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Original Article PHARMACOLOGY

Global bibliometric insights on prenatal exposures and pregnancy outcomes

Pelin Koca,[1] Elif Keskin Arslan,[1] Ayse Ozkan[2]

[1]Department of Medical Pharmacology, Izmir Bakircay University Faculty of Medicine, Izmir, Turkiye
[2]Department of Physiology, Izmir Bakircay University Faculty of Medicine, Izmir, Turkiye

ABSTRACT

OBJECTIVE: Prenatal exposure to medications or environmental agents may contribute to adverse pregnancy outcomes and birth defects. This study provides a comprehensive bibliometric overview of the global research landscape on prenatal exposures and associated outcomes.

METHODS: A systematic literature search was conducted in the Web of Science database on November 11, 2024. Articles and reviews addressing prenatal exposures and pregnancy outcomes, indexed in the Science Citation Index, Science Citation Index-Expanded, or Emerging Sources Citation Index, were screened. Data were analyzed and visualized using VOSviewer, the R-package Bibliometrix, and Microsoft Excel 2021.

RESULTS: A total of 3,361 articles were analyzed. Publications on this topic have steadily increased over the past two decades, peaking in 2022. The United States emerged as the most productive country, followed by China and Canada. Gideon Koren was identified as the most prolific author, while Reproductive Toxicology published the highest number of articles. Among the keywords, "pregnancy" remained the most frequent overall; however, "placenta," "adverse pregnancy outcomes," and "systematic review" peaked in 2022, while "meta-analysis," "outcomes," and "stillbirth" peaked in 2021.

CONCLUSION: This bibliometric study highlights the global evolution of scientific research on prenatal exposures and pregnancy outcomes. The findings offer valuable insights for clinicians, researchers, and policymakers, enabling a better understanding of the dynamic trends and emerging areas in this field.

Keywords: Birth defects; prenatal exposure; pregnancy; research trends; women.

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The discovery of teratogenic agents in the early 20th century marked the beginning of modern teratology. Although early evidence suggested some drugs and environmental exposures cause birth defects, the belief in fetal protection persisted until the 1961 Thalidomide tragedy [1, 2]. This event raised global awareness about drug safety during pregnancy [3]. Nevertheless, medications are often essential for managing maternal conditions, while environmental exposure remains a concern. Ethical constraints limit randomized controlled trials (RCTs) in pregnant women, making observational studies the main source for guidance [4]. Preclinical research also contributes valuable insights.

Examining how the scientific community has addressed these challenges through research output is critical. Bibliometric analysis maps trends and identifies leading topics, authors, and institutions [5–7]. Despite increasing publications on teratogenicity, no bibliometric study has specifically focused on prenatal exposures. This study aims to fill this gap with a global bibliometric and visualization-based analysis of prenatal exposures and maternal-fetal outcomes.

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Correspondence: Pelin KOCA, MD. Izmir Bakircay Universitesi Tip Fakultesi, Tibbi Farmakoloji Anabilim Dali, Izmir, Turkiye.
Tel: +90 531 735 47 41 e-mail: pelin.koca@bakircay.edu.tr

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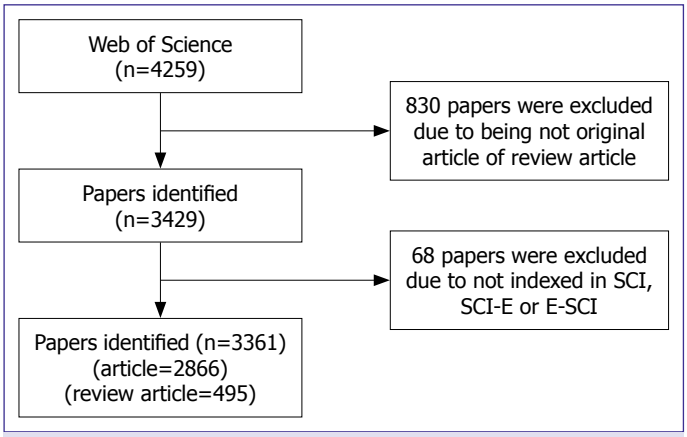


FIGURE 1. Flowchart of literature screening.

MATERIALS AND METHODS

Data Collection

A literature search was conducted in the Web of Science (WoS) database on November 11, 2024. The search formula was: "pregnancy" or "prenatal" or "maternal" (title)and "drug" or "treatment" or "exposure" or "use" (title) and "teratogenicity" or "teratogen" or "congenital malformation" or congenital malformations" or "birth defect" or "birth defects" or "pregnancy outcome" or "pregnancy outcomes" (topic). Inclusion criteria: articles and reviews indexed in Science Citation Index (SCI), Science Citation Index-Expanded (SCI-E), or Emerging Sources Citation Index (ESCI). Exclusion criteria: proceeding papers, early access, retracted publications, Social Sciences Citation Index (SSCI), Conference Proceedings Citation Index-Science (CPCI-S), and Conference Proceedings Citation Index-Social Science & Humanities (CPCI-SSH). The time frame included all WoS studies until November 11, 2024.

Data Analysis and Visualization

Bibliometric analysis was conducted using VOSviewer (v1.6.20), Bibliometrix R-package (v4.4.2) [8], and Microsoft Excel. VOSviewer enabled co-authorship, co-occurrence, and co-citation analyses, while Bibliometrix estimated indicators such as number of publications (NP), total citations (TC), local citations (LC), average citations, h-index, g-index, and total citations per year (TCpY), and visualized outputs by journal, author, and institution. Journal metrics (impact factor, "Journal Citation Indicator [JCI]," and "Journal Citation Report [JCR]" quartiles) were retrieved from WoS. Excel supported data organization. Rankings were based on NP; TC broke ties. TC reflects citations from all documents, whereas LC denotes citations within the dataset [9].

Highlight key points

- The USA leads in productivity, citations, and international collaboration within prenatal exposure research.
- Recent research trends highlight increasing focus on the placenta and maternal environmental exposures.
- Systematic reviews and meta-analyses are increasingly employed to evaluate prenatal exposures.

RESULTS

A comprehensive search in the WoS database on November 11, 2024, retrieved 4,259 records. After applying inclusion and exclusion criteria, 3,361 articles and reviews were included (Fig. 1). These publications included 16,632 authors from 4,128 institutions in 88 countries/regions and were published in 1,033 journals.

Publications Analysis

Among the 3,361 publications, 3,154 (93.8%) appeared in SCI-E journals, and 207 (6.2%) in ESCI journals. Most publications were in English (n=3,312; 98.5%), followed by French (n=16; 0.5%) and Spanish (n=12; 0.4%). Citation analysis is shown in Table 1, presenting the 10 most cited publications [10–19]. TC was 112,636; average citations per article were 33.45; and h-index was 137. Notably, nine articles each received over 500 citations. The top-cited article, "Effect of treatment of gestational diabetes mellitus on pregnancy outcomes," had 1,846 TC and highest TCpY (92.30). This RCT by Crowther et al.[10] assessed the effects of interventions on maternal and neonatal outcomes in gestational diabetes diagnosed at 24–34 weeks [10].

Annual NP indicates developmental patterns and trends [20]. Figure 2 depicts annual publication and citation trends. Publications remained under 100 annually until 2009, then increased steadily from 2010. The highest NP was in 2022 (n=237; 7.1%), followed by 2021 (n=232; 6.9%) and 2023 (n=208; 6.2%). Citation counts followed a similar pattern, peaking at 8,926 in 2021.

Table 1. Ranking of the most cited 10 publications

R	First author	Title	Journal	Type	LC	TC	TCpY	JCR quartile	JCI (2023)
1	Crowther, Caroline A. (2005)	Effect of treatment of gestational diabetes mellitus on pregnancy outcomes [10]	New England Journal of Medicine	Randomized controlled trial	0	1,846	92.30	Q1	25.31
2	Christensen, Jakob (2013)	Prenatal Valproate Exposure and Risk of Autism Spectrum Disorders and Childhood Autism [11]	Jama-Journal of The American Medical Association	Cohort	33	812	67.67	Q1	11.9
3	Skorpen, Carina Gotestam (2016)	The EULAR points to consider for use of antirheumatic drugs before pregnancy and during pregnancy and lactation [12]	Annals of The Rheumatic Diseases	Systematic literature review	31	702	78.00	Q1	5.1
4	Kutteh, William H. (1996)	Antiphospholipid antibody-associated recurrent pregnancy loss: Treatment with heparin and low-dose aspirin is superior to low-dose aspirin alone [13]	American Journal of Obstetrics and Gynecology	Cohort	12	617	21.28	Q1	3.4
5	Park-Wyllie, Laura (2000)	Birth defects after maternal exposure to corticosteroids: Prospective cohort study and meta-analysis of epidemiological studies [14]	Teratology (Birth Defects Research)	Meta-analysis	0	614	24.56	Q4	0.45
6	Mitchell, Allen A. (2011)	Medication use during pregnancy, with particular focus on prescription drugs: 1976–2008 [15]	American Journal of Obstetrics and Gynecology	Article	57	574	41.00	Q1	3.4
7	Popova, Svetlana. (2017)	Estimation of national, regional, and global prevalence of alcohol use during pregnancy and fetal alcohol syndrome: a systematic review and meta-analysis [16]	Lancet Global Health	Review	13	554	69.25	Q1	6.28
8	Greer, Ian A. (2005)	Low-molecular-weight heparins for thromboprophylaxis and treatment of venous thromboembolism in pregnancy: a systematic review of safety and efficacy [17]	Blood	Review	17	552	27.60	Q1	3.58
9	Arbyn, M. (2008)	Perinatal mortality and other severe adverse pregnancy outcomes associated with treatment of cervical intraepithelial neoplasia: meta-analysis [18]	BMJ-British Medical Journal	Meta-analysis	0	511	30.06	Q1	10.16
10	Haider, Batool (2013)	Anaemia, prenatal iron use, and risk of adverse pregnancy outcomes: systematic review and meta-analysis [19]	BMJ-British Medical Journal	Meta-analysis	0	481	40.08	Q1	10.16

R: Rank; JCR: Journal citation report; JCI: Journal citation indicator; LC: Local citation; TC: Total citation; TCpY: Total citations per year.

