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DECODING PEDIATRIC VACCINATION RESEARCH: A DECADE-LONG BIBLIOMETRIC ANALYSIS OF GLOBAL TRENDS, HOTSPOTS, AND EMERGING FRONTIERS

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Abstract

Pediatric vaccination is a key component of global public health; however, the rapid growth of the literature requires a comprehensive and up-to-date overview of research trends and thematic developments. This study aimed to map pediatric vaccination research published between 2016 and 2025, focusing on publication trends, leading contributors, collaboration patterns, and evolving thematic structures. An analysis was conducted using the Web of Science Core Collection (SCI-Expanded), with data retrieved on January 2, 2026. English-language articles and reviews were identified using topic-based search terms related to vaccination and pediatric populations, and irrelevant records were excluded. Co-authorship, co-citation, and keyword co-occurrence analyses were performed using VOSviewer and Bibliometrix. A total of 17 842 publications were included, showing a steady increase over time, with the highest number recorded in 2025. These publications received 302 716 citations (mean: 16.97 per paper; H-index: 166). The United States was the leading contributor, with 6915 publications (38.75%). Keyword analysis identified major thematic clusters related to immunology, infectious diseases, and pediatrics, with increasing emphasis on behavioural, social, and epidemiological dimensions. This study provides a comprehensive overview of global contributions and thematic developments in pediatric vaccination research, offering valuable insights to guide future research and policy-making.

Key words: pediatric vaccination, immunization, vaccine hesitancy, global health, epidemiology, public health

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Introduction. Immunization is one of the most effective public health interventions, significantly reducing the burden of infectious diseases and preventing childhood morbidity and mortality worldwide [1]. Advances in vaccine development, expanded immunization programmes, and global health initiatives have improved vaccination coverage and child survival outcomes [2, 3]. Pediatric vaccination has evolved into a complex and rapidly expanding research field. Alongside technological innovations such as mRNA-based vaccines and novel adjuvants, increasing attention has been directed toward behavioural and societal factors, including vaccine hesitancy, misinformation, and disparities in immunization coverage [4, 5]. These developments have broadened the scope and diversity of research in this area.

Given the growing volume and complexity of the literature, traditional narrative reviews may be insufficient to capture the field's structural dynamics. Quantitative approaches enable the evaluation of scientific output, identification of key contributors, and analysis of relationships among publications, authors, and research topics. Through co-authorship, co-citation, and keyword analyses, these methods help reveal major thematic clusters and evolving research trends [6–8].

Despite the expanding body of research, comprehensive studies focusing specifically on pediatric vaccination remain limited. Therefore, this study analyzes pediatric vaccination research published between 2016 and 2025, aiming to characterize publication trends, identify leading contributors and collaboration patterns, and map thematic developments to provide an updated overview for future research and policy directions.

Methods. ***Data source and search strategy.*** A comprehensive literature search was conducted in the Web of Science Core Collection (Science Citation Index Expanded, SCI-Expanded) on January 2, 2026. The search used the Topic field (TS), including titles, abstracts, author keywords, and Keywords Plus, with the query: TS = (vaccine*) AND TS = (pediatric* OR infant* OR newborn*). Only English-language articles and reviews published between 2016 and 2025 were included to capture recent developments in pediatric vaccination research.

Eligibility criteria and data screening. Studies on pediatric vaccination were included, while irrelevant records were excluded based on title and abstract screening. Screening was performed independently by two reviewers with consensus resolution. After duplicate removal, 17 842 publications were included.

Data extraction and preprocessing. Full records and cited references were exported in plain text format. Preprocessing included duplicate removal, standardization of author and institution names, and verification of bibliographic consistency. Key data, including authors, affiliations, countries, journals, keywords, and citation counts, were extracted for analysis.

Analysis. Analyses were performed using VOSviewer (version 1.6.20) and the Bibliometrix package in R (version 4.3.1). Co-authorship, co-citation, and keyword co-occurrence analyses were conducted to evaluate collaboration networks,

intellectual structure, and thematic evolution. For keyword analysis, a minimum occurrence threshold of five was applied. Standard normalization methods were used to ensure balanced representation of network relationships.

Data visualization. Network visualization maps were generated to illustrate relationships among authors, institutions, countries, and research topics. Node size reflects frequency, while link strength indicates the degree of association between items.

Ethical considerations. This study used publicly available data and did not involve human participants; therefore, ethical approval was not required.

Results. A total of 17 842 publications published between 2016 and 2025 were included in the analysis. These publications received 302 716 citations, with a mean of 16.97 citations per publication and an H-index of 166. The most highly cited article, published in 2016, received 2425 citations and focused on pneumococcal conjugate and rotavirus vaccines in the context of global immunization and sustainable development goals. Annual publication output ranged from 1430 to 2102 articles, showing some variability but an overall increasing trend. The highest levels of research output were observed in 2023 (2012 publications) and 2025 (2102 publications), indicating periods of intensified research activity. Overall, the steady growth in publication volume reflects a sustained expansion of the literature on pediatric vaccination and highlights its increasing importance in addressing public health challenges. Detailed annual trends are presented in Fig. 1.

