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# A bibliometric and visual analysis of low carbohydrate diet

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**Introduction:** Numerous studies have confirmed the effects of low carbohydrate diet (LChD) on metabolism and chronic diseases. However, there were no bibliometric studies on LChD. This study was conducted through a bibliometric analysis to investigate the current status, hotspots and frontiers trends.

**Methods:** We searched all research publications related to LChD from 2002 to 2021 on the Web of Scientific Core Collection (WoSCC). CiteSpace and VOSviewer software was used to analyze countries/regions, institutions, journals, authors, references, and keywords.

**Results:** A total of 6938 papers were included, with an increasing trend of annual publication. LChD categories mainly included nutrition, endocrinology, and neurosciences which reflected the interdisciplinary characteristics. USA was with the largest number and the world science center in LChD field. Universities were main research institutions and five of the top 10 institutions were from USA. Eric Heath Kossoff had 101 publications and ranked first. Nutrients was the leading journal. "A randomized trial of a low-carbohydrate diet for obesity" and "Obesity" were considered to be the most co-cited and cited reference respectively. The hotspots of LChD are four aspects, "ketogenic diet", "metabolism disease", "cardiovascular disease" and "cancer". We summarized that "oxidative stress", "gut microbiota", and "inflammation factors" are becoming frontiers trends of LChD research in the future and deserve further study.

**Discussion:** Over the past 20 years research on LChD has gained great attention. To better explore LChD field, multilevel mechanism studies will be required in the future.

## KEYWORDS

**bibliometric analysis, low carbohydrate diet, CiteSpace, VOSviewer, hotspots, frontiers trends**

## Introduction

Obesity-related complications affect almost all body systems and are significant risk factors for coronary heart disease, type 2 diabetes, cancers such as endometrial, breast, prostate, and skin cancers, as well as several other chronic non-communicable diseases. Diet therapy methods, theories, and applications are constantly updated as a result of ongoing research on the metabolism of the organism in normal and disease states (1). It has been demonstrated that consuming a diet high in carbohydrate increases the risk of developing metabolic and chronic diseases, and that lowering carbohydrate intake decreases the incidence of morbidity (2). The effects of LChD on health have garnered a lot of attention recently. There are many types of low carbon diet prescriptions according on the carbohydrate intake ratio. The American Diabetes Association recommended a conventional 2,000 calorie daily diet with <130 g of carbohydrates (3). The other study suggested consuming <40% of one's daily calories from carbohydrates (4). Anyway, the two prescriptions LChD above are powered by glucose first and then switch to ketone

bodies after fasting. Moreover, the ketogenic diet (KD) is another LChD that calls for a very low carbohydrate intake (<10%). KD, a sort of LChD, was initially used to cure epilepsy (5). Atkins, an American, wrote about an LChD in his 1972 book “*Dr. Atkins’ New Diet Revolution*,” in which the intake of carbohydrate was rigorously limited while the intake of protein and fat is raised (6). Currently modified Atkins diet, a easier KD, has showed very similar effects with KD (7). A LChD can lower excess body weight (8, 9), as well as the risk of diabetes, cancer, cardiovascular disease, and internal inflammatory responses brought on by obesity (10, 11). Of fact, some research has indicated that LChD can also produce negative health effects, such as gastric dysfunction (12), atherosclerosis (13), physical fatigue (14), etc.

Studies on LChD are becoming increasingly popular in recent years as a response of the academic community’s intense interest in the disease’s favorable health effects (15–17). Most of studies, nevertheless, have concentrated on how LChD affects certain disease locations. We require a thorough understanding of the development process and research trends in this subject given the rapid proliferation of research on LChD. However, there are no bibliometric and visual analysis article on LChD.

Bibliometrics, a mathematical and statistical tool for quantitatively analyzing all knowledge (18), has been used to assess distributions, collaboration, citation, keywords, hotspots, and frontiers trends (19). CiteSpace and VOSviewer are software for visualization for bibliometrics analysis (20, 21). These two software generate network maps that allow researchers to intuitively analyze the current status within the field, and determine the research hotspots and frontiers trends (22). Therefore, this study employs CiteSpace and VOSviewer software to analyze the publications on LChD from 2002 to 2021, to evaluate and analysis the research hotspots and frontiers trends. This has been the first study to use bibliometric strategies in the field of LChD. The study is expected to help researchers extract potential information for further research in the field of LChD research and offer them helpful advice in choosing ground-breaking subject matter by answering the following questions:

- (i) Which countries, institutions, journals, authors, and references are the current status of research in the field of LChD?
- (ii) What are the current hotspots and major categories of LChD?
- (iii) Where are in the future frontiers trends of LChD?

## Materials and methods

### Data acquisition and search strategy

In this study, WoSCC was selected as the data source. As a high-quality digital literature resource database, WoSCC has been accepted by many researchers, and considered as the most suitable database for literature analysis (23). All publications were retrieved from the Science Citation Index Expanded (SCI-E) of the WoSCC database on November 12, 2022. We completed the search within the same day to avoid any bias caused by database updates. The following methods were conducted for

search publications: topic words = (“low carbohydrate” OR “low-carbohydrate” OR “low carb” OR “low-carb” OR “ketogenic” OR “carbohydrate-restricted” OR “carbohydrate restricted” OR “restricted carbohydrate” OR “restricting carbohydrate” OR “carbohydrate restriction” OR “South Beach diet” OR “Atkins diet”). In order to more accurately analyze the current status, hotspots and frontiers trends of LChD, the publications from 2002 to 2021 were selected. Time span = January 1, 2002–December 31, 2021. To ensure the representativeness of the included studies, the types of publications were limited to “articles” and “reviews” (24). No languages limitation to avoid bias in the geographical distribution of publications. The content of literature records were “full records and cited references,” downloaded and saved in plain text document format.

