

Original Research

A Bibliometric Analysis of Global Research Trends in Polycystic Ovary Syndrome and Metformin

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Abstract

Background: Polycystic ovary syndrome (PCOS) stands as one of the most prevalent endocrine disorders affecting women of reproductive age. Despite being recognized for decades, numerous unresolved issues persist regarding its impact on reproductive medicine. Metformin, a widely utilized drug in clinical practice for PCOS management, has attracted researchers' attention due to its pharmacological mechanism and novel drug combination methods. **Methods:** This study employs bibliometric analysis to comprehensively examine the research progress in this field. The statistical source for this paper is Web of Science, covering the entire timespan. Utilizing various tools such as Web of Science, VOSviewer, and CiteSpace for analysis, the focus is on countries, institutions, authors, journals, and keywords. Data encompass the total number of papers published, total citations, and the average number of citations per paper. **Results:** Our analysis uncovered 2817 papers within the statistical range, with both paper count and citations exhibiting a rising trend over the years. The United States, China, and the United Kingdom emerged as influential countries in this field. Primary research areas include molecular biology, immunology, and clinical medicine. While China has made significant progress in recent years, there is room for improvement in the average number of citations per article, highlighting the importance of emphasizing article quality. **Conclusions:** The United States has spearheaded research in this field, potentially owing to support from domestic universities. Nevertheless, the notable contribution of Chinese scientists cannot be overlooked. Among universities, the most prolific are the Federal University of Virginia from United States and Fudan University from China. Notably, Glueck CJ is identified as the most productive researcher in this field. Fertility and Sterility, ranking first globally in terms of both article count and citations, emerges as the most popular journal in this field.

Keywords: polycystic ovary syndrome; metformin; web of science; bibliometrics; visual analysis

1. Introduction

Polycystic ovary syndrome (PCOS) is an endocrine disease characterized by hyperandrogenism, polycystic ovarian morphology, and ovulation dysfunction. It is most prevalent among women of childbearing age and typically presents with symptoms such as irregular menstruation, infertility, hirsutism, and acne [1,2]. According to the National Institutes of Health (NIH) standard, the prevalence of PCOS in women of childbearing age ranges from 4.0% to 8.0%. However, based on the Rotterdam Standard, the prevalence of PCOS in this demographic may be even higher [3,4]. Statistics indicate that more than half of women with PCOS are overweight or obese [5]. As of now, the etiology of PCOS remains unclear and involves multiple complex factors, including genetics, environment, and metabolism [6]. Some studies have revealed that a majority of PCOS patients experience insulin resistance, leading to an elevated risk of type II diabetes and cardiovascular and cerebrovascular diseases [7,8]. Commonly used in the treatment of PCOS are *Dendrobium nobile*, Lindlidian-

35, and metformin [9,10]. Metformin, serving as an insulin sensitizer, enhances insulin sensitivity by reducing the conversion of sugar to other substances and improving glucose uptake by relevant organs and tissues in the body [11]. It has been proven to be a suitable therapeutic drug for PCOS [12]. Therefore, conducting research on PCOS and metformin for treating infertility and reducing the risk of diabetes, cardiovascular, and cerebrovascular diseases holds significant importance.

Bibliometrics is an essential discipline that employs the intersection of mathematics and statistical methods for quantitative analysis [13]. Its purpose is to assess the social and scientific significance of a specific discipline within a given timeframe. The literature materials selected for this study are sourced from the Web of Science (core collection), widely acknowledged by many researchers as a high-quality digital literature resource database and considered one of the most suitable databases for bibliometric analysis [14]. To visually analyze papers in the related fields of PCOS and metformin, this study utilized VOSviewer,



Table 1. Ranking of countries with more than 100 publications.

Ranking	Country	Number of publications	Reference number	Average number of references
1	USA	614	30,101	49.02
2	China	377	6380	16.92
3	Italy	245	11,901	48.58
4	UK	188	8443	44.91
5	I.R.Iran	137	1685	12.30
6	Australia	133	6728	50.59
7	Turkey	121	2854	23.59
8	Spain	110	3780	34.36

CiteSpace, and other analytical methods [15,16]. The goal was to comprehend the current development trends and research focus in this field, providing a solid foundation for the scientific research of relevant personnel.

In this study, we have summarized the most prolific researchers in the field, identified the most popular journals, and predicted future research priorities. Our research findings offer valuable insights for newcomers entering the field, as well as providing guidance for researchers seeking to advance their studies in this area.

