Systematic Review and Meta-Analysis

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Bibliometric analysis of global research on vitamins and cancer between 2003 and 2022

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Abstract

Background: Vitamins are essential nutrients that play an indispensable role in maintaining the vital functions of the human body. A growing number of studies have shown a link between vitamins and cancer. However, there is no systematic review and bibliometric analysis in this field. This study aims to summarize the hotspots and emerging research topics in this field of vitamins and cancer research.

Methods: Articles on the topic of vitamins and cancer published between 2003 and 2022 were retrieved from the Web of Science core collection database (WOSCC) on May 1, 2023. Subsequently, we conducted VOSviewer and CiteSpace to examine the annual output distribution, countries/regions, institutions, journals, authors, co-cited references, and keywords.

Results: A total of 3166 publications were extracted using a timespan of 2003 to 2022. The number of publications has grown rapidly over the past 20 years. Most publications were from the United States; Harvard University was the most active institutions; Giovannucci stood out among authors with the highest number of publications, citations and H-index; *Cancer Epidem Biomar* published the most papers in this field; the highest cited reference was published in Nat Rev Cancer, authored by Feldman in 2014. Breast cancer was the most common type of cancer, while vitamin D was a research hotspot in this field. Oxidative stress may be the primary anticancer mechanism of vitamins, while also involving epithelial-mesenchymal transition, apoptosis, polymorphism, and calcium metabolism. "nanoparticle" may be the new focus of attention in the next few years.

Conclusion: This study presented an overview of the major research directions of vitamins and cancer by bibliometric methods over the past 2 decades. The results could reveal the research trends and the hotspots in the field and provide helpful information for clinical treatments of cancer.

Abbreviations: AJCN = *Am J Clin Nutr*, emt = epithelial-mesenchymal transition, IARC = International Agency for Research on Cancer, IF = impact factor, JCR = Journal Citation Reports, TLS = total link strength, WOSCC = web of science core collection database.

Keywords: bibliometric analysis, cancer, CiteSpace, vitamins, VOSviewer

1. Introduction

Cancer, a devastating disease that affects millions of people worldwide, is undeniably 1 of the most pressing health concerns of our time. It not only causes immense physical and emotional suffering to patients and their families but also poses a significant economic burden on societies across the globe. The latest edition of the World Cancer Report released by the International Agency for Research on Cancer systematically summarized that account for 19.3 million new cancer cases and almost 10.0 million cancer deaths occurred in 2020.[1] As a result, how to fight against cancer has become 1 of the foremost priorities in global medical research.

Currently, vitamins have been discovered to possess therapeutic and preventative effects against cancer.[2–4] Mechanism of vitamins are essential nutrients that not only participate in metabolic processes but also serve various functions such as antioxidation,[5] immune regulation,[6] and cell differentiation.[7] Thanks to its immense potential, vitamins have drawn attention in the cancer field. However, the clinical relationship between vitamins and cancer remains unclear. Several studies have shown that vitamin intake reduces the incidence of

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All data generated or analyzed during this study are included in this published article [and its supplementary information files].

This study did not require ethical approval because it was conducted based on the secondary literature analysis.

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cancer. Vitamins C and E, for example, are thought to have antioxidant effects that can help reduce the risk of cancer.[8,9] But other studies have cast doubt on the relationship between vitamins and cancer. Several studies have found that high doses of vitamin B12 supplements may increase the incidence of certain cancers.[10] In addition to vitamins C and E, other vitamins such as vitamins D and A have also been studied in relation to their potential impact on cancer prevention.[11,12] Some research suggests that adequate levels of vitamin D may be associated with a lower risk of certain types of cancers including colorectal,[13] breast,[14] and prostate cancers.[15] However, more evidence are still needed to establish a definitive link between vitamin D intake and reduced cancer risk. Similarly, there has been interest in studying the role of vitamin A in preventing or reducing the risk of various types of cancer.[16,17] Vitamin A plays a crucial role in maintaining immune function, although its impact on cancer prevention remains incompletely understood. Certain studies suggest that higher dietary intake or supplementation with beta-carotene (a precursor form of vitamin A) may be linked to reduced lung cancer risk among smokers.[18] However, conflicting results from other trials make it difficult to draw firm conclusions about this relationship.[19] Given the divergent relationship between vitamins and cancer, a comprehensive study that analyzes the available scientific literature and explores the potential association between vitamins and cancer is urgently needed to facilitate better cancer prevention and management in the clinic.

Bibliometric analysis is a method of quantitative analysis of scientific literature using statistical and metrological methods. It can help researchers understand research hotspots, discipline development trends, academic cooperation networks and other information in a certain field. To the best of our knowledge, no systematic review and bibliometric analysis has been performed, despite a steady increase in the number of publications on vitamins and cancer. Hence, in this study, we performed a bibliometric analysis to systematically evaluate the studies of vitamins and cancer from 2003 to 2022 by VOSviewer and CiteSpace, comprehensively reveal the relationship between vitamins and cancer in depth to assess the current status and hotspots in this domain, and provide reference for clinical and scientific research in the future.[20,21]

2. Material and methods

2.1. Data collection

Raw data were collected from the Web of Science Core Collection database (WOSCC) on May 1, 2023, with the following search strategy: Tittle = [(Vitamin) OR (Vitamins)] AND [(cancer) OR (carcinoma) OR (malignancy) OR (neoplasm) OR (neoplasia) OR (tumors)] AND Language = (English). The publications time of the literature ranged from 2003 to 2022. Only original articles and reviews included, and no geographical restrictions. After removing duplications, a total of 3166 records were retrieved in this study, including 2715 articles and 451 reviews.

2.2. Visualized analysis

Data were retrieved from the SCI-expanded database, including countries/regions, authors, journals, affiliations, the number of papers and citations, H-index, keywords, and references. Additionally, the latest impact factor (IF) was obtained from the Journal Citation Reports (JCR), which is widely recognized as 1 of the most important indices of medical journal quality and impact. The number of publications and the number of citations are 2 essential perspectives for measuring research performance, and the number of publications has long been treated as a reflection of productive capacity in scientific research, while the number of citations can demonstrate impact. The H-index is primarily used to assess the academic contributions of researchers and to predict future scientific achievements. In addition, it has been defined as the publishing output of a country or region and the production of an institution or journal. An online program (https://www.mapchart.net) was applied to generate the visualization map of the countries/regions. VOSviewer and CiteSpace software are widely used to visualize and analyze research trends in scientific literature. All downloaded publications were imported to VOSviewer to obtain the network visualization map (country/region, institution, author, journal). CiteSpace (6.1) software was employed to obtain the network visualization map (references and keywords).

