

Maternal smoking during pregnancy: A scientometric analysis of the 100 most-cited articles

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Maternal smoking during pregnancy is a severe behavioural problem that raises significant public health concerns. A notable amount of research has been published, and its evolution based on citations, knowledge structure, and impact on the scientific community is not entirely understood. This study identifies and describes the top most frequently cited 100 articles on maternal smoking during pregnancy. The top 100 articles were identified using the Scopus data database. Metadata were collected and analysed using bibliometrix and R package. The 100 most-cited articles (83 articles and 17 reviews) were published between 1971 and 2018. Those articles were cited 28 550 times, with a mean number of citations of 285.5 and a range of 189 - 812. A statistically significant positive correlation was observed in the number of the articles and citations score per year ($r=0.635$, $p<0.001$). Fifty-eight of the articles originated from the USA, with 52 in single-country publications and 6 in multiple-country publications. These articles were published in 58 journals, and the *American Journal of Epidemiology* published the most significant number of articles ($n=8$). Analysis through source clustering using Bradford's Law indicated that the top 7 journals are in zone 1 (core journal) for the fields. The most prolific author is Gilliland, with h -index 5. The highest frequency keywords are pregnancy, smoking, maternal smoking, asthma, prenatal, environmental tobacco smoke, infant, abruptio placentae, birthweight and child. Our study offers researchers a thorough examination of the traits of the 100 articles on maternal smoking during pregnancy that have received the most citations, and a way to pinpoint any remaining research gaps.

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Smoking during pregnancy increases the risk of health problems for unborn children. The likelihood that an unborn child may face health difficulties such as preterm birth, low birthweight, birth abnormalities of the mouth and lips increases the more cigarettes a person smokes while pregnant. Preliminary epidemiological evidence from prospective and case-control studies demonstrates the strong correlation between maternal smoking during pregnancy and fetal development, increased incidence of spontaneous abortion, stillbirth and sudden infant death syndrome.^[1-3] Researchers also discovered a dose-response link between maternal smoking rates, low birthweight and spontaneous abortion.^[1] Meanwhile, the observations of a higher prevalence of disruptive behavioural disorders in children whose mothers smoked during pregnancy point to the long-term cognitive and behavioural effects of prenatal exposure to nicotine.^[1] Pregnancy is an important but emotionally sensitive time for most women owing to changes in physical appearance, roles and lifestyle.^[5] These factors are associated with depressive disorder, which increases the risk of adverse perinatal outcomes, which are defined as a newborn with the occurrence

of any of the following outcomes: low birthweight; small for gestational age; preterm birth; stillbirth; or neonatal death before 7 days of life.^[4,5] Recently published studies show that there is a crucial need for social support for women during pregnancy in terms of maternal depressive symptoms, quality of life and outcomes,^[5,6] which requires policy development to enhance social support and improve the emotional, psychological and physical wellbeing of pregnant women.^[6] Further research shows that maternal smoking affects infant health,^[7] and also that prenatal smoking continues to cause a substantial number of infant deaths.^[8] Low-birthweight newborns are more likely to die, and are more susceptible to infections, respiratory problems and long-term health issues as adults.^[9] The nicotine in cigarettes may lead to changes in the uterine and umbilical cord blood arteries, reducing the amount of oxygen delivered to the fetus. The blood volume in the embryonic circulatory system may also be decreased by nicotine, or infants of mothers who smoke may have reduced respiratory function.^[10] However, many studies have brought better insight into this area of research.

In a study,^[11] researchers were able to identify potential research hotspots and frontier trends of the top 100 most frequently cited articles on maternal smoking during pregnancy that proposed that interventions and social participation are effective in preventing prenatal and neonatal adverse birth outcomes, improving self-confidence of pregnant women, increasing resistance to infections and contributing to a healthier lifestyle. Furthermore, there is increased demand for research productivity and policy development to help enhance pregnant women's psychological wellbeing globally.

A large number of research papers on maternal smoking during pregnancy have been published, followed by several systematic review papers. Hence, we attempted to use a comprehensive systematic analysis of the top 100 most-cited articles published in Scopus databases, and provide the scientific community with a thorough quantitative and qualitative evaluation of the scientific landscape of the publications in the field over the past years.

