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Exploring the nutritional landscape and emerging trends in kidney stone research: visualization and bibliometric analysis

Sa'ed H. Zyoud[1,2*], Faris Abushamma[3,4*], Husam Salameh[3,5], Amani S. Abushanab[1], Amer Koni[1,6], Adham Abu Taha[7,8], Samah W. Al-Jabi[1], Moyad Shahwan[9], Ammar A. Jairoun[10] and Muna H. Shakhshir[11*]

Abstract

Background Kidney stones, or renal nephrolithiasis, are common and dangerous, increasing the risk of chronic kidney disease. Dietary manipulation is essential for the prevention and recurrence of kidney stones. Research into nutrition and kidney stones lacks library analysis, making it difficult to identify new trends. This bibliometric study was conducted to explore the current landscape of research on nutrition and kidney stones worldwide. This paper also emphasizes significant research trends in this area over the past two decades, aiming to assist researchers in understanding the current research status and identifying potential future directions.

Methods The scholarly literature pertaining to diet and kidney stones was systematically explored utilizing SciVerse Scopus to identify pertinent research articles released from 2003 to 2022. The examination encompassed an assessment of publication patterns, key contributors, focal areas of research, prevalent themes, influential articles, and emerging research avenues. Following data extraction to Excel, analyses, including frequencies, percentages, and linear regression, were conducted. Visual exploration was facilitated through the use of the VOSviewer program version 1.6.19.

Results Between 2003 and 2022, 697 publications on nutrition and kidney stones were identified. There were 478 original articles (68.58%), 120 reviews (17.22%) and 99 other types of publications (14.20%). The United States is the most productive country, with significant growth in research in the fields of nutrition and kidney stones. The United States has demonstrated the strongest partnerships between researchers' networks from various countries. Cluster analysis revealed three major research themes: sex differences in kidney stone disease, the correlation between increased dietary acid consumption and calcium oxide kidney stones, and nephrolithiasis associated with a ketogenic diet.

*Correspondence:
Sa'ed H. Zyoud
saedzyoud@yahoo.com
Faris Abushamma
f.abushamma@najah.edu
Muna H. Shakhshir
muna.shakhshir@gmail.com

Full list of author information is available at the end of the article

Conclusions This study offers a thorough examination of nutrition and kidney stone research, encompassing key research domains, collaborative networks, and emerging patterns. The findings can aid researchers in gaining insight into the present landscape of the discipline and determining future research directions.

Keywords Nutrition, Diet, Kidney stones, Nephrolithiasis, Scopus, Visualization

Introduction

Nephrolithiasis, a medical term for kidney stones, is a widespread and significant health problem that affects approximately 12% of the world's population [1]. Approximately 600,000 cases are reported annually in the United States alone [2]. When crystals or crystalline concretions traverse the urinary system from the kidneys, kidney stones form.

These stones can increase the risk of chronic kidney disease, diabetes, heart disease, kidney failure, and high blood pressure, as well as cause discomfort, bleeding, and other consequences [2–4]. The frequency and rates of recurrence of nephrolithiasis are increasing due to the lack of effective therapies and methods. Men have a greater tendency to develop kidney stones [5]. The incidence of life-long recurrence is particularly high between the ages of 20 and 49 years [6]. This increase could be attributed to the increasing incidence of obesity, a significant risk factor for kidney stones. Genetics, nutrition, and some medical problems are additional risk factors [7, 8].

Diet significantly influences the occurrence of nephrolithiasis. According to previous research [9], dietary habits play a crucial role in the development of kidney stones. Therefore, adjusting dietary patterns is a fundamental aspect of treating nephrolithiasis. Dietary modifications can prevent calcium oxalate kidney stones, the most prevalent type [10, 11]. To determine the appropriate dietary intervention, it is necessary to consider a comprehensive nutritional assessment for individuals prone to developing stones. The most accurate method for assessing regular dietary intake is maintaining a record of seven days of food consumption. The intake of fluid, protein, carbohydrates, oxalate, calcium, and sodium chloride can affect both the urine risk profile and the likelihood of developing kidney stones [10, 11].

In recent years, bibliometric research has been utilized in various nutrition- and diet-related fields [12–16]. However, there has been a shortage of bibliometric studies focusing on nutrition, diet, and kidney stones. Consequently, this research aimed to conduct a comprehensive literature review on nutrition, diet, and kidney stones to assess the current status and significant areas of focus in this field. Consequently, this exhaustive bibliometric study aims to summarize the current state of global research on nutrition and kidney stones, as well as to predict emerging trends and significant advances in the field.

Methods

Study design

This was a descriptive cross-sectional bibliometric study.

Comparison of bibliometric and systematic review methodologies

Bibliometric analysis was carried out using the SciVerse Scopus database. It is important to distinguish between bibliometric analysis and systematic reviews or scope reviews [17–23]. Systematic review included searching several databases to collect literature on a particular subject and then filtering the retrieved literature on the basis of predefined inclusion and exclusion criteria to obtain a limited selection of articles. These selected articles are often statistically analyzed (meta-analysis) to generate new data. Similarly, multiple databases were searched for scope checks, and articles were extracted and filtered. The analysis of filtered literature, which is typically limited in quantity, is conducted concerning the study designs employed in the extracted documents. Conversely, bibliometric analysis entails utilizing a comprehensive database such as SciVerse Scopus for the extraction, analysis, and mapping of data. Additionally, bibliometric analysis offers an overview of references and research collaborations [24].

Database

In this study, publications related to nutrition and kidney stones were collected from peer-reviewed journals indexed in SciVerse Scopus. In this study, Scopus was used for its comprehensive coverage of MEDLINE, with 100% coverage. Furthermore, Scopus boasts a comprehensive collection of indexed journals, totaling approximately 33,000, surpassing that of the Web of Science (WoS). Consequently, the volume of literature available through Scopus is expected to surpass that available through WoS [25–29]. Moreover, Scopus provides numerous features to aid in citation analysis, track research collaboration, and export data to Microsoft Excel for in-depth analysis and visualization. Notably, many bibliometric studies rely on Scopus as their primary tool for retrieving data [30–36]. To prevent any potential bias arising from the continuous updates to Scopus's database, all the data were retrieved from Scopus on July 1, 2023.