3. Results

3.1. General data and annual output

From January 1, 2003, to December 31, 2022, a total of 3166 publications related to vitamins on cancer research were retrieved from the WOSCC, including 2715 articles (85.75%) and 451 reviews (14.25%), respectively. These publications were written by 15,686 authors of 3385 institutions, 90 countries/regions in 890 journals. As shown in Figure 1, the number of papers related to vitamins and cancer generally shows an upward trend with some fluctuations. Notably, the number of publications in this field peaked in 2021, with 223 publications, 2.7 times that of 2003 (n = 83). The number of annual citations had increased significantly from 2003 to 2021, reaching the highest point in 2021 (10,845 times), 278 times higher than that in 2003 (n = 39). And the number of publications and total citations decreased slightly in 2022.

3.2. Distribution of countries and institutions

A total of 90 countries contributed to publications in this field. Figure 2A displays the geographical distribution of publications by countries/regions. Figure 2B shows the 10 countries/regions' publications from 2003 to 2022. Table 1 lists the top 10 countries ranked by the number of publications in the field. Most publications were produced in the United States with 1248 papers (39.42% of 3166 papers), followed by China (n = 514, 16.23%) and Germany (n = 195, 6.16%). Regarding the H-index, the United States (109) also ranked first among the countries. Figure 2C shows the number of annual publications and the growth trend for the top 10 countries. Notably, the United States was the most prolific country in terms of annual publications until 2018, but after that, the number of publications in China increased significantly and surpassed the United States. VOSviewer software analyzed the information and constructed a visual map in Figure 3. The network shown in Figure 3A reflects the collaboration between countries. A total of 35 countries with more than 15 publications in the field were analyzed in the co-authorship analysis. The United States had the strongest total link strength (TLS = 832), indicating the United States had the most frequent collaboration with other countries. Among them, the United States and China possessed the closest international cooperation (link strength = 83) in this field.

A total of 3385 institutions made significant contributions to vitamins and cancer research. Figure 3B reflects the co-authorship between institutions. The top 10 productive institutions are shown in Table 2. The majority of them were from the United States. Harvard University with 113 papers ranked first, followed by National Cancer Institute (111) and Brigham & Womens Hospital (86). Among them, Harvard University had the highest H-index (65) and the highest number of citations (12,287). The 3 institutions with the highest total link strength

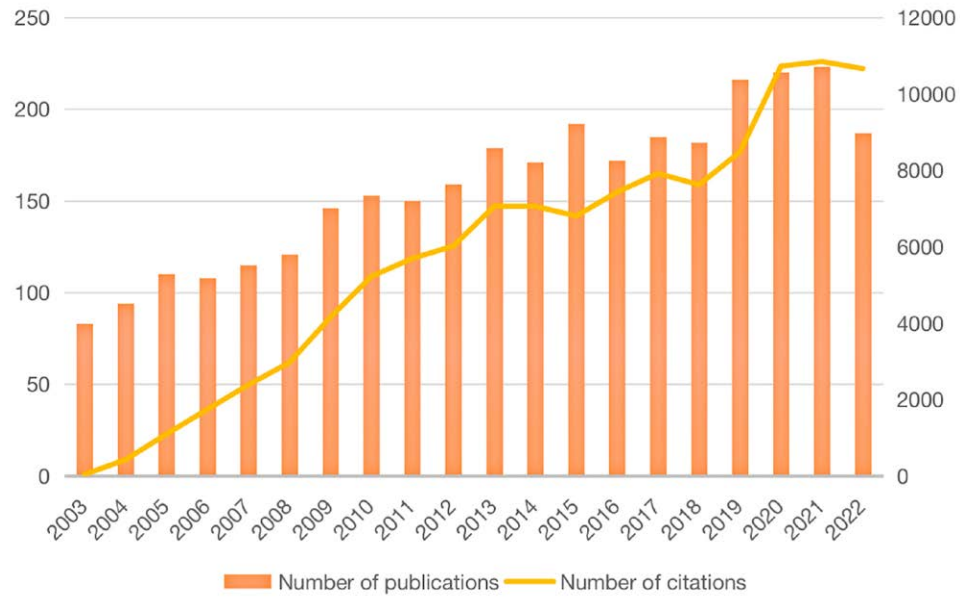

Figure 1. The annual volume and trend of publications on vitamins and cancer from 2003 to 2022.