Much work has been done using bibliometric analysis as a tool in medical literature to provide standard indicators for evaluating scientific research outcomes.^[12-25] Owing to the explosion of scientific publications and research over the past few decades and the development of electronic databases, bibliometrics has become an important instrument for tracking trends in scientific research.^[26,27] A bibliometric study helps cover the majority of scientific results. It can analyse and typically inform decision-making for interventions and policy in various scientific research fields.^[13,16,17,24,28-32] As a result, bibliometric evaluation of the 100 most-cited articles on maternal smoking during pregnancy will provide quantitative insights to upcoming researchers in the field to better understand the surge in research output associated with the 100 most-cited papers on maternal smoking during pregnancy that have been indexed in the Scopus database.

Methods

Study design and sampling

A comprehensive systematic analysis of the 100 most-cited articles was designed and followed the PRISMA guidelines (Fig. 1). Ethical approval was unnecessary since the data were downloaded from a public database, and there was no direct contact with human or animal subjects.

Data source

The data used in this study were obtained from the Scopus database (<https://www.scopus.com/>). One of the leading databases for abstracts and citations, it is used for assessing the growth and development of research output.^[30,32,33] Therefore, the data resource used in our research work is standard and reliable.

Literature search

The objective of our bibliometric analysis is to map out patterns and trends in the field of maternal smoking during pregnancy via a literature search of the relevant articles. This was obtained from Scopus using a search strategy based on keywords. All Scopus publications related to maternal smoking during pregnancy were

collected on a single day (8 July 2022), to avoid the daily update of the database. The search term was as follows:

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( TITLE ( ( smoke* OR smoking* OR tobacco* ) ) AND TITLE ( ( pregnancy* OR prenatal* OR perinatal* OR maternal* ) ) ) AND ( EXCLUDE ( PUBYEAR , 2022 ) ) AND ( LIMIT-TO ( DOCTYPE , 'ar' ) OR LIMIT-TO ( DOCTYPE , 're' ) ) AND ( LIMIT-TO ( LANGUAGE , 'English' ) )
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Inclusion and exclusion criteria

The inclusion criteria included all publications related to maternal smoking during pregnancy. The period of interest was all articles up to December 2021. The publication types were restricted to original articles and reviews published in English. Overall, 3 976 documents (3 720 articles and 256 reviews) on maternal smoking during pregnancy were identified. Later, the top 100 most-cited articles were selected based on their citation count, and the retrieval period was searchable by document start 18 August 2022, by title and content of the article. The metadata were exported to the format as CSV comma-separated values format, RIS Text File and BIB Text File, and the output of the raw data was manually screened and processed for further analysis using bibliometric tools. The impact factor (IF) of journals was obtained from Incites Journal Citation Reports (JCR); information was obtained on June 2022 from Journal Metrics Cite Score (<http://www.journalmetrics.scopus.com>).

Bibliometric analysis and mapping visualisation

Quantitative bibliographic information, including annual trend of publications, citations, number of publications, sources, authors, institutions, country or regions, keywords and references, was analysed using Rstudio (Posit, USA), which is a free and open source development environment of R and runs on Windows (Microsoft, USA) operating system, and Bibliometrix (K-Synth, Italy) package was used for data analysis and interpretation.^[34] VOSviewer (version 1.6.6) package program (Leiden University, Netherlands) was used for mapping analysis, and facilitates the visualisation of dynamics and structure of information for the analysed documents.^[35] GraphPad v9.3.1.471 (GraphPad, USA) was used to test the correlation between publications and citations, Pearson's correlation coefficient was calculated, and correlations were considered significant at $p < 0.05$.

Results

Annual trend of publication and citation analysis

The 100 most-cited articles on maternal smoking during pregnancy were published on Scopus from 1971 to 2018, including 83 articles and 17 reviews. The total number of citations for the retrieved papers was 28 550, thus the average number per document was 285.5. Of 58 sources and 493 authors with 17 international co-authorships, were reported (Table 1). The annual number of publications from 1971 to 2018 is shown in Fig. 2. A statistically significant correlation was observed between the top 100 most-cited articles and the mean average of citations per year (Pearson's correlation coefficient ($r = 0.635$, $p < 0.001$)). In addition, the top 100 most-cited articles are shown in Table S1 (appendix <https://www.samedical.org/file/2131>), with average citations ranging from 189 to 812.