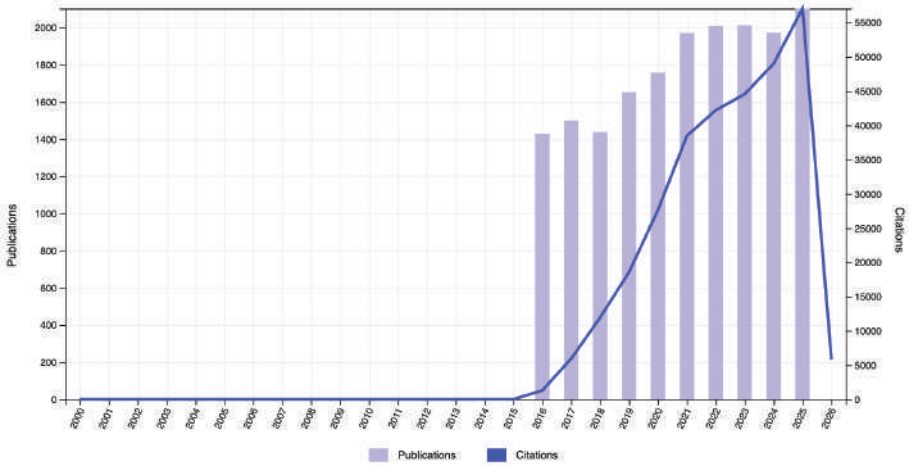


Fig. 1. Annual scientific publication Average of citations per year . Annual trends in scientific publications and average citations per year. Bars represent the number of publications, while the line indicates average citations. Publication output increased steadily from 2016, with more pronounced growth between 2016 and 2022. Citation levels peaked in the final years, reflecting increasing academic interest and impact

Over the 10-year period (2016–2025), the dataset accumulated 302 716 citations (mean: 16.97 per publication). Citation activity increased gradually, particularly after 2021, indicating growing academic visibility. Peaks in 2023 and 2025 coincided with higher publication output, although some variability reflects factors such as citation lag. Analysis of publication sources showed that pediatric vaccination research is concentrated in a limited number of specialized journals in vaccinology and pediatrics. "Vaccine" accounted for the largest share (8.65%), followed by "Human Vaccines & Immunotherapeutics" (3.86%) and "Vaccines" (3.41%). This distribution highlights the central role of domain-specific journals in disseminating research (Fig. 2).



Fig. 2. Treemap of the top 10 publication sources. Block size represents publication volume, highlighting leading journals such as Vaccine and Human Vaccines & Immunotherapeutics

Author productivity analysis showed that Madhi S. A. was the most prolific contributor (130 publications), followed by Parashar U. D. (109), Englund J. A. (92), and Esposito S. (90). In total, 84 515 authors contributed, but only 35 produced more than 50 publications, indicating a concentration of output among a small group of researchers. Research output was also concentrated among leading institutions. The Centers for Disease Control and Prevention (CDC), USA, was the most prominent (857 publications; 4.80%), while the United States Department of Health and Human Services (HHS) was the primary funding source (13.73%). Highly productive authors were mainly affiliated with a small number of institutions, predominantly in the United States.

The most productive countries. The United States ranked first in pediatric vaccination research with 6915 publications (38.75%), followed by England (1835) and China (1626). This marked difference indicates a strong concentration of research output within a single leading nation. Several other countries also demonstrated notable research activity, although at considerably lower levels

of output. This distribution likely reflects disparities in research funding, infrastructure, and global health leadership. Overall, pediatric vaccination research is characterized by a dominant leading contributor alongside a broader group of countries with moderate-to-low publication output, highlighting an uneven global distribution of scientific productivity [9].

Trend keywords and topics. Figure 3 shows the main keyword clusters in pediatric vaccination research. Vaccine hesitancy (1425) was the largest cluster, followed by respiratory viral infections (1393) and *Streptococcus pneumoniae* (1339). Other themes included pertussis vaccination (1191), enteric viruses (1136), and coronavirus-related research (1004). Additional topics such as HPV (786), influenza (746), viral disease dynamics (445), and tuberculosis (425) indicate a diverse research landscape.



Fig. 3. Treemap of the most frequent keywords. Block size reflects keyword frequency, highlighting major themes such as vaccine hesitancy and infectious diseases

The VOSviewer density map shows the distribution of key terms in the field (Fig. 4). High-density areas focus on pediatrics, vaccines, and immunization, while terms such as vaccination, influenza, and epidemiology appear as related subtopics. Lower-density terms, including human papillomavirus vaccine and attitudes, indicate less frequent topics. Overall, the literature is centred on childhood vaccination with secondary thematic clusters.