TABLE 2. The top 10 most productive authors

Rank	Authors	NP	LC	TC	h-index	g-index	Total link strength	Articles fractionalized score
1	Koren, G.	102	398	6,337	45	78	228	24
2	Werler, MM.	46	248	2,378	23	46	210	7
3	Romitti, PA.	45	100	1,355	23	36	314	4.2
4	Langlois, PH.	37	47	909	18	29	281	3.2
5	Mitchell, AA.	36	286	2,587	26	36	100	6.9
6	Schaefer, C.	35	137	975	18	31	152	7.9
7	Li, Y.	32	1	418	11	20	131	4.5
8	Reefhuis, J.	30	82	1,610	18	30	179	3.4
9	Li, J.	30	11	216	9	13	173	3.3
10	Zhang, Y.	29	56	692	14	26	161	3.3

NP: Number of publications; LC: Local citation; TC: Total citation.

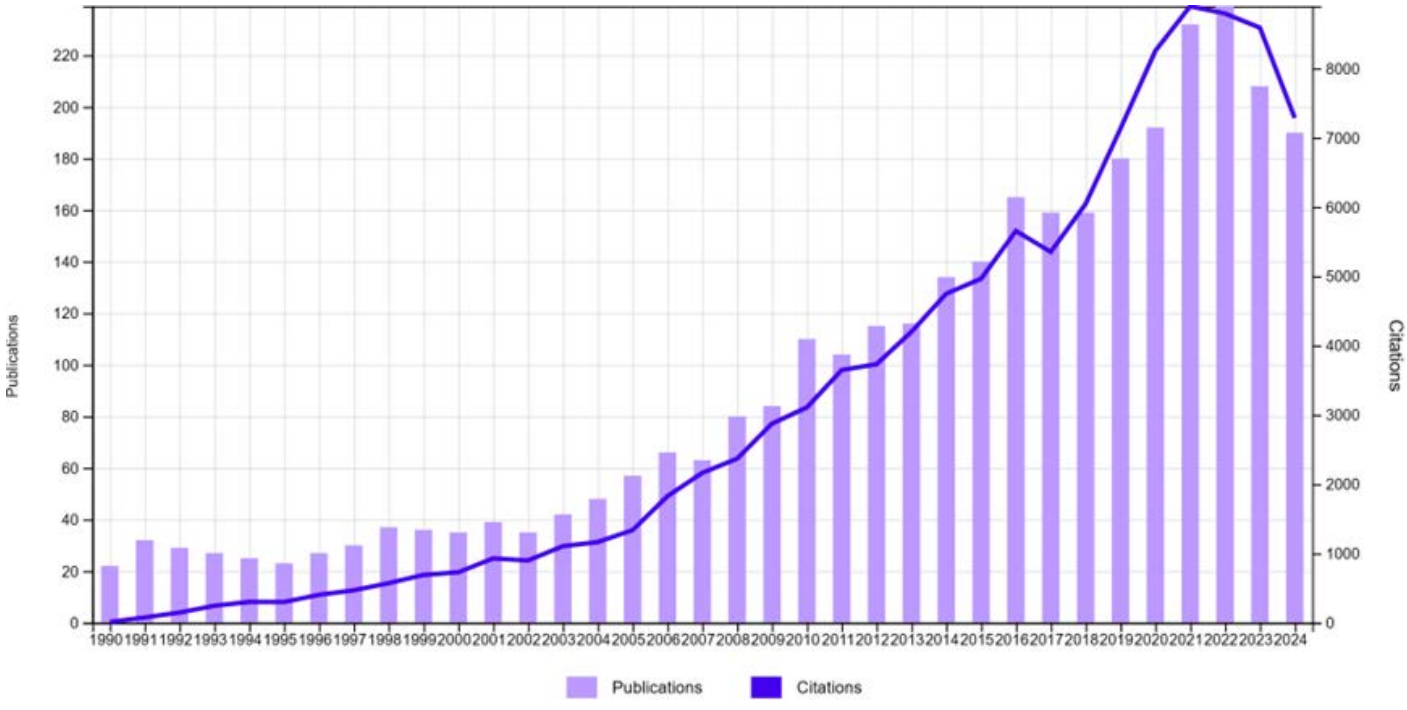


FIGURE 2. Annual citation and publication number trend chart.

Author Analysis

Most Productive Authors

A total of 16,632 authors studying prenatal exposures and pregnancy outcomes were systematically analyzed. Table 2 lists the top ten authors by NP. Leading contributors included Koren, G (n=102), Werler, MM (n=46), and Romitti, PA (n=45). The top three in LC were Koren, G (n=398), Mitchell, AA (n=286), and Werler, MM (n=248).

Koren, G had the highest h-index (45) and g-index (78), indicating strong productivity and citation impact. He was followed by Mitchell, AA (h-index 26; g-index 36) and Werler, MM (h-index 23; g-index 46).

Considering total link strength (collaboration intensity), Romitti, PA led (n=314), followed by Langlois, PH (n=281) and Koren, G (n=228).

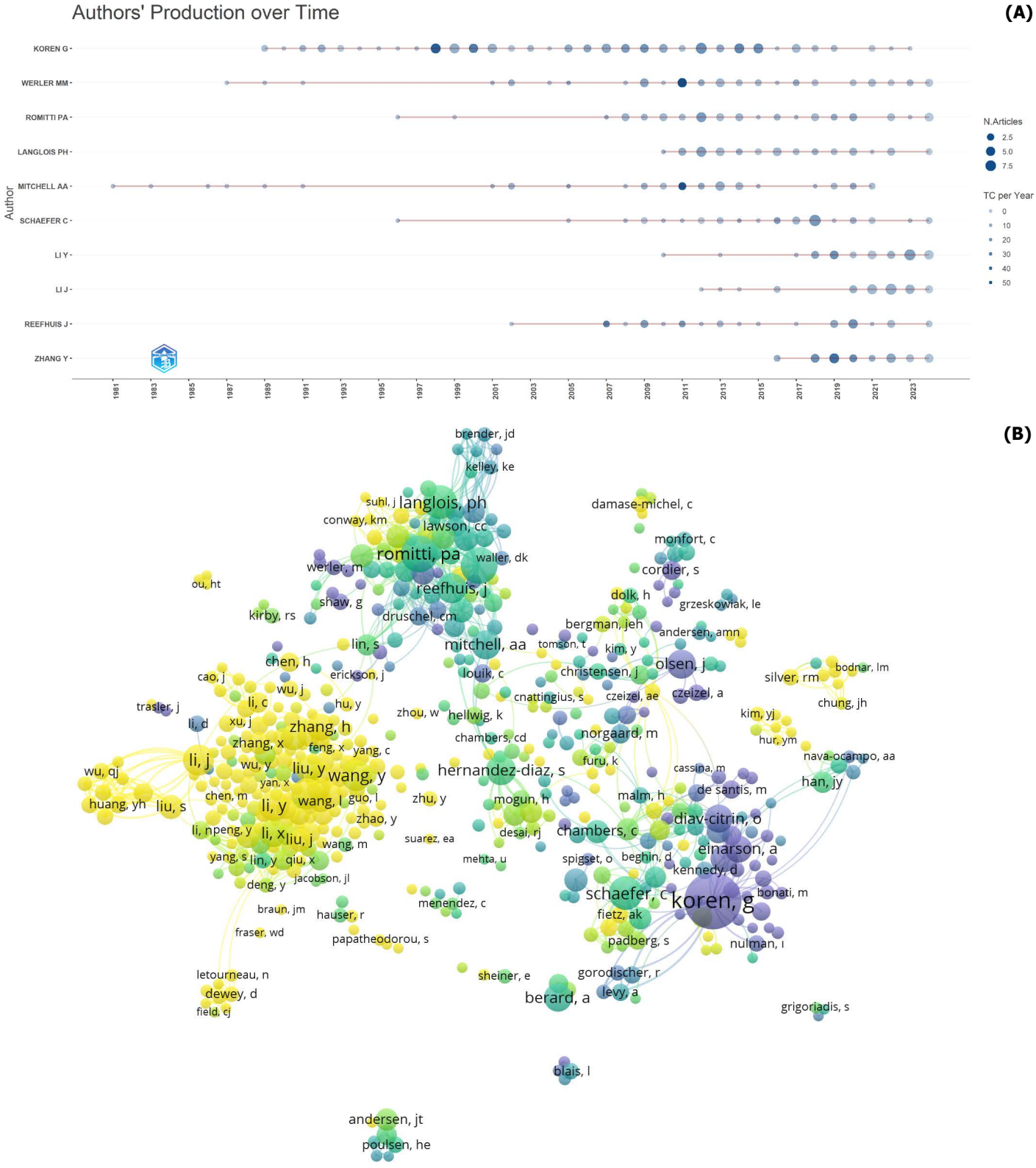
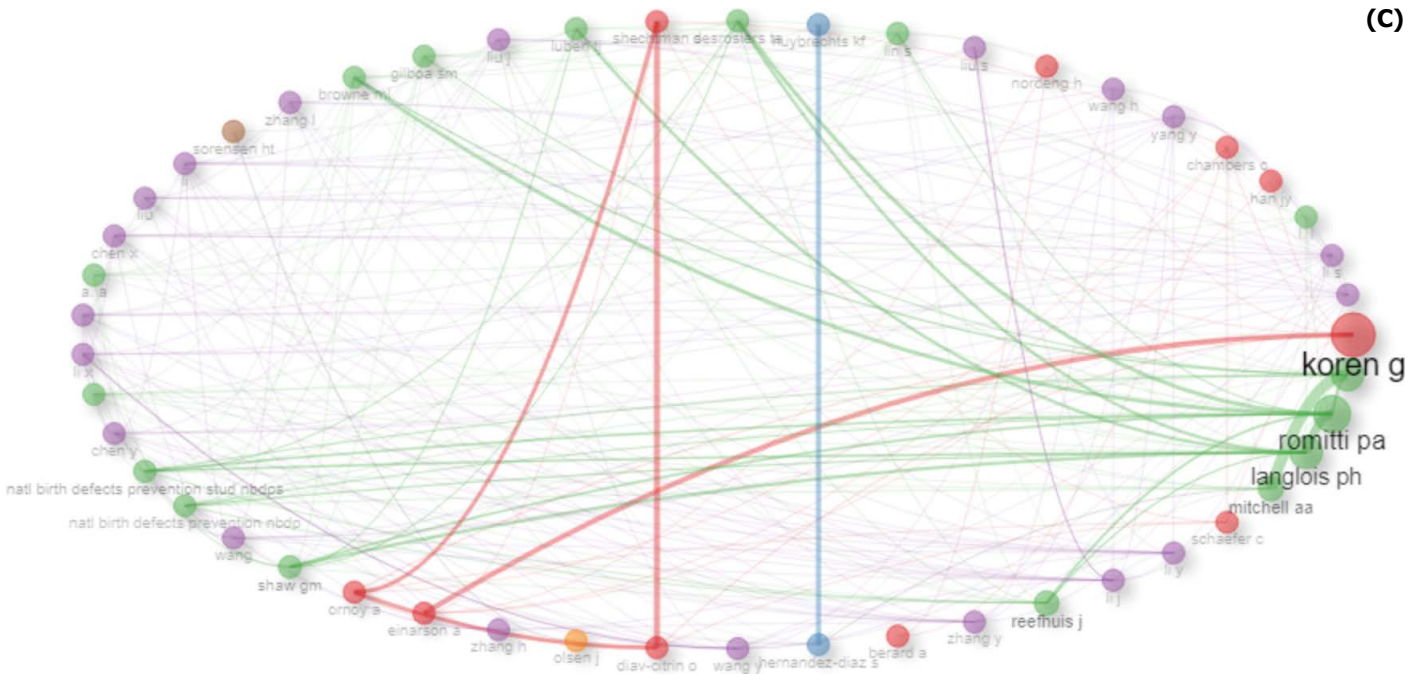