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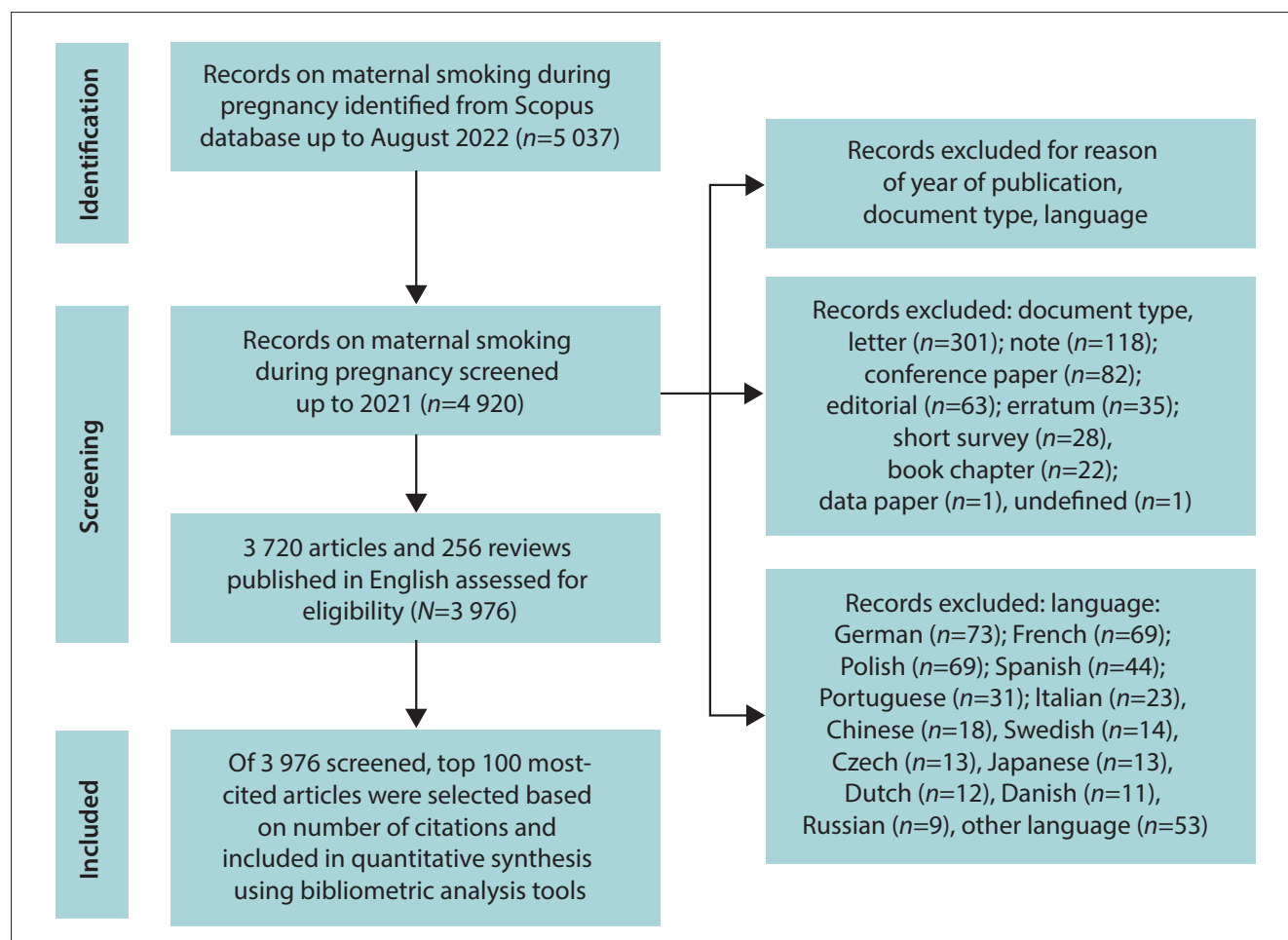


Fig. 1. Flow chart of top 100 most-cited articles on maternal smoking during pregnancy included in the study.