Search strategy

The applicable terminology related to nutrition and kidney stones was determined by utilizing PubMed Medical Subject Headings (MeSH) and referring to relevant publications that address this topic.

The research strategy was a three-step process:

First, the title search was performed using the following terms: nutrit*, nutrient, diet*, eat*, nourishment, feeding, and food.

Second, the title and/or abstract search included the following phrases on kidney stones: calculi AND kidney, nephrolith, renal AND calculus, kidney AND stones, kidney AND stone, renal AND calculi, renal AND stone, renal AND stones, calculus AND kidney, calculi AND urinary, calculus AND urinary, stones AND urinary, urinary AND stone, nephrolithiasis, ureteral AND stone, ureteral AND stones, ureteral AND calculus, ureteral AND calculi, urolithiasis, renal AND crystal, kidney AND crystal, and ureteral AND crystal.

Third, the study focused on the period from 2003 to 2022, without any restrictions on language. The research methodology employed the asterisk (*) as a wildcard and quotation marks ("") to precisely target particular terms or phrases and enhance the search process. The analyses excluded any errors or retracted documents. The research strategy used a title search for terms related to nutrition instead of a title/abstract/keyword search. This is because a title search is more reliable, as it will only produce a small number of false negatives [37–41]. However, this approach can also result in numerous false positives because many studies have focused primarily on subjects other than diet and kidney stones.

Fourth, the results of the search query were as follows: ((TITLE-ABS (Calculi AND Kidney) OR TITLE-ABS (Nephrolith) OR TITLE-ABS (Renal AND Calculus) OR TITLE-ABS (Kidney AND Stones) OR TITLE-ABS (Renal AND Calculi) OR TITLE (Renal AND Stone) OR TITLE-ABS (Renal AND Stone) OR TITLE-ABS (Calculus AND Kidney) OR TITLE-ABS (Calculi AND Urinary) OR TITLE-ABS (Stones AND Urinary) OR TITLE-ABS (Stones AND Urinary) OR TITLE-ABS (Urinary AND Stone) OR TITLE-ABS (Nephrolithiasis) OR TITLE-ABS (Ureteral AND Stone) OR TITLE-ABS (Ureteral AND Stones) OR TITLE-ABS (Ureteral AND Calculus) OR TITLE-ABS (Ureteral AND Calculi) OR TITLE-ABS (Urolithiasis) OR TITLE-ABS (renal AND crystal) OR TITLE-ABS (kidney AND crystal) OR TITLE-ABS (Ureteral AND crystal)) AND ((TITLE ("Nutrient") OR TITLE (diet*) OR TITLE (Nourishment) OR TITLE (Dietetics) OR TITLE (food) OR TITLE (*nutrition*) OR TITLE (feeding) OR TITLE (eat*)) AND PUBYEAR > 2002 AND PUBYEAR < 2023)) AND (EXCLUDE (DOCTYPE,"er")).

Validation of the search strategy

To ensure the accuracy and relevance of our findings, we meticulously refined our search query and then carefully evaluated the titles and abstracts of the top 50 most-cited publications related to the topic. Two experts in bibliometrics thoroughly reviewed these highly cited documents to ensure the absence of any false positives. The search effectively identified relevant information (no false positives) and minimized the risk of missing important findings (no false negatives). This was achieved through a comprehensive search query and a correlation test comparing retrieved information with the number of publications for the ten most active researchers in the field. The strong correlation coefficient ($r=0.957$, $p<0.001$) confirmed the accuracy of the search strategy. This validation method draws on previous bibliometric studies and reflects the meticulous and comprehensive approach of the authors to ensure accuracy [13, 37, 42].

Data export and management

Following the implementation of the search plan, the retrieved information was compiled into a Microsoft Excel spreadsheet in CSV format. This dataset included details on the document titles, abstracts, countries, annual publication volumes, document types, funding sources, citations, and journal names [43].

This analysis focused primarily on examining the frequency and percentage of publications. Additionally, a linear regression analysis was conducted using Microsoft Office Excel to evaluate the publication trends over time. The analysis exclusively focused on the top ten highest-rated measurements. To determine the impact factor (IF) of the top ten journals, data from Clarivate Analytics' 2022 IF, as reported in the 2023 Journal Citation Report (JCR), were utilized. To assess the impact of scientific research on the link between nutrition and kidney stones, the h-index, or Hirsch index, was employed as a quantitative metric.

Visualization analysis

This study examined how terms related to nutrition and kidney stones are clustered and co-occur in the titles and abstracts of research articles. It also explored how to represent these findings using visual overlay visualization and investigated collaborative networks among researchers from various countries. To perform this analysis, the researchers used VOSviewer software version 1.6.19 [44, 45]. In the visualization map, the size of each node and the associated term signify how often they cooccur, while the connections between nodes depict their relationships. Nodes that share the same color are part of the same cluster, as denoted by references [44, 45]. The terms are grouped into distinct colors based on their frequency of occurrence in published materials. To create this

