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Global trends and current status of amputation: Bibliometrics and visual analysis of publications from 1999 to 2021

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Abstract

Objective: To generalize the research status, hotspots, and development trends of amputation-related research.

Methods: The data from 1999 to 2021 were collected from the Web of Science core collection database, and analyzed through bibliometrics software (CiteSpace and VOSviewer) for the dual-map overlay of journals, top 25 references with the strongest citation bursts, top 25 keywords with the strongest citation bursts, and timeline of keywords.

Results: A total of 8,588 literature studies were involved in this study. The United States ranks the first in terms of H-index, total number of publications, and total citations. US Department of Veterans Affairs, Veterans Health Administration, and University of Washington are the major contributors to amputation. *Prosthetics and Orthotics International*, *Archives of Physical Medicine and Rehabilitation*, and *Journal of Rehabilitation Research and Development* are the main publication channels for articles related to amputation. Geertzen JHB, Czerniecki J, and Dijkstra PU are major contributors to amputation. In addition, research on limb salvage treatment and surgical methods for amputation will become a hotspot in the future.

Conclusion: The total number of publications for amputation has generally increased from 1999 to 2021. Our study is beneficial for scientists to specify the research hotspot and development direction of amputation.

Keywords

amputation, bibliometrics analysis, visual analysis, Web of Science, CiteSpace, VOSviewer

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Introduction

Amputation, the removal of the distal end of a limb, can result from diabetic foot ulcers,[1] peripheral vascular disease,[2] osteosarcoma,[3] trauma,[4] and combat injuries.[5] Among them, diabetes and vascular disease account for the majority of amputations (202 million adults living with peripheral vascular disease and 463 million with diabetes worldwide).[6] In addition, thromboangiitis obliterans (Buerger's disease) is one of the most common peripheral vascular diseases leading to amputation, which affects young people mostly.[7] Currently, the following 3 common surgical levels for amputation are available: below-knee, through-knee (total knee arthroplasty [TKA]), and above-knee strategy. The methods of amputation include guillotine amputation, Burgess flap or skew flap for transtibial, Gritti–Stokes for knee disarticulation, etc. Although TKA is less clinically used than the other two, it can be considered as a promising procedure for its biomechanical advantages and improved rehabilitation.[8] Importantly, stump bleeding, skin necrosis, and infection were the common complications after amputation surgery.[9] Meanwhile, the psychological issues cannot be ignored (e.g., anxiety and depression).[10] Necessary psychological intervention is helpful to adjust the mental state of amputees. About 10–80 percent of amputees will have a prosthesis after amputation, which may also bring some adverse effects (e.g., dermatitis).[11-13]

Unfortunately, the incidence rate of amputation has been increasing every year.[14] For example, the incidence of partial foot amputation in people with diabetes is 94.24 per 100,000.[15] Meanwhile, the amputation-related incidence varies by country: 0.3% in United States and Japan,[16] 0.3% in Ireland,[17] 0.6% in Netherlands,[18] and 5.1% in China.[19] Importantly, peripheral artery disease patients with amputation had the highest cost (average annual Medicare payout of approximately $120,000 per patient).[20] The burden of managing care, loss of functions of daily living, medical costs, and the financial stress of unemployment for amputation have brought great emotional distress.[21] Most importantly, amputation increases the risk of disability rate and mortality: more than 55% patients with amputation were permanently disabled thereafter.[20] Moreover, patients with major amputation due to CLTI (chronic limb-threatening ischemia) had a 10% higher absolute mortality rate.[22] Therefore, the amputations bring huge clinical and economic burdens to the society, and also severely reduces the quality of life.[21,23]

Bibliometrics is an interdisciplinary subject that combines statistics and bibliography to quantitatively analyze all knowledge carriers through statistical means, so as to discover research

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hotspots and development trends.[24] In the past few decades, scientists have conducted a lot of basic and clinical research on the surgical modality and prognosis of amputation.[25,26] However, few studies have analyzed the hotspots and characteristics of amputation research. A bibliometrics analysis may be helpful to scientists' objective and comprehensive understanding of the development law and future trend of amputation. Therefore, our study aims to explore the research progress of amputation from the perspective of visual analysis and bibliometrics, to clarify the future orientation and constructive information in the field.

Methods

Data sources

Web of Science Core Collection (WoSCC) database is regularly used in bibliometric analysis, which includes the Science Citation Index–Expanded, Arts & Humanities Citation Index, Social Sciences Citation Index, Conference Proceedings Citation Index—Social Science & Humanities, Conference Proceedings Citation Index—Science, Current Chemical Reactions—Expanded, Index of Copernicus, and Emerging Sources Citation Index.

Search strategy

All publications were retrieved in WoSCC on September 2022. The search formula was (TI = amputation OR amputee OR amputate). The literature studies that published between January 1, 1999 ,and December 31, 2021, were included. Article types were restricted to "article" and "review." Types of research excluded include Letter, Proceeding Paper, Meeting Abstract, Editorial Material, Correction, Book Chapters, Early Access, Biographical-Item, Book Review, News Item, Reprint, Poetry, Retraction, Data Paper, and Retracted Publication. In addition, the language was limited to English, which indicates that the study only covered literature in English, and several large populations were therefore excluded (e.g., French, Spanish, Arabic etc.).

Data collection

Full records and cited references (e.g., years of publications, titles, nationalities, authors, institutions of authors, journals of publications, keywords, total citations, etc.) were extracted from the WoSCC database for bibliometric analysis. Incidentally, both upper- and lower-limb amputation have been considered in our analysis. The relevant information was imported into CiteSpace (v.6.1.R2), Microsoft Excel 2021, and VOSviewer (v.1.6.18) for analysis. All the data in the following tables were extracted from the citation report in the WoSCC database.

Results

Trends of publications and citations over time

A total of 10,730 amputation-related articles and reviews published between 1999 and 2021 were included in our study. After the filtration of article types and removal of duplicate literature studies, 8,588 publications remained (Figure 1). The 8,588 included papers came from 27,575 authors from 6,873 institutions in 129 countries, which were published in 1,696 journals, and cited 129,757 citations from 30,324 journals. These articles have several important distribution areas: rehabilitation, orthopedics, surgery, engineering biomedical, and sport science (Figure 2). In the past 22 years, the number of citations and publications about amputation has generally shown a steady upward trend. In 2021, the number of citations and publications of amputation-related literature studies reached peaked at 26,048 and 903, respectively (Figure 3).

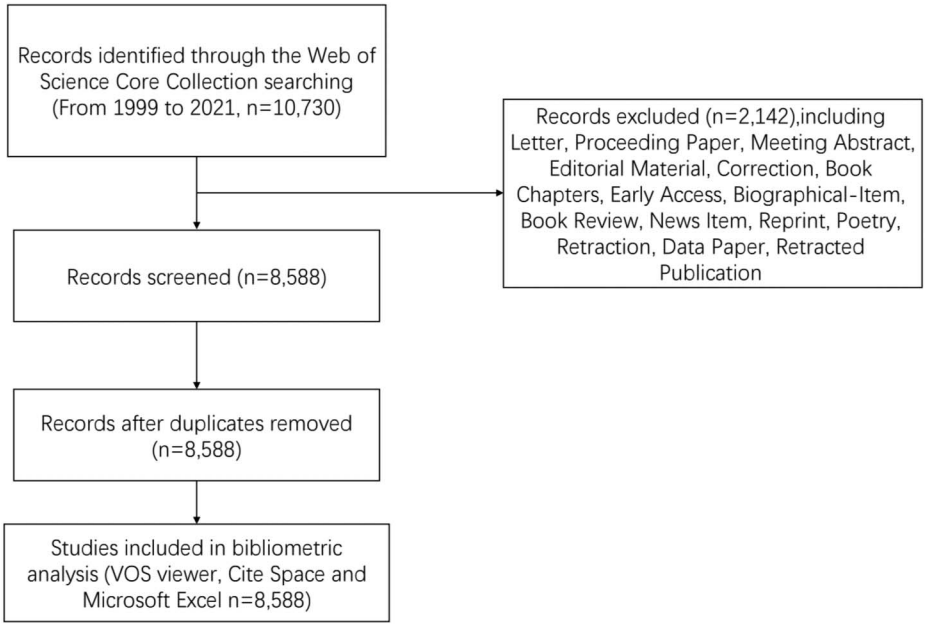

Figure 1. The process of study selection in this study.