FIGURE 3. **(A)** Authors' production over time **(B)** Visualization co-authorship of authors that contributed to the papers by years **(C)** Collaboration network of author's **(D)** Visualization of co-citation of authors. Cont →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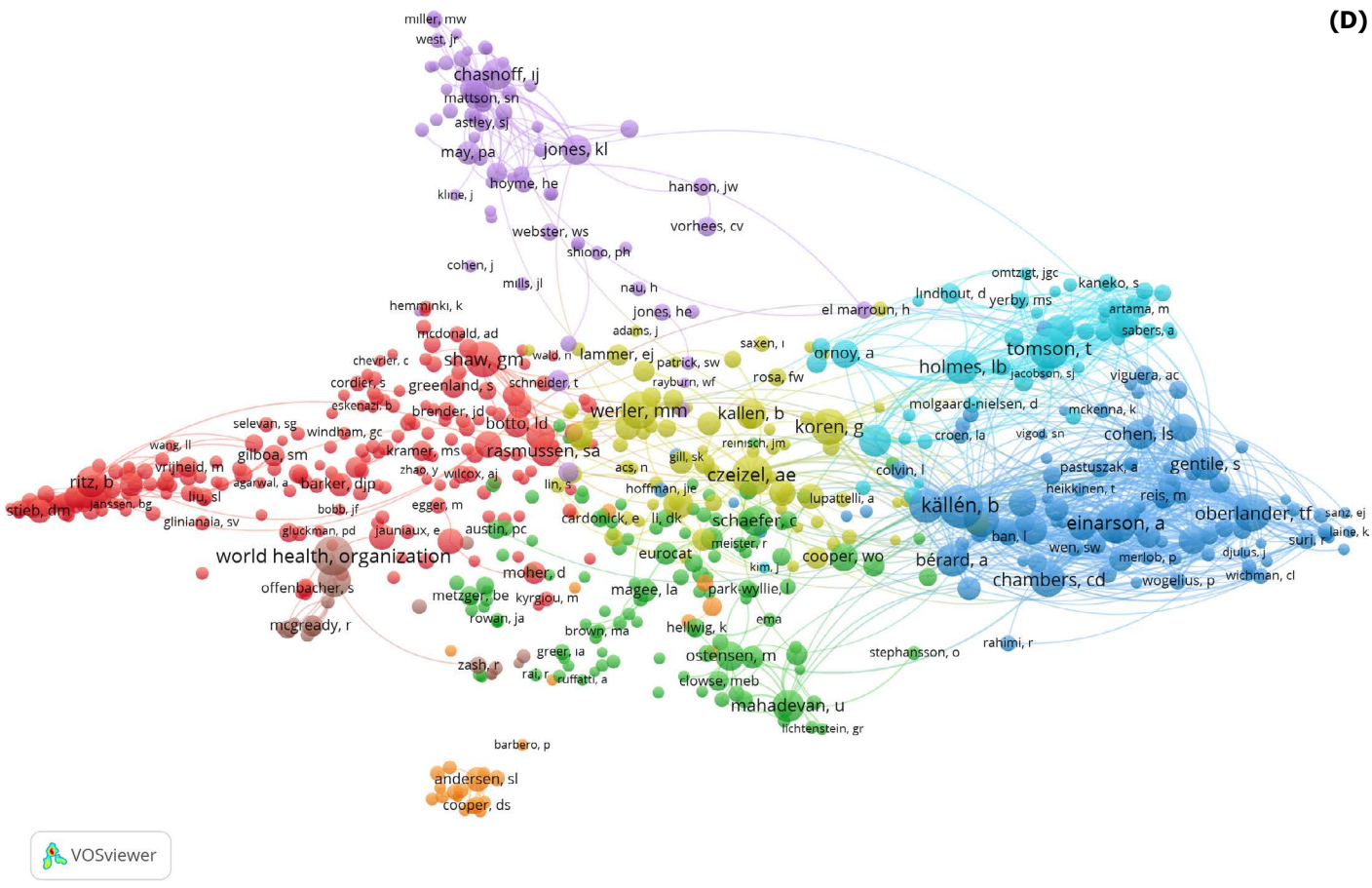
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FIGURE 3.

Table 3. The top 10 most productive journal

Rank	Journals	NP	LC	TC	h-index	g-index	Total link strength	JCR quartile	JCI (2023)
1	Reproductive Toxicology	96	1468	3051	32	52	353	Q2	1.00
2	American Journal of Obstetrics and Gynecology	70	3730	5787	43	70	219	Q1	3.4
3	Birth Defects Research Part a Clinical and Molecular Teratology	62	1493	229	27	46	329	Q3	–
4	Environmental Research	55	1306	1631	23	39	215	Q1	1.96
5	Plos One	49	1309	1644	21	40	96	Q1	0.88
6	Obstetrics And Gynecology	46	2702	2662	31	46	170	Q1	2.31
7	Pharmacoepidemiology And Drug Safety	43	1045	1211	20	34	206	Q3	0.62
8	Bmc Pregnancy and Childbirth	40	444	623	14	24	34	Q1	1.14
9	Birth Defects Research	38	1493	321	12	15	109	Q4	0.45
10	Drug Safety	37	418	1136	19	33	180	Q1	1.02

NP: Number of publications; LC: Local citation; TC: Total citation; JCR: Quartile journal citation report; JCI: Journal citation indicator.

Articles Fractionalized reflect individual author contributions to publications. This method divides a publication's contribution equally among its authors [21]. Based on this, Koren, G (n=24), Schaefer, C (n=7.9), and Werler, MM (n=7) had the highest individual contributions.

Annual productivity trends are shown in Figure 3a. Productive author-years included Schaefer, C (2018, NP=9, TCpY=19.57), Koren, G (2012, NP=8, TCpY=23.61), Li, J (2022, NP=8, TCpY=9.33), and Li, Y (2023, NP=8, TCpY=16.00).

Co-Authorship and Collaboration Network of Authors Analysis

Academic collaboration involves teamwork, with co-authorship reflecting this through joint publications. Similar names (e.g., Werler, M/Werler, MM) were consolidated during the analysis. Documents with a 'Maximum number of authors per document' greater than 25 were ignored. By setting the 'minimum number of documents of an author' to 4 and the 'minimum number of citations of an author' to 4 in VOSviewer, a total of 631 eligible authors were identified. The co-authorship and collaboration network among these authors is visually presented in Figures 3b, c.