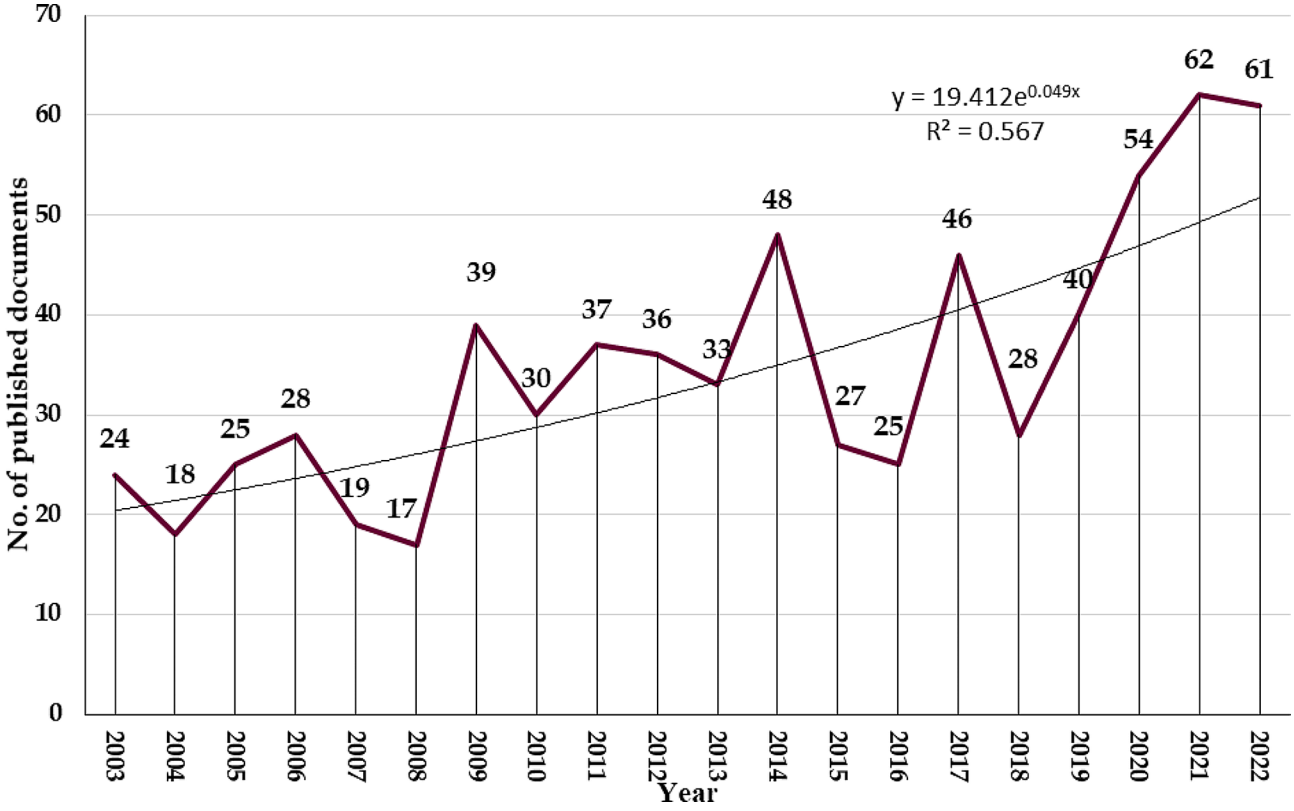

Fig. 1 Trends in annual publications on nutrition and kidney stones

visualization map, terms extracted from the titles and abstracts of publications on nutrition and kidney stones were overlaid. Each term was assigned a unique color depending on when it typically appeared in the overlay visualization map. The color blue was reserved for terms that appeared earlier in the timeline, while yellow and green represented later occurrences.

Results

Evolution and growth of publications

We identified 697 publications related to nutrition and kidney stones published between 2003 and 2022. Among these, 478 (68.58%) were original research articles, 120 (17.22%) were review articles, and the remaining 99 (14.20%) were other publication types. The number of publications steadily increased over the past two decades, with a peak in 2021 (Fig. 1). This trend is further supported by a statistically significant moderate positive correlation ($r=0.722$, $p=0.002$) between the publication year and the number of publications on this topic.

Top active countries

Ninety-two countries participated in scientific research on nutrition and kidney stones. The study revealed that the United States ($n=256$; 36.73%) was the most productive nation, followed by Italy ($n=60$; 8.61%), China ($n=44$; 6.31%), Germany ($n=42$; 6.03%) and India ($n=40$; 5.74%) (Table 1). Figure 2 represents a network visualization map illustrating research collaborations among 15 countries, each contributing at least 10 articles. The strength of cross-country collaboration is depicted by the thickness of the connecting lines and the size of the nodes, with the United States demonstrating the most robust partnerships. The strength of cross-country collaboration is depicted by the thickness of the connecting lines and the size of the nodes, with the United States demonstrating the most robust collaboration.

Table 1 Top 10 countries ranked by article output on nutrition and kidney stones from 2003 to 2022

Ranking	Country	No. of documents	%
1st	United States	256	36.73
2nd	Italy	60	8.61
3rd	China	44	6.31
4th	Germany	42	6.03
5th	India	40	5.74
6th	United Kingdom	33	4.73
7th	France	31	4.45
8th	Brazil	28	4.02
9th	Spain	27	3.87
10th	Canada	23	3.30