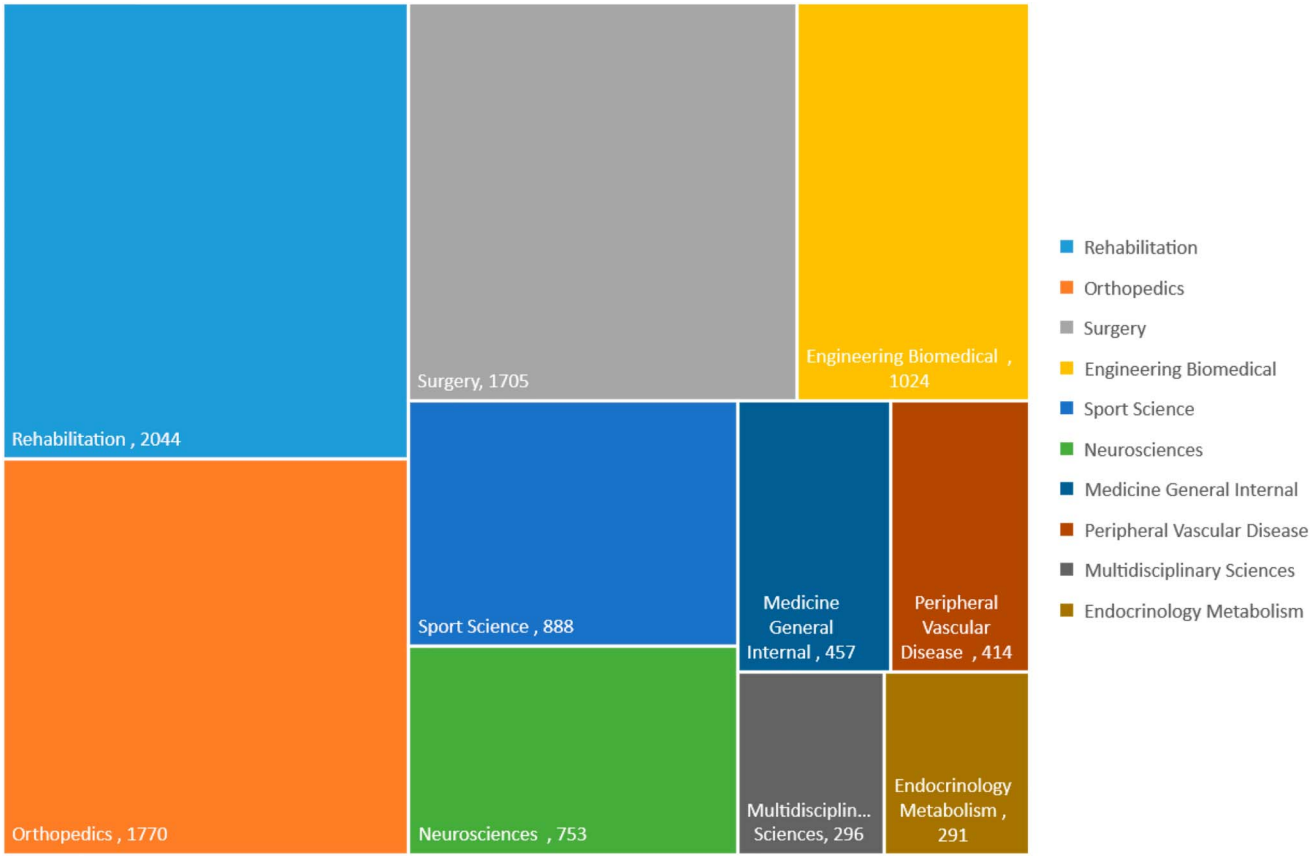

Figure 2. The research area analysis of global publications in amputations from 1999 to 2021.

Quality analysis of global publications

Country

In terms of the number of publications about amputation by country (Table 1), the United States is the country that publishes the most relevant articles (3,329 articles, 38.76%), followed by England (873 articles, 10.17%), China (484 articles, 5.64%), Germany (477, 5.55%), and Canada (461, 5.37%). As shown in Figure 4, the total number of articles on amputation has grown over time in every country, with the United States owning the fastest rate of growth. In addition, the United States ranks first in terms of total citations and H-index, whereas Germany, Italy, and Canada are the top 3 in terms of average citations.

Institution

The United States has occupied 9 of the top 10 most contributing institutions over the world (US Department of Veterans Affairs, Veterans Health Administration, University of Washington, University of Washington Seattle, Northwestern University,

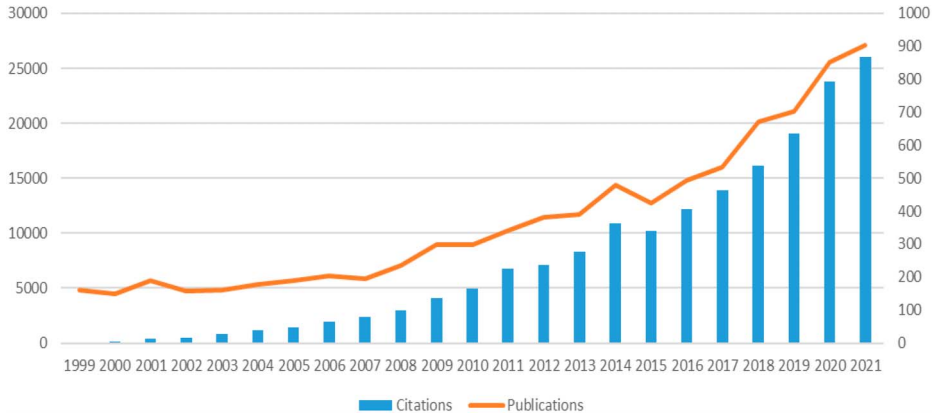

Figure 3. The trends in publications and citations of amputation research.

Table 1. The top 10 countries by publications.

Rank	Country	Publications	% of 8,588	Total citations	Average citations	H-index
1	United States	3,329	38.76	92,159	27.68	122
2	England	873	10.17	23,654	27.1	73
3	China	484	5.64	8058	16.65	46
4	Germany	477	5.55	20,171	42.29	70
5	Canada	461	5.37	15,055	32.66	58
6	Italy	437	5.09	14,651	33.53	65
7	The Netherlands	423	4.93	12,644	29.89	56
8	Australia	331	3.85	7445	22.49	46
9	Japan	292	3.40	3963	13.57	29
10	Turkey	256	2.98	2519	9.84	27

United States Department of Defense, University of Texas System, University of California System, and Walter Reed National Military Medical Center) (Table 2). The institution with the largest contribution to amputation research is the US Department of Veterans Affairs (an H-index of 56) with 348 publications and 11,591 citations. However, the institution with highest average citation is the Northwestern University.