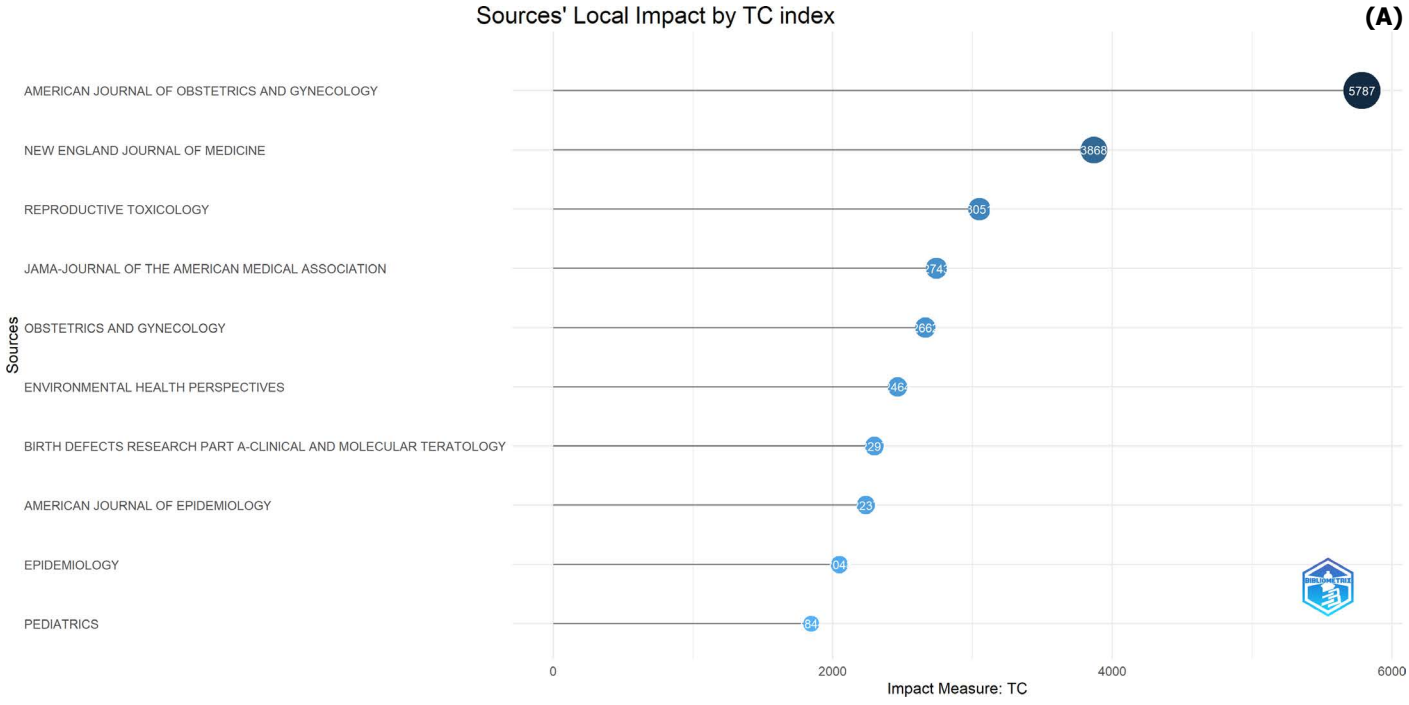
Co-Cited of Authors Analysis

Co-citation analysis is a science mapping technique assuming that publications frequently cited together are thematically related [22]. Author co-citation analysis identifies intellectual connections and research trends by highlighting relationships between frequently co-cited authors, revealing the structure of scientific collaboration and influence. The "minimum number of citations of an author" was set to 20 in VOSviewer, resulting in 683 authors out of 61,072 meeting this criterion. Kallen, B ranked highest on the list (Fig. 3d).

Journal Analysis

Most Productive Journals

A total of 1,033 journals were analyzed. Using VOSviewer with "The minimum number of documents of a source" set to 3 and "The minimum number of citations of a source" to 1, 254 journals qualified. Visualizations were performed in VOSviewer and Bibliometrix. Table 3 lists the top 10 journals, publishing 536 (16%) of 3,361 articles. "Reproductive Toxicology" led with 96 publications. "The American Journal of Obstetrics and Gynecology" ranked second by NP (n=70) but was highest in LC (3,730) and TC (5,787) (Fig. 4a). Other leading journals included "Birth Defects Research Part-A" (n=62), "Environmental Research" (n=55), and "PLOS ONE" (n=49). In impact metrics, "The American Journal of Obstetrics and Gynecology" led with h-index 43 and g-index 70, followed by Reproductive Toxicology (h-index 32; g-index 52). Among the top 10 journals, six were Q1, two Q3, one Q2, and one



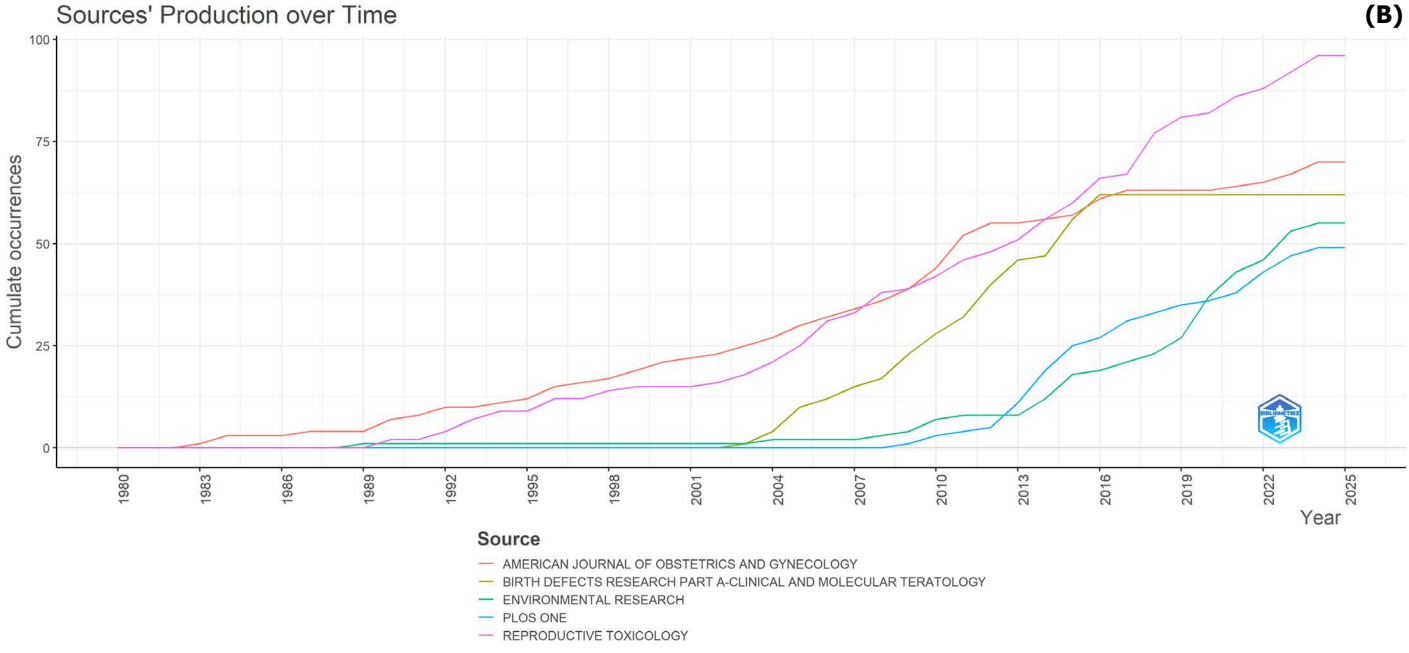
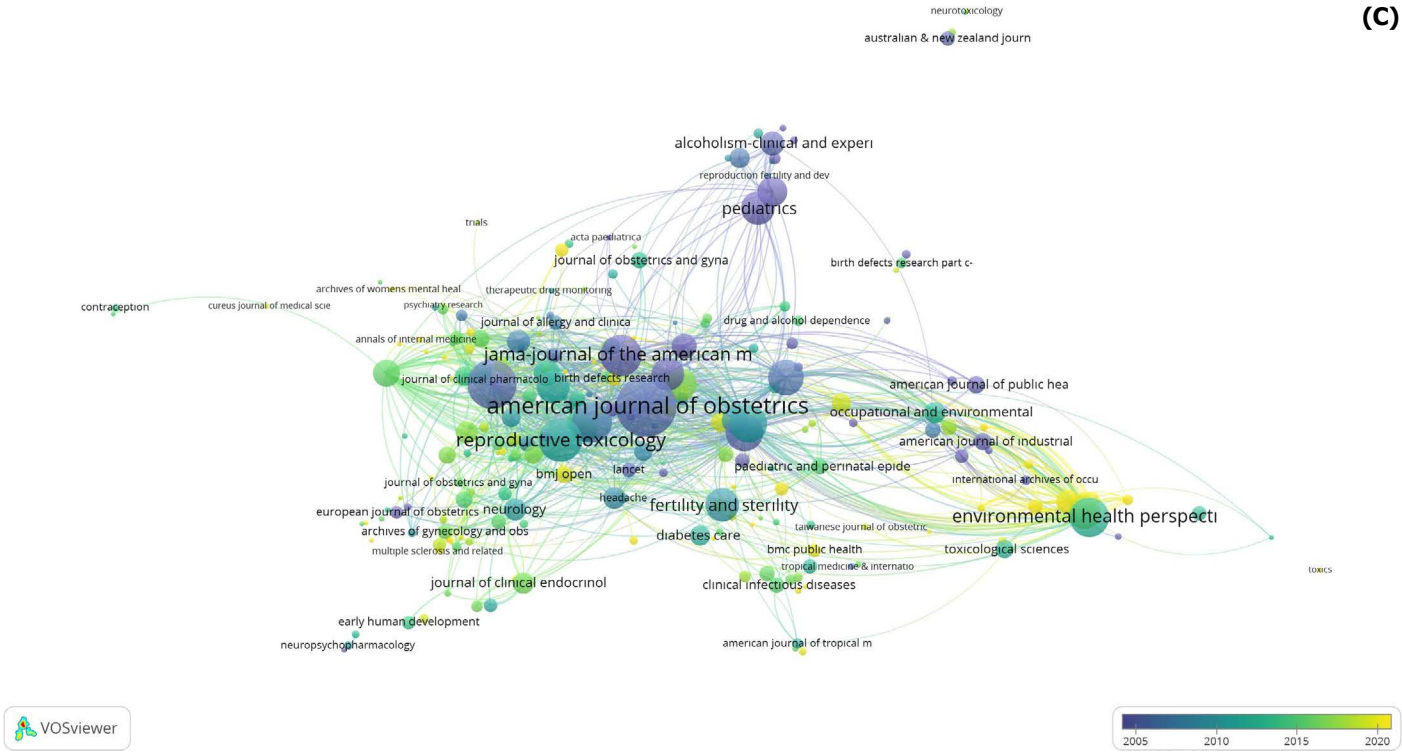