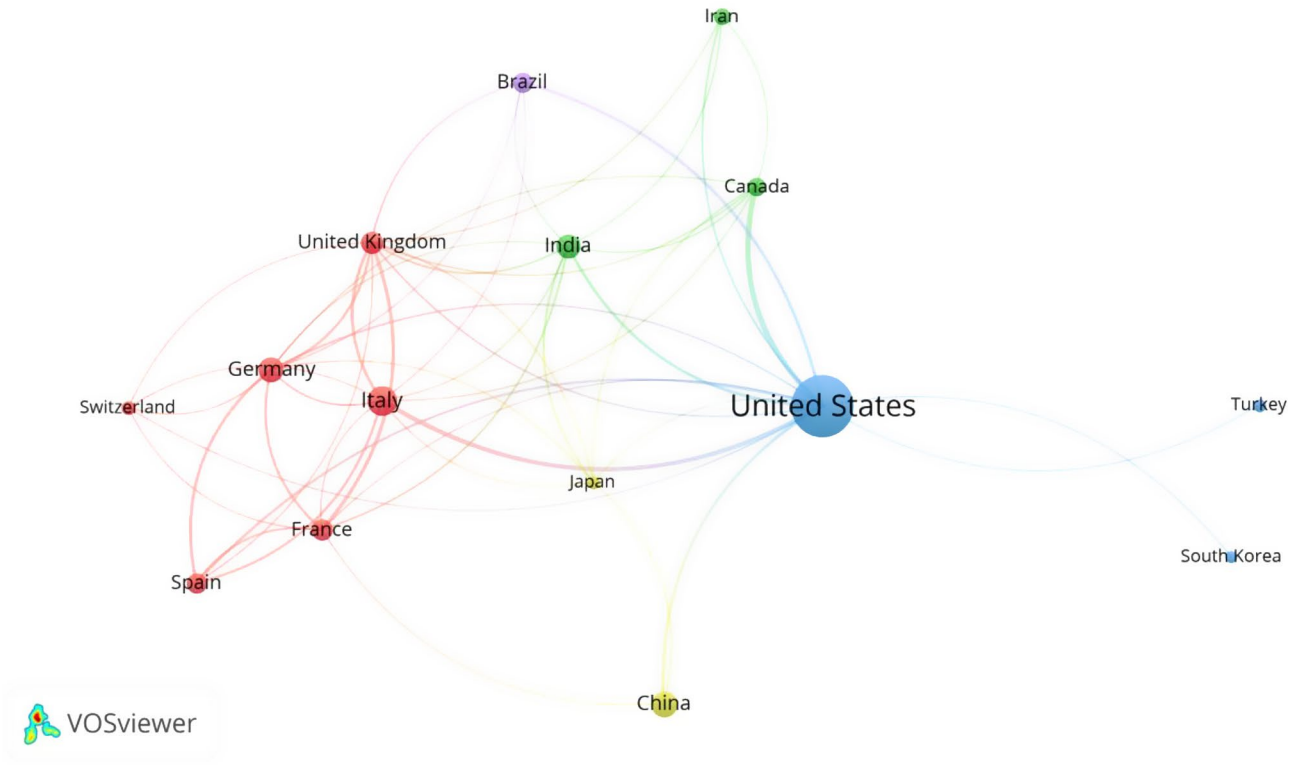

Fig. 2 Visualization of the network of international research collaboration on nutrition and kidney stones among 15 countries with a minimum research output of 10 documents. VOSviewer software version 1.6.19 was used to generate the map

Table 2 Top 10 institutions with the highest frequency of article publications on nutrition and kidney stones worldwide, ranked byproductivity

Ranking [a]	Institute	Country	No. of documents	%
1st	*Harvard Medical School*	USA	30	4.30
2nd	*Brigham and Women's Hospital*	USA	23	3.30
3rd	*Università Cattolica del Sacro Cuore, Campus di Roma*	Italy	19	2.73
4th	*Channing Division of Network Medicine*	USA	18	2.58
5th	*UT Southwestern Medical Center*	USA	17	2.44
6th	*Fondazione Policlinico Universitario Agostino Gemelli IRCCS*	Italy	16	2.30
7th	*Università di Parma*	Italy	14	2.01
7th	*Universität Bonn*	Germany	14	2.01
7th	*University of Wisconsin School of Medicine and Public Health*	USA	14	2.01
7th	*Università degli Studi di Milano*	Italy	14	2.01

Contributed institutions

Table 2 lists the top ten institutions contributing the most research on nutrition and kidney stones. The institution with the highest percentage of articles ($n=30$, 4.30%) was *Harvard Medical School*, followed by *Brigham and Women's Hospital* ($n=23$, 3.30%), *Università Cattolica del Sacro Cuore, Campus di Roma* ($n=19$, 2.73%), and the *Channing Division of Network Medicine* ($n=18$, 2.58%).

Contributed funding agencies

Table 3 presents the ten funding agencies of publications related to the field of nutrition and kidney stones. Among these agencies, the *National Institute of Diabetes and Digestive and Kidney Diseases* (USA) emerged as the global leader in funding publications in this field, accounting for 52 publications (7.46%). The *National Institutes of Health* (USA) secured the second position with 31 publications (4.45%), followed by the *National Centre for Research Resources* (USA) with 22 publications (3.16%) and the *National Natural Science Foundation of China* (China) with 17 publications (2.44%).

Contributed journals

Table 4 presents a ranking of the most productive journals in this particular field. Of the total number of documents published, which amounted to 157, the top 10 journals accounted for 22.52%. The *Journal of Urology*

Table 3 Top 10 funding agencies with the most publications on nutrition and kidney stones from 2003 to 2022

Ranking	Funding agencies	Country	No. of publication	%
1st	*National Institute of Diabetes and Digestive and Kidney Diseases*	USA	52	7.46
2nd	*National Institutes of Health*	USA	31	4.45
3rd	*National Center for Research Resources*	USA	22	3.16
4th	*National Natural Science Foundation of China*	China	17	2.44
5th	*National Cancer Institute*	USA	10	1.43
6th	*National Center for Advancing Translational Sciences*	USA	9	1.29
7th	*Sichuan University*	China	8	1.15
8th	*European Regional Development Fund*	European Union	6	0.86
8th	*West China Hospital, Sichuan University*	China	6	0.86
10th	*Japan Society for the Promotion of Science*	Japan	5	0.72

Table 4 Top 10 journals with the highest frequency of article publications on nutrition and kidney stones worldwide, ranked byproductivity

Ranking [a]	Journal/source title	No. of documents	%	IF [b]
1st	*Journal of Urology*	33	4.73	6.6
2nd	*Journal of Endourology*	21	3.01	2.7
2nd	*Nutrients*	21	3.01	5.9
4th	*Urology*	14	2.01	2.1
5th	*Journal of Renal Nutrition*	12	1.72	3.2
6th	*Kidney International*	11	1.58	19.6
6th	*Urolithiasis*	11	1.58	3.1
8th	*World Journal of Urology*	10	1.43	3.4
9th	*American Journal of Physiology-Renal Physiology*	8	1.15	4.2
9th	*Journal of Animal Physiology and Animal Nutrition*	8	1.15	2.7
9th	*Urological Research*	8	1.15	NA

had the highest number of publications, with 33 articles. This journal was closely followed by the *Journal of Endourology* and *Nutrients*, both with 21 publications each, making them the second most productive journals. *Urology* secured the fourth position with 14 publications.