### Statistical analysis

We used the CiteSpace (6.1.R3) and VOSviewer (1.6.18) for a bibliometric analysis of 6,938 publications on LChD from 2002 to 2021. The java-based program CiteSpace does bibliometric analysis of publications using distribution network maps, co-citation network maps, dual maps of journal overlay, and keyword burst citation maps (25). Nodes and links are included in the visual network diagram produced by CiteSpace. Every node is a factor, such as an author, an institution, or a country (26). Links between different nodes show a network of relationships involving co-operation, co-citation, or co-occurrence (27). A wider line indicates a more effective collaboration. The higher the centrality, the larger the circle is in terms of centrality. When a node has a purple circle around it, it has a high centrality score and is therefore an important node in the field (22). VOSviewer was used to form keyword co-occurrence of overlay visualization. The colors represent the years (28). The size of the node is proportional to the frequency of keyword occurrences (29). Data was managed, charts were made, and all data tables were created using Microsoft Excel 2021 software.

## Results

### Annual output and categories

A total of 6,938 publications including 5,350 articles and 1,588 reviews, related to LChD from 2002 to 2021 were retrieved by searching the WoSCC database. The flowchart was shown in Figure 1. The annual publications reflected the activities in the field and the attention given to certain areas of research (30). As seen in Figure 2, the number of annual publications on LChD showed an overall upward trend in spite of fluctuation slightly in some years over the past 20 years. It indicates that LChD research is becoming a research of great interest to scholars and has attracted great interest from scholars in recent years.

LChD publications in the past 20 years can be divided into 2 stages. The initial stage (2002–2010) was a steady growth period. The average number of publications was 188 publications every year, with the lowest number of publications being 72 publications

in 2002 and the highest number being 273 publications in 2009. In 1927, a low carbohydrate ketogenic diet had been reported for epilepsy (31). As an early study in 1948, LChD was used to control of dental caries (32). Since 2002, LChD was contributed to a variety of areas, including obesity (33), diabetes (34), and cardiovascular disease (35). Although the number of papers varied at this stage, the overall trend was one of consistent growth. The second stage (2011–2021) was a sustained growth period. The average number of publications annually was 476 publications. The number of publications reached 872 in 2021. Nutrition has a significant role in daily life, and it is crucial for the advancement of social development to support research on diet and health. LChD research has gained popularity as a nutritional approach and is rapidly developing into a research hotspot.

The categories refer to the disciplines covered by the dissertation research. At top 10 categories (Table 1), Nutrition

Dietetics had 1,621 publications and ranked first, followed by Clinical Neurology (1,269 publications), Endocrinology Metabolism (960 publications), Neurosciences (734 publications) and Pediatrics (472 publications). LChD research mainly covered the fields of nutrition, endocrinology, and neurosciences, reflecting the multidisciplinary nature and comprehensive knowledge.

### Analysis of countries/regions

In total, 112 countries/regions participated in 6,938 publications on LChD from 2002 to 2021. CiteSpace generated the countries/regions distribution map, and 112 nodes and 880 links were shown in the map (Figure 3). Table 2 presented the top 10 countries/regions published in LChD research field. USA had the highest number of publications, 2,862 papers, accounting for 41.25%. The Yuasa phenomenon states that the nation whose research output accounts for more than 25% of all scientific output at any given moment can be referred to as the world center of

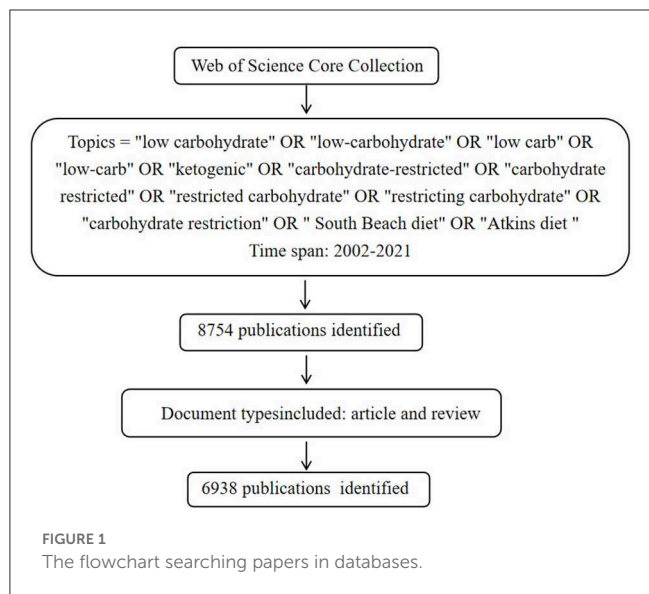
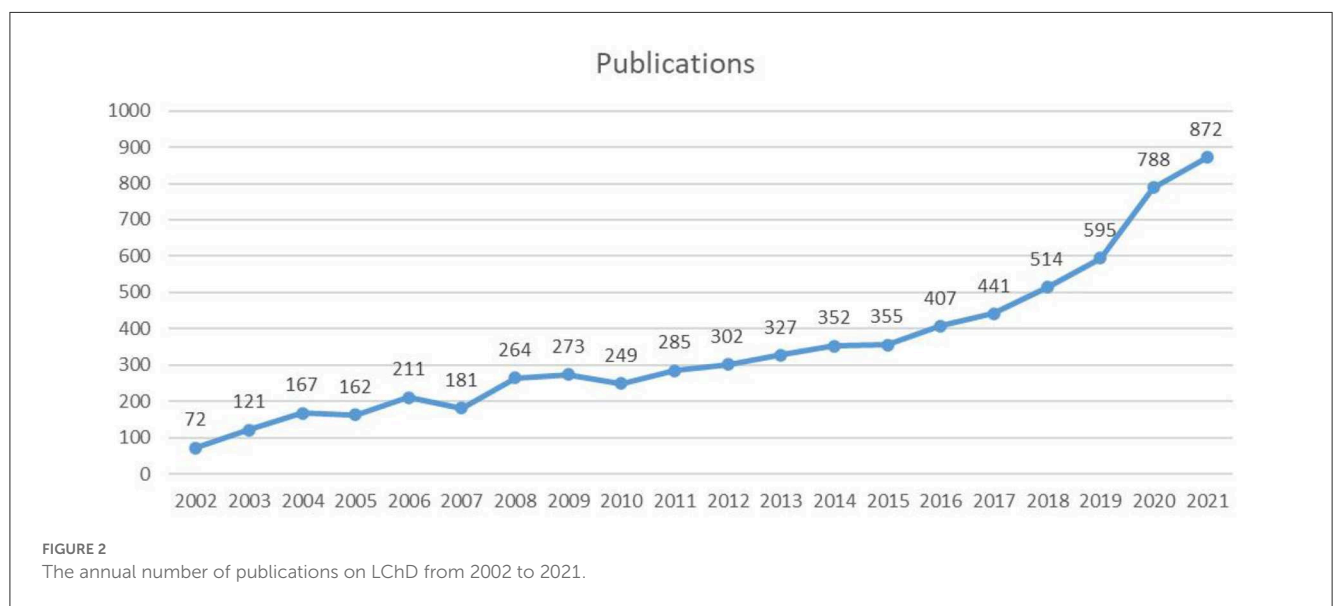