2. Materials and Methods

2.1 Data Sources and Tools

The retrieved documents are sourced from the Web of Science Core Collection (SCI-E), encompassing SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, ESCI, CCREXPANDED, IC, and other types. Citespace [17] is a Java-based data visualization and analysis software developed by Dr. Chaomei Chen's team. It employs a data normalization approach based on set theory for similarity measurement of knowledge units. The similarity algorithm facilitates the generation of Timezone and Timeline views within a specified time slice, offering a clear depiction of knowledge evolution and the historical span of literature within a specific cluster over time. This approach enhances understanding of the field's development process and trends.

In CiteSpace parameter settings, the time slice is configured at 1 year. VOSviewer [18], launched in 2010 by Nees Jan van Eck and Ludo Waltman from Leiden University, is a software tool designed for creating and exploring maps based on network data. While its primary application is in the analysis of academic records, it can be employed for various types of network data, such as social networks. VOSviewer explores co-authorship, co-occurrence, citation, bibliographic coupling, and co-citation links, offering three potential representations: network, overlay, or density visualization [19].

2.2 Retrieval Strategy

The subject search utilized the query “topic = Polycystic ovary syndrome AND topic = metformin”. The search encompassed all years and concluded on January 18, 2023.

The search, conducted on the Web of Science Core Collection (WOSCC) under the specified conditions, produced results exported to a plain text file in txt format for storage. To comply with CiteSpace requirements, which only recognizes files named “download_*.txt”, a renaming process is necessary before placing them in a designated folder named “input”. CiteSpace and VOSviewer were employed to construct relevant knowledge graphs [20,21]. Fig. 1 illustrates the flowchart depicting the literature search and selection process.

2.3 Research Methods

By employing literature statistics, the gathered literature was incorporated into the WOS tags results list, and the analytical capabilities of the Web of Science were utilized for data analysis. All acquired files and their referenced documents were stored in plain text (txt) format and subsequently imported into VOSviewer and CiteSpace as datasets for further analysis. CiteSpace and VOSviewer were instrumental in generating relevant knowledge maps, with each software program offering unique strengths that complemented one another. Through these analytical methods, the objective was to comprehensively grasp the development status and trends of PCOS and metformin.

3. Results

3.1 Analysis of Global Trends in Publications and Citations

After excluding irrelevant papers, a total of 2817 research papers and 10,248 authors from 2672 institutions across 89 countries were analyzed. These papers were published in 687 journals and received 51,793 citations from 7457 journals. Academic papers (1915) constituted 67.98% of the total, followed by reviews (556, 19.74%), conference abstracts (143, 5.08%), and social discussion materials (108, 3.83%) (Fig. 2). The number of papers has shown an increasing trend over time, with the total number of citations reaching 88,628. The average number of citations per paper is 34.16, and the h-index is 129 (Fig. 3).

3.2 Analysis of the Contributions of Countries/Regions

To identify the nationalities of the authors most actively engaged in the field, data analysis was conducted us-