Author

As shown in Table 3, among the top 10 contributors to amputation, 6 are from the United States, 2 are from the Netherlands, and Malaysia and England have one author each. Geertzen JHB has the most publications. Kuiken T has the highest total citations, average citations, and the highest H-index.

Journal

Table 4 shows the top 10 journals that publish the most amputation-related articles. The impact factor (IF) and journal quartile were taken from Journal Citation Reports 2021. The top 3 most-published journals are *Prosthetics and Orthotics International*, *Archives of Physical Medicine and Rehabilitation*, and *Journal of Rehabilitation Research and Development*. *Archives of Physical Medicine and Rehabilitation* (IF = 4.06) is the journal that keeps the highest total citation, average citations, and H-index. The dual-map overlay of journals on amputation is shown in Figure 5. The cited journals are on the right, the citing journals are on the left, and the colored path represents the citation relationship. It can be seen from the figure that 7 paths are available between the citing journals and the cited journals.

Academic collaboration

Academic cooperation and exchanges between various countries/regions, institutions, and authors are of great importance to advancing the in-depth academic research. In Figure 6(a), each node stands for a different country. Node colors represent different clusters (research topics). The node connection line represents the collaborative relationship. The thicker the connection line, the closer the cooperation between the two. The size of the node stands for the number of published literature studies that result from their collaboration. This graph lists the collaboration between the 56 most-connected countries. It is clear that the United States, the country with the most publications, dominates the amputation field. In Figure 6(b), institutions with a frequency of 10 or more are included. University of Washington pays more attention to collaborative relationships than US Department of Veterans

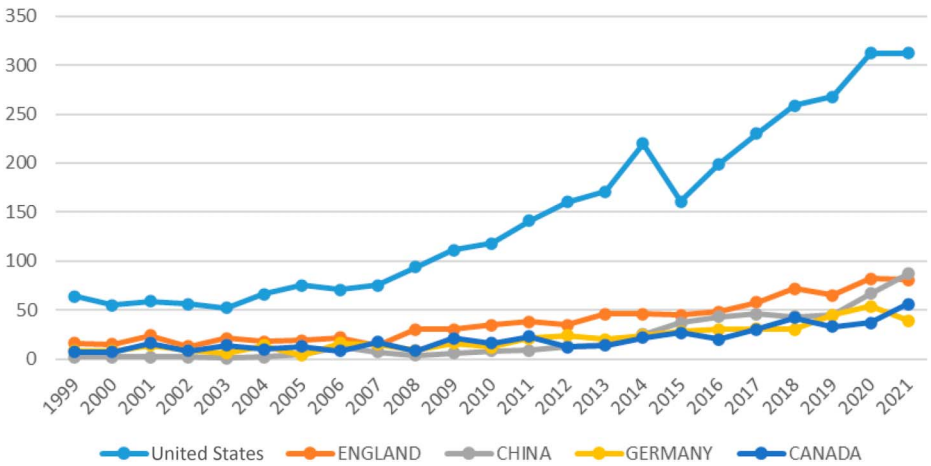

Figure 4. The amputation-related publications of top 5 countries over time.

Table 2. The top 10 institutions distributed by publications.

Rank	Institution	Publications	Total citations	Average citations	H-index	Original country
1	US Department of Veterans Affairs	348	11,591	33.31	56	United States
2	Veterans Health Administration	317	11,182	35.27	56	United States
3	University of Washington	299	10,523	35.19	54	United States
4	University of Washington Seattle	298	10,518	35.3	54	United States
5	Northwestern University	215	10,443	48.57	59	United States
6	United States Department of Defense	188	4590	24.41	39	United States
7	University of Groningen	187	5459	29.19	43	The Netherlands
8	University of Texas System	166	5863	35.32	43	United States
9	University of California System	155	3360	21.68	33	United States
10	Walter Reed National Military Medical Center	153	3529	23.07	31	United States

Affairs (which has the largest number of publications). Using VOSviewer software, 256 authors whose publication more than or equal to 10 are selected. Some of the 256 authors are not associated with others. The largest set of connected countries include 202 items (Figure 6(c)). Authors with more academic collaborations are highly fit with the results of the top 10 authors.

Co-citation analysis

Co-cited authors

Co-citation analysis stands for a method of expressing the correlation between items based on the number of simultaneous citations. Co-citation analysis shows a total of 81,725 authors in the amputation field. Flor H (886 citations) has the most citations, followed by Miller WC (709 citations) and Dillingham TR (708 citations). Our data found that 861 authors have 40 citations or more. After clustering these researchers, 7 major clusters were formed (Figure 7(A)).

Co-cited journals

The relationship among the 756 identified journals (one journal with a minimum citation count of 40 or more) is shown in Figure 7(b). The top 3 journals by citations are as follows: *Archives of Physical Medicine and Rehabilitation* (11,231 citations), *Prosthetics and Orthotics International* (9,988 citations), and *Journal of Rehabilitation Research and Development* (6,357 citations).

Co-cited references

The clustering of co-cited references reflects the direction of the research field to a certain extent. A total of 513 references with a minimum number of 40 citations are shown in Figure 7(c). The top 3 co-cited references refer to Ziegler-Graham et al[27] (631 citations), Waters et al[28] (333 citations), and Dillingham et al[30] (254 citations). These articles focus on the epidemiology, surgical treatment, and prognosis of amputation, illustrating the centrality of these aspects to amputation research. As shown in Figure 8, top 25 references with the strongest citation bursts of amputation are listed, which means those references have been cited frequently over a period. "Estimating the prevalence of limb loss in the United States: 2005 to 2050" by Ziegler-Graham et al has the strongest burstiness.[27] Apart from this reference, there are still 3 references in burstiness in 2021. Cordella et al conducted a literature review of the needs analysis of users of upper-limb prosthetics with the goal

Table 3. The top 10 authors distributed by publications.

Rank	Author	Publications	Total citations	Average citations	Country	Institution	H-index
1	Geertzen JHB	95	2509	26.41	The Netherlands	University of Groningen	27
2	Czerniecki J	70	3067	43.81	United States	US Department of Veterans Affairs	31
3	Dijkstra PU	68	1977	29.07	Netherlands	University of Groningen	24
4	Kuiken T	60	4998	83.3	United States	North Carolina State University	37
5	Abu Osman NA	57	830	14.56	Malaysia	University of Malaya	18
6	Sanders JE	53	985	18.58	United States	University of Washington	18
7	Hargrove LJ	47	2905	61.81	United States	Shirley Ryan Ability Lab	30
8	Hafner BJE	47	1268	26.98	United States	University of Washington	19
9	Wilken JM	44	1100	25	United States	Brooke Army Medical Center	20
10	Farina D	41	3168	77.27	England	Imperial College London	29

Table 4. The top 10 journals distributed by publications.

