Bibliometric Review

Medicine

OPEN

Global research trends in asthma during pregnancy

A multidisciplinary bibliometric analysis utilizing multiple databases (2008–2024)

Yingfu Zhou, MM[a], Shimei Tang, MM[a], Yong Huang, MM[a], Qin Xiu Zhang, PhD[a,b,*]

Abstract

Background: Asthma is a common chronic disease that poses a double threat to both pregnant women and the health of their fetuses. This study introduces the method of bibliometric analysis to systematically review the current research status of asthma during pregnancy worldwide, aiming to comprehensively analyze its knowledge structure, evolution trends, and emerging research frontiers.

Methods: The data are derived from the Web of Science Core Collection and the PubMed database, covering relevant literature on asthma during pregnancy. The time range is from 2008 to 2024. The search strategy combined asthma-related terms ("asthma" OR "bronchial asthma") with pregnancy-related terms ("pregnancy" OR "gestation" OR "gestational"). After screening, 4088 eligible publications were included in the bibliometric analysis. A separate search of PubMed identified 28 clinical trials for the supplementary analysis of clinical research progress. Bibliometric analyses and visualization were performed using the bibliometrix R package (developed by Massimo Aria and Corrado Cuccurullo, Department of Economics and Statistics, University of Naples Federico II [with an academic spin-off, K-Synth Srl, associated with its dissemination]), CiteSpace (developed by Chaomei Chen, College of Computing and Informatics, Drexel University), and VOSviewer (developed by Nees Jan van Eck and Ludo Waltman, Centre for Science and Technology Studies, Leiden University).

Results: This study comprised 4088 publications focusing on asthma during pregnancy. Annual publication counts demonstrated a gradual increase with intermittent fluctuations. The United States dominated both in publication output and international collaboration. Litonjua AA, Bisgaard H, and Weiss ST demonstrated high centrality and citation influence among authors. The core contributing journals included *Pediatric Allergy and Immunology* and *Journal of Allergy and Clinical Immunology*. Major research focuses encompassed mechanistic exploration, influencing factors, and fetal and child health. Research hotspots were primarily concentrated on "air pollution," "birth cohort," "pregnancy complications," and "maternal diet." In recent years, emerging research frontiers have included "inflammation," "impact," "gut microbiota," "climate change," and "survivors." Clinical trial analysis highlighted nutritional interventions (particularly vitamin D) and precision management using biomarkers like fractional exhaled nitric oxide as current research priorities.

Conclusion: This work examined the evolving trends and trajectories within pregnancy asthma research, offering a systematic roadmap for subsequent studies. The article highlighted the main contributors, research hotspots, emerging frontier topics, and key directions for future research. This study can serve as a crucial reference for researchers in this field and relevant stakeholders.

Abbreviations: ETS = environmental tobacco smoke, FeNO = fractional exhaled nitric oxide, IF = impact factor, SCI-E = Science Citation Index Expanded, TC = total citations, WoSCC = Web of Science Core Collection.

Keywords: asthma, bibliometrics, CiteSpace, pregnancy, visualization, VOSviewer

1. Introduction

Asthma constitutes a chronic respiratory disorder involving airway inflammation and hyperresponsiveness, reversible airflow limitation, and recurrent respiratory symptoms.[1] Cardinal manifestations encompass wheezing, dyspnea, chest tightness, and cough.[2] According to statistics, asthma affects approximately 5% to 13% of pregnant women worldwide,[3,4]

The authors have no funding and conflicts of interest to declare.

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

Supplemental Digital Content is available in the online version of this article (http://dx.doi.org/10.1097/MD.0000000000051630).

[a] School of Clinical Medicine, Chengdu University of Traditional Chinese Medicine, Chengdu, Sichuan, P.R. China, [b] Department of Otorhinolaryngology, Hospital of Chengdu University of Traditional Chinese Medicine, Chengdu, Sichuan, P.R. China.

** Correspondence: Qin Xiu Zhang, Department of Otorhinolaryngology, Hospital of Chengdu University of Traditional Chinese Medicine, No. 39 Shi-er-qiao Road, Chengdu, Sichuan 610072, P.R. China (e-mail: zhqinxiu@163.com).*

Copyright © 2026 the Author(s). Published by Wolters Kluwer Health, LLC. This is an open access article distributed under the Creative Commons Attribution License 4.0 (CCBY), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

How to cite this article: Zhou Y, Tang S, Huang Y, Zhang QX. Global research trends in asthma during pregnancy: A multidisciplinary bibliometric analysis utilizing multiple databases (2008–2024). Medicine 2026;105:47(e51630).

Received: 21 February 2026 / Received in final form: 24 October 2026 / Accepted: 5 November 2026

http://dx.doi.org/10.1097/MD.0000000000051630

and about 30% to 40% of pregnant asthma patients experience disease exacerbation.[5,6] However, the clinical course of asthma during pregnancy is highly variable and difficult to predict; while some patients may experience symptomatic improvement, a considerable proportion may suffer from worsening symptoms, posing significant risks to both maternal and fetal health.[7] Poorly controlled asthma is clearly associated with a higher incidence of adverse perinatal outcomes, including preeclampsia, gestational diabetes, preterm birth, and congenital malformations.[8–10] Furthermore, concerns regarding medication safety during pregnancy often lead to reduced adherence to guideline-recommended treatments among both patients and clinicians, further exacerbating disease-related risks.[11,12] Therefore, optimized management of asthma during pregnancy is essential to safeguard maternal and fetal health.

Bibliometric analysis is a scientific methodology that employs statistical data to quantitatively investigate published materials (e.g., monographs, peer-reviewed articles, research datasets, and web publications) and their associated metadata (including abstracts, subject terms, and citation networks).[13,14] As an important tool for revealing research laws and optimizing resource allocation, its core objective is to analyze and evaluate characteristics such as the quantity, distribution, citation relationships, institutions, authors, countries/regions, and collaboration networks of research information, thereby uncovering the development laws, research hotspots, trends, academic influence, and knowledge dissemination pathways in the selected field, and predicting future directions of development.[15,16] Compared with traditional systematic evaluation, bibliometric analysis has the unique advantages of efficiently handling big data, visualization and intuition, capturing dynamic trends, and reducing subjective bias. Currently, bibliometric analysis has been extensively applied across diverse disciplines including natural sciences, social sciences, and medical research.[17]

Despite the growing body of research on asthma during pregnancy, several important knowledge gaps remain. First, this field is inherently interdisciplinary, encompassing respiratory medicine, obstetrics and gynecology, allergy and immunology, environmental epidemiology, nutrition, and child health. However, the relationships among these research domains and their contributions to the overall knowledge structure have not been sufficiently characterized within an integrated analytical framework. Second, although conventional reviews have provided valuable evidence regarding disease management, maternal and fetal outcomes, and potential risk factors, they generally address specific clinical questions and do not necessarily reveal the broader structure of scholarly collaboration, the intellectual foundations of the field, or the evolution of research themes over time.

To address these gaps, the present study conducted a multidisciplinary bibliometric analysis of publications on asthma during pregnancy from 2008 to 2024, using the Web of Science Core Collection (WoSCC), together with a supplementary analysis of relevant clinical trials retrieved from PubMed. By examining publication patterns, collaboration networks, co-citation structures, keyword clusters, and thematic evolution, we aimed to characterize the development of the field, identify established research hotspots and emerging frontiers, and provide a structured overview to inform future research priorities.

2. Materials and methods

2.1. Data collection

On May 8, 2025, we executed systematic data retrieval through the Science Citation Index Expanded (SCI-E) module of the WoSCC. As shown in Figure 1, the search strategy was: TS = (“asthma” OR “bronchial asthma”) AND TS = (“pregnancy” OR “gestation” OR “gestational”) AND PY = (2008–2024). We excluded the following publication types: Editorial Materials, Letters, Early Access, Meeting Abstracts, Proceeding Papers, Correction, News Items, Retracted Publications, Book Chapters, Biographical-Item, Meetings, and non-English articles. This study’s final dataset consisted of 4088 eligible publications after rigorous selection. We obtained the full records of these documents in plain text format.

To complement the bibliometric analysis, clinical trials related to asthma during pregnancy were retrieved from PubMed. The PubMed search strategy for the supplementary clinical trial analysis was as follows (Table S1, Supplemental Digital Content 1): ((“asthma”[Title] OR “bronchial asthma”[Title]) AND (“pregnancy”[Title] OR “gestation”[Title] OR “gestational”[Title])) AND (“2008/01/01”[Date – Publication]: “2024/12/31”[Date – Publication]); Filters: Clinical Trial. The retrieved records were reviewed to identify studies relevant to the clinical research

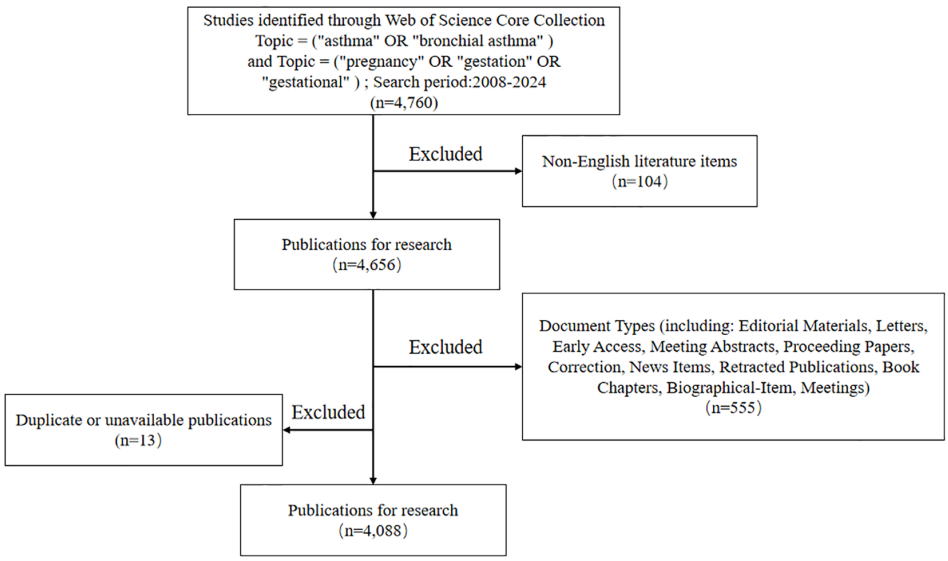

Figure 1. Schematic workflow of the systematic literature screening process.

landscape of this field. For each eligible study, the available bibliographic and clinical information was extracted, including the 1st author, publication year, study design, study population, intervention or exposure, relevant outcomes, and primary research objective, where reported. The extracted information was organized in a structured table for subsequent descriptive analysis.

2.2. Data analysis

Data analyses were conducted utilizing the bibliometrix R package (v4.3.3; developed by Massimo Aria and Corrado Cuccurullo, Department of Economics and Statistics, University of Naples Federico II [with an academic spin-off, K-Synth Srl, associated with its dissemination]), CiteSpace (v6.1.R6; developed by Chaomei Chen, College of Computing and Informatics, Drexel University), VOSviewer (v1.6.18; developed by Nees Jan van Eck and Ludo Waltman, Centre for Science and Technology Studies, Leiden University), and Microsoft Excel 2016 (Microsoft Corporation).[18–20] Through the bibliometrix package in R, we systematically constructed multidimensional knowledge graphs encompassing interactive networks of research entities (countries/regions and institutions), dissemination vehicles, and content characteristics. Additionally, we employed cross-national research collaboration network analysis (Countries' Collaboration World Map) to quantify collaborative intensity across regions and identify core collaboration hubs. To characterize dynamic features of research themes, we incorporated terms with an annual frequency ≥10 between 2008 and 2024 to reflect thematic evolution trends and track emerging hotspots.

VOSviewer was used to visualize bibliometric networks, including collaboration and co-citation networks.[21] CiteSpace was employed to construct knowledge graphs of research dynamics, evolutionary trends, and emerging themes, encompassing cluster analysis, timelines, reference citations, citation dual-map overlay, and burst detection analysis.[22,23] CiteSpace parameter configuration was set with a temporal range from 2008 to 2024, employing annual time slicing intervals. Node types were specified as 5 categories ("authors," "institutions," "countries" "keywords," and "references"), and set to "Threshold Choice = Top 50% of each Slice" and "Pruning Choice = Pathfinder and Pruning Sliced Networks." Other settings were default values.