TABLE 1 The top 10 categories on LChD from 2002 to 2021.

Rank	Category	Publications
1	Nutrition dietetics	1,621
2	Clinical neurology	1,269
3	Endocrinology metabolism	960
4	Neurosciences	734
5	Pediatrics	472
6	Biochemistry molecular biology	417
7	Medicine general internal	314
8	Medicine research experimental	282
9	Pharmacology pharmacy	269
10	Multidisciplinary sciences	227



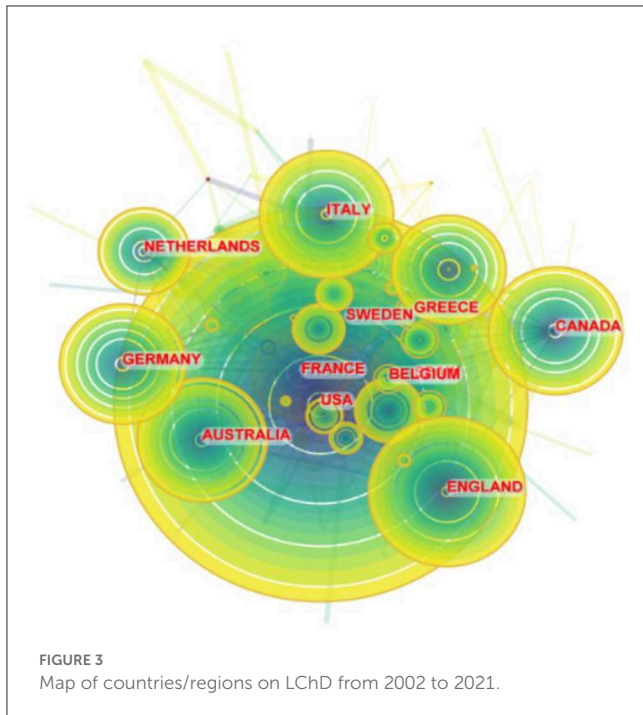


FIGURE 3 Map of countries/regions on LChD from 2002 to 2021.

TABLE 2 The top 10 countries/regions on LChD from 2002 to 2021.

Rank	Country/region	Publications	Centrality
1	USA	2,862	0.08
2	England	543	0.13
3	Italy	472	0.08
4	Germany	449	0.08
5	China	441	0.01
6	Canada	434	0.16
7	Australia	422	0.13
8	Japan	339	0.02
9	Spain	301	0.11
10	France	299	0.14

science during that time (36). As the leader in LChD research, USA published far more than a quarter of the total publications and was the world science center in the field of LChD. England (543 publications), Italy (472 publications), China (449 publications), and Germany (441 publications) followed closely behind. In terms of centrality, Canada (0.16) ranked first, followed by, Spain (0.14), Australia (0.13), England (0.13), France (0.11) and, which maintain close cooperation relationships. Countries/regions with centrality played an important role in LChD research. Germany, Canada, Australia and France each had <450 publications, but their research roles were important. In terms of publications, China had 449 papers, but the centrality was only 0.01. It demonstrated that despite having a high publications number, China had few connections and little influence over the network map. The level of LChD research in China therefore was raised effectively by deepening the field's research, advancing cross-disciplinary and

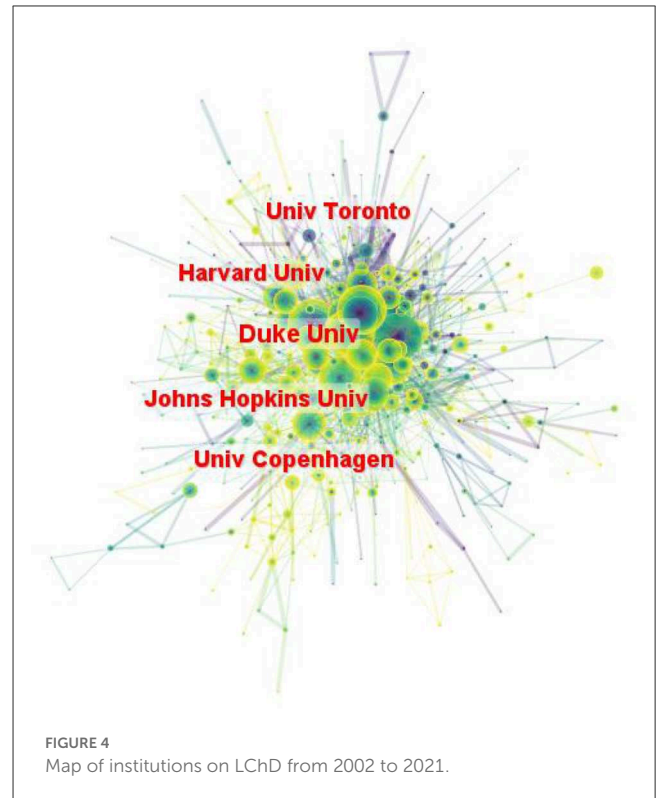


FIGURE 4 Map of institutions on LChD from 2002 to 2021.