Rank	Journal	Publications	Total citation	Average citations	H-index	IFs	JIF quartile
1	*Prosthetics and Orthotics International*	557	10,898	19.57	44	1.672	Q3
2	*Archives of Physical Medicine and Rehabilitation*	233	11,072	47.52	59	4.06	Q1
3	*Journal of Rehabilitation Research and Development*	196	8250	42.09	45	1.277	Q3
4	*IEEE Transactions on Neural Systems and Rehabilitation Engineering*	180	8483	47.13	51	4.528	Q1
5	*Disability and Rehabilitation*	174	3980	22.87	34	2.439	Q2
6	*Gait & Posture*	153	6366	41.61	40	2.746	Q2
7	*PLoS One*	132	2631	19.93	27	3.752	Q2
8	*Journal of Vascular Surgery*	113	4945	43.76	39	4.86	Q1
9	*Journal of Neuro-Engineering and Rehabilitation*	102	3377	33.11	34	5.208	Q1
10	*Clinical Biomechanics*	99	2453	24.78	31	2.034	Q3

Abbreviation: IF, impact factor; JIF, journal impact factor.

of providing design input in the field of prosthetics, increasing user satisfaction and reducing equipment abandonment.[33] Armstrong et al[31] and Narres et al[34] reviewed the incidence of lower-extremity amputations in the diabetic compared with the nondiabetic population.

Analysis of highly cited articles

The top 10 most-cited articles are shown in Table 5. Five of the top 10 cited articles are related to the upper limbs, and another 4 ones are about the lower limbs (one paper is a review on fundamental research). In addition, 5 of 10 were related to prostheses, suggesting that researchers are now paying more attention to the life quality of amputees. "Cortical control of a prosthetic arm for self-feeding" by Velliste et al (1059 citations)[36] has described a system that allows for materialized prosthetic control. This multi-degree-of-freedom demonstration of prosthetic control paves the way for the development of dexterous prosthetic devices that can eventually function the arm and hand at a near-natural level. The second one is "Targeted muscle reinnervation for real-time myoelectric control of multifunction artificial arms" by Kuiken et al (663 citations).[37] They conducted a controlled experiment and concluded that the reinnervated muscle could produce enough electromyographic information for real-time control of an advanced artificial arm. The third one is "The energy expenditure of normal and pathologic gait" by Waters and Mulroy (662

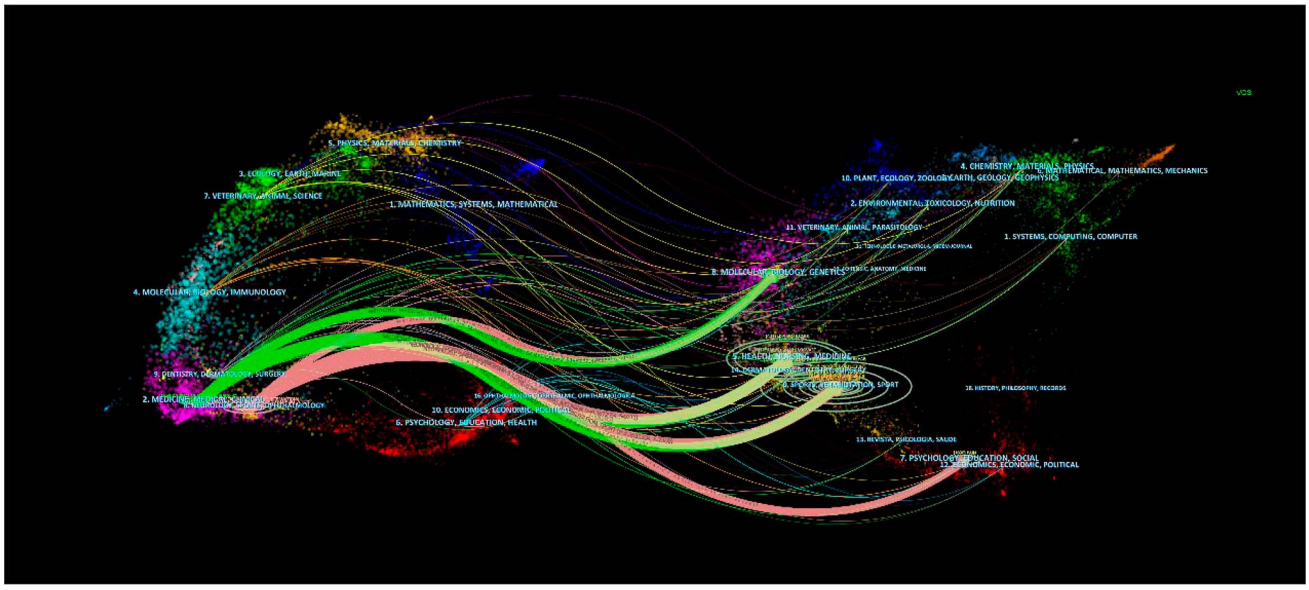

Figure 5. The dual-map overlay of journals on amputation research. The citing journals are on the left, whereas the cited journals are on the right. The colored path represents the citation relationship. In the field of amputation, both the neurology/sports/ophthalmology journals (pink lines) and medicine/medical/clinical journals (green lines) are significantly influenced by molecular/biology/genetics journals and health/nursing/medicine and sports/rehabilitation/sport journals. The ellipse indicates the numeric ratio of the authors to publications: the horizontal length represents the number of authors, whereas the vertical length represents the number of publications.

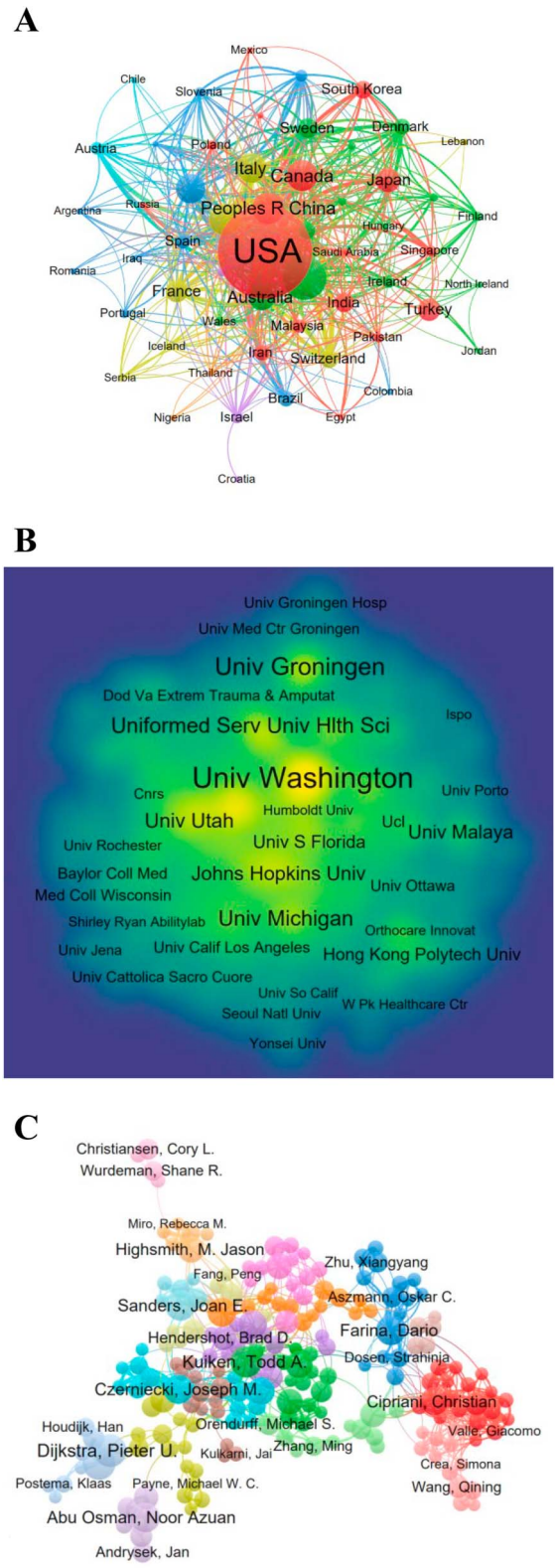

Figure 6. (a) Academic collaboration between different countries/regions. Each node stands for a different country. Node colors represent different clusters (research topics). The node connection line represents the collaborative relationship. The thicker the connection line, the closer the cooperation between the two. The size of the node stands for the number of published literature studies that result from their collaboration. (b) Collaboration between different institutions. (c) Collaboration between different authors.