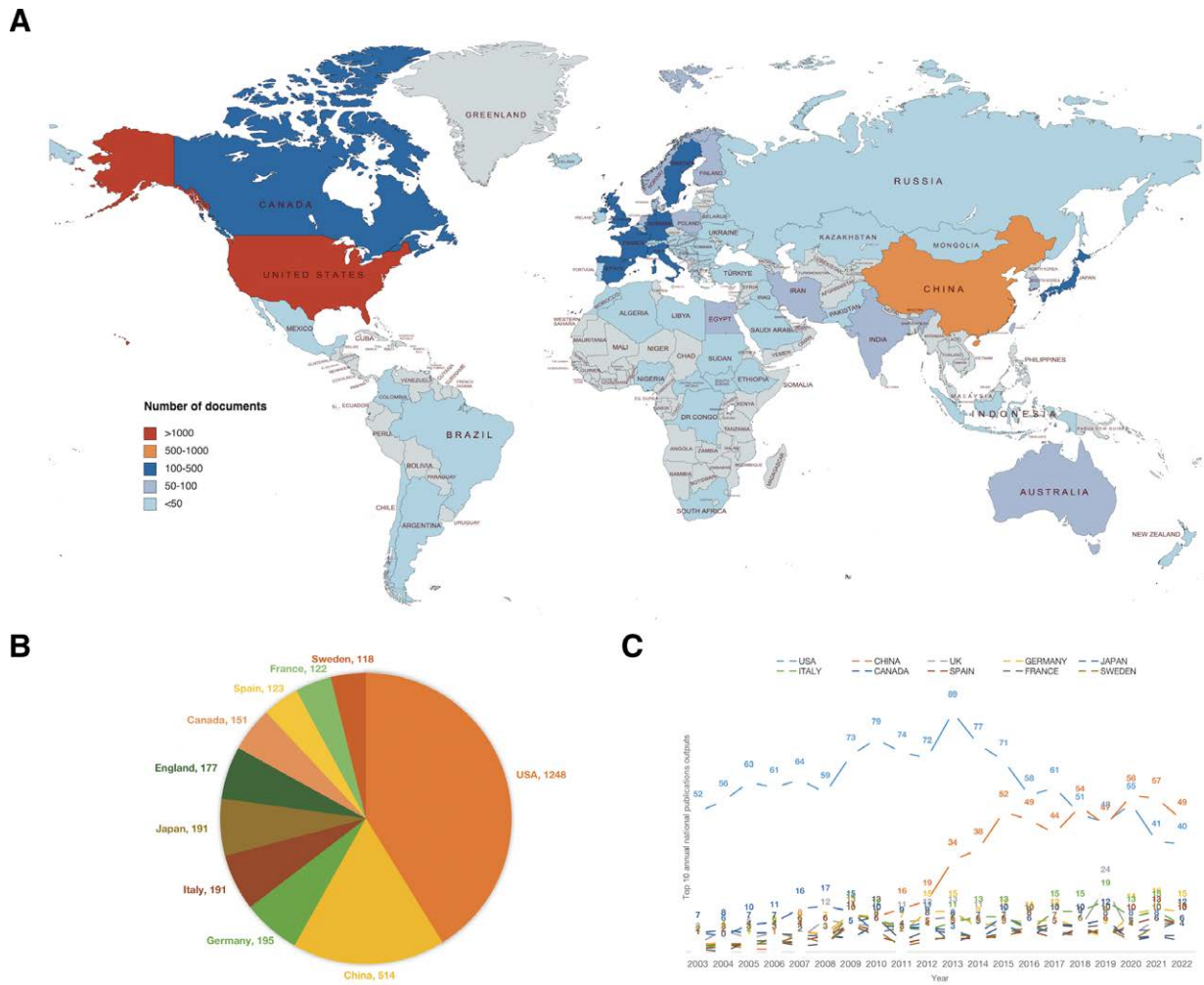

Figure 2. Visualization map of countries/regions in the field of vitamins on cancer research from 2003 to 2022. (A) Geographical distribution of the countries/regions in terms of publications. The world map of countries, exported the results from the website of https://www.mapchart.net. (B) Number of publications of the top 10 countries/regions. (C) Number of annual publications and growth trends of the top 10 countries/regions.

Table 1

The top 10 countries regarding the research on vitamins and cancer from 2003 to 2022.

Rank	Country/region	Counts	Percentage (%)	H-index	TLS
1	USA	1248	39.42	109	832
2	China	514	16.23	45	201
3	Germany	195	6.16	49	497
4	Italy	191	6.03	44	504
5	Japan	191	6.03	42	123
6	England	177	5.59	48	543
7	Canada	151	4.77	48	188
8	Spain	123	3.89	38	358
9	France	122	3.85	39	474
10	Sweden	118	3.73	39	477

were the Harvard University (total link strength = 168 times), Brigham & Womens Hospital (167), and National Cancer Institute (126), which were also the leading institutions of publications. Furthermore, the most common cooperation occurred between Harvard University and Brigham & Womens Hospital (link strength = 67).

3.3. Analysis of authors

A total of 15,686 authors contributed to the vitamins and cancer literature. Table 3 shows the 10 most prolific authors in this field. Eight of the top 10 authors were from the United States, 2 were from Spain. As shown in the data, Giovannucci published the largest number of papers (49 publications, 4880 citations, H-index = 43), followed by Albanes (32 publications, 1640 citations, H-index = 30), and White (28 publications, 1037 citations, H-index = 20). Interestingly, Giovannucci was the author with the highest number of publications, citations and H-index, indicating that he may be a core researcher in the field of vitamins and cancer research.

3.4. Analysis of journals

A total of 3166 articles were published in 890 journals. The top 10 most productive journals are shown in Table 4. These journals were mainly published in the United States (n = 5). Among them, *Cancer Epidem Biomar* had the greatest volume with 104 papers (IF 2022 = 3.8, USA), followed by *Nutr Cancer* with 91 papers (IF 2022 = 2.9, USA), *Anticancer Res* with 87 papers (IF 2022 = 2.0, Greece) ranked third. When ranked by the number of citations, the top 5 journals were *Am J Clin Nutr* (6026), *Cancer Epidem Biomar* (5341), *Int J Cancer* (3597), *J Steroid Biochem* (3314), *J Nat Cancer Inst* (3035). The top 3 journals in terms of H-index were *Cancer Epidem Biomar*, *Int J Cancer, J Steroid Biochem*. A total of 70% of the top 10 journals were in Q1 and Q2, with 50% in the United States and 20% in Switzerland.

Figure 4 is the journal's a dual-map overlay generated by using CiteSpace. On the left of the map are the citing journals, while on the right are the cited journals. Labels with different color clusters represent the discipline of the corresponding journal. Colored curves indicate the path of references, starting from the left citation graph and pointing to the right citation graph, and the thickness and density of the centerline indicate the intensity relationship between journals. As shown in Figure 4, the 2 orange citation paths showed that studies published in molecular/biology/immunology journals preferred to quote journals mostly in molecular/biology/genetics or health/nursing/medicine periodicals. In contrast, the green path showed that medicine/medical/clinical periodicals tend to cite journals primarily in the domains of molecular/biology/genetics or health/nursing/medicine periodicals, indicating that research of vitamins in cancer mechanism is gradually being transformed into medicine development and clinic practice.

3.5. Analysis of cited references

A total of 3166 articles in a period time from 2003 to 2022 were visualized and analyzed by CiteSpace. By analyzing the literature with high citation, the key knowledge base of the field could be obtained. Table 5 lists the top 10 cited references and the network of cited references is presented in Figure 5A. The most cited article was a review entitled "The role of vitamin D in reducing cancer risk and progression," published in *Nat Rev Cancer* by Feldman et al, in 2014, had the most citations (n = 159), suggesting that vitamin D significantly reduce cancer incidence and improve cancer prognosis and outcome.[22] Follow by "Global Cancer Statistics 2020: GLOBOCAN Estimates of Incidence and Mortality Worldwide for 36 Cancers in 185 Countries" with 118 citations, published in CA Cancer J Clin (with IF 254.7) by Sung et al, was an article on global cancer incidence and mortality in 2020.[1] Moreover, 6 of the top 10 co-cited references had Influence Factor above 50, indicating that these articles have greater influence and provide a theoretical foundation in this area.

We then clustered the citation-references to explore emerging trends and obtain key information from them. As shown in Figure 5B, there are 8 clusters in the knowledge map with a modularity value of 0.8106 and a silhouette value of 0.9236, indicating that the cluster structure is highly significant and the results are reliable. These clusters were divided into 3 main categories: mechanism-related (e.g., #1 oxidative stress), vitamin-related (e.g., #0 calcitriol [the metabolite of vitamin D], #2 vitamin C, #3 vitamin D, #5 vitamin E, #7 beta-carotene [a precursor of vitamin A]), and cancer-related (including #6 breast cancer and #4 skin cancer). Simultaneously, the timeline view of the cited references is generated by using Citespace to visualize the evolution of research hotspots from 2003 to 2022 (Fig. 5C). Our analysis revealed that the "vitamin D receptor" (cluster #0) was an early research hotspot and has remained a prominent area of study to this day. Additionally, "cluster #3 emt," "cluster #7 polymorphism," and "cluster #9 25-hydroxyvitamin D" were also early research fields; However, these themes have gradually been replaced by new ones over time. Clusters "#1 supplementation," "#2 breast cancer," and "#4 colon cancer" are highlighted in brighter colors, indicating that they have been cited more frequently in recent years. These results imply that historically, the utilization of vitamins in cancer research was primarily centered on investigating mechanisms and epidemiology, before gradually transitioning towards clinical implementation.