3. Results

3.1. Annual scientific production analysis

Our systematic search identified 4088 methodologically qualified publications within the SCI-E collection of WoSCC. Figure 2 illustrates the annual publication counts and trends in asthma during pregnancy research from 2008 to 2024. The fitted curve in Figure 2 indicates a gradual upward trajectory of research output, with significant goodness-of-fit ($R^2 = 0.8814$, $P < .001$). Total publication output increased from 133 articles in 2008 to 256 articles in 2024 (+92.5%). The compound annual growth rate was 4.2%. The publication volume reached its peak in 2021 (n = 365). The largest increase occurred from 2020 to 2021, with a rise of 41 articles (+12.7%), significantly higher than the trend value. During the past 5 years, publication counts concerning asthma during pregnancy have exhibited significant fluctuations, with a 29.9% decline in 2024 compared to the peak. The fitted model suggests that the development of this research field may exhibit characteristics of an S-shaped growth curve.

3.2. Countries/regions analysis

Spanning the period from 2008 to 2024, 4088 publications from 854 global journals were coauthored by 560 countries/regions worldwide. Table 1 displays the leading 20 countries/regions based on publication volume, with the USA leading all countries in publication output. During 2008 to 2024, the U.S. published 1363 articles, accounting for approximately 33.34% of all publications, significantly surpassing other countries. Over the identical duration, Australia occupied the 2nd position, with 467 publications comprising approximately 11.42%, followed by the United Kingdom with 417 publications (10.20%) and a relatively high centrality of 0.12 (>0.1). Higher centrality indicates stronger connectivity, meaning greater influence in this field.[24] Canada, France, and Switzerland all had a centrality of 0.13, demonstrating significant impacts in the research of asthma during pregnancy.

Based on the common collaborative relationships between countries, we constructed a collaboration network (Fig. 3), with a minimum collaboration frequency of 5, and the frequencies of the most frequent collaborative connections are labeled in Figure 3. As illustrated in Figure 3, the USA occupied a core position in international collaborative networks within

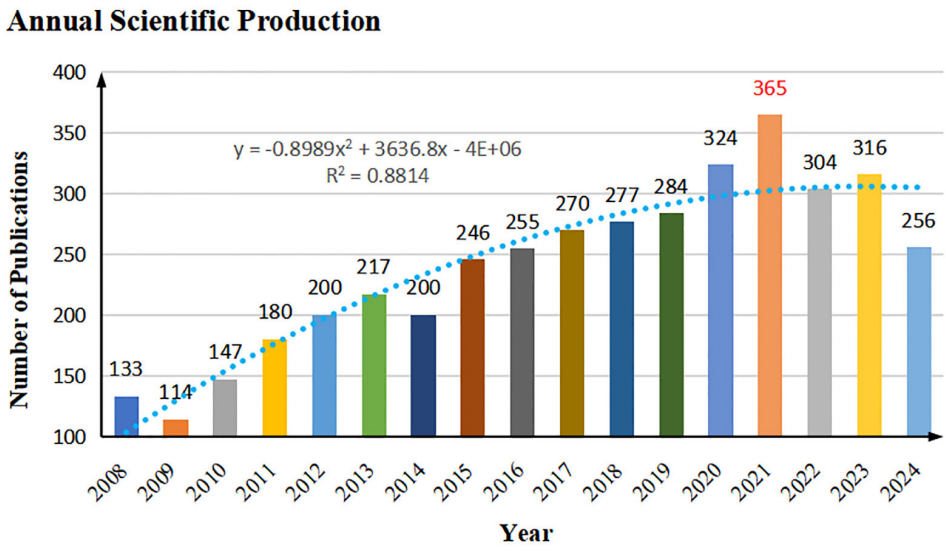

Figure 2. Global annual scientific production trends.

Table 1

Top 20 contributing countries/regions in asthma research during pregnancy.

No.	Country	Articles	Proportion (%)	Centrality	The year of centrality
1	USA	1363	33.34	0.07	2008
2	Australia	467	11.42	0.06	2008
3	England	417	10.20	0.12	2008
4	Peoples R China	401	9.81	0.03	2009
5	Denmark	292	7.14	0.03	2008
6	Canada	278	6.80	0.13	2008
7	Sweden	275	6.73	0.06	2008
8	Netherlands	244	5.97	0.07	2008
9	Germany	200	4.89	0.08	2008
10	Spain	196	4.79	0.07	2008
11	Italy	168	4.11	0.04	2008
12	France	160	3.91	0.13	2008
13	Norway	150	3.67	0.03	2008
14	Finland	148	3.62	0.05	2008
15	Japan	144	3.52	0.05	2008
16	Switzerland	94	2.30	0.13	2008
17	Taiwan	90	2.20	0.00	2009
18	Scotland	79	1.93	0.04	2008
19	Brazil	76	1.86	0.01	2008
20	Poland	76	1.86	0.02	2008

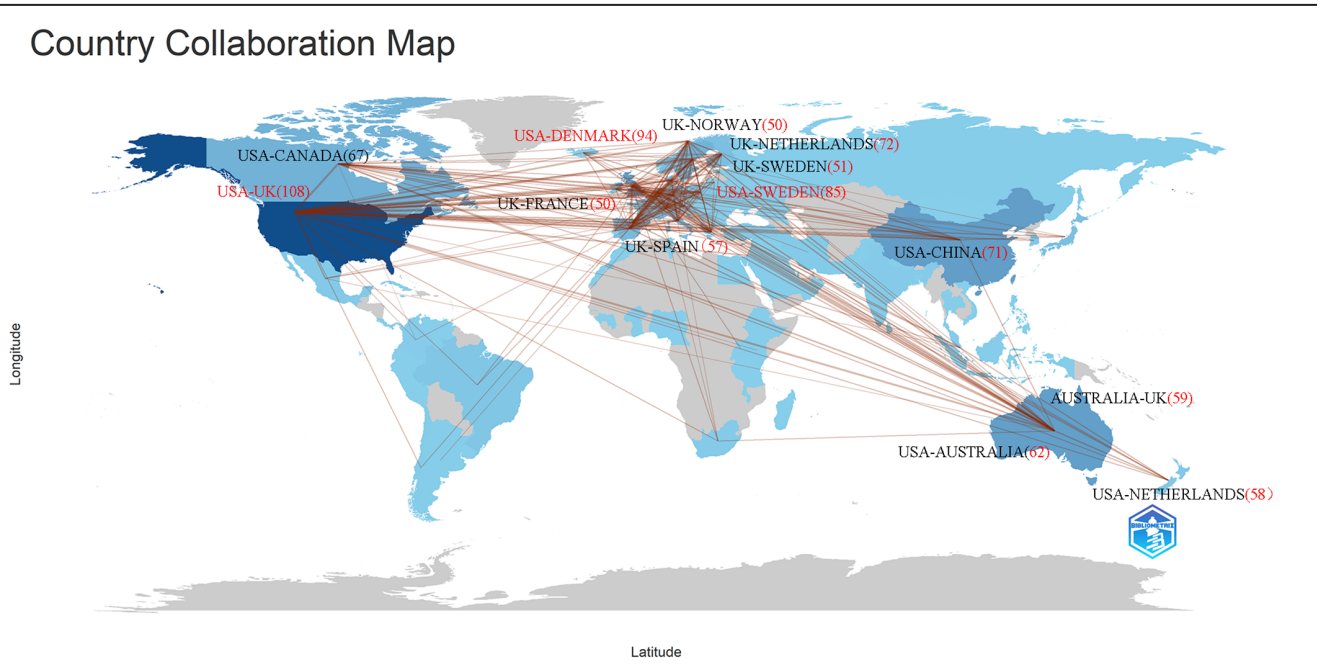

Figure 3. Visualization map of countries/regions within the field of asthma during pregnancy research.

the research field of asthma during pregnancy, demonstrating high-frequency collaborations with multiple top 10 countries, such as 108 collaborations with the United Kingdom, 94 with Denmark, 85 with Sweden, 71 with China, 67 with Canada, 62 with Australia, and 58 with the Netherlands. Among all collaborative relationships, the U.S.–U.K. collaboration was the most frequent, with a frequency of 108, followed by U.S.–Denmark collaborations (94 times). Furthermore, Figure 3 visualizes strong collaborative linkages among European nations centered around the UK. For instance, the UK collaborated with the Netherlands 72 times, Spain 57 times, Sweden 51 times, France 50 times, and Norway 50 times.

3.3. Author and institutional analysis

From 2008 to 2024, a total of 854 research institutions and 19,221 scholars worldwide participated in asthma-related research during pregnancy. A total of 44 institutions published at least 40 publications, and VOSviewer was used to construct a collaborative network map of these institutions (Fig. 4). As depicted in Figure 4, we identified significant research collaboration among most institutions, with institutions such as Univ Copenhagen, Harvard Med Sch, Karolinska Inst, Univ Western Australia, Icahn Sch Med Mt Sinai, and Univ Newcastle serving as key collaborative hubs in the field. These institutions have made outstanding contributions and exerted significant influence in the research domain of asthma during pregnancy.

A visual analysis was conducted on 42 authors with at least 20 publications each, and an author collaborative network map was constructed (Fig. 5). As shown in Figure 5, extensive collaboration exists among most authors. Among them, Litonjua, Augusto A; Bisgaard, Hans; Murphy, Vanessa E; Stokholm, Jakob; Bonnelykke, Klaus; Wright, Rosalind J; and Weiss, Scott T exhibit more active collaboration with other authors

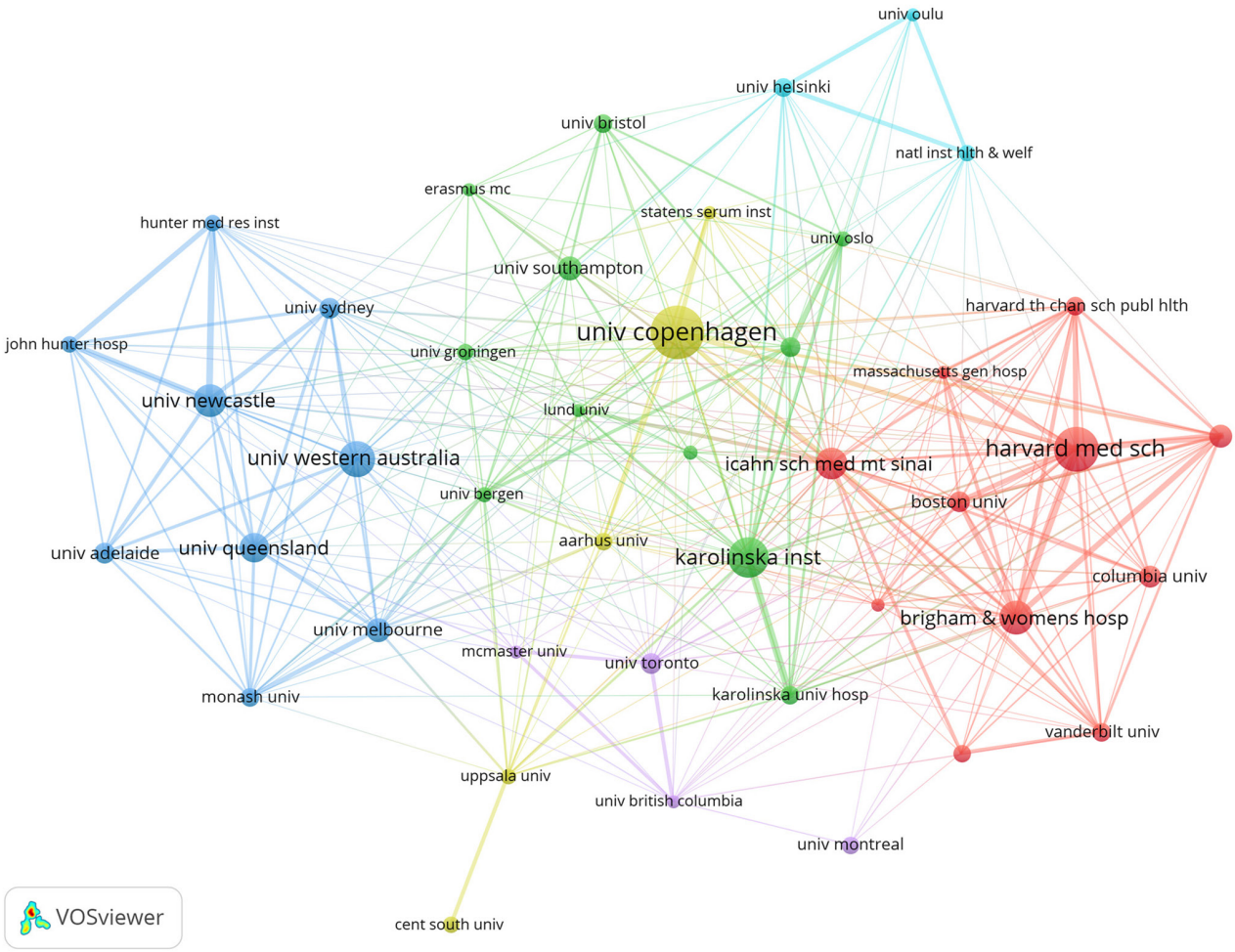

Figure 4. Institutional collaboration network analysis.

and have produced a greater volume of relevant publications. Additionally, for detailed analysis, Table 2 presents the top 10 most prolific authors in the field based on publication output. The top 10 authors are primarily based in the USA, Denmark, and Australia. Litonjua, Augusto A (n = 79) is the most productive author in terms of publication output, followed by Bisgaard, Hans from the University of Copenhagen (n = 78) and Weiss, Scott T from Harvard Medical School (n = 74). Murphy, Vanessa E from Newcastle University has the highest fractional contribution (author fractional = 12.84), followed by Clifton, Vicki L from the University of Queensland (author fractional = 11.87). Litonjua, Augusto A. has the highest total citations (TC = 4280), followed by Bisgaard, Hans (TC = 3503) and Weiss, Scott T (TC = 3455). Notably, the authors with the highest *h*-index are Litonjua, Augusto A and Bisgaard, Hans (*h* = 31), followed by Weiss, Scott T (*h* = 28). This reflects the high academic influence and international recognition of these 3 scholars' research achievements in this field.