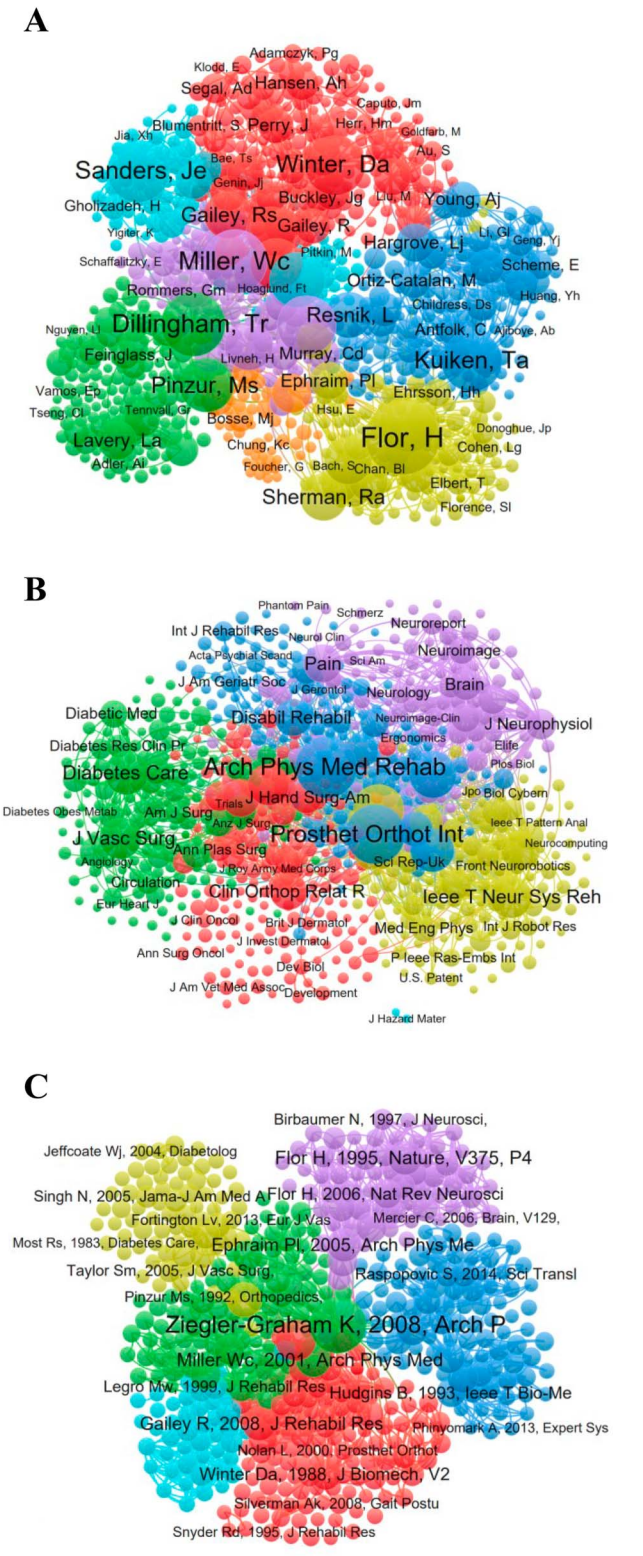

Figure 7. (a) The VOSviewer visualization map of co-cited authors devoted to amputation research. Our data found that 861 authors have 40 citations or more. After clustering these researchers, 7 major clusters were formed. Different colored nodes represent different clusters. (b) The VOSviewer visualization map of co-cited journals devoted to amputation research. (c) The VOSviewer visualization map of co-cited references devoted to amputation research.

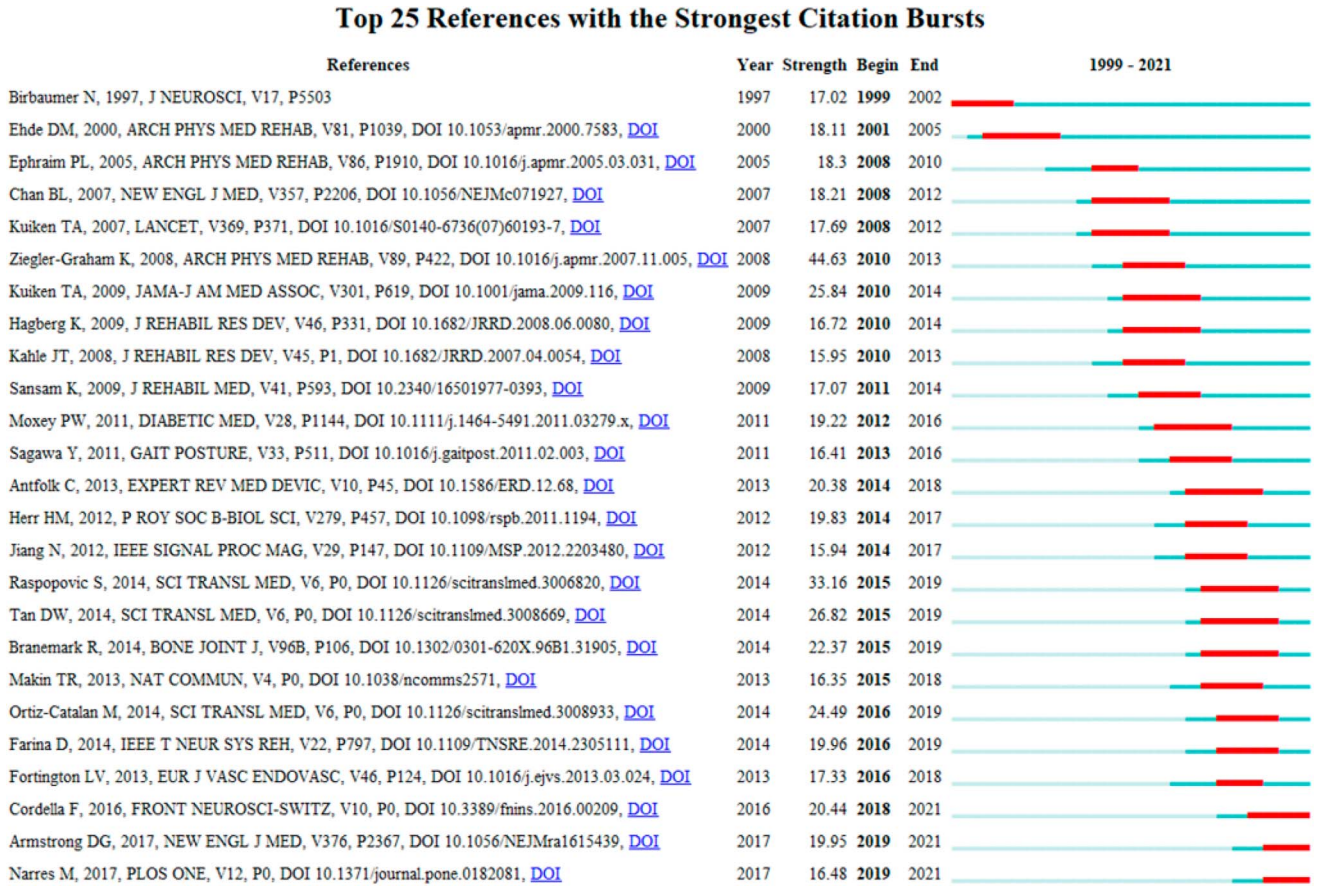

Figure 8. The top 25 references with the strongest citation bursts involved in amputation research (sorted by the starting year). The years between "Begin" and "End" represent the period when the reference was more influential. Years in light green mean that the reference has not yet appeared, years in dark green mean that the reference is less influential, and years in red mean that the reference is more influential.