3.6. Analysis of keywords, burst, and evolution

Keywords reflect research hotspots and inform the direction or trends in a related academic area. Citespace was used to analyze keywords in the field of vitamins and cancer. In total, 8732 keywords were extracted, of which 195 occurred more than 30 times. The network visualization map is shown in Figure 6A. As shown in Table 6, "vitamin D" was the most crucial term with 771 occurrences, followed by "risk" (n = 672), "breast cancer" (n = 630), "vitamin D receptor" (n = 519), and "prostate cancer" (n = 435), and "colorectal cancer" (n = 381). Interestingly, among the top 20 keywords, 5 are closely associated with vitamin D. Furthermore, in the realm of vitamins and cancer research, breast cancer takes precedence. As depicted in Figure 6B, vitamin D and breast cancer occupy a central position in the density visualization. A further analysis of keywords summarizes the application of vitamin to various types of cancer over the last 2 decades was shown in Table 7, the common vitamin types were "vitamin D," with a frequency of 771, followed by "vitamin C" (163), "vitamin D3" (132), "vitamin E

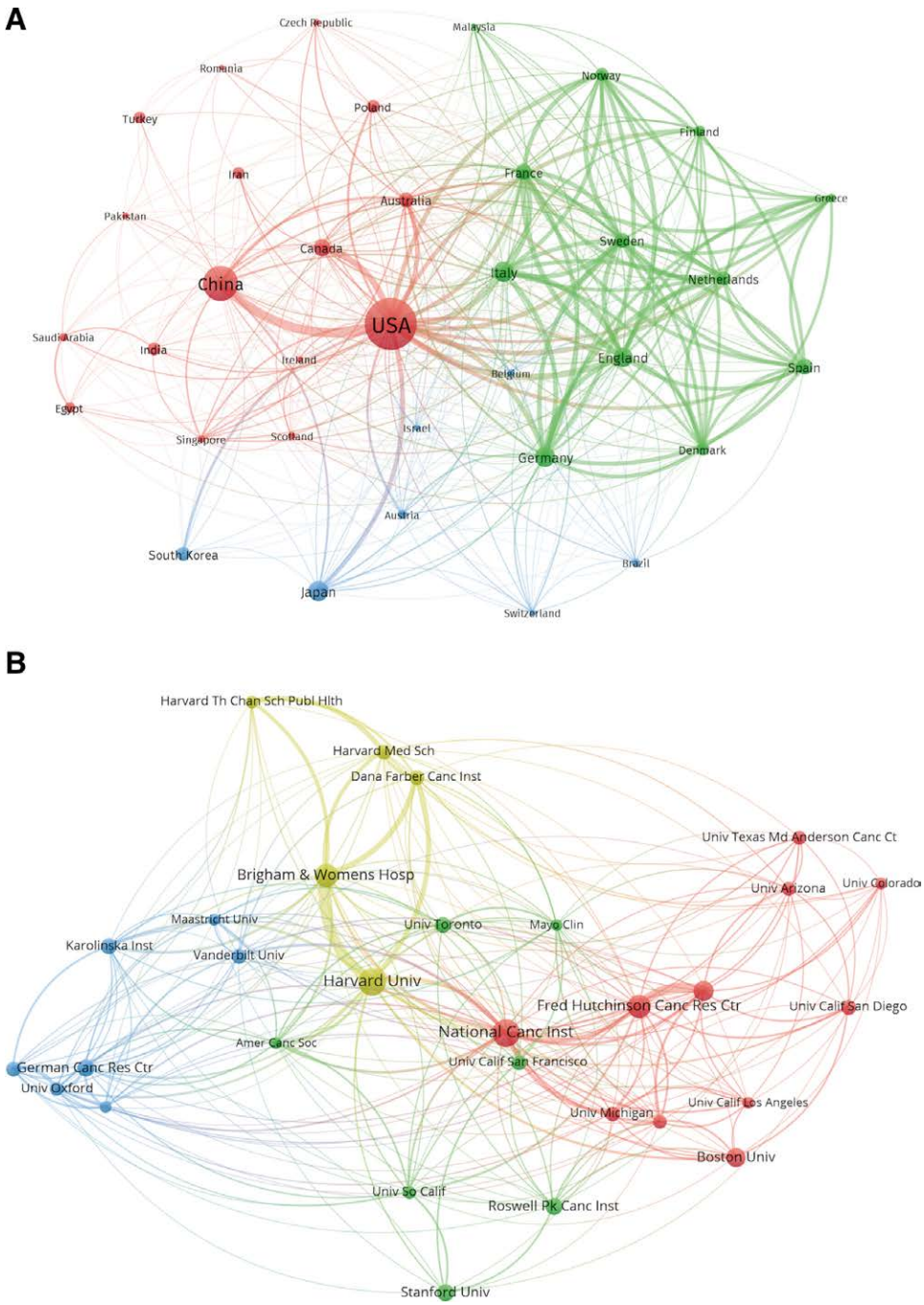

Figure 3. Network map of co-authorship between countries and institutions. (A) Collaboration network analysis of countries/regions. (B) Collaboration network analysis of institutions.

(125), and "vitamin A" (53). Breast cancer ranked first with a frequency of 630, followed by prostate cancer (435), colorectal cancer (385), colon cancer (188), and lung cancer (68), respectively. This finding may suggest that vitamins were most commonly used to treat breast cancer, while it is also crucial in the treatment of other types of cancer. Among them, vitamin D has been the most commonly studied in cancer.

In addition, the top 25 keywords with the strongest citation burst from 2003 to 2022 are shown in Figure 7. As shown, 36% (9/25) of the keywords appeared first citation burst in 2003, followed by 2011 (5/25, 20%). Among them, the keyword, "United States," ranked first with a strongest of 24.64, its citation burstiness from 2003 to 2012. Notably, the 3 keywords of "vdr," "quality of life" and "nanoparticles" are in burstiness until 2022, which implies that the sustained prosperity of the study related to the development of vitamin-grade nanotechnology. This burstiness indicates a significant interest and focus on these topics within the scientific community.

4. Discussion

4.1. General information

This study is the first bibliometric and visual analysis for the research of vitamins on cancer. In this study, a total of 3166 publications were identified, with 2715 articles and 451 reviews, spanning the period from 2003 to 2022. Although there has been a slight fluctuation in the number of published papers over the

Table 2

The top 10 most productive institutions regarding the research on vitamins and cancer from 2003 to 2022.