3.4. Core journals

According to the statistical results from R-bibliometrix, 854 journals published articles related to asthma during pregnancy between 2008 and 2024. Table 3 displays the leading 10 journals in this research domain based on publication output. Most publishers of these journals are based in the USA. *Pediatric Allergy and Immunology* (Denmark) ranked 1st in publication volume with 136 publications, comprising 3.33% of the total analyzed studies, followed by *Journal of Allergy and Clinical Immunology* (USA) (n = 133, 3.25%) and *PLoS One* (USA) (n = 103, 2.52%). Among the journals analyzed, *European Respiratory Journal* (UK, IF = 17.0) exhibited the highest impact factor (IF), followed by *Allergy* (UK, IF = 12.6) and *Journal of Allergy and Clinical Immunology* (USA, IF = 11.4). Notably, the *Journal of Allergy and Clinical Immunology* has far higher TCs (TC = 9394) and *h*-index (*h* = 57) than other journals, demonstrating comprehensive excellence in both the quality and quantity of its published articles and holding a pivotal influence in this domain.

According to Bradford's law, Figure 6 demonstrates that the core zone comprises 19 high-quality journals. Among them, *Pediatric Allergy and Immunology* and *Journal of Allergy and Clinical Immunology* rank among the top in the core zone, having made particularly substantial contributions to the research on asthma during pregnancy.

The dual-map overlay analysis elucidates journal thematic distributions. This analytical approach provides researchers with a multidisciplinary perspective, fostering innovative thinking and enabling more efficient identification of research patterns. Such methodological integration not only accelerates the discovery of novel scientific insights but also positions investigators to establish pioneering directions in this rapidly evolving field.[25] As depicted in Figure 7, the left panel features citing journals, and the right panel displays cited journals. Citation relationships are visualized through chromatic pathways. The vertical axis of each ellipse corresponds to publication volume, while the horizontal axis represents author count. Analysis

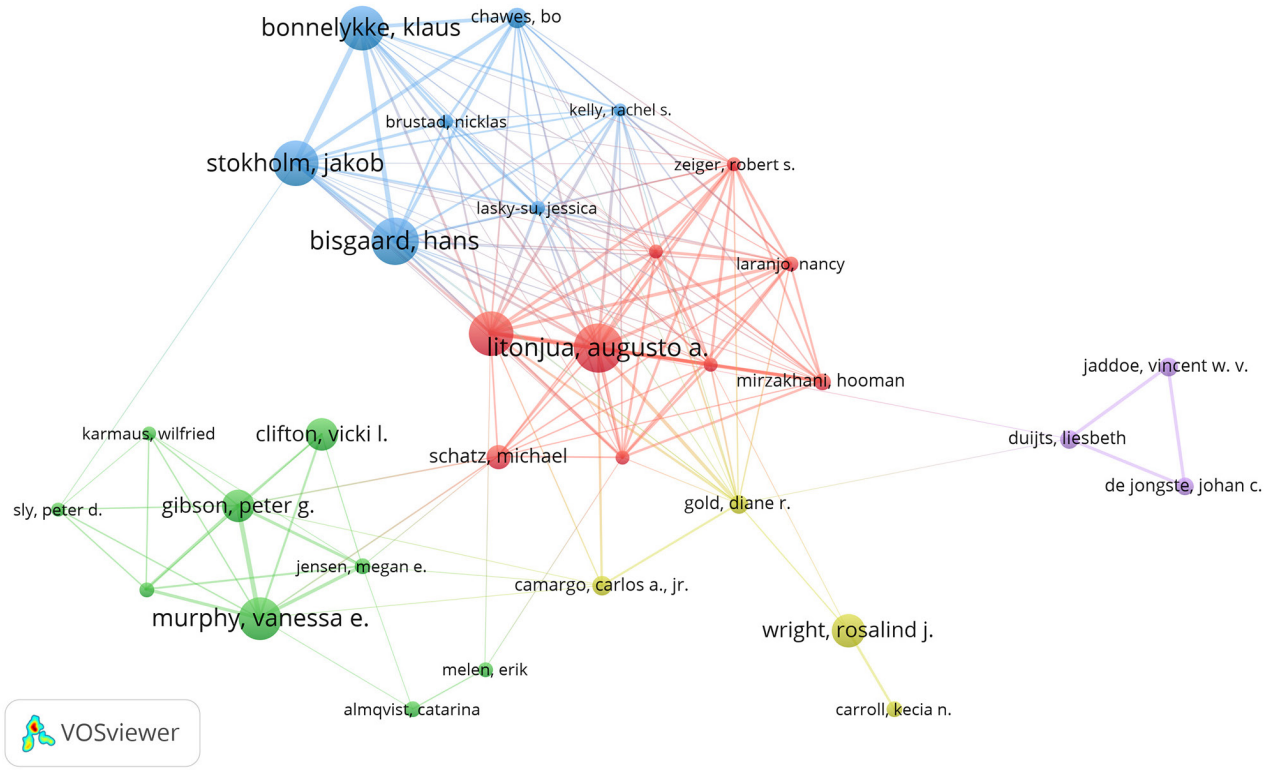

Figure 5. Visualization map of the international coauthor network.

Table 2

Top 10 contributing authors in asthma research during pregnancy.

No.	Authors	Country	Institution	Articles counts	Articles fractionalized	TC	*h*-index
1	Litonjua AA	USA	University of Rochester	79	9.71	4280	31
2	Bisgaard H	Denmark	University of Copenhagen	78	9.75	3503	31
3	Weiss ST	USA	Harvard Medical School	74	7.28	3455	28
4	Stokholm J	Denmark	University of Copenhagen	72	7.81	2400	25
5	Bonnelykke K	Denmark	University of Copenhagen	70	7.53	2364	23
6	Murphy VE	Australia	University of Newcastle	68	12.84	2700	22
7	Clifton VL	Australia	University of Queensland	61	11.87	1953	25
8	Gibson PG	Australia	University of Newcastle	54	9.39	2571	22
9	Wright RJ	USA	Icahn School of Medicine at Mount Sinai	53	6.99	2166	28
10	Duijts L	Netherlands	Erasmus University Rotterdam	49	5.03	2686	25

Articles Fractionalized represents the fractionalized publication count calculated using the bibliometrix R package. For each article, a fractional credit of (1/N) was assigned to each author, where (N) is the total number of authors of that article. The fractional credits were then summed across all articles for each author. Thus, this indicator accounts for the number of coauthors per publication and differs from the total article count.

h-index = Hirsch index, TC = total citations.

identified 5 major citation paths: 2 orange pathways and 3 green pathways. The orange and green pathways correspond to 2 primary research directions within the field of asthma during pregnancy that differ in their knowledge bases and citation patterns. The orange pathways represent research publications in Molecular/Biology/Genetics/Health/Nursing and Medicine, which are typically cited by research published in Molecular/Biology/Immunology. The green pathways denote research published in Environmental/Toxicology/Nutrition/Molecular/Biology/Genetics/Health/Nursing/Medicine, which are commonly cited in publications in Medicine/Medical/Clinical fields. This visual distinction essentially reflects the coexistence of distinct disciplinary perspectives and methodological approaches in asthma research during pregnancy. The relative independence and limited intersection between the orange and green pathways suggest that a highly integrated cross-disciplinary knowledge framework has not yet been established in this field. Deeper theoretical and empirical dialogue remains necessary between clinical mechanistic research and preventive intervention studies.

3.5. Analysis of co-cited references

Between 2008 and 2024, a total of 112,397 co-cited references on asthma during pregnancy were identified. Table 4 displays the 10 leading co-cited references by frequency. The publication by Asher MI et al (1995) in *Eur Respir J* had the greatest citation count of 295, followed by Asher MI et al (2006) in *Lancet* (citations = 190) and Martinez FD et al (1995) in *New Engl J Med* (citations = 182). Using CiteSpace, we also constructed a network map and performed cluster analysis on co-cited references, identifying 16 clusters in total. The modularity index (*Q*) of the clusters was 0.7858 (>0.3), and the

Table 3

Leading journals in asthma during pregnancy: top 10 by output and impact.

Rank	Journal	Articles	Country	IF (2023)	JCR (2023)	TC	*h*-index
1	*Pediatric Allergy and Immunology*	136	Denmark	4.3	*Q2*	3987	38
2	*Journal of Allergy and Clinical Immunology*	133	USA	11.4	*Q1*	9394	57
3	*PLoS One*	103	USA	2.9	*Q1*	2958	33
4	*Clinical and Experimental Allergy*	96	England	6.3	*Q1*	4676	39
5	*Allergy*	79	England	12.6	*Q1*	4490	38
6	*Journal of Allergy and Clinical Immunology-in Practice*	77	Netherlands	8.2	*Q1*	1935	23
7	*Pediatric Pulmonology*	76	USA	2.7	*Q1*	1334	21
8	*Journal of Asthma*	71	USA	1.7	*Q3*	1147	21
9	*European Respiratory Journal*	70	England	17.0	*Q1*	3084	33
10	*Environmental Research*	67	USA	7.7	*Q1*	2990	24

h-index = Hirsch index, IF = impact factor, JCR = Journal Citation Reports, TC = total citations.

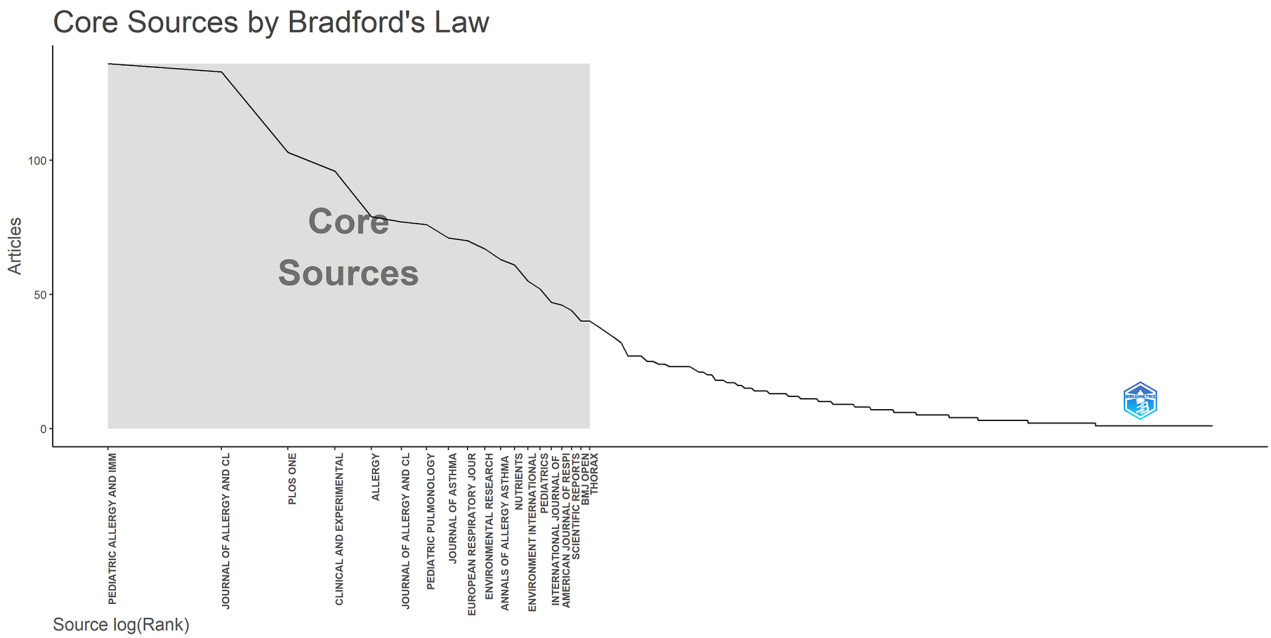

Figure 6. Core Journals by Bradford's law.