citations).[38] This review outlined the basic principles of exercise physiology as it relates to human movement, detailed the energy expenditure of normal walking, and summarized the results of energy expenditure studies in patients with specific neurological and orthopedic disabilities.

Analysis of keywords

Keywords stand for the essence and core of a paper, which reflect the research hotspots in the field. The top 10 keywords ranked in this study and their frequencies are amputation (2,279), amputees (1,146), rehabilitation (1,064), gait (740), walking (720), prothesis (611), amputee (502), management (449), outcomes (448), and lower-limb amputation (441). By clustering the keywords with frequency more than or equal to 10, a total of 1,152 qualified keywords were obtained. The map of co-occurring keywords over time is shown in Figure 9. In this figure, upper-limb prosthesis and peripheral artery disease are emerging fields that were colored yellow. In addition, a burst keyword means the word that occur frequently within a specific time period. It shows the evolution of research hotspots over time, which indicates the research trends recently and foreshadow future trends (Figure 10). The burst keyword with highest strength is reconstruction in this study. However, transfemoral amputation, meta-analysis, and upper extremity-related studies have received increasing attention in recent years. Among the literature studies involved in this study, a total of 53 meta-analysis articles (level 1 evidence) were summarized. Timeline of keywords on amputation (Figure 11) shows the top 3 high-frequency keywords in each cluster over time. It forms 7 clusters: #0 (rehabilitation), #1 (diabetic foot), #2 (limb salvage), #3 (amputation), #4 (phantom pain), #5 (artificial limbs), #6 (peripheral artery disease), and #7 (systematic review). Specifically, the fifth cluster is artificial limbs. As time goes on, we can find the keywords "prosthetics" and "prosthetic design" in the vicinity of 2007 and 2012.

Discussion

In this study, various bibliometric methods were used to generalize published research literature studies on amputation on the WoSCC database. As a punitive measure, amputation existed as early as the Babylonian King Hammurabi's Code (before about 1750), which recorded the punitive amputation of slaves who used force against free citizens.[39] The earliest article was published in 1999 restricted to the date range. A roughly upward trend is seen in publications and citations of amputation-related research through 2021, illustrating the steady growth of amputation research and the continued interest among researchers in the field. According to the Thorud et al' study, the 5-year mortality rate ranges from 53% to 100% among patients with amputation (minor or major).[32] Although amputation-related research shows an upward trend, it still does not match its high mortality. Therefore, it can be

Table 5. The top 10 cited articles.

Rank	Author	Title	Total citations	Journal
1	Velliste M	Cortical Control of a Prosthetic Arm for Self-feeding	1059	Nature
2	Kuiken TA	Targeted Muscle Reinnervation for Real-time Myoelectric Control of Multifunction Artificial Arms	663	The Journal of the American Medical Association
3	Waters RL	The Energy Expenditure of Normal and Pathologic Gait	662	Gait & Posture
4	Sadeghi H	Symmetry and Limb Dominance in Able-bodied Gait: A Review	647	Gait & Posture
5	Biddiss EA	Upper Limb Prosthesis Use and Abandonment: A Survey of the Last 25 Years	605	Prosthetics and Orthotics International
6	Armstrong DG	Negative Pressure Wound Therapy after Partial Diabetic Foot Amputation: A Multicentre, Randomised Controlled Trial	594	Lancet
7	Raspopovic S	Restoring Natural Sensory Feedback in Real-Time Bidirectional Hand Prostheses	580	Science Translational Medicine
8	Flor H	Phantom Limb Pain: A Case of Maladaptive CNS Plasticity?	572	Nature Reviews Neuroscience
9	Bosse MJ	An Analysis of Outcomes of Reconstruction or Amputation of Leg-threatening Injuries	550	The New England Journal of Medicine
10	Scheme E	Electromyogram Pattern Recognition for Control of Powered Upper-limb Prostheses: State of the Art and Challenges for Clinical Use	546	Journal of Rehabilitation Research and Development