Rank	Institution	Country	Counts	Citations	H-index	TLS
1	Harvard University	USA	113	12,287	65	168
2	National Cancer Institute	USA	111	7893	47	126
3	Brigham & Womens Hospital	USA	86	7291	55	167
4	Fred Hutchinson Cancer Research Centre	USA	81	4090	41	122
5	Washington University	USA	65	5652	37	100
6	Boston University	USA	55	7261	31	35
7	Stanford University	USA	46	4088	33	22
8	Roswell Park Cancer Institute	USA	32	3085	30	34
9	German Cancer Research Centre	Germany	30	1702	32	52
10	Toronto University	Toronto	28	1269	26	35

Table 3

Top 10 productive author in studies of vitamins and cancer from 2003 to 2022.

Rank	Author	Counts	TLS	H-index	Citations	Country
1	Giovannucci, E	49	58	43	4884	USA
2	Albanes, D	32	72	30	1640	Spain
3	White, E	28	19	20	1037	USA
4	Trump, DL	27	28	18	2214	USA
5	Weinstein, SJ	25	62	24	1096	USA
6	Grant, WB	23	18	24	2428	USA
7	Johnson, CS	23	28	17	2072	USA
8	Mondul, AM	22	42	17	605	USA
9	Munoz, A	19	1	22	1446	Spain
10	Feldman, D	18	31	22	2041	USA

Table 4

The top 10 journals in research of vitamins and cancer from 2003 to 2022.

Rank	Journals	Country	Counts	Citations	IF#	JCR	H-index
1	Cancer Epidem Biomar	USA	104	5341	3.8	Q2	48
2	Nutr Cancer	USA	91	2401	2.9	Q3	26
3	Anticancer Res	Greece	87	2772	2.0	Q4	31
4	J Steroid Biochem	England	87	3314	4.1	Q2	34
5	Int J Cancer	Switzerland	83	3597	5.9	Q1	38
6	Nutrients	Switzerland	72	997	6.4	Q1	16
7	Plos One	USA	69	2210	3.7	Q2	31
8	Am J Clin Nutr	USA	49	6026	7.1	Q1	29
9	Cancer Causes Control	Netherlands	49	2525	2.3	Q3	28
10	Cancers	USA	33	205	5.2	Q2	9

#Abbreviation for impact factor of 2022.

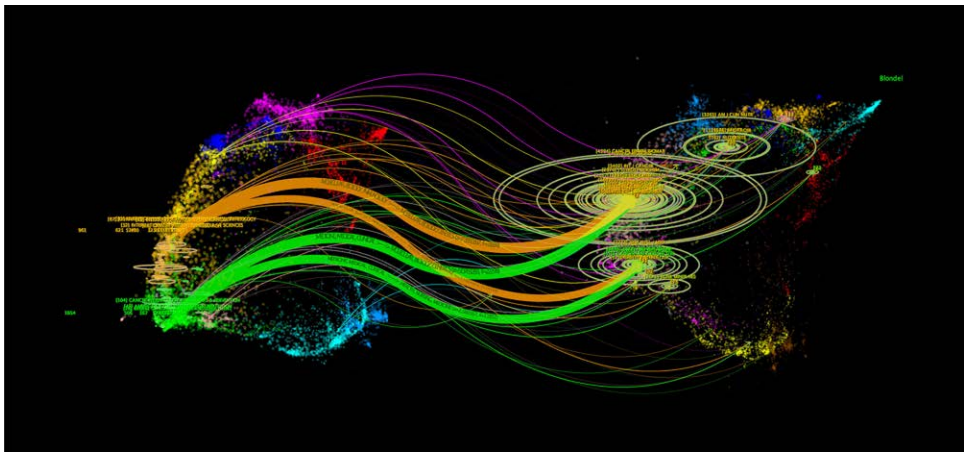

Figure 4. A dual-map overlap of journals related to vitamins and cancer from 2003 to 2022. The left is the cited journal and the right is the cited journal, the longer transverse diameter of the ellipse represents more publications in the corresponding journal.

Table 5

Top 10 co-cited references related to research of vitamins and cancer from 2003 to 2022.

Rank	Reference	Source	IF	Author	Publication year	Citations	Type
1	The role of vitamin D in reducing cancer risk and progression	Nat Rev Cancer	78.5	Feldman D	2014	159	Review
2	Global Cancer Statistics 2020: GLOBOCAN Estimates of Incidence and Mortality Worldwide for 36 Cancers in 185 Countries	CA Cancer J Clin	254.7	Sung H	2021	118	Article
3	Vitamin D Supplements and Prevention of Cancer and Cardiovascular Disease	New Engl J Med	158.5	Manson JE	2018	101	Article
4	Vitamin D signaling pathways in cancer: potential for anticancer therapeutics	Nat Rev Cancer	78.5	Deeb KK	2007	90	Review
5	Vitamin D and calcium supplementation reduces cancer risk: results of a randomized trial	Am J Clin Nutr	7.1	Lappe JM	2007	71	Article
6	Vitamin D deficiency	New Engl J Med	158.5	Holick MF	2007	70	Review
7	Prospective study of predictors of vitamin D status and cancer incidence and mortality in men	Jnci-J Natl Cancer	10.3	Giovannucci E	2006	66	Article
8	Review and meta-analysis on vitamin D receptor polymorphisms and cancer risk	Carcin	4.7	Raimondi S	2009	63	Review
9	The epidemiology of vitamin D and cancer incidence and mortality: a review (United States)	Cancer Cause Control	2.3	Giovannucci E	2005	61	Review
10	Vitamin D supplementation and total cancer incidence and mortality: a meta-analysis of randomized controlled trials	Ann Oncol	51.77	Keum N	2019	60	Review

past 20 years, an overall trend towards increased publication is evident. This can be partly attributed to the fact that cancer is already a focus and hotspot of interest. Another, more significant reason is the growing awareness of the importance of micronutrients in cancer. Publications are dispersed worldwide, among them, the United States is the country with the largest number of publications in this field, with an annual publication volume of more than 40 articles and the highest H-index, indicating that the United States leads the forefront of research on the vitamins in the field of cancer. Additionally, China ranked second in the total number of publications in this field, and after 2018, the annual publications of China has increased significantly and surpassed those of the United States (Fig. 2, Table 1). This may be attributed to the fact that Chinese scholars have paid more attention to this field in recent years. Notably, the closest cooperation was between the United States and China. Furthermore, 8 institutions and scholars of the United States were in the top ten institutions and authors in vitamins and cancer research (Table 2), indicating that the United States possesses exceptional institutions and specialized scholars, which accounts for its significant influence in this field over the past decade. Among them, Harvard University took the lead in terms of publication counts, citations and H-index, which was attributed to the contribution of Giovannucci, a distinguished authority in the field of cancer epidemiology, specializing in dietary nutrition and cancer prevention. Giovannucci was the most productive author in the field of vitamins and cancer (Table 3). His highly cited article is a meticulous meta-analysis of previous randomized controlled clinical trials, which renders it highly credible.[23] He posits that timely and adequate vitamin D supplementation is imperative, as it reduces mortality rates and prolongs survival.