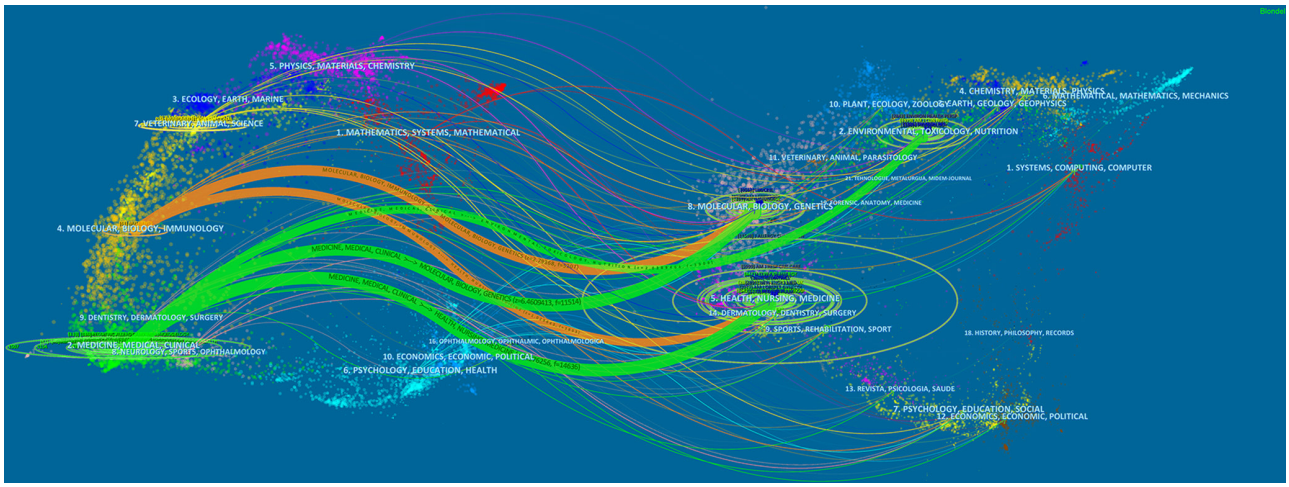

Figure 7. Dual-map overlay analysis of journals in asthma research during pregnancy.

mean silhouette $S = 0.9139$ (>0.7), indicating a high degree of homogeneity in the network structure and highly reliable clustering results.[26]

To visualize the temporal evolution of co-citation clusters, we constructed a timeline view focused on the domain of asthma during pregnancy (Fig. 8). Additionally, we compiled

a list of the 20 references exhibiting the most significant citation bursts, which is presented in Figure 9. A citation burst is defined as a marked surge in citations that a publication receives within a defined time frame.[27] The foundational research themes in the early phase (prior to 2014) were primarily "vitamin D," "inhaled corticosteroids," "folate," and "environmental tobacco smoke." For instance, the 2007 publications by Devereux G et al (strength = 24.3) and Camargo CA et al (strength = 23.86) in *Am J Clin Nutr*, which focused on the influence of vitamin D on maternal and childhood asthma, garnered early and intense citation bursts.[28,29] Furthermore, a 2011 systematic review by Murphy VE et al in *BJOG – Int J Obstet Gy* (strength = 26.89), which evaluated adverse perinatal outcomes in asthmatic women, also attracted substantial scholarly attention.[30] During the intermediate phase (2015–2020), the foundational research themes shifted focus to "stress," "cholecalciferol," and "nitrogen dioxide." This period was marked by the highly cited 2016 publications by Litonjua AA et al (strength = 33.51) and Chawes BL et al (strength = 28.38) in *JAMA – J Am Med Assoc*, which examined the effect of vitamin D supplementation on the risk of asthma in pregnant women and their offspring.[31,32] In recent years (2021–present), research focus has centered on "air pollution," "pregnancy complications," and "maternal diet." Exemplifying this trend, the publications by Garcia-Larsen V et al (2018) in *PLoS Med* (strength = 17.63) and Venter C et al (2020) in *Pediat Allerg Imm-UK* (strength = 17.41) have demonstrated significant recent citation bursts. Both studies investigated the influence of dietary factors on asthma during pregnancy and fetal immune development.[33,34]

Table 4

Top 10 most frequently co-cited references on asthma during pregnancy.

No.	Cited references	Citations
1	Asher MI, 1995, *Eur Respir J*, V8, P483	295
2	Asher MI, 2006, *Lancet*, V368, P733	190
3	Martinez FD, 1995, *New Engl J Med*, V332, P133	182
4	Murphy VE, 2011, *BJOG – Int J Obstet Gy*, V118, P1314	179
5	Camargo CA, 2007, *Am J Clin Nutr*, V85, P788	163
6	Devereux G, 2007, *Am J Clin Nutr*, V85, P853	148
7	Murphy VE, 2006, *Thorax*, V61, P169	146
8	Litonjua AA, 2016, *JAMA – J Am Med Assoc*, V315, P362	131
9	Miller MR, 2005, *Eur Respir J*, V26, P319	129
10	Erkkola M, 2009, *Clin Exp Allergy*, V39, P875	125

3.6. Analysis of keywords

We systematically analyzed keyword co-occurrence patterns across 4088 publications in the dataset using Citespace and VOSviewer, constructing visual network maps and conducting cluster analysis to identify thematic structures. The keyword co-occurrence analysis map (Fig. 10) identified 149 keywords occurring at least 50 times. Among these, highly frequent keywords such as "asthma," "pregnancy," "risk," "children," "prevalence," "association," and "childhood asthma" represent core research topics of asthma during pregnancy. This finding underscores the field's enduring emphasis on the public health impact of asthma in pregnancy and its links to diverse maternal and fetal complications. Furthermore, it underscores the academic emphasis on the impact of early-life exposure to maternal asthma on offspring's long-term respiratory health, which is directly linked to the Developmental Origins of Health and Disease hypothesis.

Keyword cluster analysis identified 7 distinct clusters, with a modularity Q value of 0.3314 and a mean Silhouette score of 0.7315, indicating a highly significant clustering structure. As shown in the timeline plot of clusters (Fig. 11), research themes related to asthma during pregnancy initially focused on "birth cohort," "women," "air pollution," "food allergy," "vitamin D," and "risk factors." During recent years, the focus has primarily been on "birth cohort," "air pollution," and "gestational weight gain." Notably, keyword cluster analysis revealed no substantial differences in research themes in this field between 2008 and 2024, which may indicate a scarcity of high-quality innovative research in this field. Additionally, we visualized the top 10

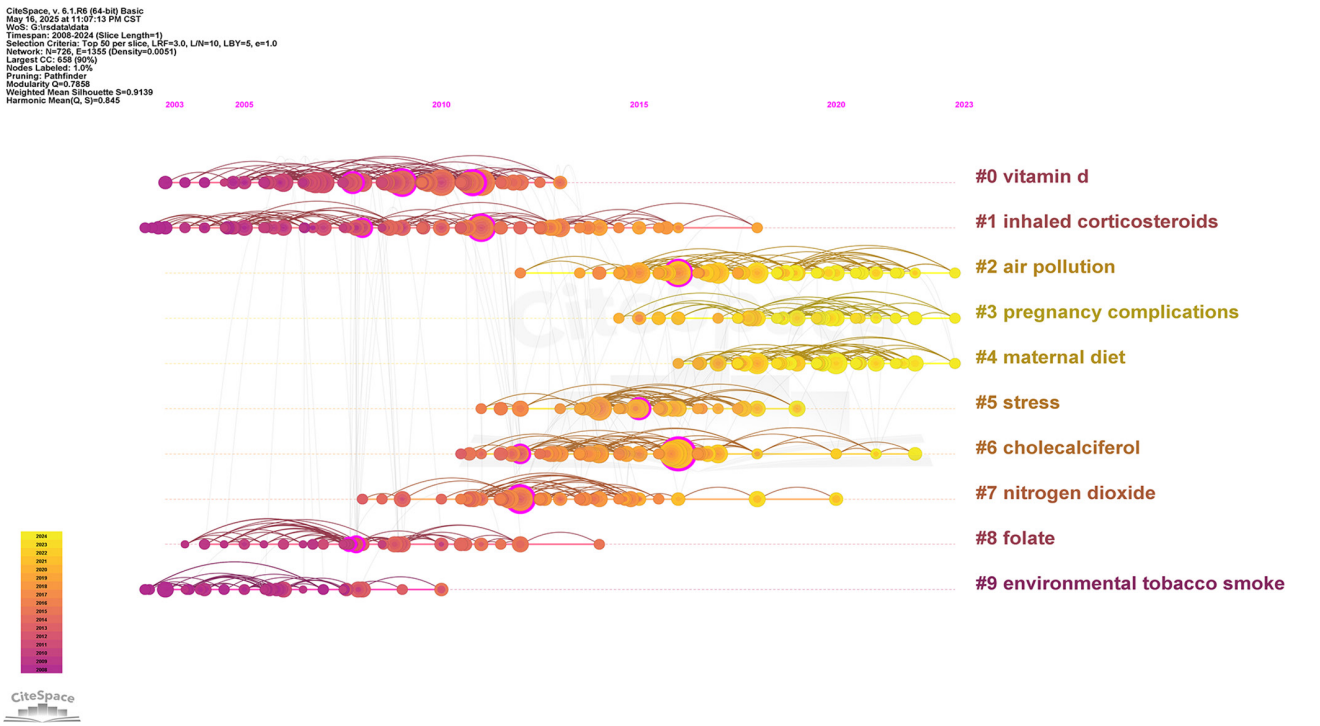

Figure 8. Visualization analysis of references. Timeline visualization of the top 10 clusters.

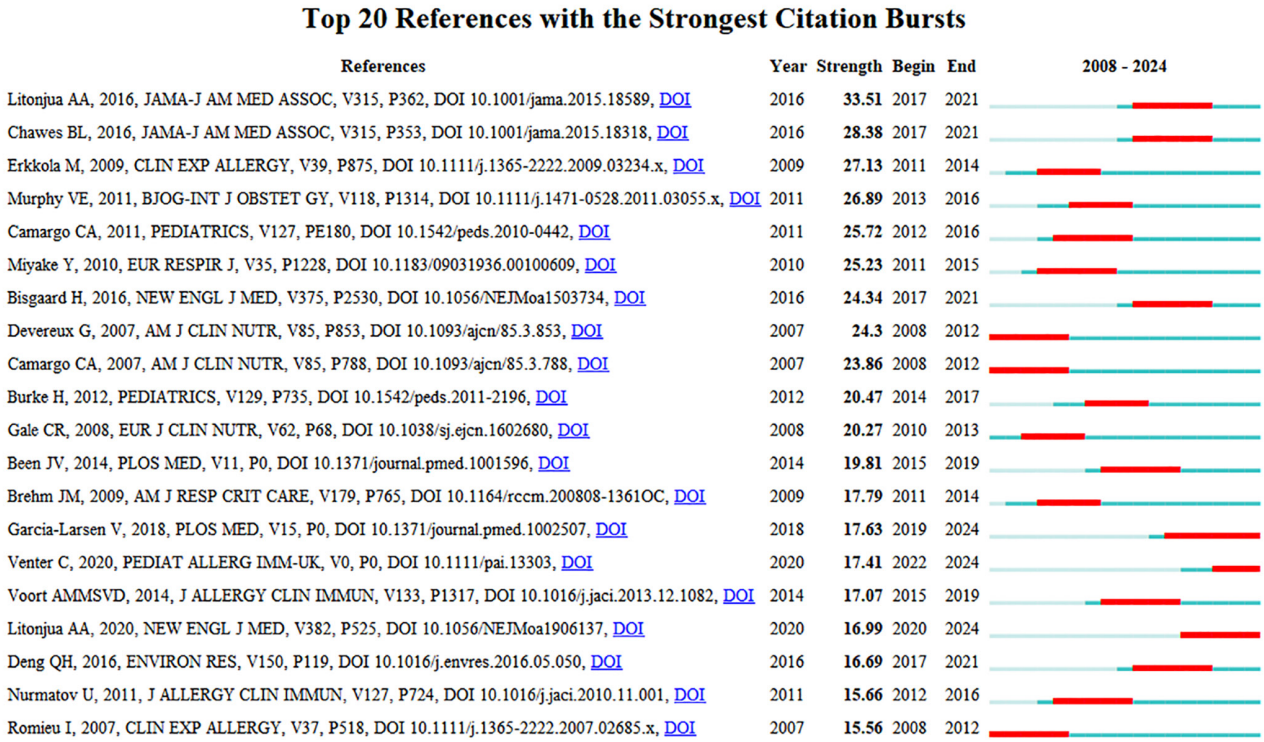

Figure 9. Visualization analysis of references. Top 20 references by citation burst strength in asthma research during pregnancy.

keywords by citation burst strength using CiteSpace (Fig. 12). As shown in Figure 12, "environmental tobacco smoke" and "parental smoking" had the highest citation burst strengths and emerged earlier. Keywords with new citation bursts in the past 4 years include "impact," "gut microbiota," "rhiniti," and "inflammation."