TABLE 3 The top 10 institutions on LChD from 2002 to 2021.

Rank	Institution	Country	Publications
1	Harvard University	USA	451
2	University of California System	USA	258
3	Johns Hopkins University	USA	216
4	Udice, French research universities	France	191
5	University of London	England	174
6	Johns Hopkins Medicine	USA	146
7	Institut National de la Santé et de la Recherche Médicale	France	131
8	University of Toronto	Canada	127
9	Assistance Publique Hopitaux Paris Aphp	France	125
10	University of Connecticut	USA	124

cross-field collaboration, and enhancing researchers' capacity for creative thinking and global communication.

### Analysis of institutions

A total of 604 institutions provided research in the field of LChD. CiteSpace generated the institutions distribution map with 604 nodes and 2,103 links (Figure 4). The institutions

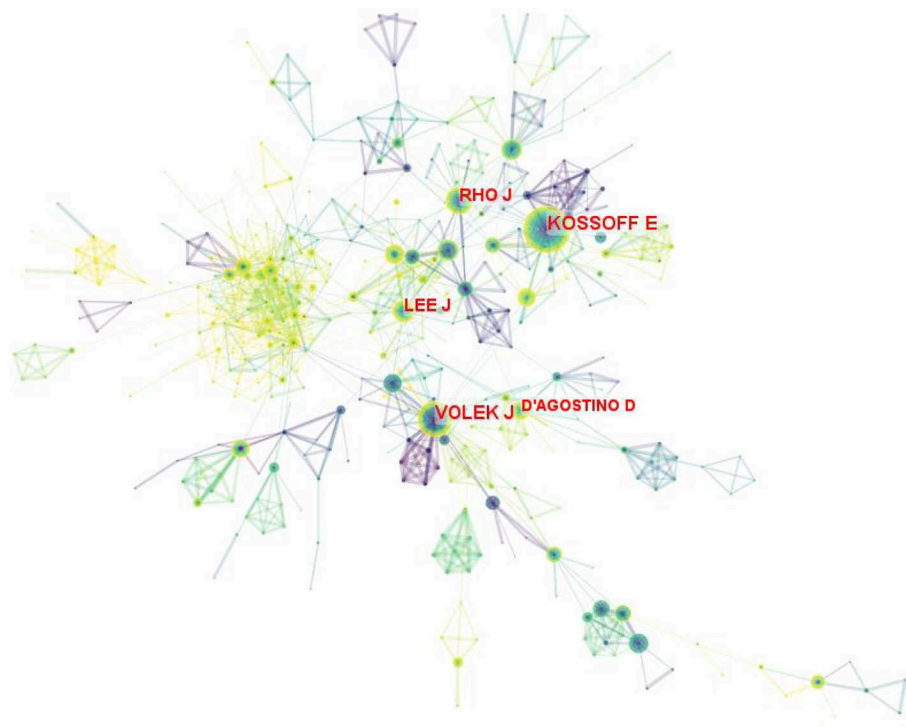


FIGURE 5  
Map of authors on LChD from 2002 to 2021.

with large numbers of publications have been identified as influential institutions (37). Table 3 listed the top 10 institutions in publications, and they were the most influential institutions in LChD research. Universities were major institutions for LChD research. Harvard University ranking first, had 451 papers, followed by University of California System (258 publications), Johns Hopkins University (216 publications), Udice French research universities (191 publications), and University of London (174 publications). Five of the top 10 institutions were from USA, which further confirmed US predominance in the field of LChD research. Duke University, Harvard University, Johns Hopkins University and University of Toronto had close collaboration relationships.

## Analysis of authors

In total of 890 authors participated in 6,938 publications on LChD from 2002 to 2021. CiteSpace generated the institutions distribution map with 890 nodes and 1965 links (Figure 5). The top 10 authors participating in the LChD research are shown in Table 4. The most productive authors were Eric Heath Kossoff (101 publications), Jeff Scott Volek (69 publications), Jong M. Rho (62 publications), William S. Yancy (45 publications), and Maria Luz Fernandez (43 publications). Eric Heath Kossoff ranked first in the number of publications devoted to the study of the effects of a high-fat, low-carb ketogenic diet on neurological disorders. He demonstrated that a high-fat, low-carb ketogenic diet reduced the number of seizures in refractory epilepsy and reported no cardiovascular or cerebrovascular events (38, 39).

TABLE 4 The top 10 authors on LChD from 2002 to 2021.