FIGURE 4. **(A)** Number of journal citations **(B)** Journals' production over time **(C)** Overlay visualization of the number of citations by time **(D)** The network visualization of the co-citation analysis at the journal level. Cont →

Q4. Figure 4b shows temporal trends: until 2013, "The American Journal of Obstetrics and Gynecology" led output; later, "Reproductive Toxicology" became dominant. Peak yearly outputs occurred in Reproductive Toxicology (NP=10, 2017), Environmental Research (NP=10, 2020), and Birth Defects Research Part A (NP=9, 2015).

Citation and Co-Citation Analysis of Journals

Citation counts over time were analyzed via overlay visualization, with node size showing citation frequency and node color indicating peak citation periods (Fig. 4c). Journals cited together in references are considered co-cited [23]. Using VOSviewer, with "minimum number of citations of a source" set to 50, 422 journals qual-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VOSviewer

FIGURE 4.

ified from 16,819. The co-citation network is in Figure 4d. "The American Journal of Obstetrics and Gynecology" had the highest co-citation frequency, followed by "Obstetrics and Gynecology" and "The New England Journal of Medicine."

Keywords Analysis

Most Frequent Keywords Analysis

Authors' keywords from publications on prenatal exposures and pregnancy outcomes were analyzed. The top keywords were "pregnancy" (n=1,135), "pregnancy outcome" (n=182), "birth defects" (n=171), "air pollution" (n=117), and "preterm birth" (n=97) (Fig. 5a).

Trend Topic of Keywords Analysis

Using a timespan from 2014 to 2024, with "minimum word frequency" set to 10 and "number of words per year" to 3, Bibliometrix identified trending keywords over the last decade (Fig. 5b). Keywords peaking in 2022 included "placenta" (n=34), "adverse pregnancy outcomes" (n=34), and "systematic review" (n=21). Keywords peaking in 2021 included "meta-analysis" (n=54), "outcomes" (n=35), and "stillbirth" (n=33).

Co-Occurrence of Keywords Analysis

VOSviewer was used for co-occurrence analysis to explore relationships among core concepts, identify major themes and trends, and analyze frequency and patterns of simultaneous keyword appearances [24]. Setting the "minimum number of occurrences of a keyword" to 5 yielded 401 keywords from 5,308. The co-occurrence network is shown in Figure 5c. Figure 5d presents a three-field plot of authors, keywords, and journals, visualized in Bibliometrix with the "number of items" set to 15.

Countries/Regions Analysis

Most Productive Country Analysis

This study covers 125 countries/regions, with corresponding authors from 88. The top 10 productive countries by corresponding authorship are listed in Table 4. The USA ranked first in NP (1,030) and NC (44,101). China was second in NP (372) but fifth in citations (5,229). The UK had the highest average citations. Publications were categorized as single- or multi-country. Figure 6a shows distribution by collaboration type, with the USA leading multi-country studies (n=163). UK (43.1%) and Spain (43.2%) had the highest multi-country collaboration proportions relative to total output.

Publication outputs by country over time (Fig. 6b) show the USA (5,225), China (1,933), and Canada (1,245) as most active, followed by the UK (716) and Australia (691). China's output surged after 2019; 25% of publications predate 2019, 75% appeared later.

Collaboration Network of Country Analysis

Figures 6c, d depict cross-country collaborations. The USA was central, collaborating most with the UK (n=63), Canada (n=62), China (n=58), and Denmark (n=38). The UK ranked second, frequently collaborating with the Netherlands (n=34), Italy (n=30), and France (n=26).

Institutions and Publishers Analysis

Institutions and publishers were analyzed by total NP (Table 5). The University of Toronto led with 229 documents (1.36%), followed by the Centers for Disease Control and Prevention (158, 0.94%) and Boston University (149, 0.89%). Elsevier was the top publisher (n=815, 24.78%), followed by Wiley (n=583, 17.73%) and Springer Nature (n=385, 11.71%).

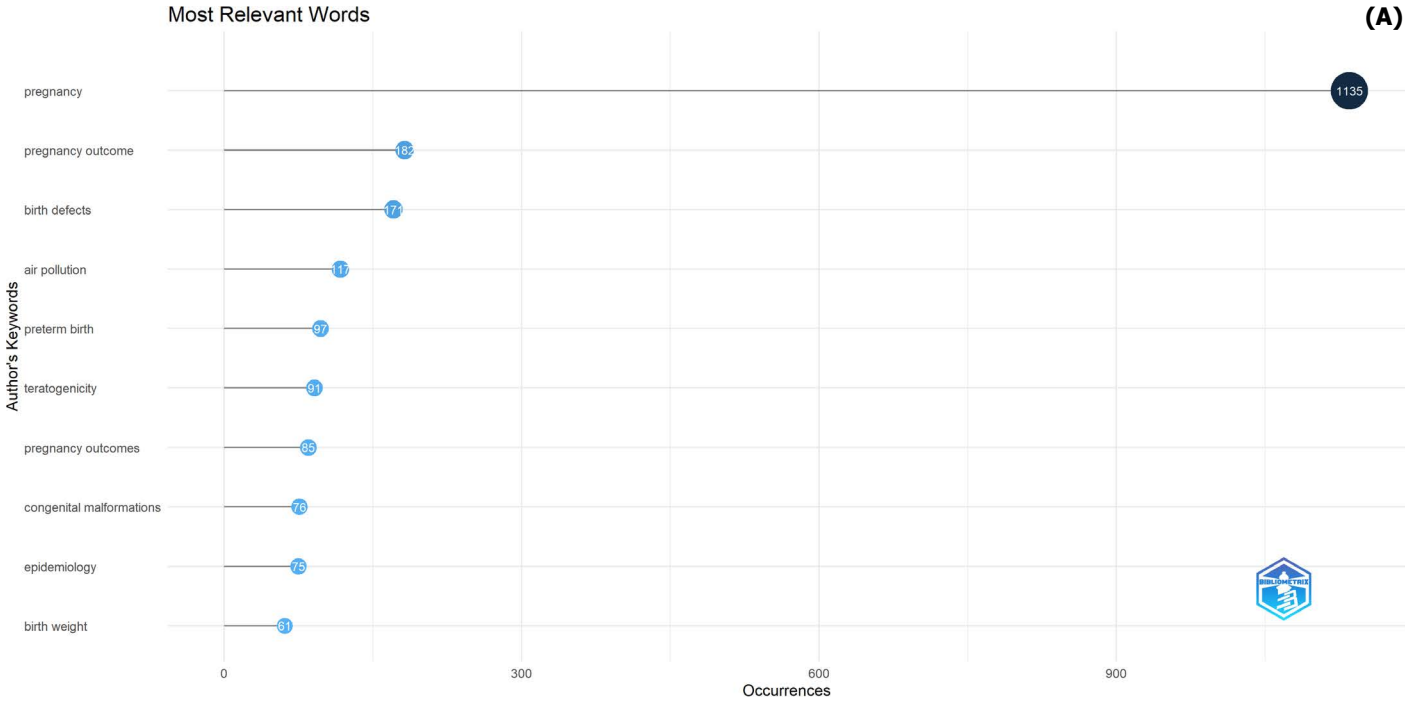
Boston University was the sole publisher until 1989. The University of Toronto nearly doubled its publications in 1998, from 17 to 31. By 2022, all leading institutions had over 100 publications. (Fig. 7a).

Funding Agencies

The most frequent funding sources were the United States Department of Health and Human Services (n=514, 16.27%), the National Institutes of Health (NIH), USA (n=420, 13.29%), and the National Natural Science Foundation of China (n=133, 4.21%) (Fig. 7b).

DISCUSSION

Bibliometric studies offer an overview of the literature in a specific field, reflecting current status and emerging trends, allowing researchers to rapidly track developments [25–27]. For newcomers, bibliometric analyses identify highly cited articles, key authors, leading countries, and collaboration patterns.