3.7. Topic evolution

We constructed a theme trend evolution map for asthma-related research during pregnancy between 2008 and 2024 using the R-bibliometrix package (Fig. 13), with a minimum frequency of 10. As shown in Figure 13, research themes in the early period (2008–2014) primarily focused on "passive smoking," "parental smoking," "perinatal risk factors," "environmental tobacco smoke," and "immune responses." From 2015 to 2020 (mid-term), research themes such as "birth cohort," "maternal smoking," "children," "prevalence," "childhood asthma," "exposure," "sensitization," and "lung function" consistently appeared with high frequency. In the past 4 years, research has shifted to themes including "inflammation," "biomarkers," "depression," "climate-change," "rationale," and "survivors."

3.8. Clinical progress analysis

Our search of the PubMed database identified a total of 28 clinical trials related to asthma during pregnancy. We reviewed and extracted data from these trials (Table S2, Supplemental Digital Content 2). Statistical analysis revealed that 9 trials (approximately 32.1%) focused on nutritional and supplemental interventions, establishing this as the most active area of investigation in recent years, primarily involving vitamin D and fish oil. Subsequently, 7 trials (25.0%) investigated the impact of asthma management or exposure during pregnancy on the long-term health and development of offspring. Furthermore, 6 trials (approximately 21.4%) explored the use of biomarkers, such as fractional exhaled nitric oxide (FeNO), to guide treatment decisions in gestational asthma. Finally, 5 studies (17.9%) concentrated on maternal characteristics, such as prepregnancy weight, and their influence on asthma course and outcomes.

4. Discussion

4.1. General information

Publication records sourced from the SCI-E within the WoSCC, spanning the years 2008 to 2024, form the basis of this analysis. Our study encompassed 4088 documents related to asthma during pregnancy published in 854 journals, citing 112,397 references and involving 19,221 authors. From 2008 to 2021, the annual number of publications on asthma during pregnancy generally increased, reaching a peak of 365 publications in 2021. Subsequently, the annual output declined to 256 publications in 2024, representing a 29.9% decrease from the peak. Despite these recent fluctuations, the overall publication trajectory across the study period remained upward.

Research output concerning asthma during pregnancy is predominantly contributed by the USA, Australia, and the UK. The USA has the highest publication output, accounting for approximately 33.34% of all publications, far exceeding other countries and occupying a core position in this research field. Four countries – the United Kingdom, Canada, France, and Switzerland – exhibit higher centrality, having made significant contributions and exerted substantial influence in this field. Regarding international collaboration, the United States serves as a core collaborative hub, engaging in high-frequency cooperation with multiple countries among the top 10, which may be one of the key reasons for its high research output. Additionally, some countries/regions demonstrate distinct regional collaboration patterns; for example, European countries centered on the United Kingdom exhibit close cooperation, reflecting the critical impact of factors such as geographical proximity, language, and national cooperation policies on global collaboration. This

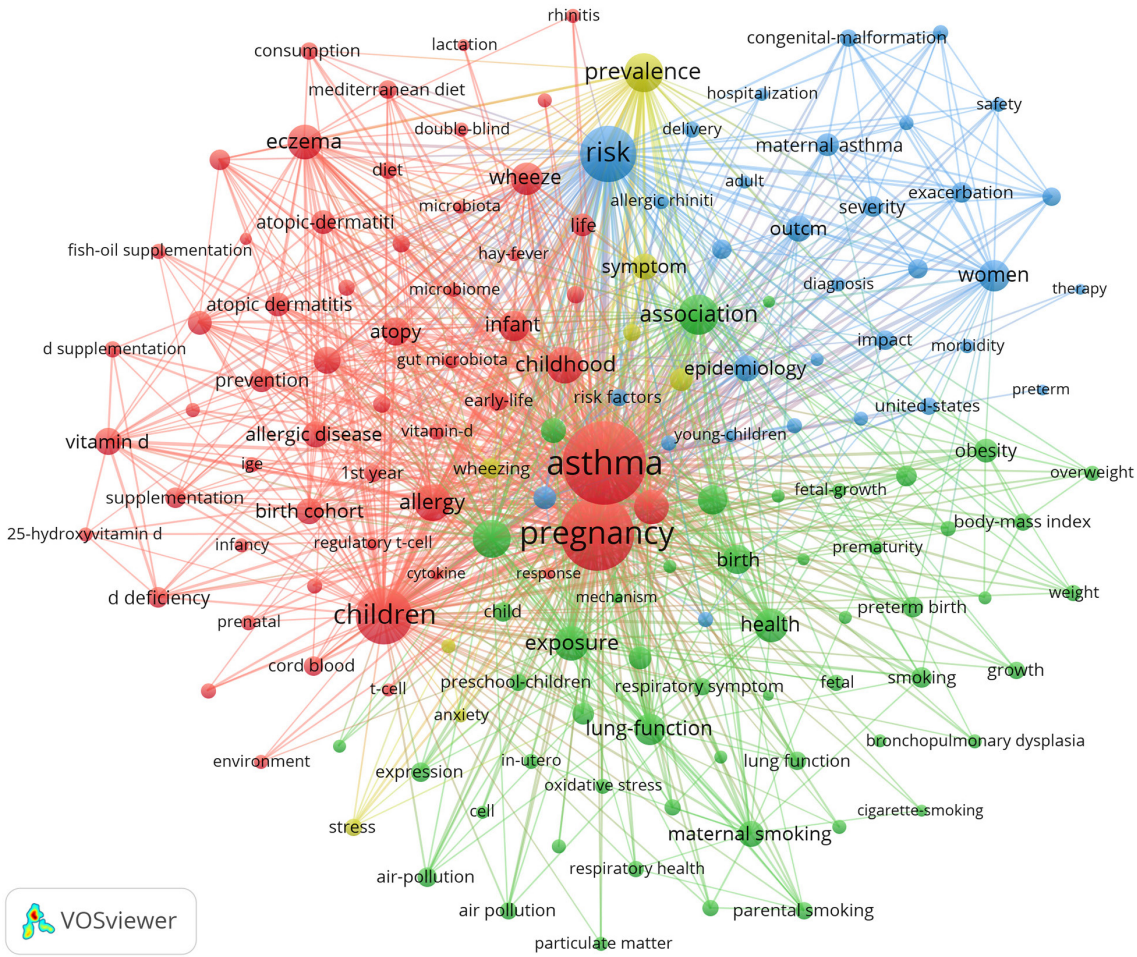

Figure 10. Keyword co-occurrence analysis network.

suggests that to promote global cooperation and reduce concentration in collaboration, it is essential to foster multilateral cooperation mechanisms and expand multilingual collaboration models, thereby further advancing the balanced development of research on asthma during pregnancy.

Regarding authors, extensive collaboration is evident among most authors. The most collaboratively active authors with high publication output include Litonjua, Augusto A; Bisgaard, Hans; Murphy, Vanessa E; Stokholm, Jakob; Bonnelykke, Klaus; Wright, Rosalind J; and Weiss, Scott T, primarily from the United States, Denmark, and Australia. Litonjua, Augusto A from the University of Rochester (USA) has the highest publication count, followed by Bisgaard, Hans from the University of Copenhagen (Denmark) and Weiss, Scott T from Harvard Medical School (USA). Their research interests predominantly focus on investigating factors during pregnancy that influence the risk of childhood asthma in offspring of women at risk of having asthmatic children – such as vitamin D or n-3 long-chain polyunsaturated fatty acids supplementation during pregnancy reducing offspring asthma risk, and antenatal antibiotic use or smoking increasing childhood asthma risk.[35–39] It is noteworthy that Dr Litonjua has extensive experience in cohort studies investigating the early origins of asthma and the role of vitamin D. Dr Bisgaard, as the lead investigator of the Copenhagen Prospective Studies on Asthma in Childhood, has made substantial contributions to the field of early-life risk factors for asthma. Meanwhile, Dr Weiss has a strong background in the genetic epidemiology of asthma and its interaction with environmental factors. Their status as core references in this field stems not only from their sustained high research output but also from the fact that their work forms the theoretical and evidence base for asthma prevention and risk intervention during pregnancy. Additionally, visual analysis reveals that author collaboration primarily occurs within national or institutional boundaries, with overall collaboration levels remaining low and requiring further enhancement.

4.2. Knowledge base

Co-cited references denote publications cited simultaneously by numerous studies; as such, they constitute the foundational knowledge base of a specific field. Through bibliometric analysis, we identified that 2 publications by Asher MI et al had the highest citation frequencies. Their team's articles published in *Eur Respir J* in 1995 and *Lancet* in 2006 were the 1st to evaluate the prevalence and global trends of childhood asthma via questionnaires, indirectly advancing the progress of research on asthma during pregnancy.[40,41] In 1995, the article by Martinez FD et al in *New Engl J Med* 1st statistically demonstrated that infants of asthmatic mothers were more likely to exhibit persistent wheezing symptoms, laying the research foundation for understanding the effect of asthma during pregnancy on pediatric health outcomes.[42] In 2005, Miller MR et al published an article in *Eur Respir J* describing standardized spirometry, which made significant contributions to improved asthma diagnosis.[43] In 2006, research by Murphy VE et al in *Thorax* demonstrated that uncontrolled asthma exacerbations in pregnancy compromise fetal outcomes, highlighting the necessity of preventive

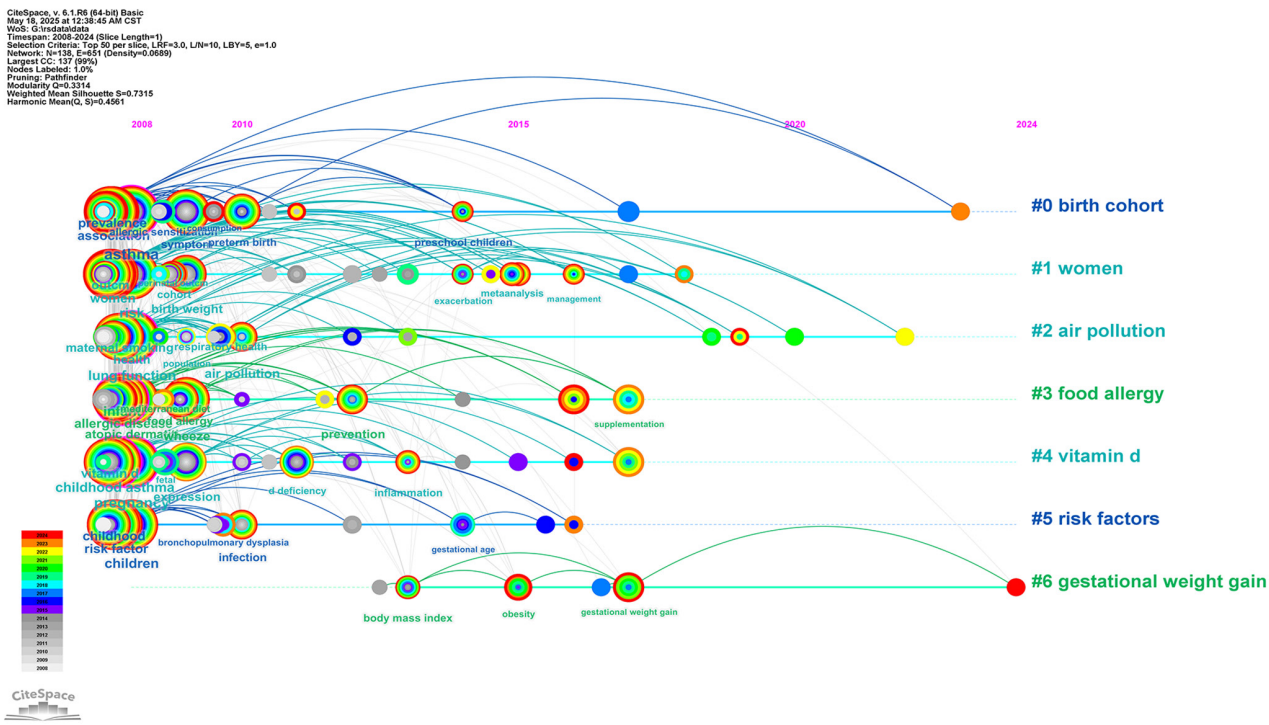

Figure 11. Timeline distribution of clusters of keywords.