Rank	Author	Affiliations	Publications
1	Kossoff Eric H.	Johns Hopkins University	101
2	Volek Jeff	University System of Ohio	69
3	Rho Jong M.	University of Calgary	62
4	Yancy William S.	Duke University	45
5	Rodriguez Fernandez Maria Luz	University of Connecticut	43
6	Cross J. Helen	UCL Great Ormond St Inst Child and Lealth	43
7	Kim Heung Dong	Yonsei University Health System	40
8	Westman Eric	Lund University	39
9	Auvin Stéphane	University of California System	37
10	Clifton Peter Marshall	University of South Australia	37

In addition ketogenic diets are being applied to a range of neurological disorders from autism to Alzheimer's disease (40). Jeff Scott Volek was the second position of papers. He reported that in individuals with atherosclerotic dyslipidemia, a 12-week carbohydrate restriction diet improved postprandial vascular function more than a low-fat diet (41). An study revealed that



LChD (10%) not only decreased lipid deposition but avoided the buildup of plasma and aortic oxidation, decreased inflammatory cytokines within the artery wall, and prevented atherosclerosis (42). Jong M. Rho was in the third place in terms of number of publications. In addition to a high-fat, low-carbon-water ketogenic diet that improves epilepsy (43), he emphasized that a ketogenic diet enhances mitochondrial function and reduces autistic behavior in humans and rodent models of autism spectrum disorder (44, 45). The authors' collaboration displayed a geographical concentration and general decentralization.

## Analysis of journals

Researchers can accurately understand the core journals in a topic by analyzing its source journals, which also serves as a

TABLE 5 The top 10 journals on LChD from 2002 to 2021.

Rank	Journal	Publications	IF (2021)
1	Nutrients	292	6.706
2	Epilepsia	203	6.740
3	Epilepsy Research	134	2.991
4	PLoS One	116	3.752
5	American Journal of Clinical Nutrition	105	8.472
6	Epilepsy and Behavior	96	3.337
7	Journal of Child Neurology	78	2.363
8	British Journal of Nutrition	76	4.125
9	Seizure European Journal of Epilepsy	74	3.414
10	Nutrition	73	4.893

reliable resource for further field research (46). A total of 1,545 academic journals published 6,938 publications in the field of research on LChD from 2002 to 2021. As shown in Table 5, the top 10 journals accounted for 17.93% of the total publications. The most productive journals were Nutrients (292 publications), Epilepsia (203 publications), Epilepsy Research (134 publications), PLoS One (116 publications), and American Journal of Clinical Nutrition (105 publications). Of the top 10 journals, eight journals' IF more than 3.0. With a maximum of 8.472, the top 2 journals had an IF >6.0. This shows that high IF journals are open to publishing LChD research.

Figure 6 illustrated the dual-map overlay of journals that produced literature linked to the topic of LChD. On the map, the right labels represented the disciplines of the journals that published the cited papers, while the left labels represented the fields of the citing journals. Citation links can show the in and out of the citation dataset. Figure 6 showed 5 reference pathways. Three yellow pathways indicate articles published in molecular/biological/immunology journals mainly citing journals in the molecular/biology/genetics field. Two green pathways suggest that articles published in medicine/clinical journals mainly cite journals in the molecular/biology/genetics/health/nursing/medicine fields. One red pathway shows that the publications from neurology/sports/ophthalmology mainly cite journals in the molecular/biology/genetics field.

## Analysis of co-cited references

The co-cited reference analysis is one of the important indicators in bibliometric research and is usually used to explore research priorities in specific academic fields (47). CiteSpace generated the co-cited reference map, and 1,693 nodes and

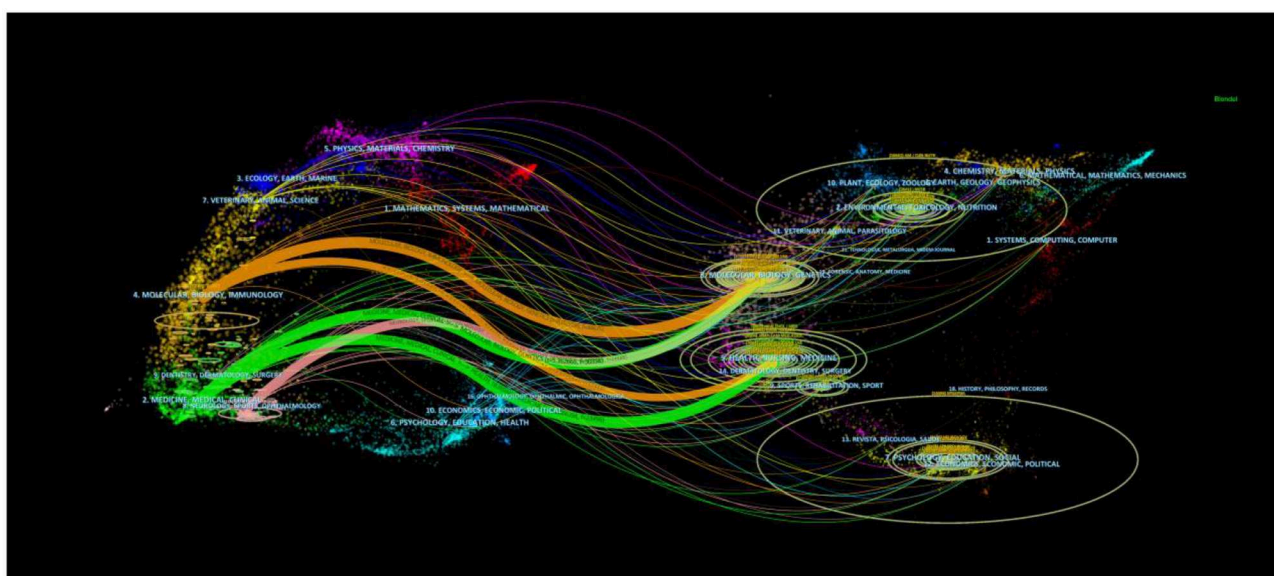
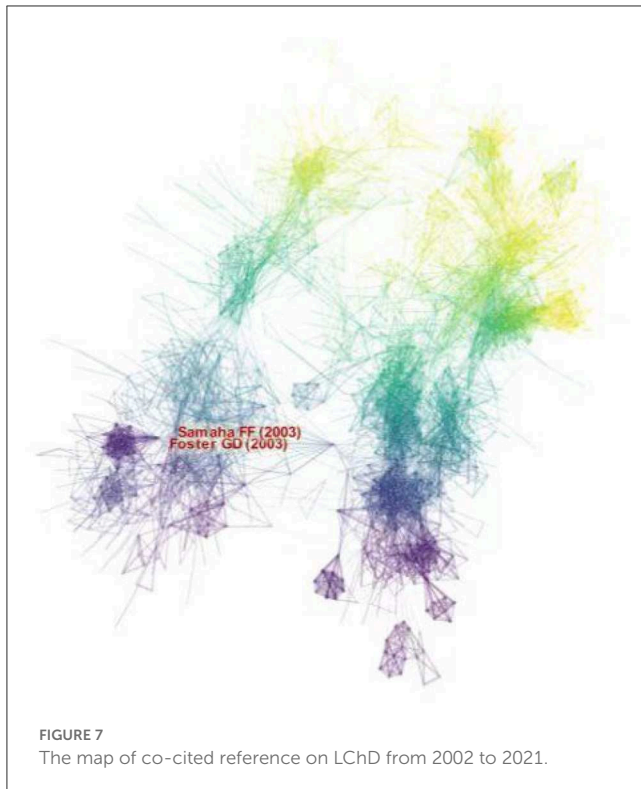