Journals analysis in Table 4 indicates that only 724 papers were published in the top 10 active journals, accounting for a mere 22.87% of all publications. Among them, *Cancer Epidem Biomar* (n = 104) had the highest number of articles on vitamins and cancer, followed by *Nutr Cancer* (n = 91), *Anticancer Res* and *J Steroid Biochem* (n = 87). Additionaly, there are 4 journals cited over 3000 times, with the majority of top 10 journals (70%) in Q1 and Q2 JCR regions having high IF, implying that publishing research of Vitamins and cancer in high-quality publications is not a challenge. To elaborate a little, *Cancer Epidem Biomar* is a journal that publishes population-based research on cancer etiology, prevention, surveillance, and survivorship. It focuses on clinical aspects of research. Notably, the *Am J Clin Nutr* (AJCN) (IF = 7.1) has a higher IF and citation rate. AJCN is widely recognized as a leading peer-reviewed publication that encompasses primary research in nutrition and dietetics. This includes research on topics such as obesity, vitamins and minerals, nutrition and disease, and energy metabolism. AJCN belongs to the top journals in in nutrition and dietetics. We consider these journals to be a "primary channel" for future findings in the field, and meanwhile, they have stimulated scholars with an interest in this subject to scrutinize them more closely.

The analysis of co-cited references provides a comprehensive reflection of the knowledge domain within this research field. Moreover, within the realm of cancer research on vitamins, we discovered that the majority of the top 10 highly cited references focused specifically on vitamin D and its effects, it is clear that further investigation into the relationship between vitamin D and cancer is necessary to fully understand its potential impact on human health. The most highly cited reference, authored by Feldman and published in *Nat Rev Cancer* with 159 citations, reported that vitamin D deficiency is associated with an increased risk of cancer development. Avoiding deficiency and supplementing with vitamin D may be a cost-effective and safe approach to reducing cancer incidence while improving prognosis and outcomes, which may have implications for the treatment and prevention of cancer.[22] The fact that it received the highest number of citations suggests a high level of recognition and Acknowledgments from other scholars.

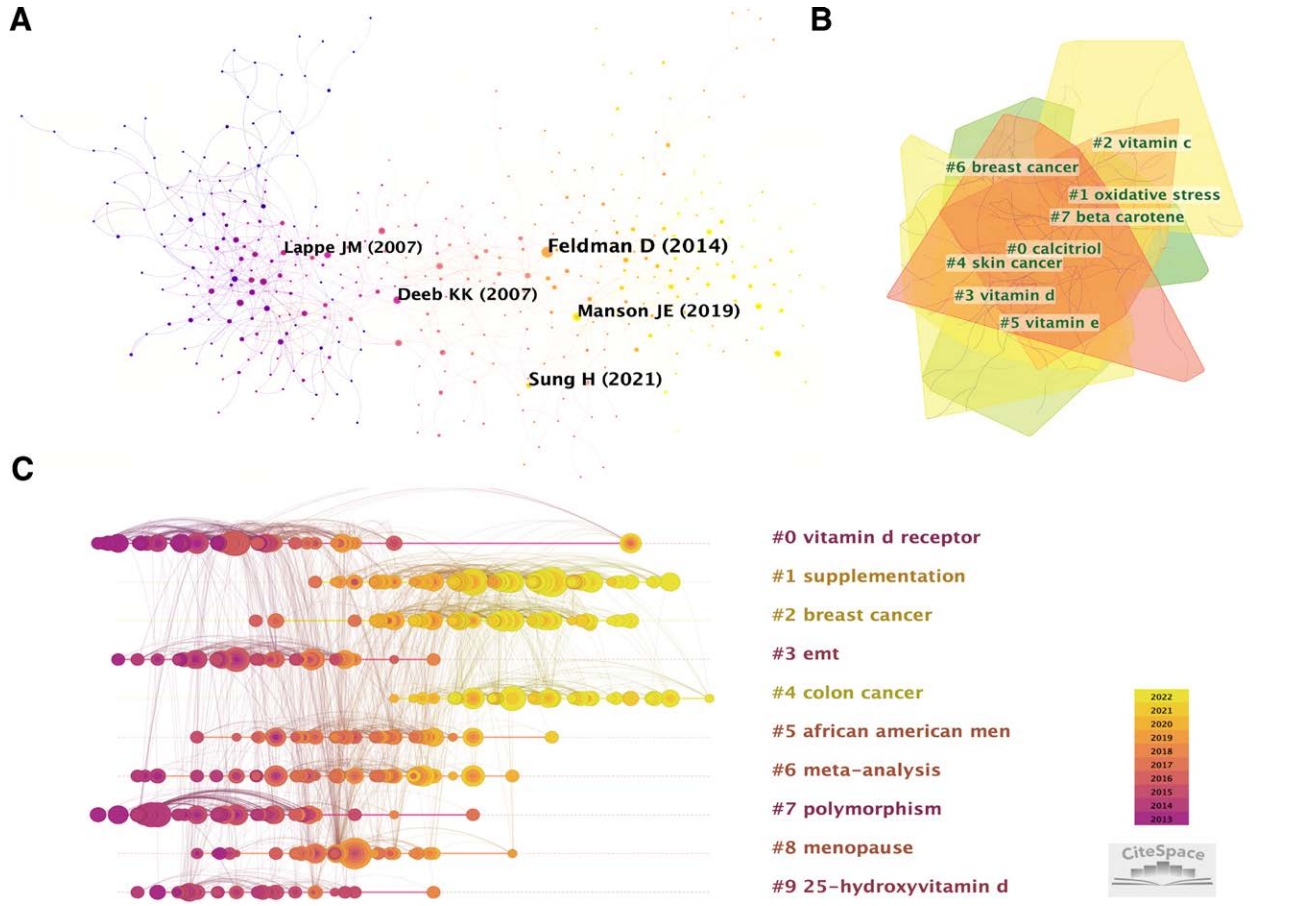

Figure 5. CiteSpace network visualization map of cited references. (A) The network visualization of the publications. The cluster (B) and the timeline view (C) of references related to Vitamin and cancer research.