Top 10 Keywords with the Strongest Citation Bursts

Keywords	Year	Strength	Begin	End	2008 - 2024
environmental tobacco smoke	2008	21.3	2008	2013	
parental smoking	2008	20.9	2008	2011	
gestational age	2014	18.19	2014	2019	
cohort	2009	16.84	2012	2018	
atopy	2008	15.17	2008	2014	
impact	2015	14.49	2020	2024	
gut microbiota	2016	14.31	2021	2024	
metaanalysis	2015	13.44	2015	2018	
rhiniti	2009	13.37	2021	2024	
inflammation	2013	12.76	2021	2024	

Figure 12. Citation burst intensity of top 10 keywords.

strategies for gestational asthma.[44] In 2007, Devereux G et al and Camargo CA et al preliminarily confirmed the effect of vitamin D on asthma in pregnant women and pediatric populations, providing critical research directions for subsequent studies.[28,29] In 2009, Erkkola M et al further supported the finding that maternal vitamin D consumption in pregnancy reduces childhood asthma risk.[45] These highly co-cited articles collectively present the core knowledge foundation and development trajectory of the research field on asthma during pregnancy. These key works jointly form the conceptual and methodological basis of this field, not only promoting the deepening of asthma during pregnancy from descriptive studies to mechanism exploration and intervention strategies, but also providing a stable reference framework and continuous theoretical tension for the structural evolution of the subsequent knowledge map.

The overlap between highly cited references and the clinical research priorities identified in this study provides additional insight into the development of the field. Vitamin D is 1 illustrative example. Earlier studies investigating the relationship between maternal vitamin D status, prenatal supplementation, and asthma-related outcomes in offspring helped establish a research foundation for subsequent investigations. Consistent with this knowledge base, nutritional interventions, particularly vitamin D supplementation, remained a prominent focus among the clinical studies identified in our analysis. This continuity suggests that vitamin D has served as a sustained research theme linking foundational evidence with subsequent clinical investigation. More recent studies have further examined questions such as baseline vitamin D status, supplementation timing, and offspring respiratory outcomes.[32] Nevertheless, sustained

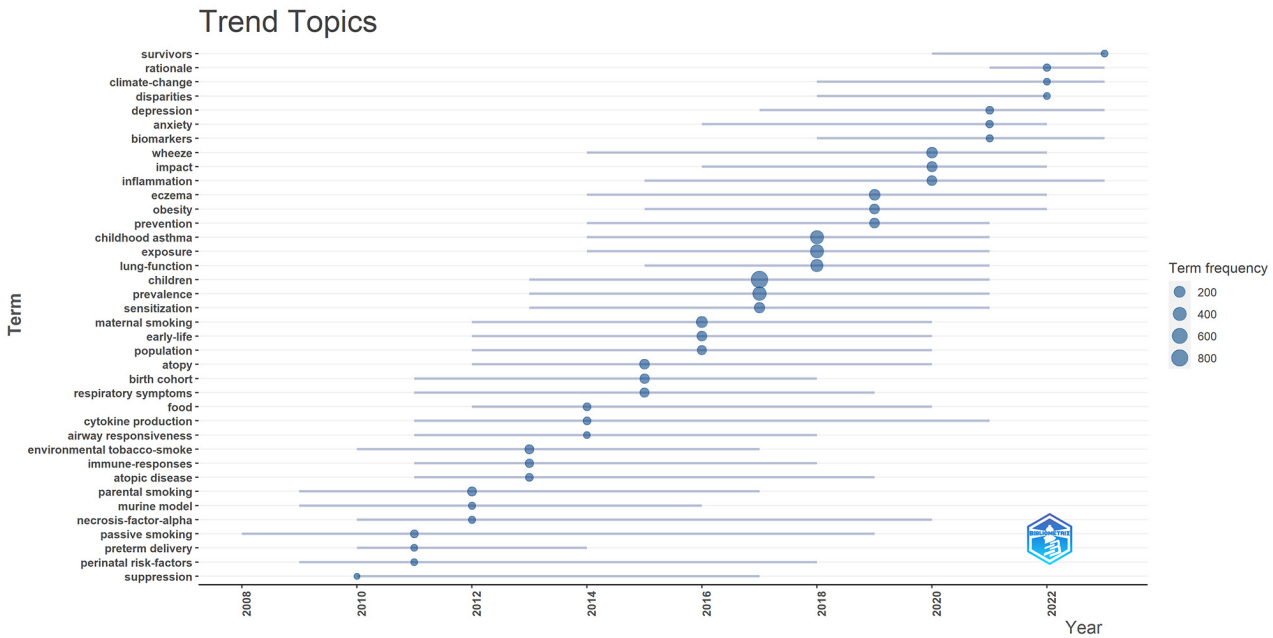

Figure 13. Trend topics in asthma research during pregnancy.

research attention and high citation counts should not be interpreted as definitive evidence of clinical efficacy. The findings instead highlight the continued effort to clarify the potential role of prenatal vitamin D supplementation and the need for further evidence to determine which populations and intervention strategies may benefit most.

4.3. Hotspots and frontiers

This comprehensive bibliometric analysis systematically elucidates the emerging hotspots and key research themes within the field of asthma during pregnancy from 2008 to 2024. The results demonstrate that research priorities and emerging frontiers within this field have largely converged on 4 principal themes. First, a substantial body of research has concentrated on the relationship between environmental exposures and offspring health, with particular emphasis on the potential impact of exogenous factors – such as air pollutants and environmental tobacco smoke (ETS) encountered by asthmatic mothers during pregnancy – on child health outcomes. Second, nutritional interventions and disease prevention in gestational asthma have been extensively discussed and demonstrate a distinct evolutionary trajectory. Third, maternal and fetal complications alongside long-term health have emerged as another critical research avenue, where investigators are exploring not only asthma per se but also the collective impact of various perinatal comorbidities on the long-term health of both mother and child. Finally, gut microbiota composition has emerged as a focal keyword in current research on pregnancy-associated asthma, with the field progressively advancing toward mechanistic studies at the micro level to elucidate the intrinsic biological pathways linking maternal asthma to offspring health outcomes.

The bibliometric findings of this study clearly demonstrate that the impact of environmental exposures on offspring health constitutes an enduring and continuously evolving central theme in the field of asthma during pregnancy. Significant research efforts are aimed at elucidating the adverse outcomes resulting from exposure to various environmental agents during pregnancy – such as air pollutants and ETS – on the respiratory and immune systems of the offspring of asthmatic women.[46,47] The potential mechanisms likely involve multiple biological pathways, including oxidative stress, intrauterine inflammatory responses, placental dysfunction, and epigenetic modifications. These mechanisms collectively disrupt fetal lung development and immune programming, thereby increasing offspring susceptibility to asthma and other allergic diseases. Substantial evidence from animal studies supports this hypothesis, demonstrating that maternal exposure to particulate matter during pregnancy significantly elevates airway hyperresponsiveness and inflammatory cell infiltration in offspring.[48,49] Research indicates that prenatal exposure to particulate matter (particulate matter with an aerodynamic diameter of 2.5 μm or less and particulate matter with an aerodynamic diameter of 10 μm or less) and sulfur dioxide (SO_2) increases the risk of childhood asthma, rhinitis, and eczema; conversely, reducing or avoiding exposure to these pollutants can effectively lower the incidence of these conditions.[50,51] Additionally, women exposed to ETS during pregnancy face a higher probability of developing pregnancy complications themselves.[52] These findings not only underscore the critical role of environmental factors in the development and progression of asthma but also drive a fundamental shift in asthma prevention strategies toward the early stages of life. They suggest that clinical and public health interventions should be shifted to the prenatal or even preconception period. Through environmental risk management and individualized exposure intervention, primary prevention of asthma can be achieved. Future research should prioritize prospective birth cohort studies and interventional trials to evaluate the long-term health benefits of reducing specific environmental exposures during pregnancy, thereby advancing the management of asthma in pregnancy toward precision prevention.

In the field of research on asthma prevention during pregnancy, nutritional intervention strategies exhibit a distinct evolutionary trajectory. Early research focused mainly on the supplementation of single nutrients, particularly vitamin D and folic acid, and extensively explored the potential effects of their adequate levels' potential effects on the risk of asthma in offspring. Studies have shown that correcting the vitamin D deficiency of pregnant women in the early stage of pregnancy may reduce the risk of uncontrolled asthma and subsequently weaken its impact on the risk of preeclampsia.[53] For pregnant women with asthma risk, supplementing vitamin D can reduce the risk of asthma or recurrent wheezing

in their offspring until the age of 3.[54] Additionally, the timing and dosage of folic acid supplementation have become the focus of research. Substantial evidence demonstrates that early and appropriate folic acid supplementation is effective in preventing fetal neural tube defects.[55,56] However, excessive intake, especially before and during pregnancy, may be associated with an increased risk of asthma in offspring.[57,58] Nevertheless, as more evidence accumulates, researchers increasingly recognize that the isolated effect of nutrients is inevitably regulated and corrected by the overall dietary structure. Therefore, the research frontier has shifted from examining single supplements to exploring the long-term effects of the mother's overall dietary pattern during pregnancy (such as the Mediterranean diet) on the offspring's immune system and asthma risk.[59] A growing body of evidence indicates that the Mediterranean diet, characterized by high consumption of fruits, vegetables, fish, whole grains, and healthy fats, is associated with a decreased risk of asthma and allergic conditions in children.[60,61] This research highlights that future studies should shift from general recommendations to more scientifically informed strategies of precise nutrition and dietary guidance.

Maternal-infant complications are one of the core issues that have long been of concern in the field of pregnancy asthma research, and they have a profound impact on the health of both mothers and infants. Numerous studies have confirmed that pregnancy asthma significantly increases the risk of maternal complications, including preeclampsia, gestational diabetes, rhinitis, obesity, depression, placental abruption, etc. Poor asthma control directly increases the risk of adverse delivery outcomes such as premature birth and cesarean section.[4,62] For the fetus, chronic hypoxia and the inflammatory state caused by maternal asthma may lead to complications such as intrauterine growth restriction, low birth weight, neonatal asphyxia, etc. Severe asthma attacks are even the direct cause of fetal distress.[63,64] More importantly, this impact has significant long-term effects. For example, the risk of future metabolic and cardiovascular diseases in the mother may increase.[4] The incidence of asthma, allergic diseases, and lung function developmental disorders in the offspring significantly increases during childhood, and it may even affect the trajectory of neurocognitive development.[65–67] This research focus highlights the shift from perinatal asthma management to a health perspective throughout the entire life cycle, suggesting that clinical practice should place greater emphasis on optimizing pregnancy asthma control to improve the long-term prognosis of both mothers and infants. Future research should pay more attention to the long-term effects of early-life exposure, expand the follow-up period, and establish cross-generational cohorts to systematically clarify the impact of maternal asthma and its control level on the health of offspring in adolescence and even adulthood.

In the causal chain of the impact of gestational asthma on the health of the offspring, the maternal gut microbiome and its interaction with the immune system have become a crucial intermediary link. Current research generally holds that during pregnancy, the mother, as a "biological interface," the internal and external environmental factors (such as asthma status, diet, antibiotic use, etc) alter the structure and function of her gut microbiota.[68–70] This change systematically regulates the maternal immune state through microbial metabolites (such as short-chain fatty acids), cytokine networks, etc.[71,72] These regulated immune signals can be transmitted across the placenta to the developing fetus, influencing its immune programming and causing it to tend to produce a type 2 helper T cells-dominant response after birth. Eventually, this leads to an increased long-term susceptibility of the offspring to diseases such as asthma and allergic rhinitis.[73–75] Furthermore, maternal dysbiosis induced by asthma during pregnancy may also be transmitted to the newborn during delivery (via the birth canal) and postpartum lactation. This can result in the infant being colonized with an "unhealthy" microbiota at the earliest stage of life, accompanied by impaired immune maturation, thereby increasing the risk of childhood asthma and allergies.[76,77] In summary, the maternal asthma condition during pregnancy is likely to transfer the risk of disease susceptibility to the offspring by disrupting the core hub of the "gut microbiome-immune axis." However, the specific molecular mechanisms and potential for transformation still need to be further explored. Future research should focus on constructing a more refined and dynamic "mother-fetus-microbiome" interaction network, which may provide new, precise prevention strategies beyond symptom control for the management of pregnancy-related asthma.