FIGURE 6 Dual-map overlay of academic journals from 2002 to 2021.



9,455 links were shown in the map (Figure 7). The top 5 co-cited references in terms of frequency were in Table 6. Analysis of co-cited references provided basic data for LChD research. Noteworthy were three publications from the New England Journal of Medicine and two from the Annals of Internal Medicine, both of which have significant academic influence. The five references were all clinical trials. In most co-cited reference, obese people were given Atkins diet, and lost more weight in the first 6 months (48). Additionally, high density lipoprotein cholesterol levels increased and triglyceride levels decreased more in Atkins diet participants than in control group, indicating that Atkins diet had a higher impact on the risk factors for coronary heart disease. The second-most co-cited reference reported that patients who received a carbohydrate-restricted diet with 30 g per day or less, lost more weight than control group did and had relative improvements in their insulin sensitivity and triglyceride levels (49). The third most co-cited reference of 132 obese people on who were restricted carbohydrate intake to <30 g per day showed more beneficial effects than those on conventional diets at 1 year; the effects of restricted carbohydrate on atherogenic dyslipidemia and glycemic control remained more favorable (34). Diet therapies were given to moderately obese subjects, and a low-carbohydrate diet and a Mediterranean diet were found to have beneficial effects on lipids and blood glucose, respectively (50). Individualized dietary regimens tailored to individual preferences and metabolism are recommended. A low-carbohydrate, ketogenic diet exhibited higher participant retention and more weight loss compared to low-fat diets in the literature with the sixth greatest co-citation frequency (51).

## References analysis

High cited references lay the foundation and accelerate the development of research in the field (23). The top 10 cited references were listed in Table 7. Of the top 10 references, 7 references were articles and 3 were reviews. Three references were published in the New England Journal of Medicine and two were published in Lancet. “Obesity” published by Haslam et al. in 2005, was cited 3,136 times, and ranked first. Shai et al. published in 2008 in New England Journal of Medicine of “Weight loss with a low-carbohydrate, Mediterranean, or low-fat diet” was cited 1,250 times, and ranked second. Foster et al. published in 2003 in “A randomized trial of a low-carbohydrate diet for obesity” in New England Journal of Medicine was cited 1,124 times, and ranked third.

## Analysis of keywords

The map of keywords can present the main research objects and the hot topics and frontiers trends. In this study, VOSviewer software performed the keyword co-occurrence of overlay visualization (Figure 8). A total of 9,750 keywords, 172 keywords met the thresholds when the minimum number of occurrences of a keywords was 20. From Figure 8, we found that the keywords research hotspots were categorized into “ketogenic diet,” “metabolism disease,” “cardiovascular disease” and “cancer.” Bursts keywords were frequently used at a period time, reflecting the frontiers trends. We used CiteSpace software to map the top 32 keywords with the strongest citation bursts from 2002 to 2021 (Figure 9). We summarized that “oxidative stress,” “gut microbiota,” and “inflammation factors” are becoming frontiers trends of LChD research in the future.

## Discussion

We performed a bibliometric analysis of the publications from WoSCC on LChD from 2002 to 2021 using CiteSpace and VOSviewer software. We then summarized the current status, hotspots and frontiers trends in this field.

A total of 6,938 publications including 5,350 articles and 1,588 reviews, related to LChD from 2002 to 2021 were retrieved by searching WOSCC database. The number of annual publications on LChD showed an overall upward trend in spite of fluctuation slightly in some years. LChD research mainly involved the categories of nutrition, endocrinology, and neurosciences, reflecting the multidisciplinary nature and comprehensive knowledge about LChD research. USA was with the largest number and the world science center in LChD field, and Australia, Canada, England, France and Germany maintained close cooperation relationships. Universities were major institutions for LChD research. Five of the top 10 institutions were from USA, which further confirmed US predominance in the field of LChD research. Duke University, Harvard University, Johns Hopkins University and University of Toronto had close collaboration relationships. The most productive authors were Eric Heath Kossoff, Jeff Scott Volek, Jong M. Rho, William S.

TABLE 6 The top 5 co-cited reference on LChD from 2002 to 2021.