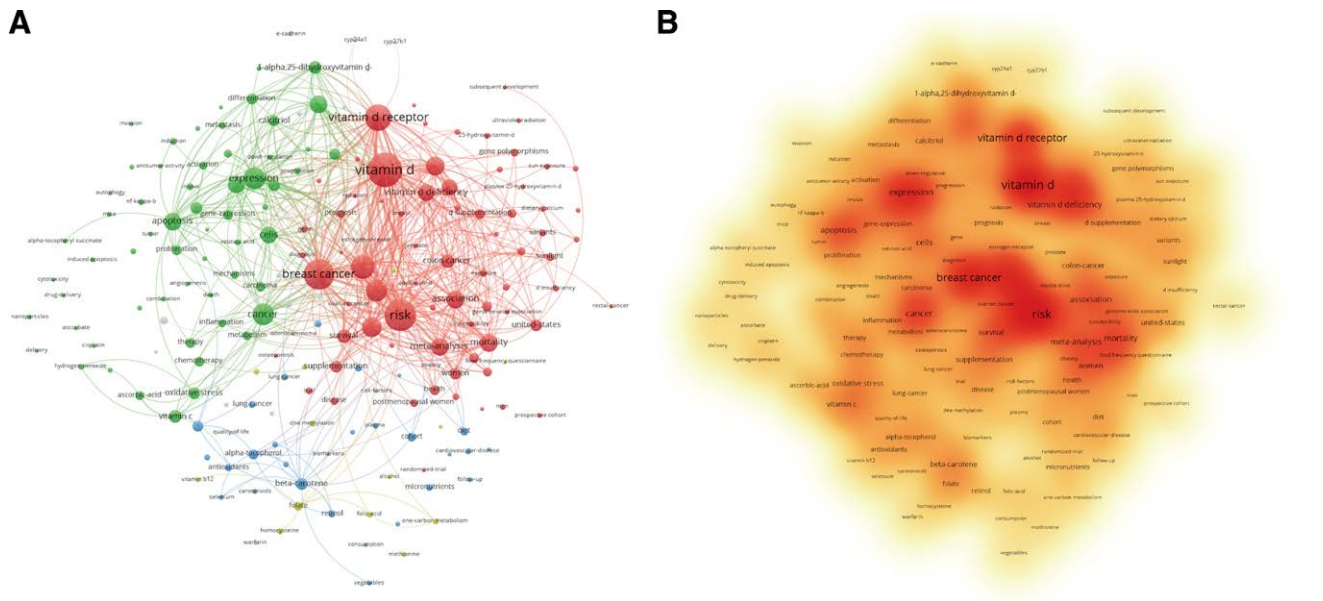

Figure 6. Map of keywords in the field of vitamins and cancer research from 2003 to 2022. (A) Map of keywords occurrence. (B) Density visualization map of keywords.

4.2. Hotspots and development trends

Hotspots and frontiers in this field can be revealed through the analysis of cluster and timeline view of co-cited reference, as well as the examination of highest frequency keywords, and keyword bursts. By conducting a comprehensive analysis, we are able to draw key insights into the field of vitamins and cancer research.

Table 6

The top 20 keywords in the research of vitamins and cancer from 2003 to 2022.

Rank	Vitamin	Frequency	Rank	Cancer	Frequency
1	Vitamin D	771	11	Association	289
2	Risk	672	12	Apoptosis	282
3	Breast cancer	630	13	Mortality	278
4	Vitamin D receptor	519	14	1,25-Dihydroxyvitamin-D3	276
5	Prostate cancer	435	15	Meta-analysis	274
6	Colorectal cancer	385	16	Vitamin D deficiency	264
7	Cancer	381	17	Cells	251
8	Expression	378	18	Growth	249
9	Prevention	334	19	Calcium	237
10	25-Hydroxyvitamin D	303	20	Survival	196

Table 7

The top 5 vitamin and cancer types in vitamins and cancer research.

Rank	Vitamin	Frequency	Rank	Cancer	Frequency
1	Vitamin D	771	1	Breast cancer	630
2	Vitamin C	163	2	Prostate cancer	435
3	Vitamin D3	132	3	Colorectal cancer	385
4	Vitamin E	125	4	Colon cancer	188
5	Vitamin A	53	5	Lung cancer	68

The cluster of co-cited references highlight the prominent areas of shared interest. The figure displays 8 clusters in Figure 5B, encompassing various types of vitamins, different types of cancers, and the corresponding mechanisms. The results indicating that vitamins A, C, D, and E are currently the focal points of research in the field of cancer, particularly breast cancer and skin cancer. Among them, oxidative stress may be the commonly observed mechanism through which these vitamins exert their anticancer effects. Oxidative stress is characterized by an imbalance in the redox properties of certain cellular environments,[24] which can be the result of too many harmful substances such as free radicals and reactive oxygen species have the potential to inflict damage on cellular DNA, proteins, and lipids, thereby fostering mutations that may contribute to cancer development.[25–27] Vitamins A, C, D, and E possess potent antioxidant properties that effectively protect against oxidative stress.[28,29] Furthermore, these vitamins exhibit other mechanisms that may aid in the prevention or treatment of cancer. For instance, vitamin A regulates cell growth and differentiation[30] while vitamin C enhances immune function.[31] Additionally, vitamin D modulates calcium metabolism,[32] and vitamin E exerts anti-inflammatory effects.[33] Overall, while more research is needed to fully comprehend the molecular mechanisms by which these vitamins work against cancer, it is clear that their potential as therapeutic agents for this devastating disease is undeniable.

The timeline of co-cited reference is listed in Figure 5C, showing that "vitamin D receptor," "supplementation," "breast cancer," "epithelial-mesenchymal transition (EMT)," "colon cancer," "African American men" and "meta-analysis," "polymorphism," "menopause" and "25-hydroxyvitamin D" directions are very significant in accordance with the citation counts. Both the "vitamin D receptor" and "25-hydroxyvitamin D" are related to vitamin D. This result showed that researchers have paid more attention to vitamins D than to other vitamins. These keywords were spread out in the cluster according to the year in which they appeared. Previous research hotspots in this field have primarily focused on experimental and epidemiological investigations. Recently, there has been an increased emphasis on "supplementation (cluster #1)," "breast cancer (cluster #2)" and "colon cancer (cluster #4)," highlighting the translation of experimental research achievements into clinical applications. The co-occurrence frequencies of keywords are presented in Table 6, highlighting the prominent occurrence of terms such as "vitamin D," "risk," "vitamin D receptor," "breast cancer," "expression," "apoptosis," and "association," indicating that the research on vitamin and cancer was mainly focused on vitamin D and breast cancer. Vitamin D is involved in regulating epithelial-mesenchymal transition (EMT), a process implicated in cancer metastasis. Recent studies have shown that vitamin D regulates EMT, which affects the occurrence and development of primary breast tumors as well as the dissemination of distant organs.[34]

As you can see from Figure 7, "quality of life" and "Nanoparticles" are the current burst keywords in the field of vitamins and cancer. The concept of quality of life has gained increasing attention as researchers recognize that treating cancer is not just about prolonging survival, but also improving patients' overall well-being. The past few years have witnessed the exploration of innovative treatments by researchers and healthcare professionals,[35–37] aiming to enhance the quality of life for cancer patients, even though these interventions may not directly cure cancer or replace conventional treatments. Furthermore, in this era of advanced medical research, nanoparticles have emerged as a promising field for the development of innovative cancer treatments.[38,39] Traditional chemotherapy drugs often exhibit limited efficacy due to their inability to selectively target cancer cells while sparing healthy ones.[40,41] However, by utilizing nanoparticles as carriers for these drugs, it may be feasible to deliver higher doses directly to tumor sites while minimizing damage to surrounding tissue.[42,43] This approach holds tremendous potential for enhancing treatment outcomes while minimizing adverse effects. Meanwhile, vitamin supplements have also been utilized in the field of nanoparticles, primarily in combination with other drugs to selectively target malignant cells.[44,45] By encapsulating vitamins within nanoparticle structures, delivering high doses of vitamins directly to the tumor site. This approach can help alleviate vitamin malabsorption in cancer patients or mitigate the adverse effects caused by excessive intake of vitamins.

