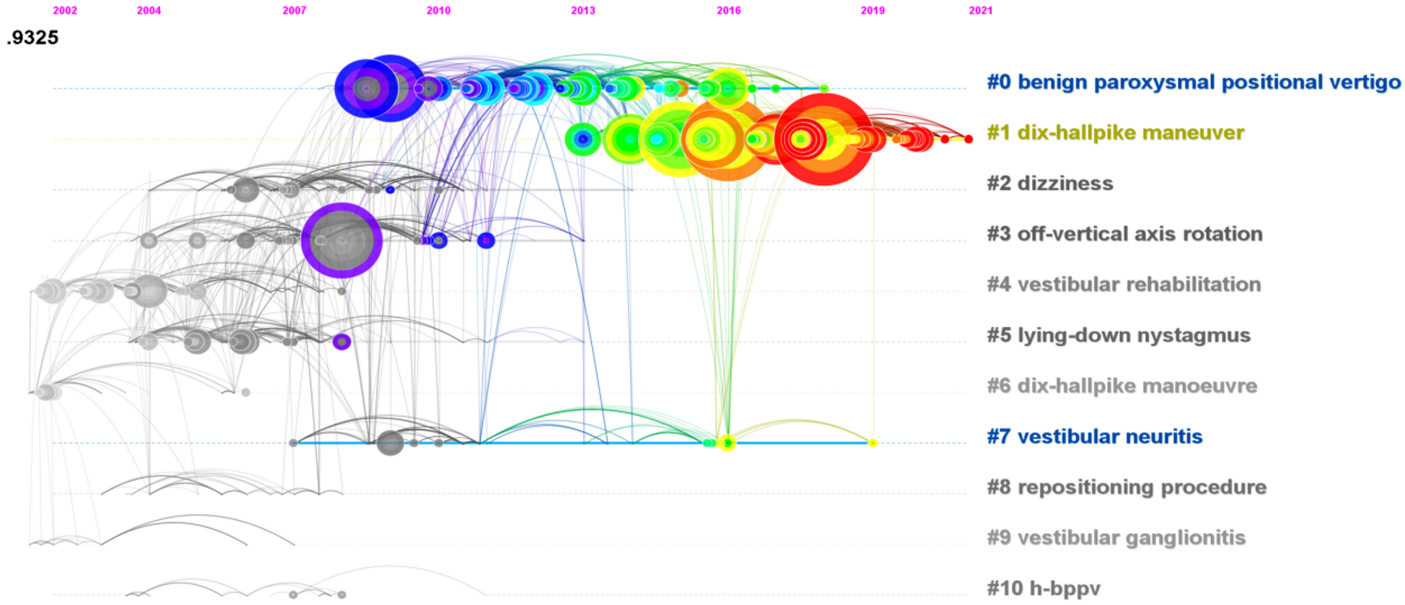

Figure 8. The timeline view of co-cited clusters with cluster labels related to benign paroxysmal positional vertigo generated by CiteSpace software.

of BPPV in the recent 5-6 years, we predict that the importance of China's contribution will continue in an upward trend in the future. Brazil is the only country from South America ranked in the top 20 countries. Egypt is the only representative for the African countries. This suggests that the development level of economic society and health care affects the research level of BPPV.

Among 107 institutions in this research field, Osaka University became more influential around 2010; however, in 2016, Johns Hopkins University and Seoul National University were the more influential institutions. From 2018 to now, Shanghai Jiao Tong University, Peking University, and Capital Medical University from China began to contribute more to this research area. Previous studies have shown that more inter-institutional communication and author collaboration may improve research productivity and quality.[15] Although Seoul National University occupied the center location of the collaboration network. This indicates the need to continuously eliminate academic barriers in the future to strengthen and improve cooperation and communication between different research institutions and teams.

Figure 9. A network map of keywords in the research field of benign paroxysmal positional vertigo from 2002 to 2021 generated by VOSviewer.