Citation analysis

The documents obtained contained a combined total of 16,654 citations, with an average of 23.89 citations per document and an h-index of 66. Overall, 116 documents (16.3%) did not have citations, while 37 documents had 100 or more citations. The top 10 articles, determined by the number of citations they received, collectively amassed 3,660 citations [46–55]. The number of citations for these publications ranged from 247 to 578 (Table 5).

Table 5 The 10 most cited publications in research related to nutrition and kidney stones from 2003 to 2022

Ranking	Authors	Year	Source title	Cited by
1st	Schlemmer et al. [54]	2009	*Molecular Nutrition and Food Research*	578
2nd	Kumar et al. [50]	2010	*Food Chemistry*	575
3rd	Dobson et al. [52]	2008	*Toxicological Sciences*	416
4th	Curhan et al. [48]	2004	*Archives of Internal Medicine*	379
5th	Taylor et al. [47]	2004	*Journal of the American Society of Nephrology*	377
6th	Gossner et al. [53]	2009	*Environmental Health Perspectives*	294
7th	Kang et al. [51]	2004	*Epilepsia*	280
8th	Vucenik and Shamsuddin [55]	2006	*Nutrition and Cancer*	266
9th	Taylor et al. [46]	2009	*Journal of the American Society of Nephrology*	248
10th	Remer et al. [49]	2003	*American Journal of Clinical Nutrition*	247

Research themes

Figure 3 shows the frequently used terms found in the titles and abstracts related to the topics of nutrition and kidney stones. The size of each circle corresponds to how often a term is mentioned, and the proximity of circles indicates how often these terms appear together. The terms are categorized based on their connections and are color-coded for easy distinction. Upon conducting cluster analysis, we identified three primary clusters, represented by the colors blue, red, and green. The blue group refers to *'gender differences in kidney stone disease*, the red cluster focuses on the '*correlation between increased dietary acid consumption and the appearance of calcium oxalate kidney stones'*, while the green cluster addresses the 'nephrolithiasis *associated with the ketogenic diet.*' The blue cluster shows significant associations with terms from other clusters. Figure 3 presents an overview of these three clusters.

Future research direction analysis

In Fig. 4, VOSviewer employs a color-coding scheme to symbolize individual terms based on their frequency across all the collected publications. The color blue was assigned to terms that first surfaced in the literature, while the color yellow was used for terms that had been recently identified. Before 2015, studies in this field concentrated primarily on *"nephrolithiasis associated with the ketogenic diet"* and "*correlation between increased dietary acid consumption and the occurrence of calcium*