4.4. Clinical progress

Through a systematic analysis of 28 clinical trials related to asthma during pregnancy retrieved from the PubMed database, we identified several key trends and priority research areas. First, nutritional and supplemental interventions represent a pivotal area of research in the management of asthma in pregnancy. Among these, vitamin D has emerged as a primary nutritional intervention, with recent emphasis on personalized supplementation strategies – such as baseline vitamin D levels and gestational stage.[78] For example, research published in 2023 showed that high-dose vitamin D supplementation (4400 IU) in severely deficient expectant mothers effectively corrected the deficiency, and this intervention was correlated with a decreased incidence of offspring asthma or recurrent wheezing.[79] Furthermore, the efficacy of vitamin D supplementation is influenced by timing, with the greatest benefits observed when supplementation is initiated early in pregnancy (during the 1st trimester). Second, the management of asthma during pregnancy has shifted from a symptom-oriented approach to a biomarker-guided precision management strategy. Biomarkers such as FeNO and peripheral blood eosinophil count are now utilized to assess maternal airway inflammation,[80] thereby facilitating the development of individualized treatment plans and enabling more precise disease control.[81] Research indicates that tailoring asthma medication for pregnant patients based on FeNO levels effectively lowers the risk of severe exacerbations and acute attacks, thereby preventing unnecessary overtreatment.[82,83] Vanessa E. Murphy et al found that when eosinophilic inflammation or symptoms are mild, a reduction in the dose of inhaled corticosteroids could be considered, offering a feasible management strategy for pregnant individuals and healthcare providers seeking to minimize inhaled corticosteroids exposure during pregnancy.[84] Third, gestational weight management has garnered increasing attention. Research indicates that excessive gestational weight gain may not only exacerbate asthma severity in pregnant individuals but also increase the risk of wheezing in their offspring.[85,86] This suggests that maternal body mass index and gestational weight gain serve as key modifiable factors influencing both asthma control and offspring asthma risk, underscoring the critical importance of weight management within the comprehensive management of asthma during pregnancy. Finally, substantial advancements have occurred in elucidating the enduring outcomes for both mothers and children, alongside the impacts on development. Research by Joerg Matt et al demonstrated that optimizing asthma management during pregnancy may reduce the risk and severity of childhood asthma by decreasing the recurrence of infant bronchiolitis.[87] Ailee R. Jone et al found that maternal asthma exposure during pregnancy may lead to persistent alterations in offspring retinal microvasculature, potentially mediated by changes in intrauterine angiogenesis mechanisms.[88] Furthermore, a study by Jiatao Zhang et al revealed that exposure to extreme apparent temperatures

during early and late pregnancy could increase the risk of childhood asthma and wheezing, particularly among offspring of asthmatic parents, where the risk appears more pronounced.[89] In summary, clinical research on asthma during pregnancy has evolved from single-nutrient interventions to a comprehensive management paradigm that is multidimensional, individualized, and technology-driven. Studies are increasingly focusing on biomarker-guided therapy, maternal metabolic health, and the long-term health of the offspring. Future research should further integrate multi-omics data – such as genomics, epigenomics, metabolomics, and microbiome data.

Through quantitative research, we have found that the translation of research results into clinical practice still faces significant implementation gaps. This gap is particularly prominent in resource-limited environments. A large amount of high-quality evidence often comes from research systems in high-income countries, and its global applicability is constrained by multiple factors such as population genetic background, medical resource allocation, social and cultural factors, and climate environment differences. Therefore, future research needs to strengthen the "fair health" perspective. At the design stage, it should consider the feasibility and accessibility of research results under different resource settings and promote the establishment of pregnancy asthma management paths that are adapted to local needs. In addition, to truly achieve patient-centered care, future research should go beyond the number of published papers and citation frequency, and pay more attention to and integrate patient-oriented outcome indicators, such as asthma control levels, pregnancy-related quality of life, long-term health of mother and child, and medical experience, etc. Thus, the quality and fairness of global pregnancy asthma management can be improved, and scientific knowledge can be effectively transformed into a health guarantee for every pregnant woman.

5. Limitations

The methodology employed in this study inherently entails certain limitations. First, our English-only focus may have missed significant non-English studies, such as Chinese, German, and Japanese. Second, bibliometric indicators such as citation counts and publication volume are influenced by factors including disciplinary trends, journal impact, and publication date, and thus may not fully reflect the academic quality or clinical relevance of the research, thereby affecting the interpretation of influence and impact. In addition, the use of the WoSCC may lead to an overrepresentation of high-impact journals while underrepresenting regional or specialty journals, creating a database selection bias. Furthermore, disparities in research funding and scholarly infrastructure across regions likely contribute to geographic imbalances in the literature, which may not accurately reflect global research activity or need. There is also a temporal lag between emerging clinical practices and their reflection in published, citable literature, meaning that bibliometric patterns may not capture the most current shifts in research or clinical focus. Moreover, this study did not include gray literature such as conference abstracts, reports, or preprints, which may contain valuable early findings or alternative perspectives. Finally, bibliometric analysis primarily measures research productivity and visibility rather than directly assessing scientific quality, methodological rigor, or clinical applicability, necessitating cautious interpretation of quantitative findings.

6. Conclusions

This study maps the global research landscape of asthma during pregnancy from 2008 to 2024 through a multidisciplinary bibliometric analysis, integrating knowledge networks, thematic evolution, and clinical trial trends. The field encompasses several major themes, including environmental exposures, nutritional interventions, maternal and fetal outcomes, and offspring health, with emerging interest in inflammation, the gut microbiome, and biomarkers. The supplementary analysis of clinical trials further characterizes clinical research priorities, particularly nutritional supplementation, biomarker-guided asthma management, and long-term offspring outcomes. These findings provide a structured overview of the field and help identify priorities for future interdisciplinary research and clinical investigation. However, bibliometric patterns reflect research activity rather than clinical efficacy; the potential benefits of specific interventions and the clinical significance of emerging topics require further validation through well-designed prospective studies and clinical trials.

Author contributions

Data curation: Yingfu Zhou.
Formal analysis: Shimei Tang.
Investigation: Shimei Tang.
Methodology: Qin Xiu Zhang.
Project administration: Qin Xiu Zhang.
Software: Yingfu Zhou.
Supervision: Yong Huang.
Validation: Yong Huang.
Visualization: Yingfu Zhou.
Writing – original draft: Yingfu Zhou, Shimei Tang.
Writing – review & editing: Yingfu Zhou, Qin Xiu Zhang.

References

[1] Mims JW. Asthma: definitions and pathophysiology. Int Forum Allergy Rhinol. 2015;5(Suppl 1):S2–6.
[2] Holgate ST, Wenzel S, Postma DS, Weiss ST, Renz H, Sly PD. Asthma. Nat Rev Dis Primers. 2015;1:15025.
[3] Lee S, Hetherington E, Leigh R, Ramage K, Metcalfe A. Impact of asthma medications during pregnancy on asthma exacerbation, maternal, and neonatal outcomes. J Allergy Clin Immunol Pract. 2024;12:1549–57.e3.
[4] Bonham CA, Patterson KC, Strek ME. Asthma outcomes and management during pregnancy. Chest. 2018;153:515–27.
[5] Abdullah K, Zhu J, Gershon A, Dell S, To T. Effect of asthma exacerbation during pregnancy in women with asthma: a population-based cohort study. Eur Respir J. 2020;55:1901335.
[6] Murphy VE, Gibson PG, Schatz M. Managing asthma during pregnancy and the postpartum period. J Allergy Clin Immunol Pract. 2023;11:3585–94.
[7] Ali Z, Hansen AV, Ulrik CS. Exacerbations of asthma during pregnancy: impact on pregnancy complications and outcome. J Obstet Gynaecol. 2016;36:455–61.
[8] Meakin AS, Saif Z, Seedat N, Clifton VL. The impact of maternal asthma during pregnancy on fetal growth and development: a review. Expert Rev Respir Med. 2020;14:1207–16.
[9] Murphy VE, Schatz M. Asthma in pregnancy: a hit for two. Eur Respir Rev. 2014;23:64–8.
[10] Bravo-Solarte DC, Garcia-Guaqueta DP, Chiarella SE. Asthma in pregnancy. Allergy Asthma Proc. 2023;44:24–34.
[11] Zanforlin A, Corsico AG, Di Marco F, Patella V, Scichilone N. Asthma in pregnancy: one more piece of the puzzle. Minerva Med. 2016;107(1 Suppl 1):1–4.
[12] Jones CE, Jamil Y. Management of asthma in pregnancy. Clin Med (Lond). 2025;25:100277.
[13] Ninkov A, Frank JR, Maggio LA. Bibliometrics: methods for studying academic publishing. Perspect Med Educ. 2022;11:173–6.
[14] Cooper ID. Bibliometrics basics. J Med Libr Assoc. 2015;103:217–8.
[15] Thompson DF, Walker CK. A descriptive and historical review of bibliometrics with applications to medical sciences. Pharmacotherapy. 2015;35:551–9.
[16] Hassan W, Duarte AE. Bibliometric analysis: a few suggestions. Curr Probl Cardiol. 2024;49:102640.
[17] Hu Y, Yu Z, Cheng X, Luo Y, Wen C. A bibliometric analysis and visualization of medical data mining research. Medicine (Baltim). 2020;99:e20338.