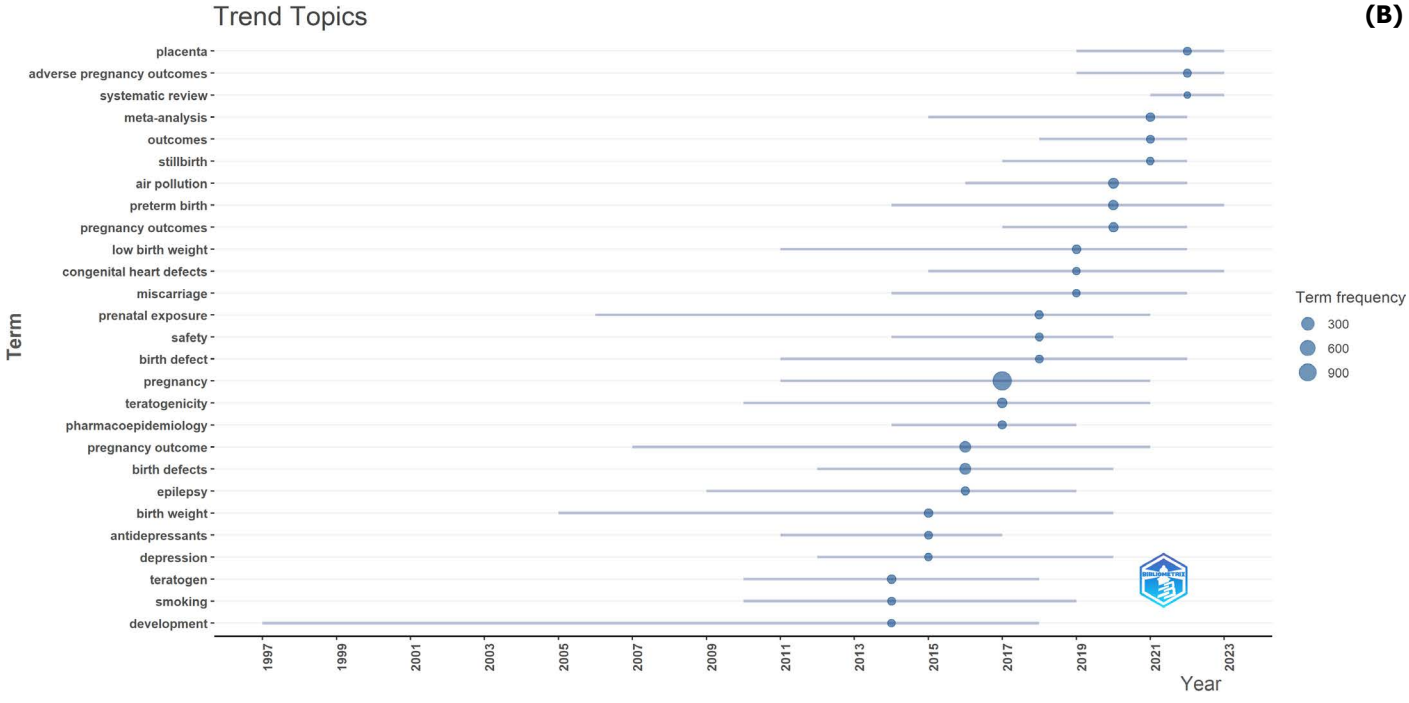
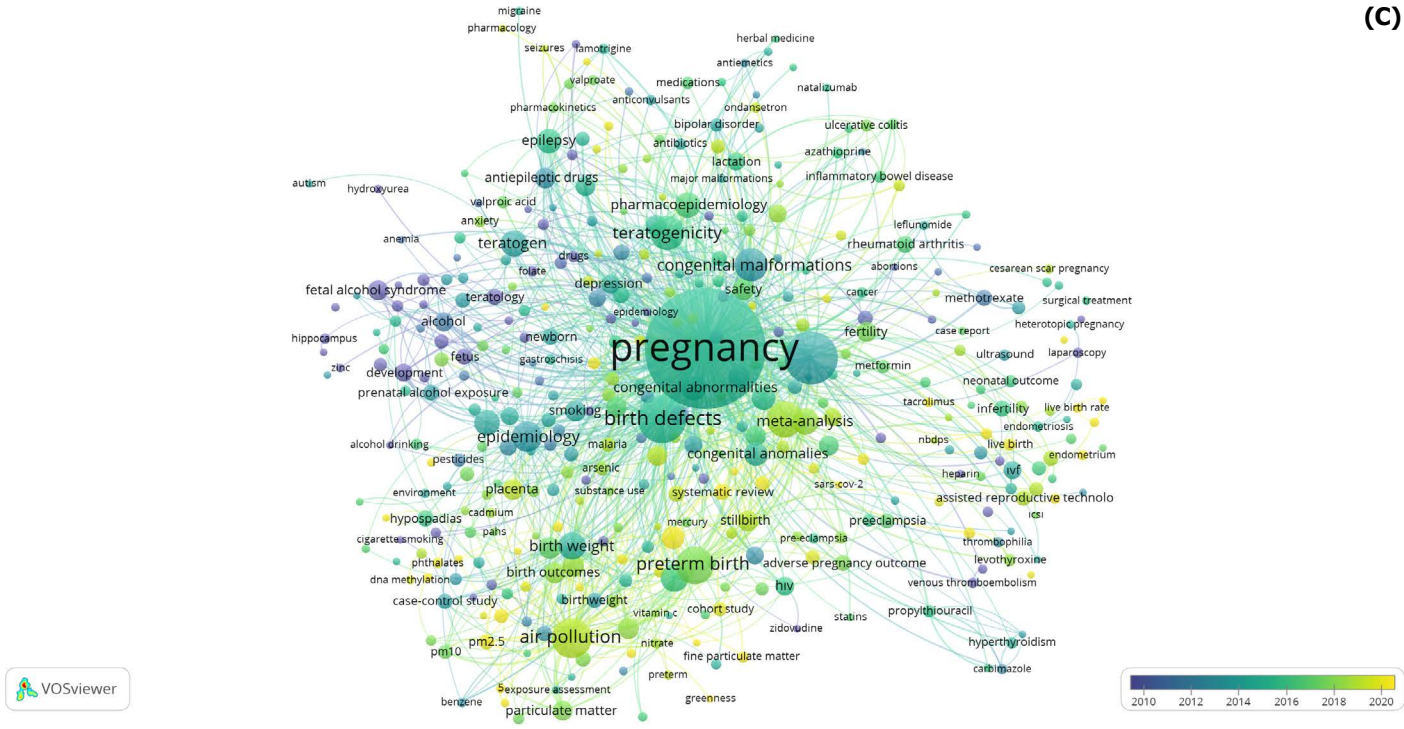


FIGURE 5. **(A)** The chart of the most frequently used keywords **(B)** Trend topic keywords in the last 10 years **(C)** Visualization of co-occurence of keywords **(D)** The relationship between authors-keywords-journals on the three-field plot. Cont →

AU: Authors; DE: Author's keywords; SO: Journals.

This study represents the first comprehensive worldwide bibliometric analysis focused on prenatal exposures and pregnancy outcomes. It analyzed 3,361 documents from the WoS database, mostly indexed in SCI-E. The most cited article was "Effect of Treatment of Gestational Diabetes Mellitus on Pregnancy Outcomes." NP increased notably after 2010. Among authors, Koren, G led in NP and academic metrics (h-


(C)
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medications
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pharmacokinetics
anticonvulsants
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bipolar disorder
ulcerative colitis
epilepsy
antibiotics
azathioprine
lactation
autism
hydroxyurea
antiepileptic drugs
major malformations
inflammatory bowel disease
valproic acid
pharmacoepidemiology
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rheumatoid arthritis
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congenital malformations
abortions
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safety
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teratology
methotrexate
surgical treatment
epidemiology
alcohol
fertility
heterotopic pregnancy
hippocampus
newborn
case report
pregnancy
ultrasound
laparoscopy
zinc
fetus
gastroschisis
metformin
development
neonatal outcome
prenatal alcohol exposure
congenital abnormalities
tacrolimus
infertility
live birth rate
smoking
birth defects
meta-analysis
endometriosis
epidemiology
malaria
nbdps
live birth
alcohol drinking
congenital anomalies
endometrium
pesticides
arsenic
heparin
ivf
environment
placenta
substance use
systematic review
sars-cov-2
assisted reproductive technolo
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cadmium
mercury
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preeclampsia
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cigarette smoking
pahs
pre-eclampsia
thrombophilia
birth weight
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preterm birth
adverse pregnancy outcome
levothyroxine
dna methylation
birth outcomes
hiv
venous thromboembolism
case-control study
birthweight
vitamin c
cohort study
statins
propylthiouracil
zidovudine
air pollution
pm2.5
nitrate
hyperthyroidism
pm10
fine particulate matter
preterm
carbimazole
exposure assessment
benzene
particulate matter
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birth defects
air pollution
pregnancy outcome
epidemiology
preterm birth
prenatal exposure
congenital malformations
pregnancy outcomes
birth weight
teratogenicity
meta-analysis
teratogen
low birth weight
reproductive toxicology
bmc pregnancy and childbirth
birth defects research part a-clinical and molecular teratology
american journal of obstetrics and gynecology
obstetrics and gynecology
environmental research
neurotoxicology and teratology
pharmacoepidemiology and drug safety
drug safety
human reproduction
teratology
environment international
birth defects research
(D)

FIGURE 5.