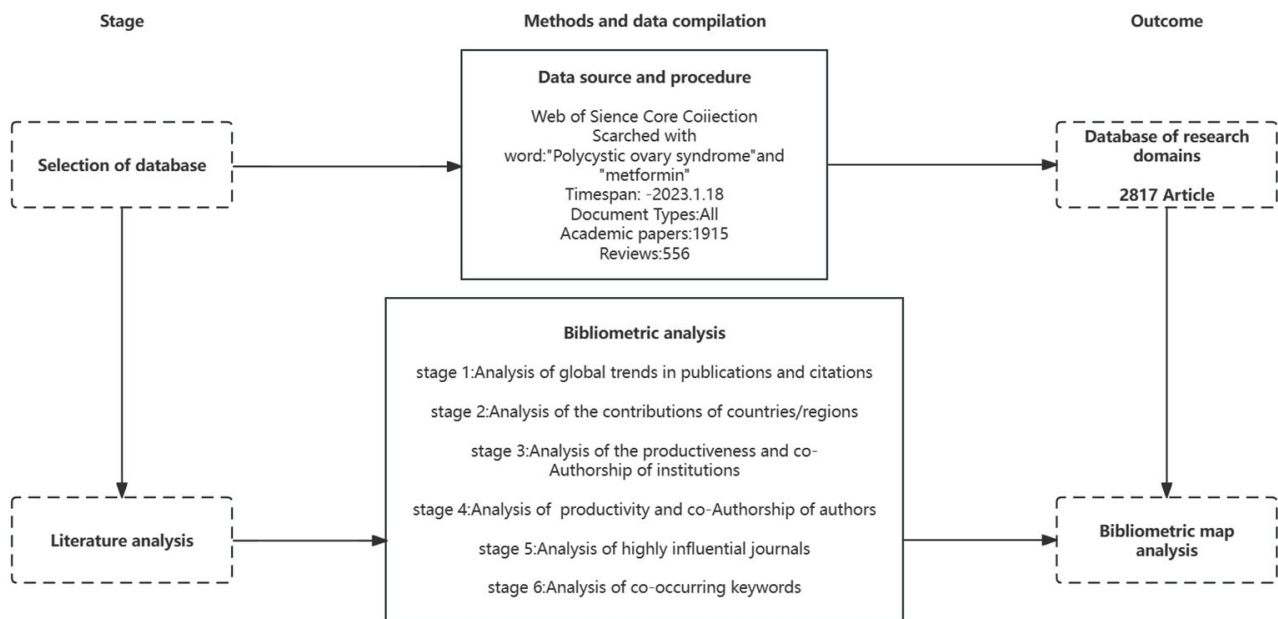


Fig. 1. Flow chart of the study.

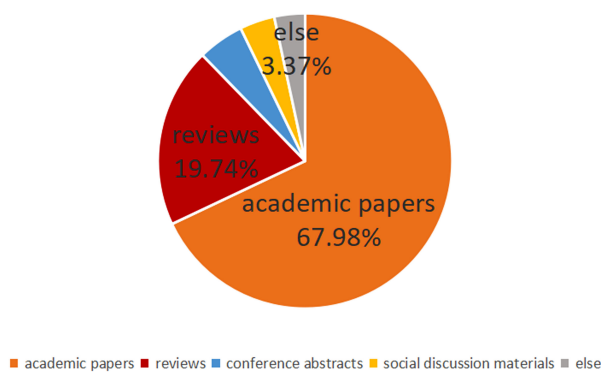


Fig. 2. Types of literatures.

ing VOSviewer. The results revealed authors from 89 countries contributed to the papers. By filtering countries with over 100 papers, the top nations in terms of paper count were the United States, China, Italy, the United Kingdom, and Iran (Table 1). The United States led with the highest paper count at 614 papers and 30,101 citations. Australia boasted the highest average number of citations, averaging 50.59 citations per paper. A national visualization map, generated using CiteSpace (Fig. 4), displayed 89 nodes representing countries, with the circle size indicating the total number of papers published by each country. Connections between nodes illustrated collaboration between countries within the same article. Fig. 4 indicates a notable tip effect, with a majority of contributions originating from scholars in a select few countries.

3.3 Analysis of the Productiveness and Co-Authorship of Institutions

VOSviewer was employed to analyze the institutions associated with the documents. The results revealed contributions from 2672 institutions, with the highest number of publications originating from Virginia Commonwealth University (64 papers and 5808 citations, averaging 90.75 citations per paper) (Fig. 5). This suggests that articles from this institution are of notable quality and have garnered significant attention in the realm of PCOS and metformin research. Upon scrutinizing the documents published by the institution, it was observed that the predominant type was research papers. A visual analysis was conducted for institutions with 10 or more documents, resulting in the creation of a visual map (Fig. 6). The size of the circular nodes in the figure corresponds to the number of documents published by each institution. Thicker connections between nodes indicate a higher degree of collaboration between the two entities. Nodes of different colors signify distinct clusters, with the figure displaying 22 clusters. Figs. 5,6 illustrate that research institutions affiliated with universities have a substantial output of documents.