Top sources

There were 58 peer-reviewed journals cited in the top 100 most-cited articles on maternal smoking during pregnancy (1971 - 2018). The *American Journal of Epidemiology* is top-ranked ($n=8$), with citation score (total number of citations (TNC)) 1 851). A total of 10 journals contributed 42% of the publications (Table S2 (appendix <https://www.samedical.org/file/2131>)). Source clustering through Bradford's Law indicated that the top 7 journals are the *American Journal of Epidemiology*, *American Journal of Public Health*, *American Journal of Respiratory and Critical Care Medicine*, *Pediatrics*, *Archives of General Psychiatry*, *American Journal of Preventive Medicine* and *American Journal of Psychiatry*. The core journals on maternal smoking during pregnancy are shown in sources clustering through Bradford's law in Fig. S1 (appendix <https://www.samedical.org/file/2132>).

Contribution of authors

A total of 493 unique authors have contributed to collaborating on the top 100 most-cited articles on maternal smoking during pregnancy. The results revealed that the most active author is Gilliland, with 5 articles and 1 779 total citations (Table S3, appendix <https://www.samedical.org/file/2131>). Further relations between 'authors', 'author keywords' and 'affiliations' on maternal smoking during pregnancy are presented in Fig. 3. Additional scientific productivity compliance

Table 1. Summary of global research

Description	Results
Timespan	1971 - 2018
Sources (journals, books, etc), n	58
Documents, n	100
Total citations, n	28 550
Document average age, years	22.2
Average citations per doc, n	285.5
References, n	5 475
Document contents	
Keywords Plus, n	889
Author's keywords, n	160
Author	
Author, n	493
Author of single-authored docs, n	6
Author collaboration	
Single-authored docs, n	6
Co-authors per doc, n	5.71
International co-authorships, %	17
Document type	
Article, n	83
Review, n	17
Articles received funding, n (%)	47 (47)

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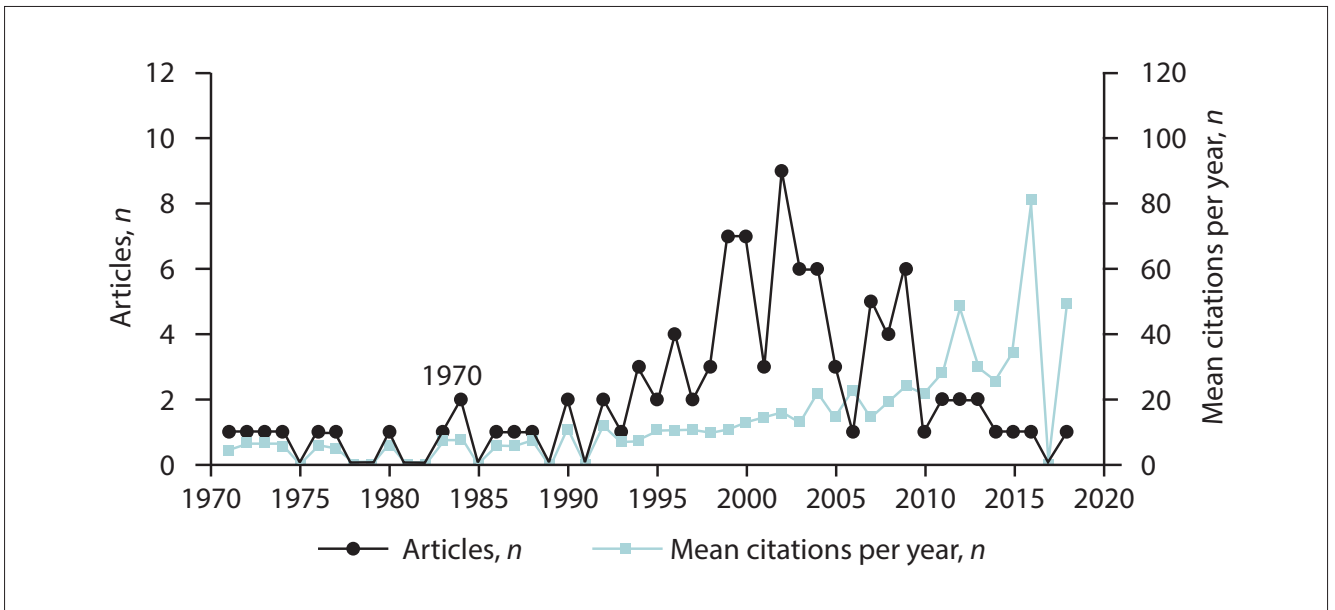


Fig. 2. Annual trends of the top 100 most-cited articles on maternal smoking during pregnancy (1971 to 2018).