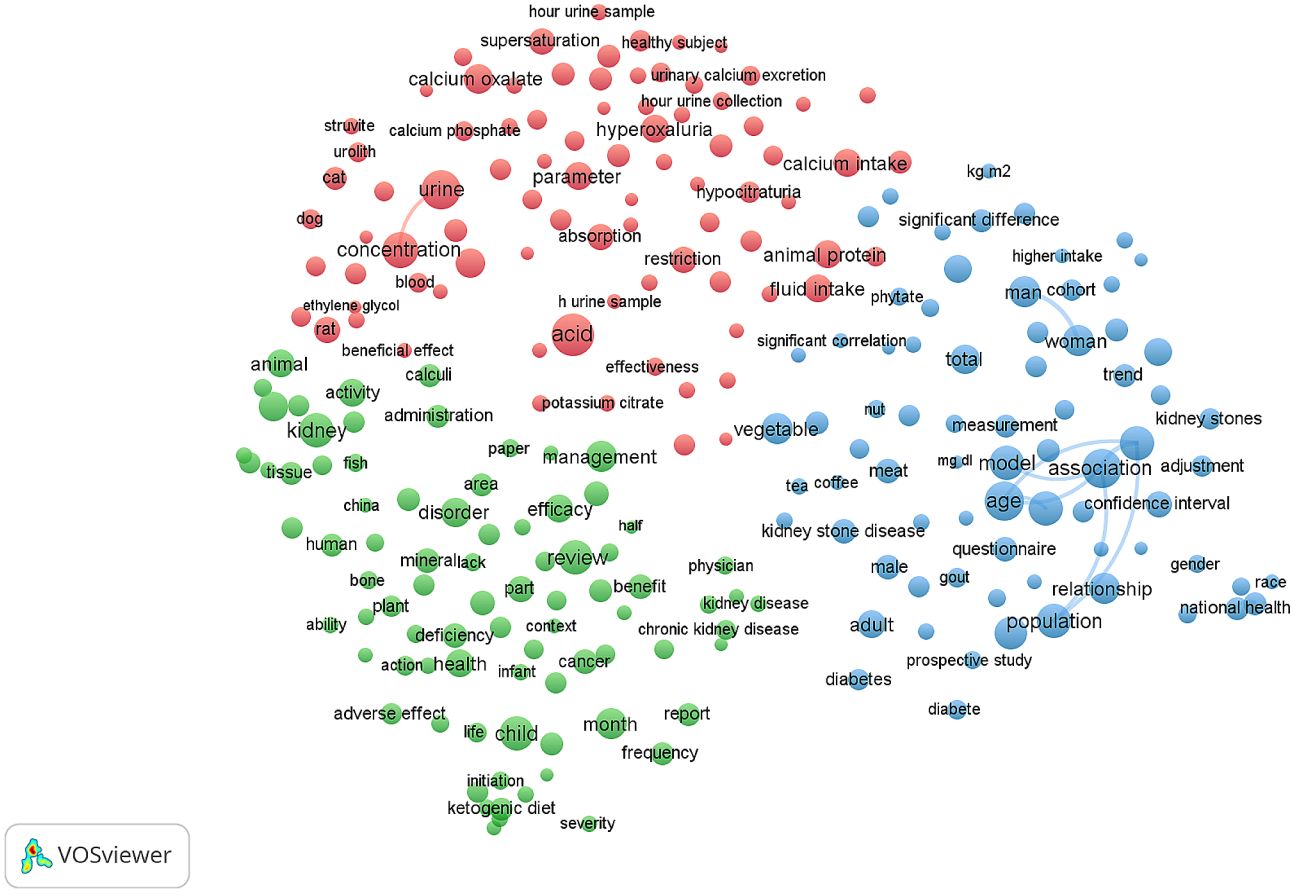

Fig. 3 Map visualizing the network analysis of terms found in titles and abstracts, with a minimum frequency of ten or more

oxalate kidney stones." However, the most recent research trends, discovered after 2015, focused primarily on *"gender differences in kidney stone disease.'*

Discussion

In this study, we performed a bibliometric analysis using VOSviewer software to examine the developmental patterns and main research areas related to nutrition and kidney stones. Our investigation used the Scopus database and focused on publications from 2003 to 2022. We acquired 697 relevant documents published between 2002 and 2021, providing us with a substantial dataset. The findings of our study demonstrate a consistent and significant increase in the volume of research related to the literature on nutrition and kidney stones over the past two decades. We anticipate that this trend will persist in the foreseeable future.

Research on nutrition-related kidney stones has increased significantly in recent decades. In 2003, 107 articles were published on this subject, and 229 were published in 2021. Correlation analysis revealed a moderately positive correlation between publication number and year ($r=0.722$, $p=0.002$). Several factors may explain the increase in research output [2, 56]. First, nutrition seems to have gained more importance in preventing and treating kidney stones. Second, research methods can help researchers study nutrition and kidney stones. In addition, research funding could be increased. For these reasons, interest in this area is growing. Learning more about the role of nutrition in preventing and treating kidney stones is encouraged.

This study illuminates the study of nutrition and kidney stones worldwide. This proves that the United States is a pioneer in this field and that international cooperation is strong. This partnership is crucial to understanding the causes and prevention of kidney stones. This is expected, as the United States is the world leader in science, especially medicine [57]. Our findings confirm previous studies [13–15, 58–60] showing that the United States is the leader in nutritional research. These findings may help to illuminate research on nutrition and kidney stones worldwide. First, it shows that the United States is leading the research in its articles. Strong research infrastructure and many American researchers in this area may explain this. Our findings indicate that research into nutrition and kidney stones is increasing in developing countries. This is important because kidney stones are a global problem,

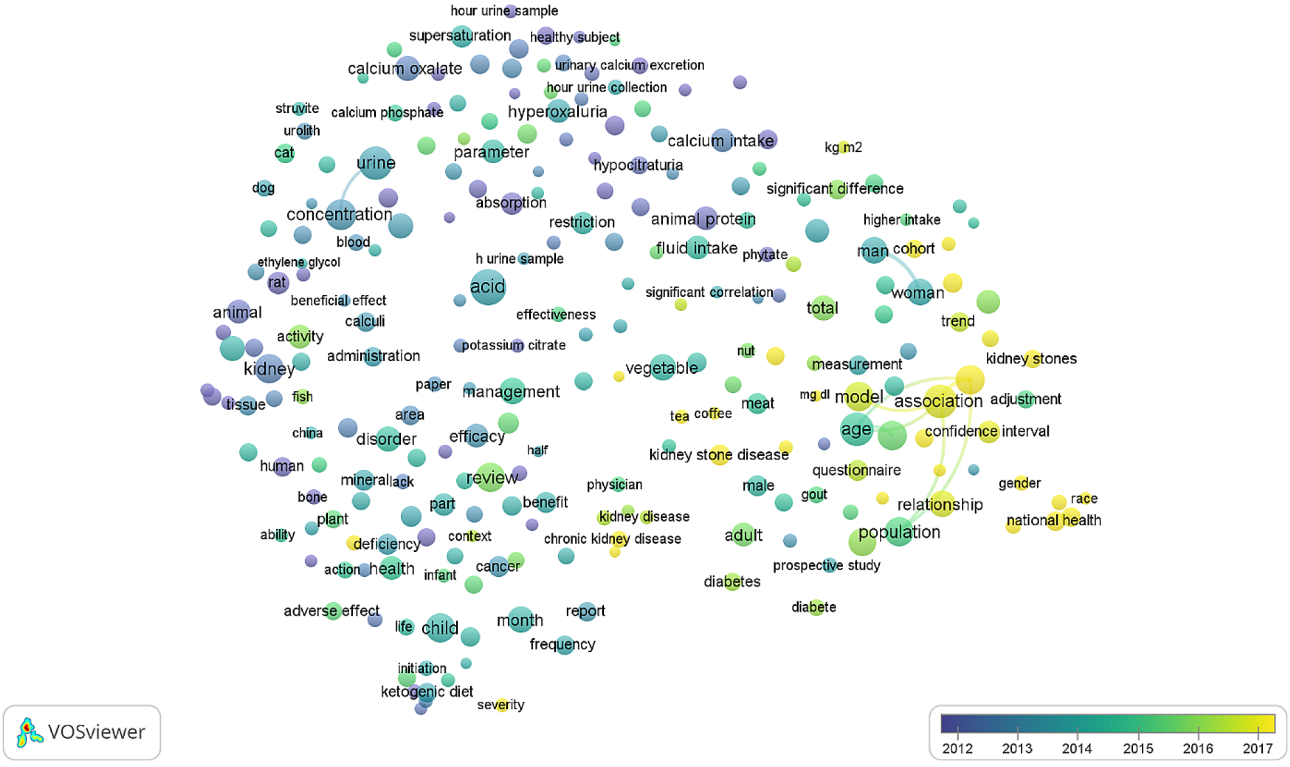

Fig. 4 Map of a network visualization analysis of terms in titles and abstracts based on their frequency of appearance. Blue indicates earlier occurrences of the terms, whereas yellow indicates later occurrences. VOSviewer software version 1.6.19 was utilized to create the map

and understanding their risks and prevention strategies is vital.