3.4 Analysis of Productivity and Co-Authorship of Authors

By analyzing the literature's authors, we can pinpoint representative scholars and core research forces within a specific field of study. According to Price's Law, approximately half of the articles are written by a group of high-yield writers, constituting about the square root of all writers. Utilizing VOSviewer for a visual analysis of the authors, we identified that the maximum number of papers published by an individual author is 45. Consequently, this

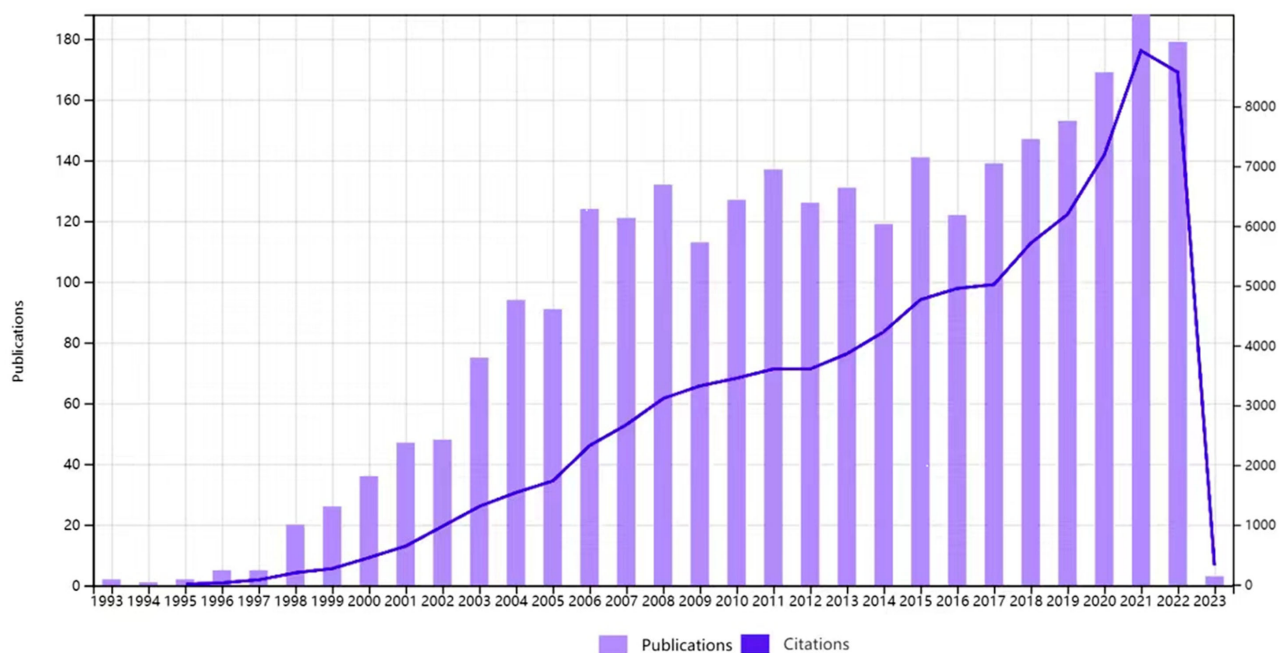


Fig. 3. Annual publication and citation chart.