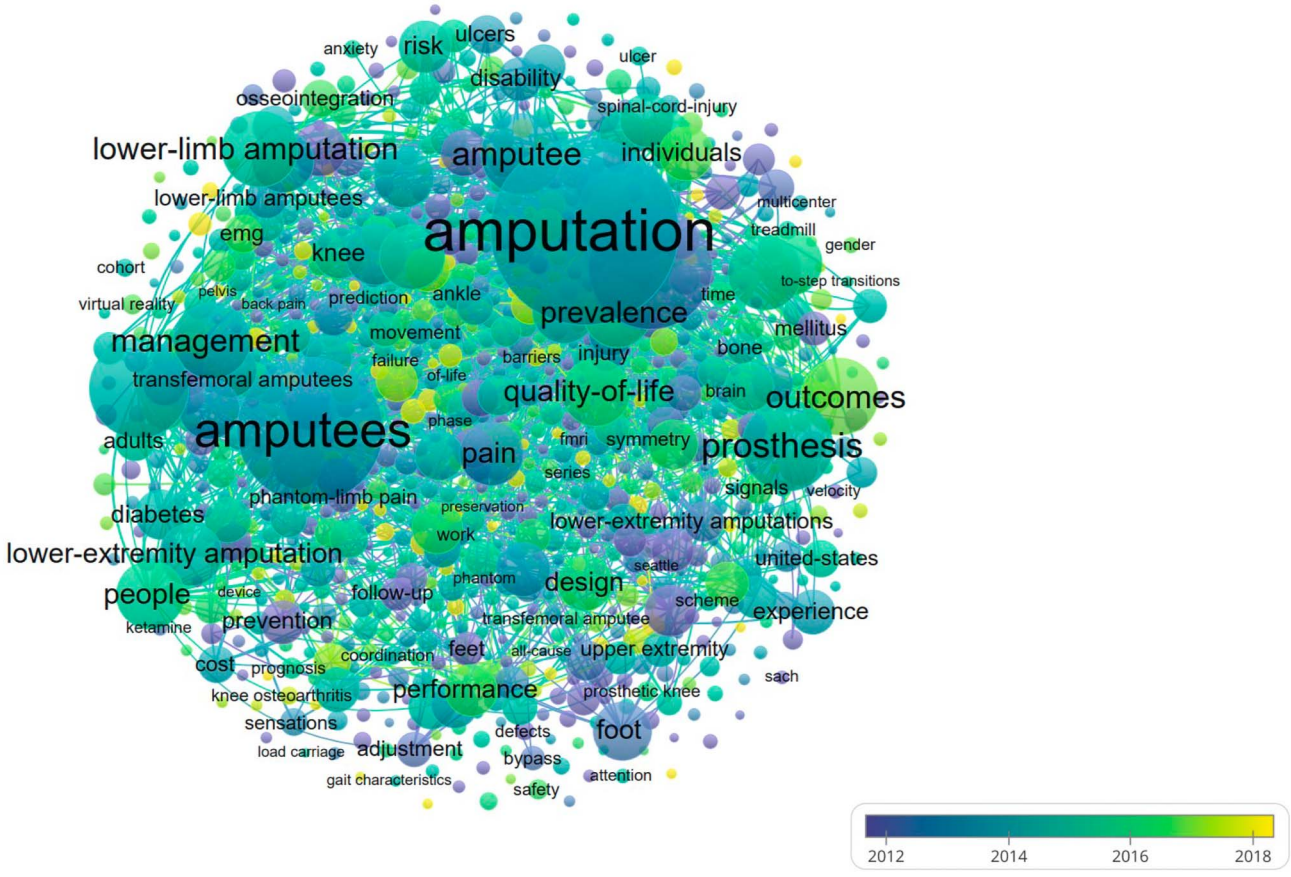

Figure 9. The VOSviewer visualization map of co-occurring keywords for amputation research over time. The size of the nodes indicates occurrence frequency. The different colors indicate the relevant year of publication. Yellow keywords came later than blue keywords.

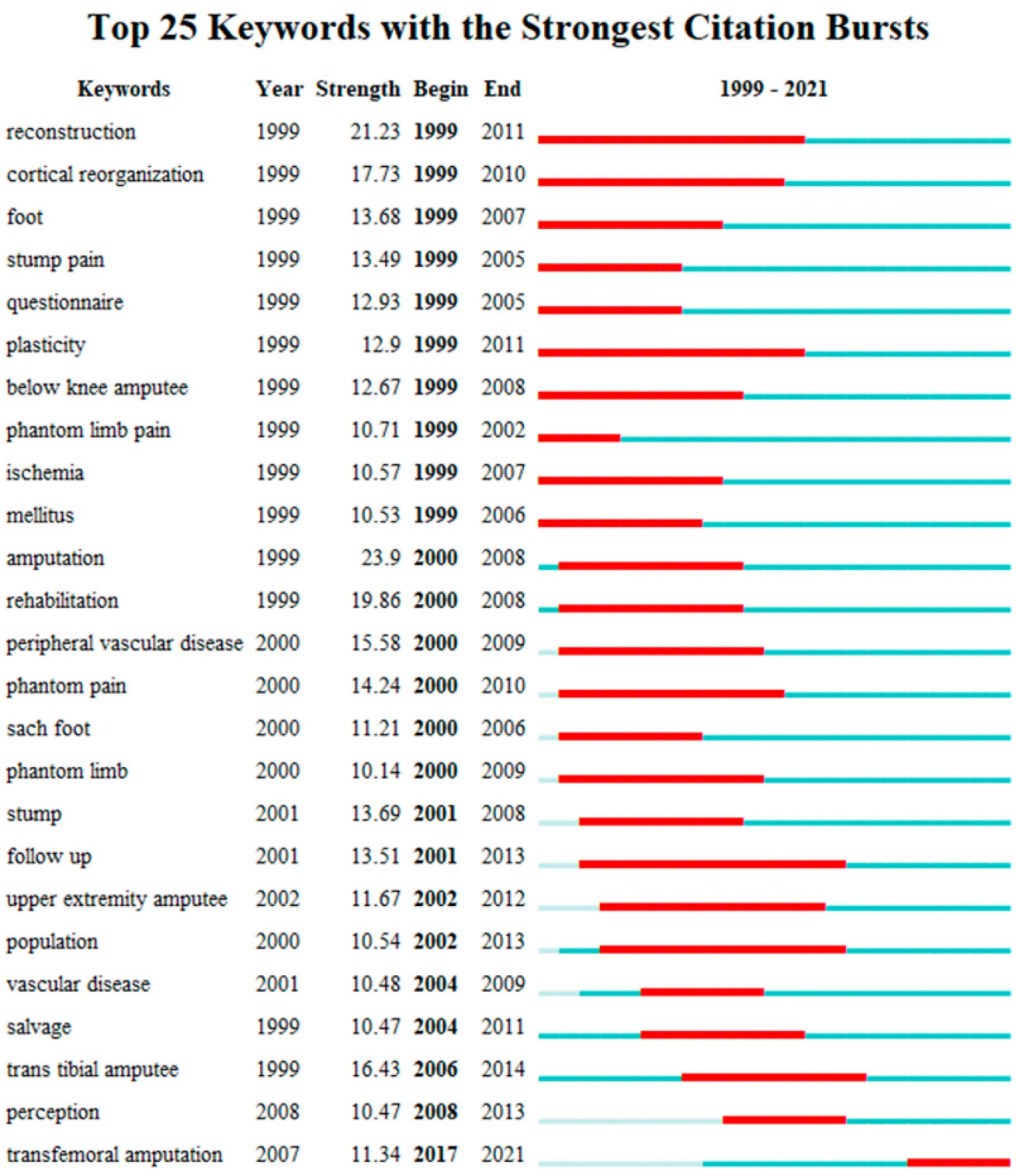

Figure 10. Top 25 keywords with the strongest citation bursts of amputation articles from 1999 to 2021. The years between "Begin" and "End" represent the period when the keyword was more influential. Years in light green mean that the keyword has not yet appeared, years in dark green mean that the keyword is less influential, and red years indicate that the keyword is more influential.

predicted that amputation-related researches will continue to increase globally. More researchers will participate in amputation research in the near future, just following the United States.

The H-index, which was proposed by Hirsch in 2005,[40] stood for the academic influence of countries, institutions, journals, or authors in a certain field. H-index is proportional to academic influence in the fields. The United States has the highest H-index, which is almost the sum of second country (England) and third country (China). It reveals the insurmountable academic influence of the United States in the field of amputation. Four of the top 10 countries are developed countries in Europe, which suggests that geography has a certain influence on scientific research either. Nine