Table 4. The top 10 most productive corresponding author's countries/regions

Rank	Countries/regions	NP	TC	Average citations	SCP	MCP	MCP %
1	USA	1,030	44,101	42.80	867	163	15.8
2	China	372	5,229	14.10	308	64	17.2
3	Canada	250	11,234	44.90	176	74	29.6
4	United Kingdom	130	5,944	45.70	74	56	43.1
5	Australia	124	5,628	45.40	84	40	32.3
6	Denmark	120	4,504	37.50	85	35	29.2
7	France	95	2,692	28.30	75	20	21.1
8	Italy	95	2,575	27.10	76	19	20.0
9	Netherlands	87	3,056	35.10	54	33	37.9
10	Sweden	79	3,519	44.50	56	23	29.1

NP: Number of publications; TC: Total citation; SCP: Single country publication; MCP: Multiple countries publication.

Table 5. The top 5 most productive institutions and publishers

Rank	NP (%)[a]
Institutions	
1 University of Toronto	229 (1.36)
2 Centers for Disease and Prevent	158 (0.94)
3 Boston University	149 (0.89)
4 Washington University	137 (0.82)
5 The University of North Carolina	121 (0.72)
Publishers	
1 Elsevier	815 (24.78)
2 Wiley	583 (17.73)
3 Springer Nature	385 (11.71)
4 Lippincott Williams & Wilkins	203 (6.17)
5 Taylor & Francis	141 (4.29)

NP: Number of publications; a: Arranged according to the total number of publications of institutions/publishers.

index, g-index, TC, LC), while Schaefer, C ranked first in annual productivity. The highest publication activity by year occurred in Reproductive Toxicology (NP=10, 2017), Environmental Research (NP=10, 2020), Birth Defects Research Part A (NP=9, 2015). The most frequent keywords were "pregnancy," "pregnancy outcome," "birth defects," "air pollution," and "preterm birth." Trend analyses showed that in 2021 "meta-analysis," "outcomes," and "stillbirth" gained prominence; in 2022, "placenta," "adverse pregnancy outcomes," and "systematic review" led. The USA, China, and Canada had the highest NP; the USA led in TC and collaborations, partnering strongly with the UK, Canada, China, and Denmark. The UK followed closely, collaborating with the Netherlands, Italy, and France. The University of Toronto was the most productive institution.

The rise in annual NP post-2009 may be attributed to the creation of teratogenicity information services and regional-national databases, alongside increased sample sizes. Notably, OTIS, ENTIS, and TERIS—established by teratology experts in the 1980s–1990s—are key organizations providing specialized resources on teratogens [28–30]. Their sustained activity since the 2000s likely contributed to the growth of teratogenicity research.

The top-cited Crowther et al. [10] RCT (TC=1,846; TCpY=92.30) assessed dietary and insulin therapies' impact on gestational diabetes-related perinatal outcomes. The study's randomized controlled design and the challenge of conducting RCTs in pregnancy may explain its high citations [10]. Koren, G's leadership in productivity and impact metrics highlights significant scientific contributions. Articles Fractionalized scores further underscore contributions by Koren, Schaefer, Werler, and Mitchell. Romitti, PA showed highest academic collaboration network strength.

The most frequently occurring keywords were "pregnancy," "pregnancy outcome," "birth defects," "air pollution," and "preterm birth." The three-field plot showing

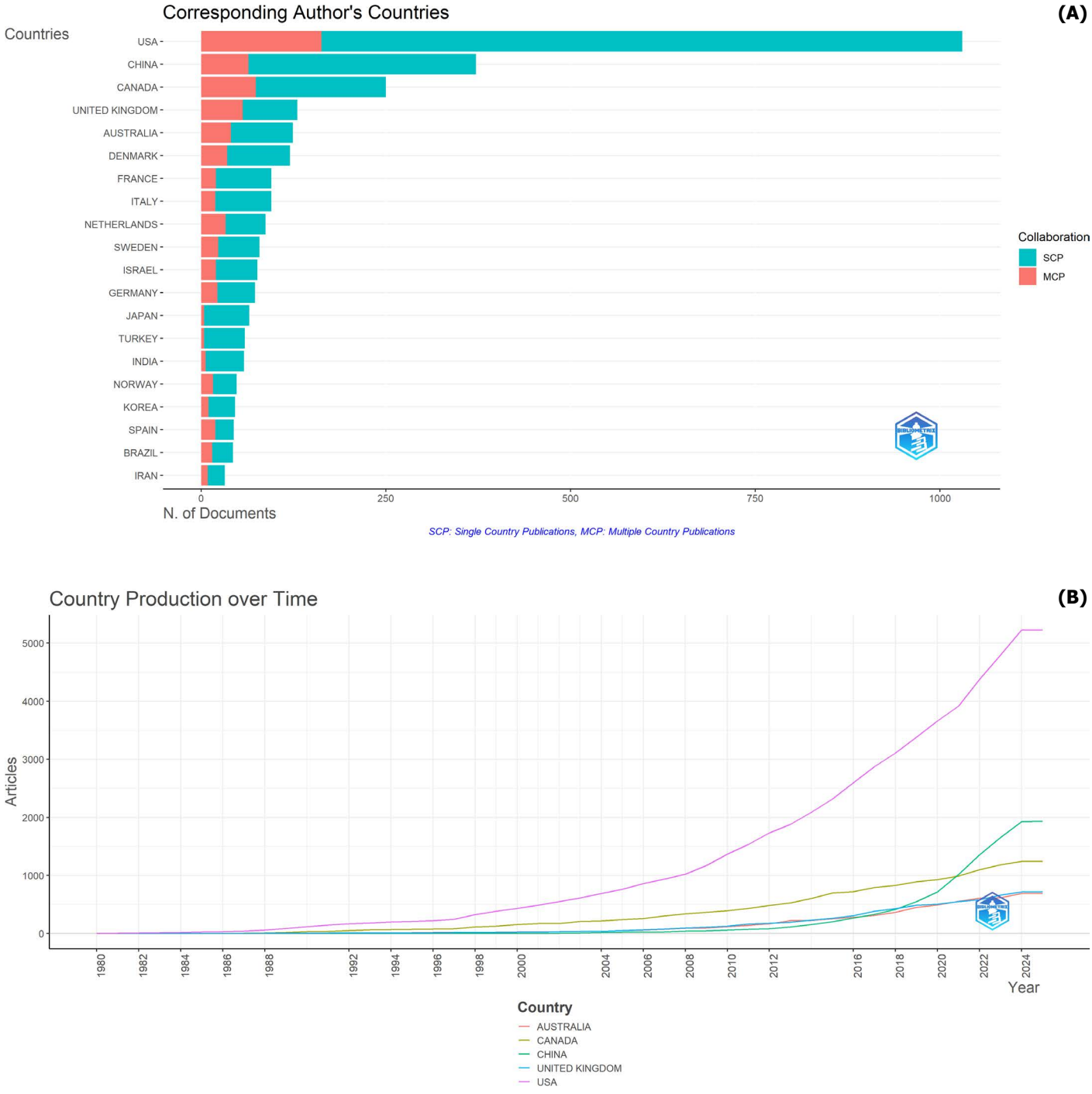

FIGURE 6. **(A)** The distribution of publication numbers in the countries **(B)** Countries' Production over time **(C)** Countries' collaboration network **(D)** Countries' collaboration world map

Cont →

MCP: Multiple countries publication; SCP: Single country publication.

relationships among authors, keywords, and journals confirmed "pregnancy" as the most recurrent keyword, with "air pollution" ranking third, consistent with its overall prominence. Journal-level analysis highlighted that publications focusing on environmental exposures, such as Environmental Research, which peaked in 2020, and Reproductive Toxicology and Birth Defects Research Part A in other years, showed high annual output. These findings reflect increasing research interest and growing clinical awareness of maternal environmental