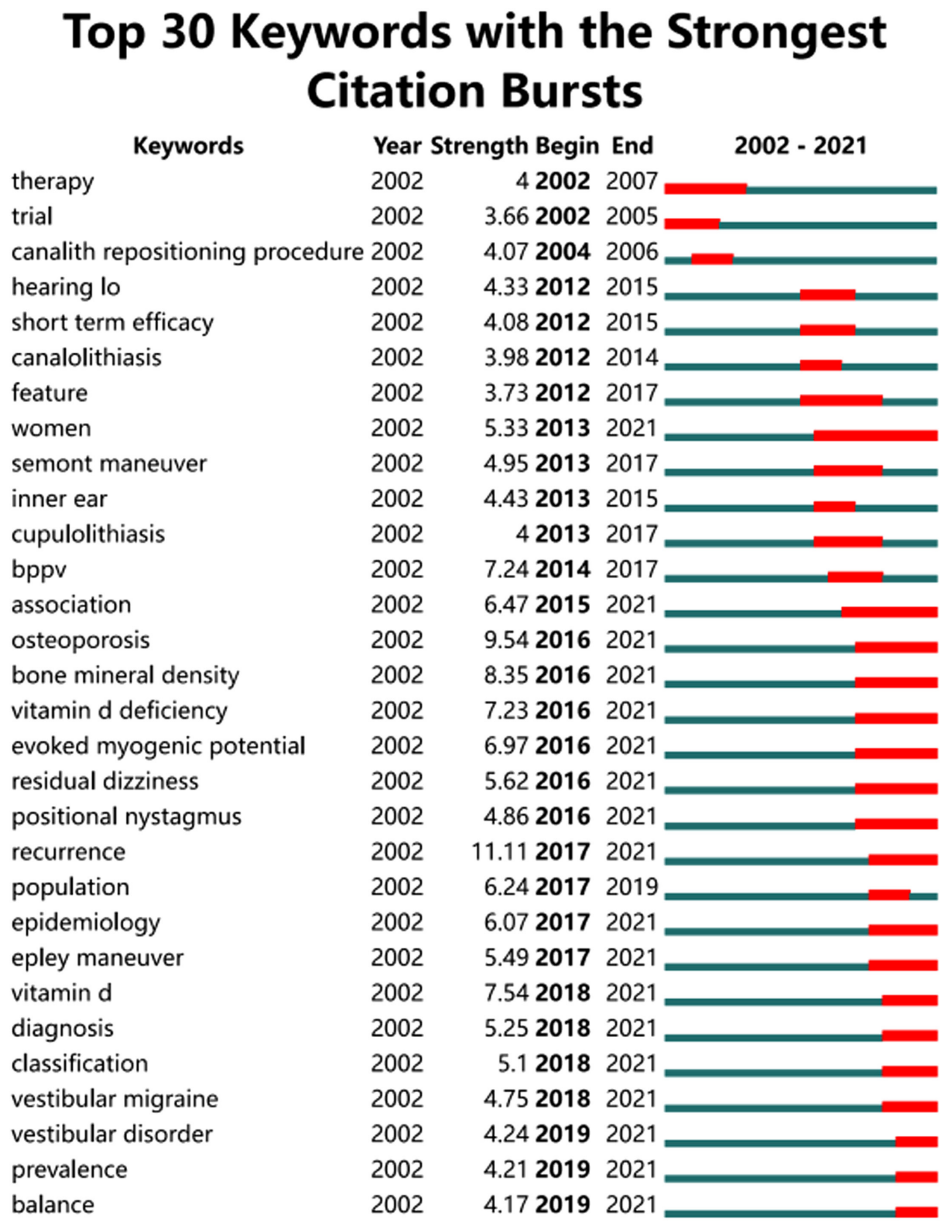

Figure 10. Keywords with the strongest citation burst in the research field of benign paroxysmal positional vertigo from 2002 to 2021 generated by CiteSpace software.

Kim J is the most influential author in the field of BPPV, followed by Kim C, Lee J, Kim S, and Kim H from South Korea. The cooperation between Korean authors is very close, which may be the reason for their high scientific research output in this field. Chinese authors and institutions have been very active in this research field in the past 3 years, and it is predicted that they will have more scientific research output in the future.