[18] Aria M, Cuccurullo C. bibliometrix: an R-tool for comprehensive science mapping analysis. J Inform. 2017;11:959–75.
[19] Chen C. CiteSpace II: detecting and visualizing emerging trends and transient patterns in scientific literature. J Am Soc Inf Sci. 2005;57:359–77.
[20] van Eck NJ, Waltman L. Software survey: VOSviewer, a computer program for bibliometric mapping. Scientometrics. 2010;84:523–38.
[21] Jiang ST, Liu YG, Zhang L, Sang XT, Xu YY, Lu X. Immune-related adverse events: a bibliometric analysis. Front Immunol. 2022;13:1096806.
[22] Chen C. Searching for intellectual turning points: progressive knowledge domain visualization. Proc Natl Acad Sci USA. 2004;101(suppl_1):5303–10.
[23] Chen C, Song M. Visualizing a field of research: a methodology of systematic scientometric reviews. PLoS One. 2019;14:e0223994.
[24] Li W, Xia Z, Wang Y. A bibliometric analysis of publications on ferritinophagy from 2014 to 2021. Front Biosci (Landmark Ed). 2022;27:193.
[25] Wu F, Gao J, Kang J, et al. Knowledge mapping of exosomes in autoimmune diseases: a bibliometric analysis (2002–2021). Front Immunol. 2022;13:939433.
[26] Yang M, Zhang H, Liu W, et al. Knowledge graph analysis and visualization of artificial intelligence applied in electrocardiogram. Front Physiol. 2023;14:1118360.
[27] Ke L, Lu C, Shen R, Lu T, Ma B, Hua Y. Knowledge mapping of drug-induced liver injury: a scientometric investigation (2010–2019). Front Pharmacol. 2020;11:842.
[28] Devereux G, Litonjua AA, Turner SW, et al. Maternal vitamin D intake during pregnancy and early childhood wheezing. Am J Clin Nutr. 2007;85:853–9.
[29] Camargo CA, Rifas-Shiman SL, Litonjua AA, et al. Maternal intake of vitamin D during pregnancy and risk of recurrent wheeze in children at 3 y of age. Am J Clin Nutr. 2007;85:788–95.
[30] Murphy VE, Namazy JA, Powell H, et al. A meta-analysis of adverse perinatal outcomes in women with asthma. BJOG. 2011;118:1314–23.
[31] Litonjua AA, Carey VJ, Laranjo N, et al. Effect of prenatal supplementation with vitamin D on asthma or recurrent wheezing in offspring by age 3 years: the VDAART randomized clinical trial. JAMA. 2016;315:362–70.
[32] Chawes BL, Bønnelykke K, Stokholm J, et al. Effect of Vitamin D3 supplementation during pregnancy on risk of persistent wheeze in the offspring: a randomized clinical trial. JAMA. 2016;315:353–61.
[33] Garcia-Larsen V, Ierodiakonou D, Jarrold K, et al. Diet during pregnancy and infancy and risk of allergic or autoimmune disease: a systematic review and meta-analysis. PLoS Med. 2018;15:e1002507.
[34] Venter C, Agostoni C, Arshad SH, et al. Dietary factors during pregnancy and atopic outcomes in childhood: a systematic review from the European Academy of Allergy and Clinical Immunology. Pediatr Allergy Immunol. 2020;31:889–912.
[35] Mirzakhani H, Litonjua AA, McElrath TF, et al. Early pregnancy vitamin D status and risk of preeclampsia. J Clin Invest. 2016;126:4702–15.
[36] Wolsk HM, Chawes BL, Litonjua AA, et al. Prenatal vitamin D supplementation reduces risk of asthma/recurrent wheeze in early childhood: a combined analysis of two randomized controlled trials. PLoS One. 2017;12:e0186657.
[37] Bisgaard H, Stokholm J, Chawes BL, et al. Fish oil-derived fatty acids in pregnancy and wheeze and asthma in offspring. N Engl J Med. 2016;375:2530–9.
[38] Stensballe LG, Simonsen J, Jensen SM, Bønnelykke K, Bisgaard H. Use of antibiotics during pregnancy increases the risk of asthma in early childhood. J Pediatr. 2013;162:832–8.e3.
[39] Joubert BR, Felix JF, Yousefi P, et al. DNA methylation in newborns and maternal smoking in pregnancy: genome-wide consortium meta-analysis. Am J Hum Genet. 2016;98:680–96.
[40] Asher MI, Keil U, Anderson HR, et al. International Study of Asthma and Allergies in Childhood (ISAAC): rationale and methods. Eur Respir J. 1995;8:483–91.
[41] Asher MI, Montefort S, Björkstén B, et al. Worldwide time trends in the prevalence of symptoms of asthma, allergic rhinoconjunctivitis, and eczema in childhood: ISAAC phases one and three repeat multicountry cross-sectional surveys. Lancet. 2006;368:733–43.
[42] Martinez FD, Wright AL, Taussig LM, Holberg CJ, Halonen M, Morgan WJ. Asthma and wheezing in the first six years of life. The Group Health Medical Associates. N Engl J Med. 1995;332:133–8.
[43] Miller MR, Hankinson J, Brusasco V, et al. Standardisation of spirometry. Eur Respir J. 2005;26:319–38.
[44] Murphy VE, Clifton VL, Gibson PG. Asthma exacerbations during pregnancy: incidence and association with adverse pregnancy outcomes. Thorax. 2006;61:169–76.
[45] Erkkola M, Kaila M, Nwaru BI, et al. Maternal vitamin D intake during pregnancy is inversely associated with asthma and allergic rhinitis in 5-year-old children. Clin Exp Allergy. 2009;39:875–82.
[46] Seeni I, Ha S, Nobles C, Liu D, Sherman S, Mendola P. Air pollution exposure during pregnancy: maternal asthma and neonatal respiratory outcomes. Ann Epidemiol. 2018;28:612–8.e4.
[47] Shiroshita A, Kataoka Y, Wang Q, et al. Joint associations of air pollutants during pregnancy, infancy, and childhood with childhood persistent asthma: nationwide database study in Japan. Ecotoxicol Environ Saf. 2024;281:116626.
[48] Gregory DJ, Kobzik L, Yang Z, McGuire CC, Fedulov AV. Transgenerational transmission of asthma risk after exposure to environmental particles during pregnancy. Am J Physiol Lung Cell Mol Physiol. 2017;313:L395–405.
[49] Fedulov AV, Leme A, Yang Z, et al. Pulmonary exposure to particles during pregnancy causes increased neonatal asthma susceptibility. Am J Respir Cell Mol Biol. 2008;38:57–67.
[50] Bao L, Liu Y, Zhang Y, et al. Association analysis of maternal exposure to air pollution during pregnancy and offspring asthma incidence. Reprod Health. 2025;22:29.
[51] Deng Q, Lu C, Li Y, Sundell J, Dan N. Exposure to outdoor air pollution during trimesters of pregnancy and childhood asthma, allergic rhinitis, and eczema. Environ Res. 2016;150:119–27.
[52] Fazel N, Kundi M, Kazemzadeh A, Esmaily H, Akbarzadeh R, Ahmadi R. Environmental tobacco smoke exposure during pregnancy affects complications and birth outcomes in women with and without asthma. BMC Pregnancy Childbirth. 2020;20:314.
[53] Mirzakhani H, Carey VJ, McElrath TF, et al. The association of maternal asthma and early pregnancy vitamin D with risk of preeclampsia: an observation from Vitamin D Antenatal Asthma Reduction Trial (VDAART). J Allergy Clin Immunol Pract. 2018;6:600–8.e2.
[54] Wolsk HM, Harshfield BJ, Laranjo N, et al. Vitamin D supplementation in pregnancy, prenatal 25(OH)D levels, race, and subsequent asthma or recurrent wheeze in offspring: secondary analyses from the vitamin D antenatal asthma reduction trial. J Allergy Clin Immunol. 2017;140:1423–9.e5.
[55] Viswanathan M, Urrutia RP, Hudson KN, Middleton JC, Kahwati LC. Folic acid supplementation to prevent neural tube defects: updated evidence report and systematic review for the US preventive services task force. JAMA. 2023;330:460–6.
[56] Ferrazzi E, Tiso G, Di Martino D. Folic acid versus 5-methyl tetrahydrofolate supplementation in pregnancy. Eur J Obstet Gynecol Reprod Biol. 2020;253:312–9.
[57] Parr CL, Magnus MC, Karlstad O, et al. Maternal folate intake during pregnancy and childhood asthma in a population-based cohort. Am J Respir Crit Care Med. 2017;195:221–8.
[58] Zetstra-van der Woude PA, De Walle HE, Hoek A, et al. Maternal high-dose folic acid during pregnancy and asthma medication in the offspring. Pharmacoepidemiol Drug Saf. 2014;23:1059–65.
[59] Chatzi L, Torrent M, Romieu I, et al. Mediterranean diet in pregnancy is protective for wheeze and atopy in childhood. Thorax. 2008;63:507–13.
[60] Biagi C, Nunzio MD, Bordoni A, Gori D, Lanari M. Effect of adherence to mediterranean diet during pregnancy on children's health: a systematic review. Nutrients. 2019;11:997.
[61] Zhang Y, Lin J, Fu W, Liu S, Gong C, Dai J. Mediterranean diet during pregnancy and childhood for asthma in children: a systematic review and meta-analysis of observational studies. Pediatr Pulmonol. 2019;54:949–61.
[62] Yland JJ, Bateman BT, Huybrechts KF, et al. Perinatal outcomes associated with maternal asthma and its severity and control during pregnancy. J Allergy Clin Immunol Pract. 2020;8:1928–37.e3.
[63] Javorac J, Živanović D, Zvezdin B, Jovin VM. Breathing for two: asthma management, treatment, and safety of pharmacological therapy during pregnancy. Medicines (Basel). 2024;11:18.
[64] Namazy JA, Murphy VE, Powell H, Gibson PG, Chambers C, Schatz M. Effects of asthma severity, exacerbations and oral corticosteroids on perinatal outcomes. Eur Respir J. 2013;41:1082–90.
[65] Roff AJ, Robinson JL, Hammond SJ, et al. Maternal asthma during pregnancy and risks of allergy and asthma in progeny: a systematic review and meta-analysis. BJOG. 2025;132:1045–55.

[66] Whalen OM, Karayanidis F, Murphy VE, Lane AE, Mallise CA, Campbell LE. The effects of maternal asthma during pregnancy on child cognitive and behavioral development: a systematic review. J Asthma. 2019;56:130–41.
[67] Husain SF, Cremaschi A, Suaini NHA, et al. Maternal asthma symptoms during pregnancy on child behaviour and executive function: a Bayesian phenomics approach. Brain Behav Immun. 2024;118:202–9.
[68] Liu ZZ, Sun JH, Wang WJ. Gut microbiota in gastrointestinal diseases during pregnancy. World J Clin Cases. 2022;10:2976–89.
[69] Siena M, Laterza L, Matteo MV, et al. Gut and reproductive tract microbiota adaptation during pregnancy: new insights for pregnancy-related complications and therapy. Microorganisms. 2021;9:473.
[70] Alhasan MM, Cait AM, Heimesaat MM, et al. Antibiotic use during pregnancy increases offspring asthma severity in a dose-dependent manner. Allergy. 2020;75:1979–90.
[71] Gray LE, O'Hely M, Ranganathan S, Sly PD, Vuillermin P. The maternal diet, gut bacteria, and bacterial metabolites during pregnancy influence offspring asthma. Front Immunol. 2017;8:365.
[72] Rooks MG, Garrett WS. Gut microbiota, metabolites and host immunity. Nat Rev Immunol. 2016;16:341–52.
[73] Vuillermin PJ, Macia L, Nanan R, Tang ML, Collier F, Brix S. The maternal microbiome during pregnancy and allergic disease in the offspring. Semin Immunopathol. 2017;39:669–75.
[74] Gao Y, Nanan R, Macia L, et al. The maternal gut microbiome during pregnancy and offspring allergy and asthma. J Allergy Clin Immunol. 2021;148:669–78.
[75] Azad MB, Kozyrskyj AL. Perinatal programming of asthma: the role of gut microbiota. Clin Dev Immunol. 2012;2012:932072.
[76] Alsharairi NA. The infant gut microbiota and risk of asthma: the effect of maternal nutrition during pregnancy and lactation. Microorganisms. 2020;8:1119.
[77] Kim H, Sitarik AR, Woodcroft K, Johnson CC, Zoratti E. Birth mode, breastfeeding, pet exposure, and antibiotic use: associations with the gut microbiome and sensitization in children. Curr Allergy Asthma Rep. 2019;19:22.
[78] Brustad N, Eliasen AU, Stokholm J, Bønnelykke K, Bisgaard H, Chawes BL. High-dose vitamin D supplementation during pregnancy and asthma in offspring at the age of 6 years. JAMA. 2019;321:1003–5.
[79] Shadid IL, Brustad N, Lu M, et al. The impact of baseline 25-hydroxyvitamin D level and gestational age on prenatal vitamin D supplementation to prevent offspring asthma or recurrent wheezing. Am J Clin Nutr. 2023;117:1342–52.
[80] Murphy VE, Jensen ME, Mattes J, et al. The breathing for life trial: a randomised controlled trial of fractional exhaled nitric oxide (FENO)-based management of asthma during pregnancy and its impact on perinatal outcomes and infant and childhood respiratory health. BMC Pregnancy Childbirth. 2016;16:111.
[81] Morten M, Collison A, Murphy VE, et al. Managing asthma in pregnancy (MAP) trial: FENO levels and childhood asthma. J Allergy Clin Immunol. 2018;142:1765–72.e4.
[82] Powell H, Murphy VE, Taylor DR, et al. Management of asthma in pregnancy guided by measurement of fraction of exhaled nitric oxide: a double-blind, randomised controlled trial. Lancet. 2011;378:983–90.
[83] Murphy VE, Porsbjerg CM, Robijn AL, Gibson PG. Biomarker-guided management reduces exacerbations in non-eosinophilic asthma in pregnancy: a secondary analysis of a randomized controlled trial. Respirology. 2020;25:719–25.
[84] Murphy VE, Jensen ME, Gibson PG. Exacerbations of asthma following step-up and step-down inhaled corticosteroid and long acting beta agonist therapy in the managing asthma in pregnancy study. J Asthma. 2022;59:362–9.
[85] Ali Z, Nilas L, Ulrik CS. Excessive gestational weight gain in first trimester is a risk factor for exacerbation of asthma during pregnancy: a prospective study of 1283 pregnancies. J Allergy Clin Immunol. 2018;141:761–7.
[86] Murphy VE, Jensen ME, Robijn AL, et al. How maternal BMI modifies the impact of personalized asthma management in pregnancy. J Allergy Clin Immunol Pract. 2020;8:219–28.e3.
[87] Mattes J, Murphy VE, Powell H, Gibson PG. Prenatal origins of bronchiolitis: protective effect of optimised asthma management during pregnancy. Thorax. 2014;69:383–4.
[88] Jones AR, Tuckwell C, Wright IMR, et al. The impact of maternal asthma during pregnancy on offspring retinal microvascular structure and its relationship to placental growth factor production in utero. Microcirculation. 2020;27:e12622.
[89] Zhang J, Bai S, Lin S, et al. Maternal apparent temperature during pregnancy on the risk of offspring asthma and wheezing: effect, critical window, and modifiers. Environ Sci Pollut Res Int. 2023;30:62924–37.