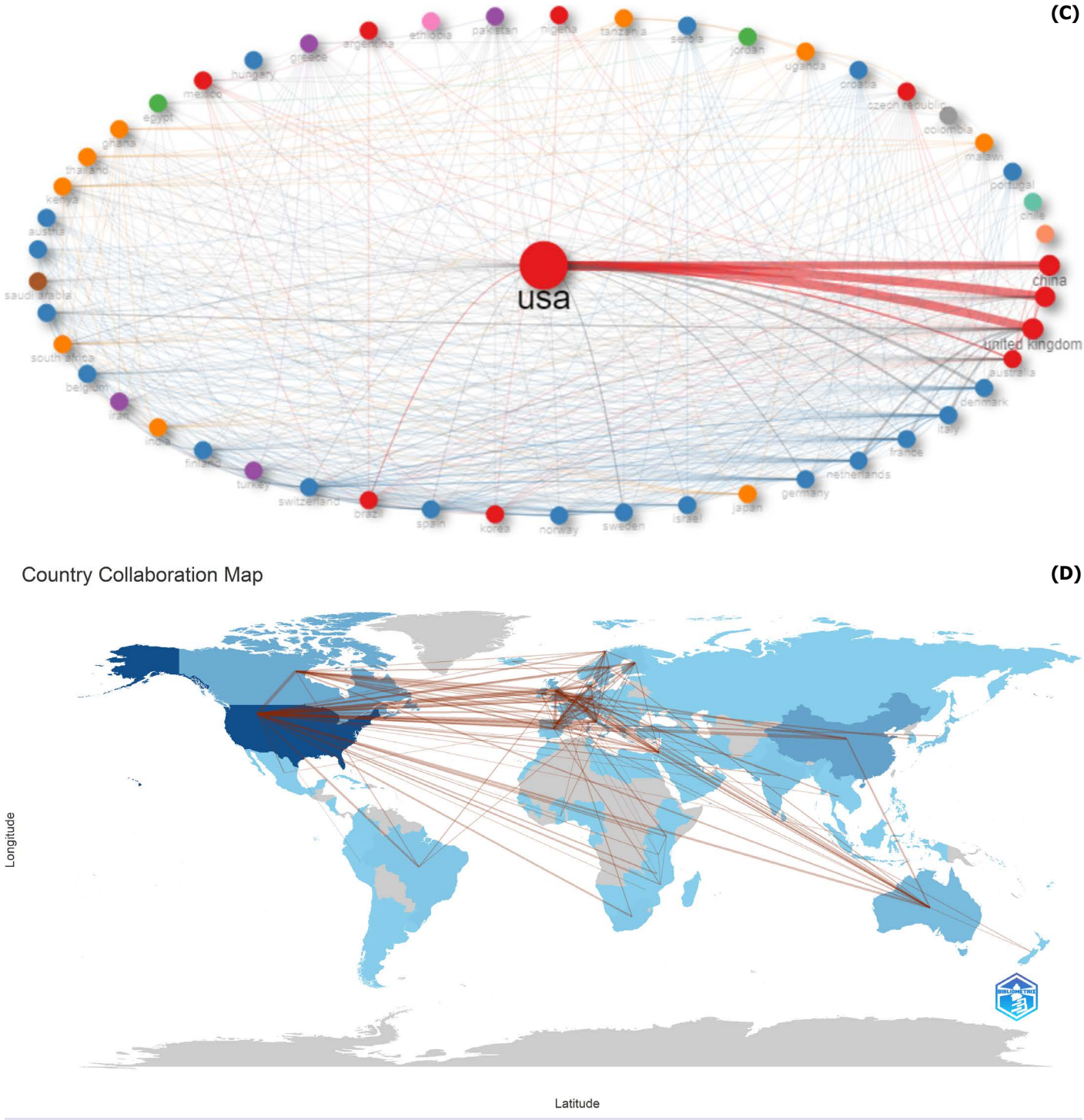

Figure 6.

exposures' impact on pregnancy outcomes, underscoring the importance of systematically evaluating these effects for maternal and fetal health.

The rising prominence of the keyword "placenta" in 2022 indicates an increasing research focus on placental transfer and health within prenatal exposure and pregnancy outcomes. Studies on the transfer of drugs and substances through the placenta have significant clinical relevance, particularly for individualized drug safety assessments during pregnancy. Additionally, the growing use of "systematic review" and "meta-analysis" keywords in 2021 and 2022 reflects a methodological shift to-

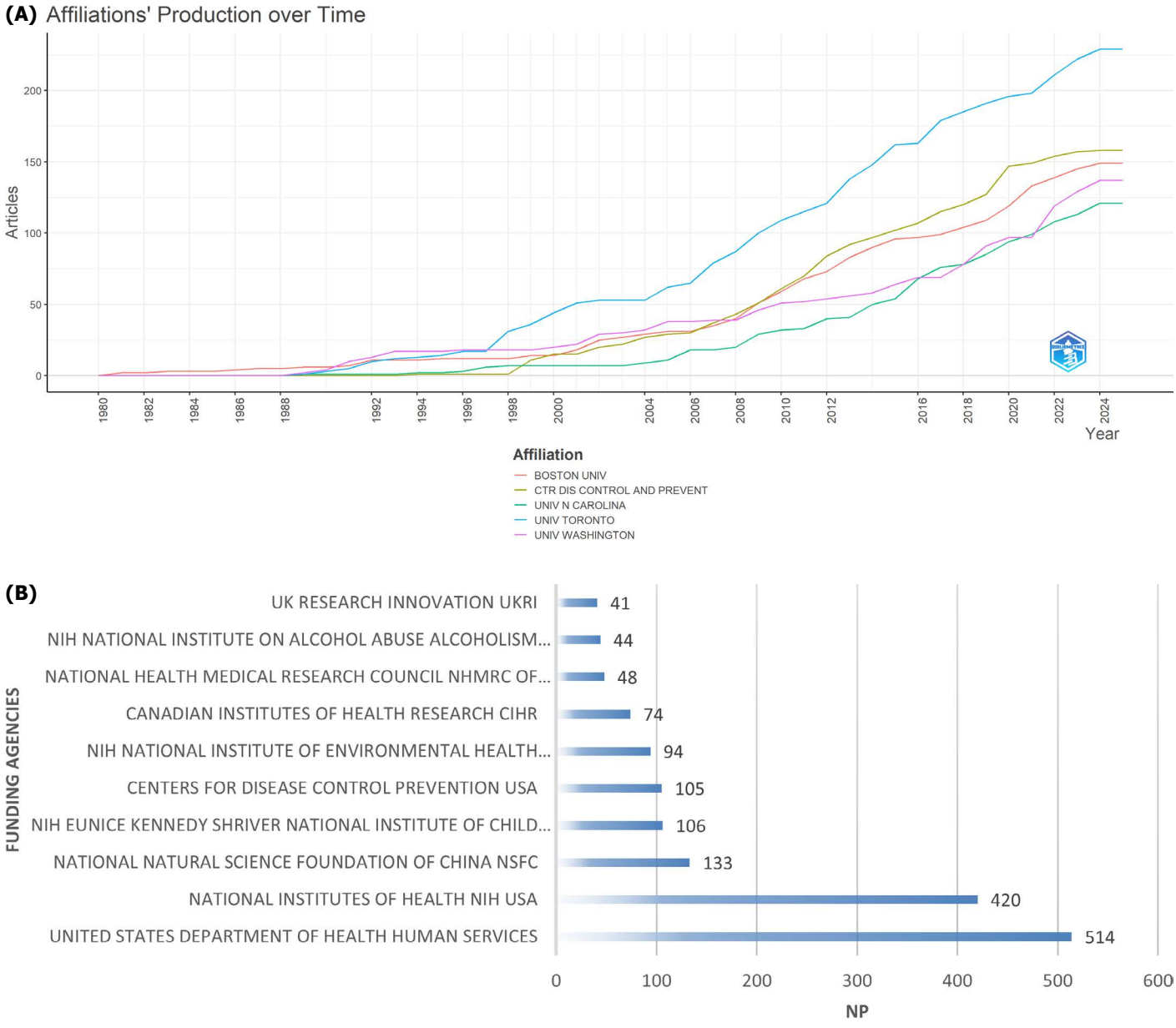

FIGURE 7. **(A)** Affiliations' production over time **(B)** The 10 most supportive funding agencies.

ward quantitative synthesis and comprehensive outcome evaluations. While this trend improves clinicians' access to current evidence, the methodological heterogeneity among these reviews necessitates cautious interpretation when applying findings in practice.

This study identifies the USA as the leading country in NP, citations, and collaborations on prenatal exposure and pregnancy outcomes research. China and Canada follow in NP rankings. The USA shows the highest collaboration rates, mainly partnering with the UK, Canada, China, and Denmark, while the UK ranks second and collaborates extensively with the Netherlands, Italy, and France. These findings reveal that international collaborations are largely concentrated among high-income countries, potentially limiting the generalizability and clinical relevance of results globally. To address this, expanding partnerships to include low- and middle-income countries is crucial for equitable dissemination and implementation of prenatal care advances worldwide.

Canada's productivity aligns with University of Toronto's leadership. Koren, G's tenure there and founding of the "Motherisk" program, which provides evidence-based teratogenic risk information during pregnancy and lactation, significantly boosted Canadian research output [31].

Conclusion

In conclusion, maternal exposure to drugs or substances can cause fetal abnormalities, posing significant challenges in prenatal care. Factors such as maternal age, chronic diseases, and environmental exposures have intensified research interest in this field. This bibliometric study reveals a growing body of literature focused mainly in developed countries, underscoring the need to include developing nations for a more comprehensive understanding. The increase in systematic reviews and meta-analyses reflects efforts toward standardizing research protocols and improving data sharing. Enhancing open access and fostering interdisciplinary collaboration are essential to better disseminate knowledge and translate findings into clinical practice. Ultimately, this study provides an overview of current research trends and offers guidance for future investigations aimed at improving maternal and fetal health outcomes.

Strengths and Limitations

This bibliometric study on prenatal exposures and outcomes guides future research. The search was limited to WoS to ensure data quality, possibly excluding studies from Scopus or PubMed, which may affect generalizability [32, 33]. Only SCI, SCI-E, and ESCI articles were included, ensuring rigor but possibly omitting some studies. Manual screening was avoided to reduce bias, though this may impact precision [34]. Non-English studies were included to reflect broader impacts. Productivity was measured by NP and Articles Fractionalized value, which may not perfectly capture individual contributions.

Ethics Committee Approval: This study is a bibliometric analysis based on data obtained from the Web of Science database. The study did not involve human participants, animals, or any personal/clinical data. Therefore, ethical approval and informed consent were not required.

Informed Consent: Not applicable. This bibliometric analysis was based on data retrieved from publicly available databases and did not involve human participants or personal data.

Conflict of Interest: No conflict of interest was declared by the authors.

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Use of AI for Writing Assistance: The authors declared that artificial intelligence was not used in the study.

Authorship Contributions: Concept – PK, EKA; Design – PK, EKA, AO; Supervision – PK, EKA; Data collection and/or processing – PK, EKA, AO; Analysis and/or interpretation – PK, EKA, AO; Literature review – PK, EKA; Writing – PK, EKA; Critical Review – PK, EKA.

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