Discussion. This study provides an overview of pediatric vaccination research published between 2016 and 2025, highlighting a substantial expansion in scientific output, evolving research themes, and an uneven global distribution of contributions. Publication activity showed a dynamic trend, remaining stable between 2016 and 2018 before increasing markedly from 2019. This growth continued through 2021 and plateaued at high levels until 2023, followed by a slight decline in 2024 and renewed growth in 2025. Citation activity also increased, particu-

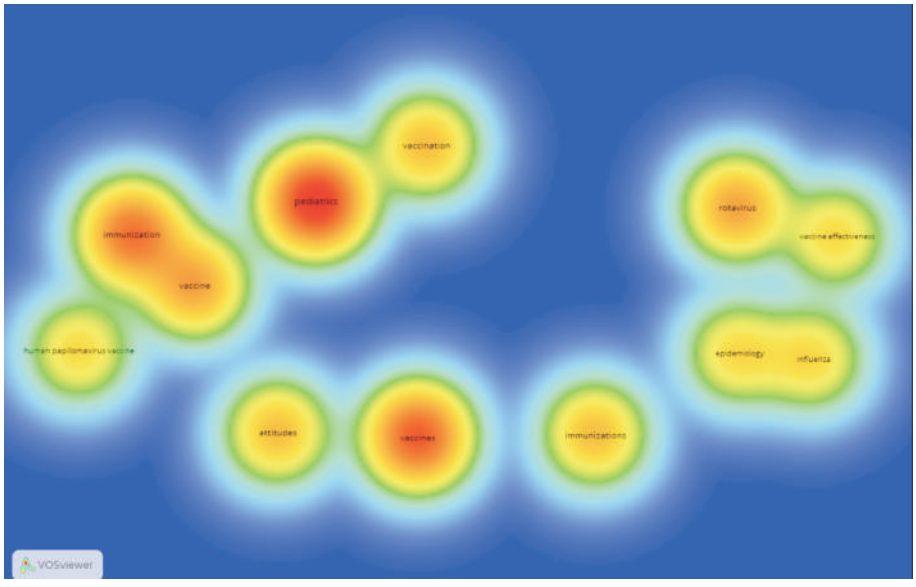


Fig. 4. Density map of the keyword co-occurrence network generated using VOSviewer. Colours from blue to red indicate increasing keyword density. High-density regions highlight core topics such as pediatrics and vaccination, while related themes form connected clusters

larly after 2021, indicating growing academic impact, although some variability reflects factors such as citation lag. Analysis of publication sources indicated that research is concentrated in a limited number of specialized journals, particularly in vaccinology and pediatrics. Journals such as "Vaccine" and "Human Vaccines & Immunotherapeutics" serve as key dissemination platforms. Similarly, authorship patterns showed that, despite many contributors, output is concentrated among a small group of highly productive researchers, highlighting their central role in shaping the field. Institutional and funding analyses demonstrated the dominance of major public health organizations and governmental funding bodies. Institutions such as the Centers for Disease Control and Prevention (CDC) and funding agencies such as the United States Department of Health and Human Services (HHS) were identified as key contributors, underscoring the importance of institutional support in sustaining research productivity. The concentration of leading institutions in the United States also reflects broader disparities in research capacity and resource distribution.

Country-level findings confirmed the dominance of the United States, followed by England and China, highlighting an uneven global distribution of research productivity. Keyword analysis revealed evolving research priorities, with vaccine hesitancy as the most prominent theme. Traditional topics such as respiratory viral infections and *Streptococcus pneumoniae* remain central, while coronavirus-related research reflects the impact of the COVID-19 pandemic. Overall, pediatric

vaccination research has evolved into a multidisciplinary field integrating clinical, epidemiological, and behavioural perspectives, with increasing attention to public acceptance and health system factors. This study has limitations, including restriction to the Web of Science database, English-language publications, and predefined search terms. Citation-based metrics may also not fully reflect the broader impact of research. These findings highlight the need for greater international collaboration, particularly involving low- and middle-income countries, and for efforts to reduce disparities in research productivity and improve translation into public health practice.

Conclusion. This study demonstrates a clear increase in pediatric vaccination research between 2016 and 2025, with the United States leading global output. Vaccine hesitancy emerged as a key research focus alongside infectious diseases and COVID-19-related topics. Overall, the findings reflect a shift toward a more multidisciplinary research landscape.

Author contributions: Conception: Hüseyin Ilgın Bal; Design: Hüseyin Ilgın Bal; Supervision: Hüseyin Ilgın Bal; Data Collection and/or Processing: Hüseyin Ilgın Bal, Yunus Emre Avcı; Literature: Hüseyin Ilgın Bal, Yunus Emre Avcı; Review: Hüseyin Ilgın Bal, Yunus Emre Avcı; Writing: Hüseyin Ilgın Bal; Critical Review: Hüseyin Ilgın Bal, Yunus Emre Avcı.

Data availability: The data supporting this study's findings are available from the corresponding author upon reasonable request.

Conflict of interests: The authors declare no competing interests.

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