Rank	Frequency	Cited reference	Source	Reference
1	287	A randomized trial of a low-carbohydrate diet for obesity	New England Journal of Medicine	(48)
2	234	A low-carbohydrate as compared with a low-fat diet in severe obesity	New England Journal of Medicine	(49)
3	178	The effects of low-carbohydrate vs. conventional weight loss diets in severely obese adults: 1-year follow-up of a randomized trial	Annals of Internal Medicine	(34)
4	171	Weight loss with a low-carbohydrate, Mediterranean, or low-fat diet	New England Journal of Medicine	(50)
5	154	A low-carbohydrate, ketogenic diet vs. a low-fat diet to treat obesity and hyperlipidemia: a randomized, controlled trial.	Annals of Internal Medicine	(51)

TABLE 7 The top 10 cited references on LChD from 2002 to 2021.

Rank	Title	Author	Type	Journal	Year	Citations
1	Obesity	Haslam DW, et al.	Review	<i>Lancet</i>	2005	3,136
2	Weight loss with a low-carbohydrate, Mediterranean, or low-fat diet	Shai I, et al.	Article	New England Journal of Medicine	2008	1,250
3	Hepatic fibroblast growth factor 21 is regulated by PPAR alpha and is a key mediator of hepatic lipid metabolism in ketotic states	Michael K Badman, et al.	Article	Cell Metabolism	2007	1,125
4	A randomized trial of a low-carbohydrate diet for obesity	Foster GD, et al.	Article	New England Journal of Medicine	2003	1,124
5	Comparison of the Atkins, Ornish, Weight watchers, and Zone diets for weight loss and heart disease risk reduction	Dansinger ML, et al.	Article	JAMA	2005	1,100
6	Nutrition recommendations and interventions for diabetes—a position statement of the American Diabetes Association	American Diabetes Association, et al.	Article	Diabetes Care	2008	1,074
7	Childhood obesity	Han JC, et al.	Review	<i>Lancet</i>	2010	1,010
8	Weight-loss outcomes: A systematic review and meta-analysis of weight-loss clinical trials with a minimum 1-year follow-up	Franz MJ, et al.	Review	Journal of the American Dietetic Association	2007	953
9	The ketone metabolite beta-hydroxybutyrate blocks NLRP3 inflammasome-mediated inflammatory disease	Youm YH, et al.	Article	Nature Medicine	2015	935
10	A low-carbohydrate as compared with a low-fat diet in severe obesity	Samaha FF, et al.	Article	New England Journal of Medicine	2003	844

Yancy, and Maria Luz Fernandez. The authors' collaboration showed a geographical concentration and general decentralization. The most productive journals were *Nutrients*, *Epilepsia*, *Epilepsy Research*, *PLoS One*, and *American Journal of Clinical Nutrition*. "A randomized trial of a low-carbohydrate diet for obesity" and "Obesity" were considered to be the most co-cited and cited reference respectively.

Based on the keywords the keyword co-occurrence of overlay visualization, we can explore the hotspots. From Figure 8, we summarized and analyzed four hotspots in LChD field. Here, we further analyzed the following aspects according to the application field of LChD: ketogenic diet, metabolism disease, cardiovascular disease and cancer.

(i) Ketogenic diet: The KD is a type of low-carb diet, characterized by high fat and very low carbohydrate. KD works on the basis of the biological principle of starvation,

using fat as the main energy source of the body (52). KD initially achieved satisfactory results in pediatric refractory epilepsy and obesity (53). In recent years, research on KD has been extended to metabolic (54), cardiovascular (55), cancer (56), neurological (57), and respiratory (58) diseases with positive results, especially in hyperglycemia (59), hyperlipidemia (60), and insulin resistance (61). Of course there are some shortcomings. The long-term efficacy, such as weight regain (62), cardiovascular events (63), and bone metabolism (64), cannot be ignored. Therefore, the use of KD for disease treatment needs to be individualized according to different diseases and patients' data.

(ii) Metabolism disease: In this study, obesity and diabetes are common metabolic diseases. By consuming less carbohydrates, restricting the body's usage of exogenous glucose, and boosting lipolysis and fatty acid oxidation to meet the body's energy needs, low carbohydrate nutrition