Research carried out in the United States is advancing the understanding of the link between diet and kidney stones around the world. Diet plays a crucial role in the formation of kidney stones, with certain dietary habits significantly impacting the risk. High salt intake, consumption of red meat, and consumption of foods rich in oxalates, such as certain vegetables and nuts, have been associated with an increased risk of urolithiasis due to their contribution to increased urine calcium and oxalate levels, which are key components in calcium oxalate stones [61, 62]. On the other hand, the Mediterranean diet, characterized by a high intake of fruits, vegetables, whole grains, and olive oil and moderate consumption of fish and poultry, has been linked to a lower risk of urolithiasis [63, 64]. Therefore, there are significant differences in diet among countries, cultures, and even religions, which may contribute to the formation of urinary stones. Understanding such variation helps to create an international consensus across countries to unmask obstacles related to diet and stone formation. Thus, several strategies can be put in place to raise awareness regarding diet and stone formation globally [65–73]. Sharing knowledge and strengthening capabilities allows for an international agreement and consensus about the influence of people's diets on their risk of developing new kidney stones. Thus, people become aware of their stone formation risk and can take personal measures to avoid new stone formation [74].

Cultural and geographic aspects have a significant impact on exploring the relationship between diet and kidney stone formation [9, 75–77]. Researchers may show some bias in analyzing the dietary risk of stone formation because they rely on the most common type of stone, which is related to the most common local food and beverage [78–80]. For instance, researchers tend to analyze stone formation in developed countries while ignoring poor countries for several reasons. This trend results in a research landscape that predominantly features studies from wealthy countries, lacks global diversity in research participation, and requires more collaborative efforts across different regions and disciplines to fully represent the broad spectrum of kidney stone types and dietary influences [5, 81–83]. Thus, new international studies involving patients from different backgrounds and geographical locations should be conducted to gain better insight into how local diet and lifestyle affect individuals' risk of stone formation.

Term clustering and co-occurrence analysis can identify actively researched topics. In the last two decades, three topics have been extensively studied. The first cluster, "gender differences in kidney stones," explored how sex affects the risk of kidney stones. The second cluster,

"correlation between increasing dietary acid consumption and the occurrence of calcium oxide kidney stones," explored how diet affects stone formation and how to prevent and treat it. The third cluster, "nephrolithiasis associated with ketogenic diet", investigated how a ketogenic diet causes kidney stones.

Our research revealed sex differences in kidney stone disease, a recent hot topic. Diet, fluid intake, and obesity can influence the formation of kidney stones in men and women. However, hormonal influences and anatomical and lifestyle factors can explain why men develop kidney stones more frequently than women do [5, 6]. The risk factors for kidney stones vary depending on sex [84, 85]. High testosterone levels can cause stones due to the urine composition [86, 87]. Longer urethrae in men may slow the passage and growth of stones [56]. High protein and sodium intake can have a greater effect on men [9, 10, 88]. However, pregnancy hormones increase the risk of kidney stones in women [89]. A recent systematic review examined sex differences in kidney stone disease [6]. The study revealed that the risk of kidney stones decreased between men and women. Women, especially adolescents, have more kidney stones. Kidney stones also reduce the quality of life of women and increase the risk of infection after surgery. High temperatures cause kidney stones in men.

Another area of research that is receiving significant attention is the connection between increased consumption of acidic foods and the occurrence of calcium oxalate kidney stones. Several studies conducted to date [9, 90–93] have examined the relationship between dietary acid load and calcium oxalate stones. Consistently, these studies have demonstrated a greater risk of kidney stones in individuals with higher dietary acid load scores. Compelling evidence underscores the importance of dietary intake in the formation of kidney stones [9, 11, 46, 94, 95]. Adopting a healthy eating pattern such as the DASH diet (Dietary Approaches to Stop Hypertension), which emphasizes consuming fruits, vegetables, and whole grains while limiting salt, saturated fat, and sugary beverages, can lower the risk of kidney stones. This is because certain foods increase the pH of urine, thus reducing the possibility of the formation of kidney stones. Conversely, a diet rich in animal proteins and sugar beverages can reduce the pH of the urine, thereby increasing the risk of kidney stones.

The potential relationship between a ketogenic diet (KD) and kidney stones is currently being studied. Although KD has established benefits such as weight loss characterized by its high fat and low carbohydrate composition, some studies suggest that it may also increase the risk of kidney stones [96–99]. This potential risk is due to increased urine excretion of calcium and uric acid, the main components of kidney stones. In addition, the restriction of fluids often recommended during KD can further contribute to stone formation. However, other studies [100–102] have not established a definitive association between KD and kidney stones. Interestingly, some studies suggest that increased calcium excretion in the urinary tract associated with high-fat diets may even protect against calcium-based stones. Consequently, while further research is necessary to definitively explain the relationship between KD and kidney stones, people with a history of renal lithiasis (kidney stones) may benefit from consulting a health professional to discuss possible food changes.

Kidney stone formation is indeed a complex and multifactorial process. The relationship between environmental factors and an increased risk of kidney stones is well established, as exposure to hot climates can lead to higher rates of dehydration, concentrating minerals in the urine that can precipitate into stones. This phenomenon is particularly noticeable in regions with hot climates, such as some Arab countries and Africa, where the prevalence of kidney stones tends to increase [76, 81, 103, 104]. Maintaining adequate hydration by increasing water intake is a critical preventive measure, as it dilutes urinary minerals and prevents homogenous and heterogeneous nucleation [105–107]. In addition, a preference for sugary beverages and salty foods in wet climates can exacerbate this hazard [106, 108, 109]. Similarly, engaging in regular physical activity can also mitigate this risk by improving overall metabolic health and potentially reducing urine concentrations of stone-forming minerals. Although genetic predispositions to kidney stones cannot be modified, understanding the influence of modifiable lifestyle factors is crucial for prevention and management [2].