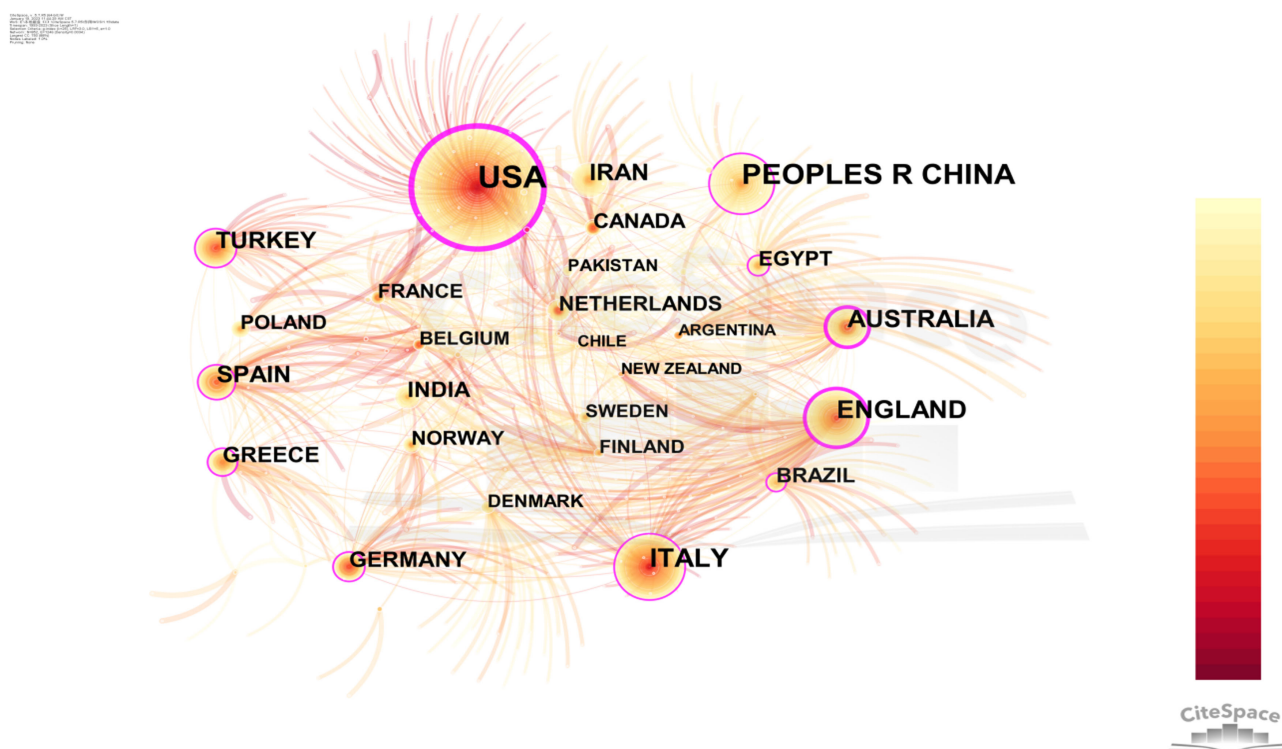


Fig. 4. Visual map of the countries.

study focuses on the five main authors who contributed significantly to these papers. According to the data, a total of 257 core writers have published papers, accounting for more than 50% of the total number of papers. This suggests the establishment of a relatively stable author cooperation network in this field (Fig. 7). Authors with over

30 papers were selected as high-productivity authors and are listed in Table 2. Among these highly productive authors, Glueck has the highest paper count, with 45 papers published during this period and 3051 citations obtained, averaging 67.80 citations per article. Wang ranked second, with 43 papers published and 3439 citations obtained, av-