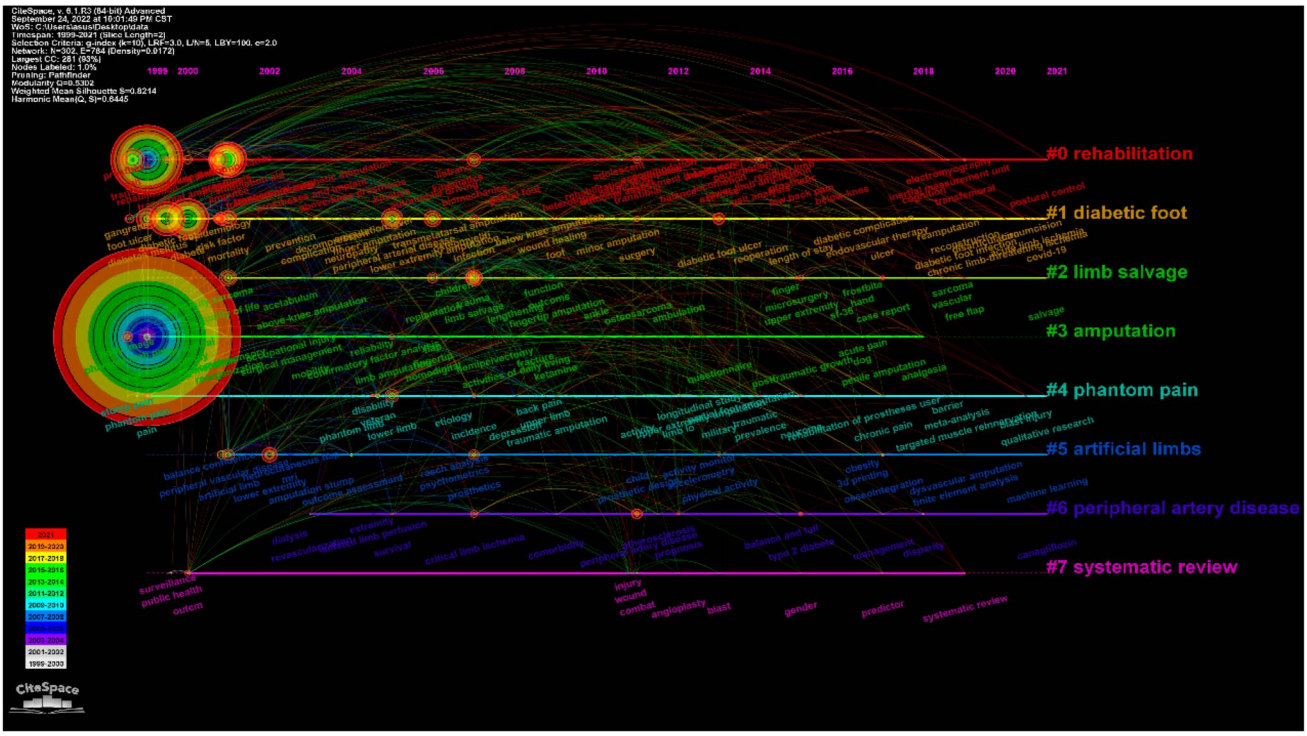

Figure 11. The timeline of keywords on amputation research from 1999 to 2021. Timeline of keywords on amputation shows the top 3 high-frequency keywords in each cluster over time. There are 7 clusters: #0 (rehabilitation), #1 (diabetic foot), #2 (limb salvage), #3 (amputation), #4 (phantom pain), #5 (artificial limbs), #6 (peripheral artery disease), and #7 (systematic review).

of the top 10 institutions are from the United States (e.g., US Department of Veterans Affairs and Veterans Health Administration). Interestingly, 4 of them are related to military and national defense, indicating that a large number of veterans in the United States provide plenty of samples for research. It may be an important reason for considerable research on amputation in the United States. In addition, the Netherlands (a relatively small country) has the third largest number of publications, probably because the research was served as an important part of health education and training. Nevertheless, the most published authors are not from the United States. Geertzen JHB and Dijkstra PU are from the University of Groningen in Netherlands. Almost all the top 10 authors are from the top 10 institutions, which reveals the complementary role between distinguished scholars and first-class research platforms. Among the top 10 journals, *Prosthetics and Orthotics International*, *Archives of Physical Medicine and Rehabilitation*, and *Journal of Rehabilitation Research and Development* rank top 3. The journals mainly involve clinical, nursing, sports, and other aspects, which is consistent with dual-map analysis. As an authoritative journal in the field of rehabilitation medicine, *Archives of Physical Medicine and Rehabilitation* (IF = 4.06) has the highest total citations, average citations, and H-index.

Academic cooperation, which is mutually beneficial for all parties, is widespread among various countries, institutions, and outstanding authors. It is obvious that the countries, institutions, and authors with more cooperation have more publication output and ranked higher. It proves that benign cooperation does effectively promote the development of academic research in amputation. In the figure of the co-citation analysis section, the research by K. Ziegler-Graham et al is evident in the map of co-cited references.[27] They concluded that one in 190 Americans lived with the loss of a limb in 2008. If left unchecked, the number could double by 2050. This prevalence study of amputations reminds us of the importance of controlling underlying conditions associated with amputation. The analysis of the highly cited articles showed that the top 10 highly cited articles were mainly distributed in etiology,[41] epidemiology,[29,42] and treatment research.[35,43]

The year distribution of keywords and burst keywords reveals the research trends of amputation clearly. In the past 5 years, the research focuses on transfemoral amputation, meta-analysis, and upper extremity. Among them, transfemoral amputation is a rescue procedure for chronically infected TKA. Shirley et al[44] concluded that patients who received transfemoral amputation (TFA) due to TKA failure were more likely to be prosthetic candidates. From the timeline of amputation keywords, reconstruction and diabetes and phantom limb pain is the subject of continuous research from 1999 to 2021, and only 52.9% were satisfied with the quality of life.[45] Therefore, the mental health of amputees also needs to be improved through certain living assistance and clinical treatment.

Excitingly, the therapy of transverse tibial bone transport can enhance distraction osteogenesis and vascularization to treat severe diseases, such as thromboangiitis obliterans, diabetic foot, achieve the effect of limb salvage, and improve the pain and numbness symptoms of patients.[46,47] However, there is a certain recurrence rate after surgery, and patients still need to actively control the primary disease (e.g., glucose control). Besides, attention should be paid to psychosocial factors of amputees in the future, and a collaborative approach between surgeons, rehabilitation doctors, prosthetists, therapists, and families is key to ensuring optimal therapeutic outcomes.[48]

Strengths and limitations

To the best of our current knowledge, few studies have extensively investigated the research status and trends in amputation. Our study is the first bibliometric and visual analysis of amputation. We used VOSviewer, CiteSpace, and other software programs to visualize countries, journals, authors, institutions, and other information. Our study provides useful information for scientists in this field to better understand the changing process of amputation research, and also provides new research ideas and perspectives for exploring the frontiers of amputation research.

However, the limitations should also be acknowledged. We restricted our search to articles published in English language, and the potential missing articles may affect our study data. Nevertheless, English articles in WoSCC are the most commonly used data source in bibliometric research and represent the majority of information. Influenced by the database, this study only included articles from 1999 to 2021. Furthermore, because of the limited capabilities of the analysis software, only the WoSCC database was considered in our study, which may lead to incomplete data analysis.

Conclusion

We present the global status and trends of amputation-related publications from 1999 to 2021. Amputation publications have roughly increased over time over the past 22 years. The United States ranks first in terms of H-index, total number of publications, and total citations. Three US institutions, US Department of Veterans Affairs, Veterans Health Administration, and University of Washington, are the major contributors to amputation. *Prosthetics and Orthotics International*, *Archives of Physical Medicine and Rehabilitation*, and *Journal of Rehabilitation Research and Development* are the main publication channels for articles related to amputation. Geertzen JHB, Czerniecki J, and Dijkstra PU were major contributors to amputation. In addition, research on limb salvage treatment and surgical methods for amputation will become a hotspot in the future. Our study is beneficial for scientists to specify the research hotspot and development direction of amputation.

Equal contribution

Z.L. and M.W. have contributed equally to this article and share the first authorship. Y.Z. and J.L. have contributed equally to this article and share the corresponding authorship.

Author contributions

The authors disclosed the following roles as contributors to this article: Y.Z. was responsible for deciding and conceptualizing this article, and revising the draft. Z.L. and Y.Z. were responsible for writing the manuscript. M.W., Q.L., and B.H. were responsible for collecting and analyzing the data. Y.T., M.L., S.P., and H.G. were responsible for preparing the figures and tables. Y.Z. and J.L. was the guarantor of the overall content. All authors approved the final version of the manuscript and agreed to be accountable for all specs of the work.

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The authors disclosed no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Supplemental material

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