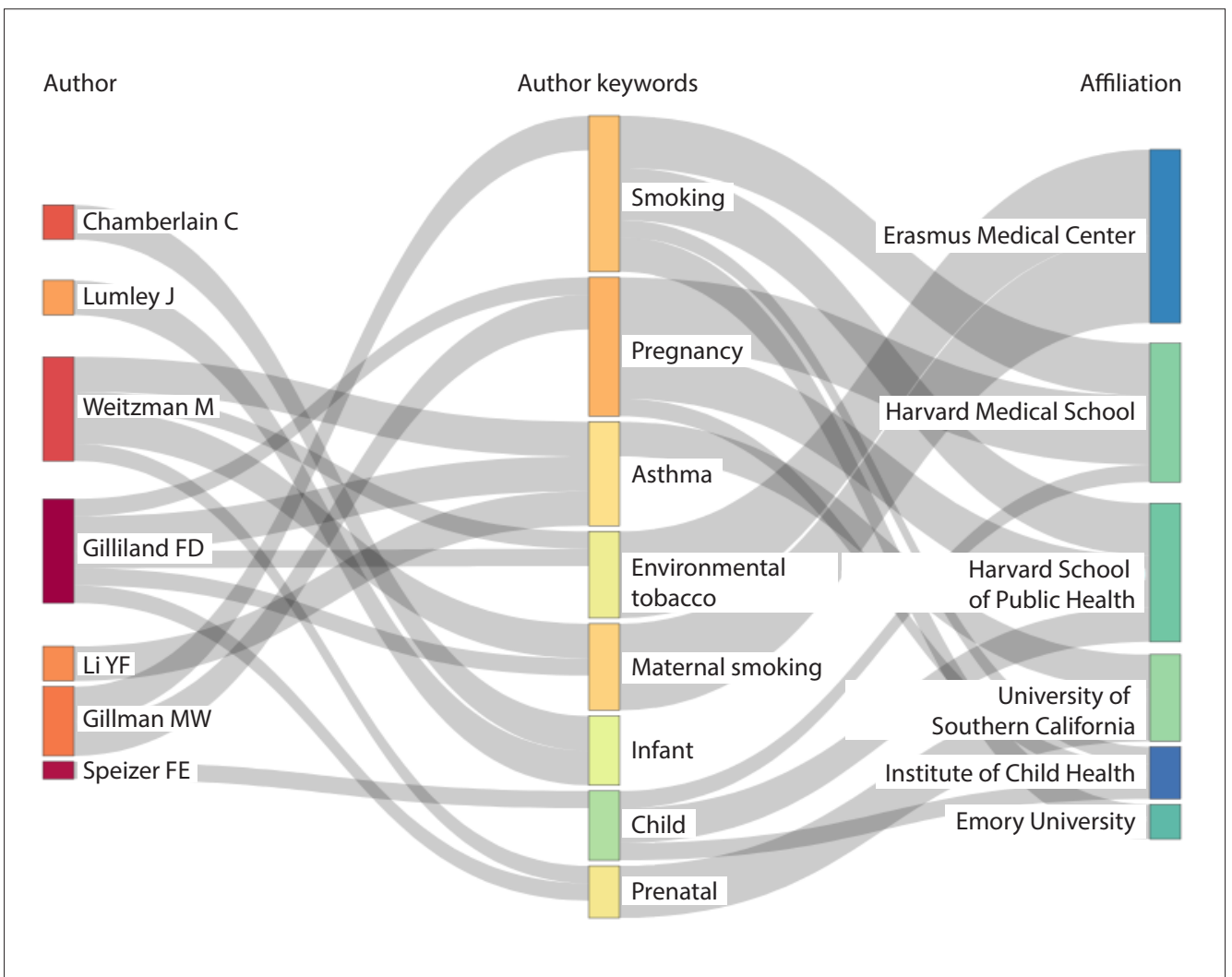


Fig. 3. Three-field plot of the author keywords analysis.

of a group of authors compared with the number of contributions is demonstrated in Fig. S5 (appendix <https://www.samedical.org/file/2132>), using Lotka's law of scientific productivity. We notice that 434 (88.03%) authors contributed to one article, and 46 (9.33%) authors contributed to two written articles in the field.