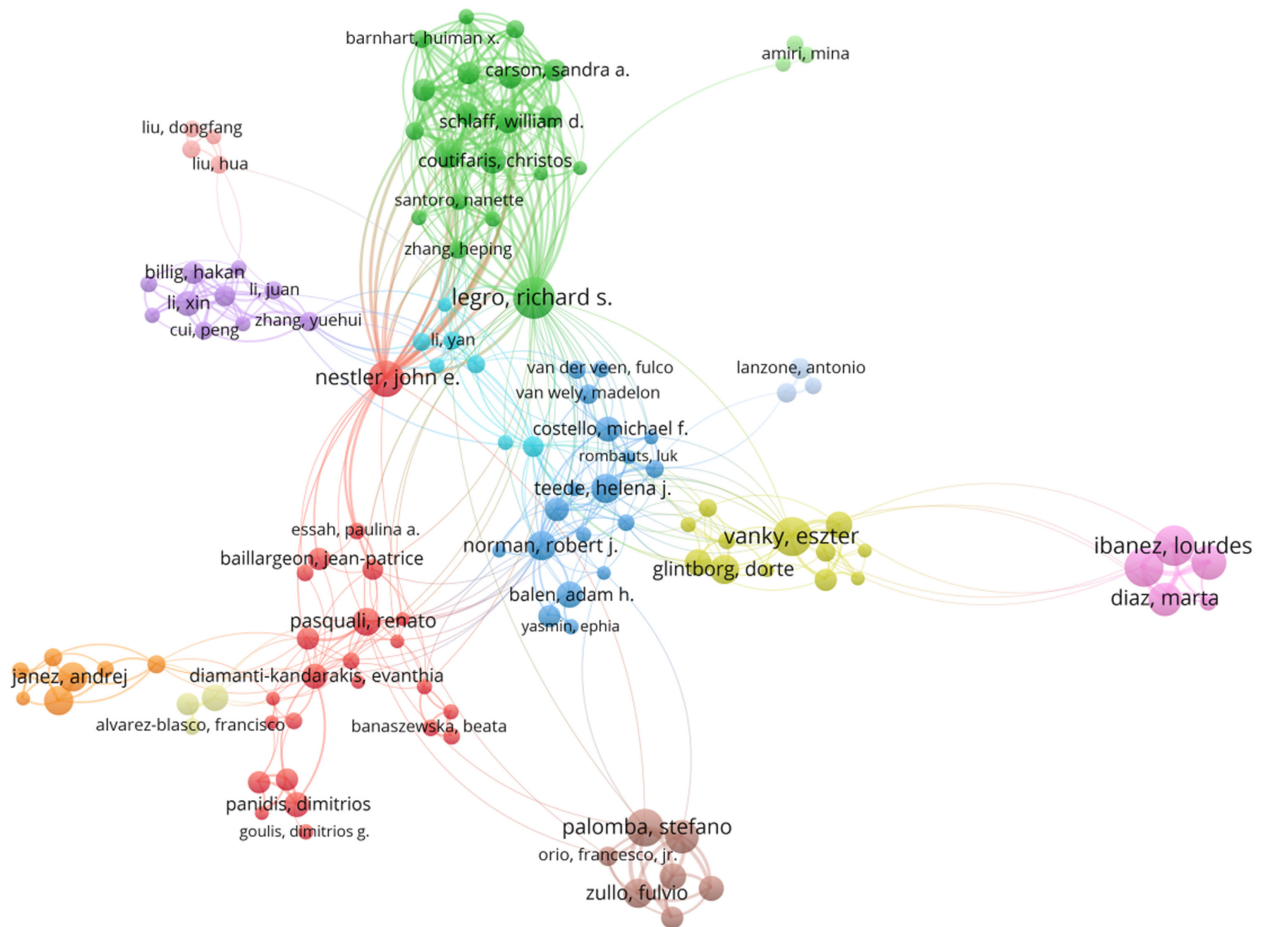


Fig. 7. Collaborative network of 257 core authors.

eraging 74.98 citations per article. Both scholars have affiliations with the Cholesterol Center of the Jewish Hospital in Ohio, USA, and have collaborated extensively during this period. Their research primarily focuses on adolescent and pregnant women with PCOS, delving into the outcomes of pregnancy treatment with metformin [22], its prevention [23], and efficacy [24].

3.5 Analysis of Highly Influential Journals

By utilizing VOSviewer for a visual analysis of the journals containing the published documents, we observed that the majority originated from influential journals in the field of reproductive science, with only a small fraction appearing in comprehensive journals. We compiled a list of journals with over 40 articles (Table 3). Notably, the Journal of Fertility and Sterility, Journal of Clinical Endocrinology & Metabolism, Human Reproduction, and Genetic Endocrinology stood out, each boasting 228, 147, 137, and 129 papers, respectively. All four journals are affiliated with the Chinese Academy of Sciences, with the first three belonging to the first district of the Chinese Academy of Sciences and ranking as top journals in the field of repro-

ductive science. These journals exhibit an average citation count exceeding 40, indicating the high quality of the articles published, a recognition affirmed by academics and appreciated by scholars in the reproductive science domain. By filtering out journals featuring more than 10 articles in each issue, we generated a visual network map (Fig. 8), revealing a clear clustering pattern.