Research strengths and limitations

This is the first bibliometric study to examine the association between nutrition and kidney stones. It provides a quantitative analysis of the most influential publications on the subject. The authors recognize the significant contributions to the development of this specialized discipline. However, there are some limitations to the investigation. First, the search was restricted to Scopus, excluding other databases such as PubMed, Google Scholar, and Web of Science. This may have caused the omission of pertinent articles. Regrettably, in bibliometric analyses, only one database can be utilized due to the inability to merge and analyze data from multiple databases. This is in contrast to systematic reviews, which typically aim to retrieve a comprehensive set of relevant studies using multiple databases. Additionally, to address publication bias, systematic reviews often go beyond simply searching databases. They may include contacting relevant researchers to identify unpublished studies, particularly those with negative or null results, which may

be underreported. This helps ensure a more complete understanding of the research landscape, including situations where for example, no significant link between kidney stones and nutritional status was found. Second, the research strategy may contain errors. Both false-positive and false-negative results may have been included. However, the authors believe that title searches substantially reduce the number of research errors. With 697 articles in total, we anticipate that the occurrence of false positive or negative results will be minimal, thereby having little impact on result accuracy. Additionally, employing keywords solely in title search, rather than including title/abstract/keywords, would reduce the likelihood of false positives and negatives, while also limiting the number of non-relevant articles to a tolerable minimum. Third, the accuracy and completeness of the keywords used determine the reliability of the data. Therefore, some significant and influential articles may not have been included in the list, as their titles did not contain any particular mentions of nutrition or diet.

Conclusions

This is the first bibliometric analysis of nutrition and kidney stone research. Over the past two decades, the field of nutrition and kidney stones has experienced substantial growth in research output, reaching its peak in 2021. Research productivity in this area has been particularly notable in the United States, with Italy, China, Germany, and India also actively contributing. The United States has also shown strong collaborative efforts with other countries in this field. Research topics within this domain can be grouped into three primary groups: investigating sex differences in kidney stone disease, exploring the link between increased dietary acid consumption and the development of calcium oxalate kidney stones, and studying the connection between the ketogenic diet and the occurrence of kidney stones. These findings generally indicate a growing interest in nutrition and kidney stones, with a focus on gender disparities, dietary influences, and management strategies. Continued research in these areas can significantly improve our understanding, prevention, and treatment of kidney stone disease.

Future Clinical Perspectives

Nutritional and kidney stone research has many implications:

- Additional research is needed to fully understand the complex relationship between nutrition and kidney stones, particularly the impact of different nutrients on the formation of calcium oxide stones. These data can lead to the development of individual dietary interventions and preventive measures.
- An ongoing investigation is essential to expand options and discover innovative prevention therapies. In combination with contemporary interventions such as medications, gradual food changes can improve patient results and reduce stone formation.
- It is imperative that researchers from all over the world cooperate to advance our understanding of the impact of nutrition on renal stones. The integration of global information and knowledge can lead to robust evidence-based approaches for the prevention and treatment of a wide range of problems.
- Further research on the increasing emphasis on sex differences in kidney stones is needed. Subsequent investigations should investigate the underlying factors and variables that contribute to these differences to develop a specific prevention and therapeutic strategy for each sex.

Abbreviations

MeSH	Medical Subject Headings
IF	impact factor
JCR	Journal Citation Report
DASH	Dietary Approaches to Stop Hypertension
WoS	Web of Science
KD	ketogenic diet

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Author contributions

S.H.Z. contributed to the data management, conceptualization, methodology, data collection, interpretation, and preparation of the original draft. F.A. participated in the data interpretation and validation and contributed to the conceptualization and methodology of the study. M.H.S. contributed to the conceptualization and methodology of the study, participated in data interpretation, and contributed to manuscript writing while making revisions to the initial draft. H.S., A.S.A., A.K., A.A.T., S.W.A., M.S., and A.A.J. participated in data interpretation and validation, contributed to manuscript writing, and made revisions to the initial draft. All authors provided a critical review and approved the final manuscript before submission.

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Data availability

The datasets generated and/or analyzed during the current study are available upon request from the corresponding authors.

Declarations

Ethics approval and consent to participate

There was no need for ethical approval because the data for the bibliometric research were extracted directly from the database without further human intervention.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Author details
[1]Department of Clinical and Community Pharmacy, College of Medicine and Health Sciences, An-Najah National University, Nablus 44839, Palestine
[2]Clinical Research Centre, An-Najah National University Hospital, Nablus 44839, Palestine
[3]Department of Medicine, College of Medicine and Health Sciences, An-Najah National University, Nablus 44839, Palestine
[4]Department of Urology, An-Najah National University Hospital, Nablus 44839, Palestine
[5]Department of Hematology and Oncology, An-Najah National University Hospital, Nablus 44839, Palestine
[6]Division of Clinical Pharmacy, Hematology and Oncology Pharmacy Department, An-Najah National University Hospital, Nablus 44839, Palestine
[7]Department of Biomedical Sciences, Faculty of Medicine and Health Sciences, An-Najah National University, Nablus 44839, Palestine
[8]Department of Pathology, An-Najah National University Hospital, Nablus 44839, Palestine
[9]College of Pharmacy and Health Sciences, Ajman University, Ajman, United Arab Emirates
[10]Department of Health and Safety, Dubai Municipality, Dubai, United Arab Emirates
[11]Department of Nutrition, An-Najah National University Hospital, Nablus 44839, Palestine

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