Most productive and cited countries

Twelve countries contributed to publications on maternal smoking during pregnancy. The most productive, with two or more articles, are presented in Table S2 (appendix <https://www.samedical.org/file/2131>). According to the number of publications, most articles originated from the USA (total number of publications (TNP) = 58, total number of citations (TNC)=16 698), followed by the UK (TNP=13, TNC=3 753) and the Netherlands (TNP=4, TNC=1 063). Furthermore, intra-country and inter-country collaboration on maternal smoking during pregnancy are presented.

Keywords analysis

Co-occurrence analysis keywords are the essence of academic articles; thus, keyword analysis is an essential indicator of a research hotspot. In this study, the keywords co-occurrence network map was constructed with VOSviewer (University of Illinois, USA). Of 889 keywords plus (words or phrases that frequently appear in the titles of an article's references) and 316 titles words, 2 587 keywords in abstracts are reported. The top 10 frequencies are presented in Table S5 (appendix <https://www.samedical.org/file/2131>). In this study, the top 100 authors' keywords visualisation map was constructed using biblioshiny (K-Synth, Italy), an app providing a web interface for Bibliometrix. The 10 ten most frequent authors' keywords are pregnancy, smoking, maternal smoking, asthma, prenatal, environmental tobacco smoke, infant, abruptio placentae, birthweight and child (Fig. S6, appendix <https://www.samedical.org/file/2132>).

Conceptual structure for top keyword plus

In conceptual structure, the analysis of 50 top keywords is divided into three clusters: first cluster in red (4 keywords: review, fetus, infant mortality, and prematurity); second cluster in blue (7 keywords: child behaviour, risk factors, preschool, humans, pregnancy complications, tobacco smoke pollution and maternal exposure); and third cluster in green (36 keywords), as presented in Fig. S2A. Further analysis of 50 keywords plus using correspondence analysis were grouped based on the association and similarities into three different clusters. The first cluster in red with focus themes (four keywords: pregnancy outcome, premature labour, smoking cessation and review), the second cluster in blue (three keywords: support, birthweight and infant mortality), and third cluster in green included keywords with focus themes (USA, fetus, infant newborn, low birthweight, prematurity, gestational age risk factors), as presented in Fig. S2B.

Co-citation analysis

Journals

Co-citation analysis was done using VOSviewer. In total, 20 journals (minimum number of documents per author = 2) were analysed (Fig. S3A). The journal with the largest total link strength was the

American Journal of Public Health (TLS=21), followed by *American Journal of Psychiatry* (TLS=19), *Archives of General Psychiatry* (TLS=19) and *Pediatrics* (TLS=18).

Authors

Co-citation analysis of 42 authors with a minimum of two documents was based on the total length strength (TLS). The authors with the largest TLS were Gilliland (TLS=61), followed by Weitzman (TLS=51), Peters (TLS=48), Li (TLS=41) and Speizer (TLS=38) (Fig. S3B).

Most relevant affiliations

Of the 188 most relevant affiliations reported, the University of Southern California is the top affiliation, with 8 articles, Harvard Medical School with 7 articles and Harvard School of Public Health with 7 articles (Fig S4).

Discussion

This study examined the top 100 articles on maternal smoking during pregnancy based on trends and citation scores. The study adopted a bibliometric technique to analyse published research productivity on maternal smoking during pregnancy, using approaches from similar studies.^[13-15,17,24] Aggregating the trends of highly cited research on maternal smoking during pregnancy published in Scopus databases can enhance policy intervention, support future research direction and help target the risk factors. While there has been no bibliometric research conducted in this domain, our research presents a novel contribution to the field by thematically analysing the top 100 most-cited articles on maternal smoking during pregnancy. Citations as an index for authors' performance, knowledge structure and the growth of research indicated the impact on the scientific community.^[15,36]