3.6 Analysis of Co-Occurring Keywords

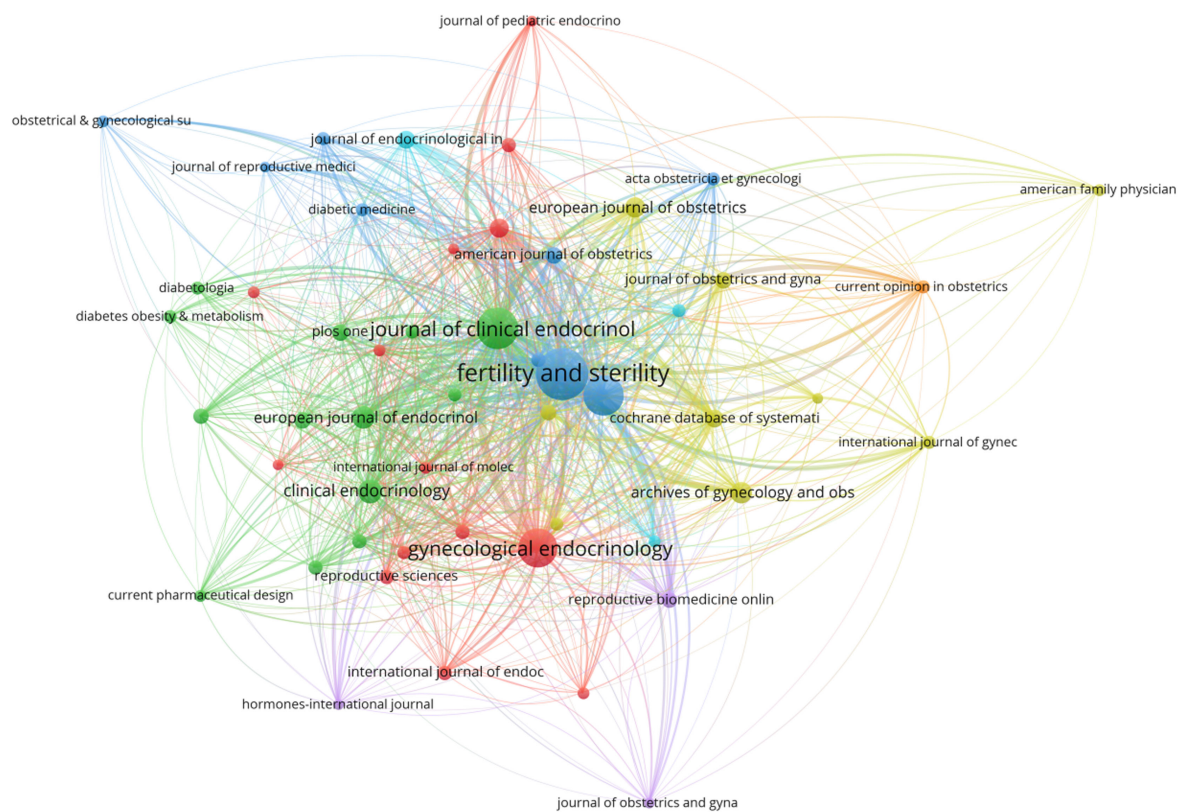
Analyzing keyword networks is crucial for identifying hotspots within a field. VOSviewer was employed to analyze the source file, revealing a total of 5382 keywords. Keywords with a frequency equal to or greater than 10 times were selected to construct a keyword visualization network (Fig. 9). In Fig. 9, the closer the color is to red, the more recent the year associated with the keyword. A majority of the keywords identified appeared around 2020, highlighting the current focus of research in the field of PCOS, particularly on topics such as insulin resistance, obesity, hyperandrogenemia, and clomiphene. Subsequently, using Citespace to generate the keyword explosion map (Fig. 10), it was observed that “metformin therapy” emerged as the most

Table 2. Chart of high productivity authors.

Ranking	Author's name	Number of publications	Citation times	Average number of references
1	Glueck CJ	45	3051	67.80
2	Wang P	43	3439	74.98
3	Legro RS	39	3543	90.85
4	Lbanez Lourdes	37	838	22.65
5	Vanky Eszter	35	781	22.31
6	De Zegher Francis	34	762	22.41
7	Palomba Stefano	33	1260	38.18
8	Nestler John E.	30	1761	58.70

Table 3. Journals with more than 40 articles.

Ranking	Journal title	Volume of journal articles	Number of citations	Average number of references
1	Fertility and sterility	228	9335	40.94
2	Journal of Clinical Endocrinology & Metabolism	147	13,212	89.88
3	Human Reproduction	137	6012	43.88
4	Gynecological Endocrinology	129	2495	19.34
5	Clinical Endocrinology	48	1517	31.60
6	European Journal of Endocrinology	42	1959	46.64

**Fig. 8. Journal visualization network.**

strongly associated term in the outbreak. This prominence is attributed to the widespread use of metformin as a common treatment for PCOS.

4. Discussion

The Web of Science is a widely recognized digital database renowned among scholars for its extensive collection of documents. The website's data analysis capability allows researchers to calculate the number of papers

Top 25 Keywords with the Strongest Citation Bursts

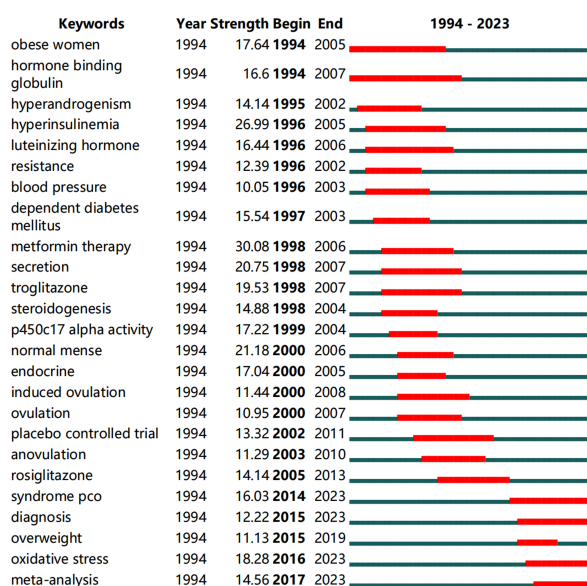


Fig. 10. Keyword outbreak diagram.