Ninety percent of journals in the field of BPPV belong to otolaryngology and neurology, and focus primarily on clinical manifestation, diagnostic method, maneuver, basic peripheral and central vestibular mechanisms, vestibular anatomy, imaging, modeling, and behavioral studies in animals and humans, and vestibular rehabilitation. The rest were classified as comprehensive journals. These results point to the need to strengthen collaboration and exchange between different subjects in the future. Meanwhile, an analysis of the overlay of the journals and cited journals manifests basic medicine and clinical medicine interact closely.

Highly Cited and Co-itation References

References with citation bursts indicate these studies have received particular attention from associated academic circles during a specified period of time. Among the top 20 most cited references on BPPV, "Benign Paroxysmal Positional Vertigo" was the highest JIF (170.076) paper, which was published in *New England*. This reference provides a comprehensive review of various aspects of BPPV. "Clinical Practice Guideline: Benign Paroxysmal Positional Vertigo (Update)" is the top-cited paper in the field, which serves as a handbook to guide clinical work related to BPPV.

From the timeline view for the major clusters of cited references, we found that Dix–Hallpike maneuver is the focus of research from 2013

to 2021, which is the gold standard test for the diagnosis of BPPV.[1,16] However, the speed of head movement, days of onset, and the angle of the occipital plane during the test may affect its diagnostic accuracy. The above may be the reason why the Dix–Hallpike maneuver continues to be the focus of research.

Burst Keywords as Indicators of Emerging Hotspots

Co-occurrence keyword clustering includes eight categories: basic research, epidemiology, repositioning therapy, risk factors, vestibular rehabilitation, vestibular function examination, association with osteoporosis, association with neuroscience, and other treatment. The co-occurrence keyword reflects the main research direction of BPPV.

Burst keywords refer to those keywords that have been cited in a large number of articles and have received a lot of attention in a certain professional field for a period of time.[17] They are often considered as another important indicator of future research trends.[18] Interestingly, the most recent burst keyword was "recurrence" (2017-2021). It may be speculated to the very high recurrence rate of BPPV, ranging from 15% to 67.3%.[19-22] Additionally, BPPV recurrence is a very important concern for patients. The research on recurrence is to better solve the clinical problems and find the risk factors associated with recurrence in order to reduce it. Since 2015, burst keywords in the field have been as follows: "association" (2015-2021), "osteoporosis" (2016-2021), "bone mineral density" (2016-2021), "vitamin d deficiency" (2016-2021), "vitamin d" (2018-2021). This maybe because the occurrence of osteoporosis may be a risk factor for treatment failure. Some studies have found that decreased bone mineral density is a risk factor for the onset and recurrence of BPPV.[23-27] While others hold different views.[28,29] It can be predicted that, because of the controversy on this issue, the correlation between bone mineral density and the occurrence and recurrence of BPPV will still be a research hotspot in the future. The burst keyword "women" appeared in 2013 and continues to this day. Females have a higher incidence of BPPV than males.[2,3]

Strengths and Limitations

In this study, there are several limitations that should be pointed out: i) Web of science was the only database used to search publications, which may lead to incomplete literature retrieval; ii) English publications was the only 1 language included in the analysis, thus excluding literature from non-English speaking countries in East Asia, such as Japan, South Korea, and China, which may have been published in their native languages; iii) There might be a possibility of bias when choosing publications. Regardless of these limitations, we announce the focus areas and future research trends of BPPV to a certain extent.

CONCLUSION

The annual number of publications would continue to grow. The United States was in the lead as the country with the largest number of publications (244, ranked first), high centrality (rank second), and high degree of international collaboration. *Otology & Neurotology* was found to be the most productive journal, with *Neurology* being the second most productive journal on this subject and also had the highest journal impact factor (JIF). Kim J, Kim C, Lee J, Kim S, and Kim H from South Korea were the top 5 authors with the highest number of publications, and Seoul National University is the most influential institution in terms of the number of published papers and total link strength. The top five cited burst keywords in this field include recurrence, osteoporosis, bone mineral density, vitamin D deficiency, and BPPV. The future research of BPPV will concentrate on osteoporosis and recurrence.

Ethics Committee Approval: This study was approved by Ethics committee of Beijing Rehabilitation Hospital (Approval No: 2021-065; Date: October 30, 2021).

Informed Consent: N/A

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