In recent years, academic research and professional publications have examined research impact by using systematic and thematic analysis.^[15,17,21,37,38] Using information from the Scopus database, we identified the 100 articles that had been cited most frequently, the top contributing publishers, and the countries representative of the most prolific authors. The earliest article on the subject was published in 1971, entitled 'The epidemiology of smoking during pregnancy: Smoking prevalence, maternal characteristics, and pregnancy outcomes'. This article explores the characteristics of smoking during pregnancy, inferring causation that can influence a pregnancy's outcome. It has received increasing attention globally among scholars.^[39]

Bibliometric analysis frequently includes a stage called 'journal analysis', which can give researchers crucial information for selecting the best journals to submit their work to. The present study's findings give readers a list of the best journals for submission of articles on maternal smoking during pregnancy. According to the analysis, the *American Journal of Epidemiology* was the best journal in which to publish research that has implications for maternal smoking during pregnancy. Future discoveries related to this topic are likely to be published in this journal.^[15,21-23,25,31,33,40-42] The study also provided keyword cluster analysis using conceptual structure analysis of the top 50 keywords using multiple correspondence analysis and correspondence analysis parameters. These analyses

help researchers in the field of maternal smoking during pregnancy by providing information on the subject and study areas that are significant in this domain, and providing a better understanding of the topic based on cluster distribution.

The USA is top leading country reported. This result is consistent with other earlier studies showing that the USA and other nations have consistently held the most dominant positions in scientific research productivity.^[43] This may show that further study of maternal smoking during pregnancy will necessitate substantial financial and human resources in other countries. The economic strength of the top-reported nations, including the USA, UK, Netherlands, Sweden, Australia, Denmark, Canada, Germany and New Zealand, plays a significant part in scientific research. Therefore, countries with strong economies contribute significantly to advancing and enhancing scientific research.

This study used keyword frequency analysis, including authors' keywords, keywords plus, titles and abstracts. These key phrases summarise the main points of recent scholarly studies on pregnant women who smoke. From the analysis of top keywords based on the frequency of occurrence, the study found that most research was focused on 'pregnancy', 'female', 'smoking', 'human', 'infant', 'adult', 'child', 'newborn' and 'male.' We concluded that pregnancy smoking in females was a current research hotspot. These topics are often considered an indicator of research frontiers. Future researchers can locate study hotspots for maternal smoking during pregnancy using this keyword analysis. The keyword of an article can represent its primary objective, and the frequency of its occurrence reflects the structure and development of themes focused on by researchers, as well as the diversity of locations in which maternal smoking during pregnancy research has been conducted. The authors' keywords (pregnancy, smoking, maternal smoking, asthma, prenatal, environmental tobacco smoke, infant, abruptio placentae, birthweight and child) are popular hotspots in the field of maternal smoking during pregnancy-related publications. The frequency of their occurrence reflects the structure and development of research into maternal smoking during pregnancy.

Strengths and limitations

Despite being the first comprehensive bibliometric study on the top 100 most-cited articles on maternal smoking during pregnancy, our study has some limitations, which can be considered as scope for future research. First, this study screened the Scopus database for articles on maternal smoking during pregnancy. Therefore, articles indexed in the Web of Science, Google and PubMed were not included in these investigations. In the future, researchers may need to consider more peer review databases. Second, the study consists of articles and reviews published in English, so other document types and articles published in other languages were not included in the analysis. In addition, the comprehensive funding organisation analysis was not considered. Future research may focus on these issues and present more comprehensive information to fill the research gap and provide the scientific community with knowledge to enhance future research production. Despite these restrictions,

the patterns and trends observed in this study provide useful insights for researchers interested in the research fields by analysing the top 100 most-cited articles on maternal smoking during pregnancy.

Conclusion

The present study is the first illustrating the themes associated with the top 100 most-cited articles on maternal smoking during pregnancy, and emerging trends, using a bibliometric approach. The USA is undoubtedly the main driving force in the field's core global research position. Future researchers should seek more extensive co-operation between countries. The study further shows research directions for maternal smoking during pregnancy could focus on current hotspots. We believe that promising research directions could concentrate on the following topics: 'pregnancy', 'smoking', 'maternal smoking', 'asthma', 'prenatal', 'environmental tobacco smoke', 'infant', 'abruptio placentae', 'birth weight' and 'child', based on the authors' keywords analysis. This bibliometric study provides a comprehensive analysis of research into maternal smoking during pregnancy, which could provide helpful references for scholars and policymakers in this area.

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Conflicts of interest. None.

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