American scholars have played a pivotal role in advancing this field, evident when analyzing the author's nationality. The United States holds the top global position in terms of total publications, citations, and the average number of publications. Notably, at Virginia Commonwealth University, scholars assert that metformin, despite being an established drug, harbors untapped potential to enhance metabolic status and endothelial function in women with PCOS [43,44]. The institution is actively exploring the mechanisms of metformin's action in PCOS-afflicted women [45,46] and expresses a willingness to collaborate with other institutions and individuals seeking such partnerships. While Chinese scholars have made noteworthy contributions, there is a recognized need to elevate the quality of their articles. At the institutional level, a concentration of high-volume papers is observed predominantly in the United States. Noteworthy institutions in this research domain include Virginia Commonwealth University (USA), Barcelona University (Spain), and Adelaide University (Australia), all holding top positions globally. In China, Fudan University and Heilongjiang University of Traditional Chinese Medicine exhibit robust research capabilities in this field, although there remains a discernible gap when compared to the United States. Researchers are encouraged to consider these institutions as valuable references for further research and potential collaborations.

Glueck CJ, Wang P, and Legro Richards, three highly productive researchers, along with the top three journals, namely, "Fertility and Sterility", "Journal of Clinical Endocrinology & Metabolism", and "Human Reproduction", are globally renowned for their exceptional contributions to the total number of papers published in the field, as well

as the total number of citations and the average number of citations per paper. Notably, Jack, the author, shares a similar focus on the clinical application of metformin in treating PCOS [47], with a specific emphasis on the teenage population [48]. Researchers seeking valuable insights can prioritize these authors and journals for their literature reviews. A preliminary examination of literature published in the past five years highlights persistent research themes in this field, including the diagnosis of PCOS, novel application methods of metformin in PCOS, clinical experimental research, and biochemical mechanism investigations. The study envisions increased international collaboration in the future, emphasizing the potential for breakthroughs in basic scientific research in developing countries to bring positive advancements for patients with PCOS.

Furthermore, an examination of keywords has the potential to unveil emerging research themes. In light of the keyword analysis conducted on relevant studies, it is suggested that oxidative stress may emerge as a focal point for future investigations in this field [49,50]. Given the recent advancements in genomics and proteomics technologies, there is speculation that forthcoming research may involve molecular biological interventions to inhibit oxidative stress [51,52]. This anticipated shift represents a prospective trajectory for research in the field and holds significant implications for its advancement.

While this article presents a visual analysis of the PCOS and metformin-related fields, certain shortcomings and deficiencies should be acknowledged. The data source is confined to the Web of Science Core Collection, potentially leading to partial literature omission due to incomplete database inclusion. This limitation has the potential to impact the comprehensiveness and accuracy of the results.

5. Conclusions

In conclusion, this study has conducted a visual analysis of the literature on PCOS and metformin. The United States emerges as the leading contributor to research in this field, potentially attributed to the support from domestic universities. Notably, the contribution of Chinese scientists in this domain is also significant. Among universities, the most prolific ones are the United States Federal University of Virginia and China's Fudan University. The most productive researcher in this field is Glueck CJ. The pre-eminent journal in this field is Fertility and Sterility, securing the top position globally in terms of both the number of articles published and citations received. Over the past five years, the focal points of research in this field include the diagnosis of PCOS, novel application methods of metformin in PCOS, clinical experimental investigations, and biochemical mechanism research, all of which warrant further attention.

Availability of Data and Materials

All the data are available upon reasonable request from corresponding author.

Author Contributions

XL and WN designed the whole study; BT, TT and YH performed the analysis; MZ and ML prepared the figures and tables. All the authors approved the manuscript for submission. XL and WN drafted the manuscript. All the authors contributed to editorial changes in the manuscript. All the authors read and approved the final manuscript. All the authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

Not applicable.

Acknowledgment

Not applicable.

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Conflict of Interest

The authors declare no conflict of interest.

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