### Top 32 Keywords with the Strongest Citation Bursts

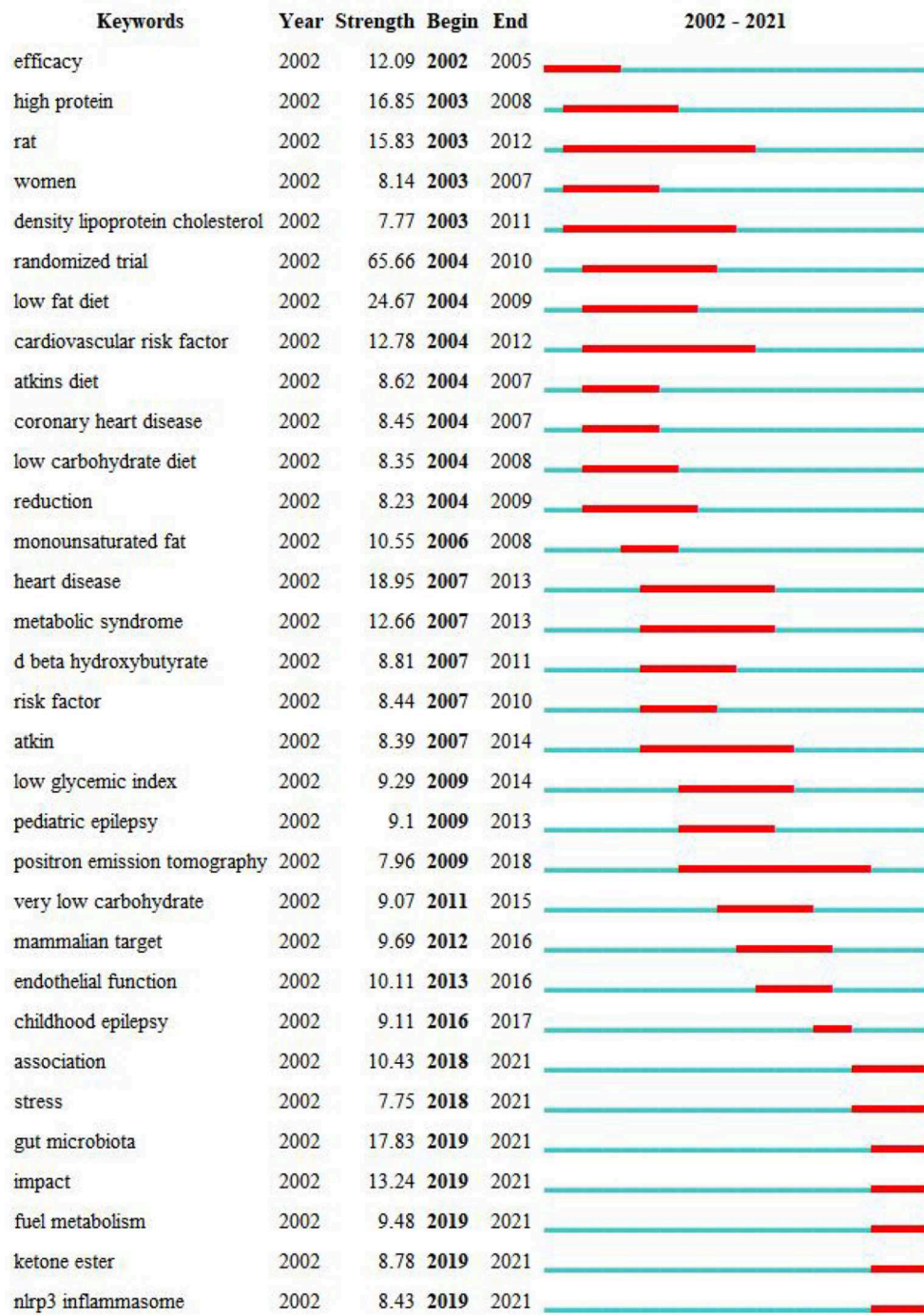


FIGURE 9 Map of keyword with the strongest citation bursts on LChD from 2002 to 2021.

be an important pathogenic factor, such as diabetes mellitus, obesity, heart disease, and cancer (81). The metabolite of the carbohydrate is glucose. The intake of excessive carbohydrates produces more glucose and increases the oxidative pressure on mitochondria, which increases the

production of excessive reactive oxygen species, leading to the occurrence of disease (82). Low-carbohydrate intake reduces to reduce the occurrence of oxidative stress in the body, thus reducing the incidence of disease (83). A review showed that the low-carbon ketogenic diet-mediated

reduction in glucose levels and enhanced electron transport in the mitochondria further disrupt the energy metabolism of tumor cells, thus adversely affecting tumor cell proliferation (83).

- (ii) Gut microbiota: Gut flora can regulate body metabolism and participate in the occurrence of diseases through a variety of mechanisms. With increasing research on gut microbiota, the dietary pattern was identified as one of the main drivers of gut microbiota change. Recently, carbon aquatic ketone diet has been shown to effectively treat neurological diseases (84), tumor (85, 86), metabolic diseases (87), inflammatory bowel disease (88), etc. Its effect source is related to the participation of intestinal flora in neurodevelopment (84), various pathways to hinder tumor cell growth (89, 90), inhibit the growth of bifidobacterium and reduce the inflammatory factor (89). The current research on intestinal microbiota has explained the action mechanism of low-carbon ketogenic diet to some extent, but the number of studies is too small, requiring further exploration in the future to provide a more solid theoretical basis for the application of low-carbon ketogenic diet.
- (iii) Inflammation factors: With the development of life science and technology, the current literature also further explains the disease treatment and prevention of LChD from the inflammation level. Tumor necrosis factor- $\alpha$ , interleukin-6, lipocalin, and C-reactive protein are inflammation factors produced by adipose tissue (91–94). Dietary habits can influence immune function and have anti-inflammatory effects (95). The diets of 9.6% energy from carbohydrate (96) and carbohydrate <40 g/day (97) enhanced lipocalin and lowered C-reactive protein levels in obese patients. According to Jonasson et al. (98), type 2 diabetic individuals who took LChD of 20% energy from carbohydrate, had lower serum levels of interleukin-1 receptor and interleukin-6. An further experiment revealed that LChD lessens lipid deposition, avoids the buildup of plasma and aortic oxidation, lowers inflammatory cytokines in the arterial wall, and inhibits atherosclerosis (99). There will be a spectrum of levels at which research on LChD is conducted, with more inflammation factors becoming increasingly prevalent in the future.

## Limitations

To the best of our knowledge, the present study is the first bibliometric analysis to assess LChD. However, it has many limitations. First, considering that the data difference and incompleteness of other database data, we only analyzed publications from the WoSCC. Next, to better present the analysis result and to ensure the quality of the included literature, we included only articles and reviews published in English. This may lead to some screening bias.

## Conclusion

We searched all research publications related to LChD on the Web of Scientific Core Collection (WoSCC). CiteSpace software was used to analyze countries/regions, institutions, journals, authors, references, and keywords. LChD is a popular diet, attracting attention from scholars. The hotspots of LChD are three aspects, “metabolism disease,” “cardiovascular disease,” and “risk factor.” We summarize that “research on prevention and treatment,” “research on diet,” and “research on molecular level” are becoming frontiers trends of LChD research in the future directions and deserve further study.

## Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

## Author contributions

HP and GL: conceptualization. XH: methodology, writing-original draft preparation, and writing-review and editing. CL and LZ: software. LZ: investigation, data curation, and supervision. GL and XH: resources. GL and CL: visualization. All authors have read and agreed to the published version of the manuscript.

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## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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