Overall, it is clear that there is a shift towards more patient-centered care in the field of vitamins and cancer research. As scientific discoveries continue to unfold, we can expect further breakthroughs that will ultimately benefit those affected by this devastating disease.

5. Strength and limitations

This study represents the first bibliometric analysis to systematically investigate the research on vitamins and cancer over the past 2 decades. The review highlights research hotspots and trends in this field, utilizing various analytical methods to provide comprehensive and objective guidance for future studies.

However, our study has some limitations. Firstly, we only extracted data from the Web of Science core collection database, which may limit the comprehensiveness of our findings.

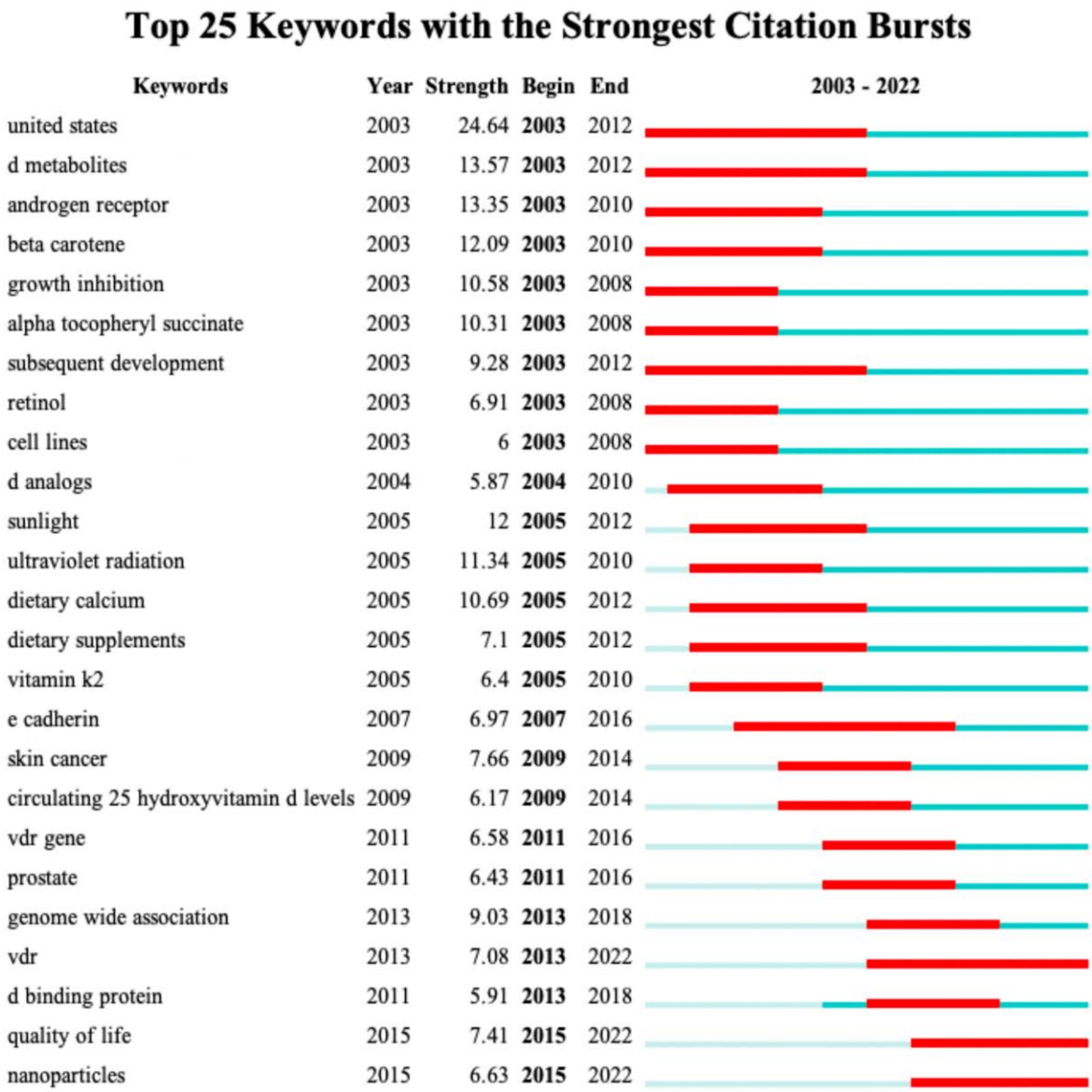

Figure 7. Top 25 keywords with the strongest citation bursts from 2003 to 2022. The red segment of the blue line denoted the burst duration of a keyword.

Secondly, there were inconsistencies in the standardization of some data that could have led to biased results. For example, analysis software treated "vdr" and "vitamin D receptor" as different keywords. Additionally, while we endeavored to ensure relevance to our research topic, it is possible that some papers were overlooked.

6. Conclusion

In summary, research focusing on vitamins and cancer has entered a period of vigorous development due to increased public health awareness. Our article presents the first bibliometric analysis using CiteSpace and VOSviewer to identify research trends and hotspots in this field. Active collaboration exists among several institutions worldwide, with the United States serving as a crucial bridge for cooperation. Giovannucci, a researcher from Harvard University, is a leading figure in the field of vitamin and cancer research with the highest number of publications, citations, and H-index. Vitamin D is 1 of the most appealing stars in this field and will be a significant focus in the future. Individuals with low levels of vitamin D are at higher risk for certain cancers, including breast, colon, and prostate cancer. Oxidative stress may serve as a crucial pathway for the anticancer effects of vitamins. Moreover, vitamin's anticancer properties may be associated with various factors such as emt, apoptosis, polymorphism, and calcium metabolism. Meanwhile, vitamin combined with nanoparticles is the new hotspot and frontier in the field of vitamins and cancer. The concerted efforts of scientists worldwide may eventually enable the utilization of targeted nutritional interventions as an integral component of a comprehensive approach to the prevention or treatment of diverse cancer types.

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