e-ISSN : 2597-6052

MPPKI MEDIA PUBLIKASI PROMOSI KESEHATAN INDONESIA

Review Articles Open Access

Trends in Digital Health Education for Iron Supplementation During Pregnancy (2010-2025): A Bibliometric Study

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ARTICLE INFO

Manuscript Received: 19 May, 2025
Revised: 19 Aug, 2025
Accepted: 26 Sep, 2025
Date of Publication: 04 Oct, 2025
Volume: 8
Issue: 10
DOI: 10.56338/mppki.v8i10.8346

KEYWORDS

Digital Health;
Iron Supplementation;
Pregnancy

ABSTRACT

Introduction: Iron deficiency anemia is one of the major health issues that significantly impacts pregnant women, both in developing and developed countries. Interventions through health education, particularly digital-based education, are increasingly being used to improve compliance with iron supplementation. However, little is known about how global research trends on this topic have evolved over time. This study aims to analyze global research trends in scientific literature related to digital health education and mHealth interventions for iron supplementation and anemia prevention in pregnant women. To achieve this, a bibliometric analysis was conducted to map publication growth, collaboration networks, and emerging themes in the field.
Methods: Data retrieval was conducted through the PubMed database using relevant keywords "Iron" AND "Anemia" AND 'Pregnancy' AND ("Health education" OR "Mobile health" OR "Digital health"). Articles published between 2010 and 2025 were selected. Bibliometric analysis was conducted using the VOSviewer tool to map keywords, author collaborations, and publication trends.
Results: A total of 78 relevant publications were identified, with a significant increase in the past decade. Ethiopia, the USA, China, Egypt, and Indonesia were among the countries with the highest contributions. Dominant themes included mHealth and app-based approaches. Network mapping revealed major thematic clusters in technology-based interventions, compliance behavior, and pregnancy outcomes.
Conclusion: Research trends indicate growing interest in the use of digital platforms to educate pregnant women about iron supplementation and anemia prevention. This reflects a paradigm shift toward more personalized and technology-based interventions. Further studies are needed to evaluate the effectiveness and sustainability of various digital intervention models.

Publisher: Fakultas Kesehatan Masyarakat Universitas Muhammadiyah Palu

INTRODUCTION

Iron deficiency anemia is one of the most common nutritional problems among pregnant women worldwide and has serious consequences for both the mother and the fetus. In mothers, this condition increases the risk of complications such as postpartum hemorrhage, infection, preeclampsia, fatigue, cognitive impairment, and postpartum depression, while in fetuses it can cause stunted growth, low birth weight, premature birth, and cognitive, motor, and socio-emotional developmental disorders (1). Iron supplementation has long been recommended as a preventive intervention to reduce the incidence of anemia during pregnancy; however, compliance among pregnant women remains low in many countries, including Indonesia (2,3), due to factors such as perceived side effects, lack of knowledge, and limited access to accurate health information (4). Importantly, this problem is not confined to a single region: in Sub-Saharan Africa and South Asia, prevalence is very high and often severe; in Latin America and Eastern Europe, the burden exists but receives less attention; and even in high-income countries such as the United States and Western Europe, anemia persists among vulnerable groups, including migrants and low-income women. Recognizing these global differences provides a more comprehensive understanding of the problem and enhances the generalizability of this study.

Advances in digital technology have created new opportunities for improving public health education, including for pregnant women. Various approaches such as mobile health (mHealth), smartphone-based applications (5,6), SMS reminders (7–9) and social media are now being used to convey information about the importance of iron consumption (10–12). These interventions are not only flexible and easily accessible, but can also be tailored to individual needs and characteristics. As the use of digital platforms in the healthcare sector continues to grow, the number of scientific studies evaluating the effectiveness and implementation of digital education in the context of pregnancy-related anemia is also increasing (13,14).

Although a number of studies have evaluated the effectiveness of various digital education models, such as mobile applications, SMS-based reminders, and social media in improving iron consumption compliance, there has been no bibliometric study that systematically analyzes scientific trends in this field. A bibliometric study is necessary to understand the extent to which this topic has developed, identify the key actors in this research, and pinpoint thematic gaps that could serve as the basis for further research. This study addresses this gap by mapping the global scientific development of digital health education for iron supplementation in pregnant women using a bibliometric approach.

Research Objectives

Based on this background, this study aims to analyze global scientific trends related to digital health education in the context of iron supplementation and anemia prevention in pregnant women through a bibliometric approach. By mapping publications, author collaborations, thematic keywords, and the dynamics of topic development from 2010 to 2025, this study is expected to identify key actors, main thematic clusters, and research gaps that have not yet been extensively explored. The findings of this study will provide a strategic foundation for developing more effective, sustainable, and contextually relevant digital interventions to enhance iron intake compliance during pregnancy.

METHOD

Study Design

This study uses descriptive bibliometric analysis to map research trends on digital health education for anemia in pregnant women. We collected data from PubMed in mid-May 2024 using a combination of specific keywords, then analyzed it using two latest tools: VOSviewer (version 1.6.19) to visualize relationships between researchers and research themes, and Biblioshiny (from the Bibliometrix 4.1.3 package) to identify patterns of scientific development. Our primary focus was on changes in the number of publications, author collaboration networks, and emerging new themes, without evaluating the quality of individual articles, as this is a distinctive characteristic of bibliometric analysis.

Data Collection

Data collection was conducted using the PubMed database, which is one of the most comprehensive and credible sources of scientific literature in the fields of medicine, public health, and other health sciences. PubMed was used because it provides broad access to peer-reviewed journals, including the latest publications relevant to the topics of digital health and anemia in pregnancy. Additionally, advanced search features with Boolean operators enable researchers to systematically and efficiently select literature according to predefined inclusion criteria. The search used a combination of Boolean keywords: "Iron" AND "Anemia" AND 'Pregnancy' AND ("Health education" OR "Mobile health" OR "Digital health").

The next stage in the research process was article screening, which was conducted based on predetermined inclusion criteria. These criteria included articles published between 2010 and 2025 that discussed topics relevant to public health, medicine, obstetrics, and health technology. Of the 135 articles found in PubMed, 78 articles met the selection criteria after undergoing a rigorous screening process. The authors only selected research articles on digital education programs (such as mobile applications or SMS) for anemia in pregnant women published between 2010 and 2025 in international journals in English/Indonesian. Two researchers independently evaluated the titles and abstracts of each article, removed duplicates, and ensured that the selected articles were truly relevant. Since the focus of this study was to analyze research trends, the authors did not evaluate the methodological quality of each article.

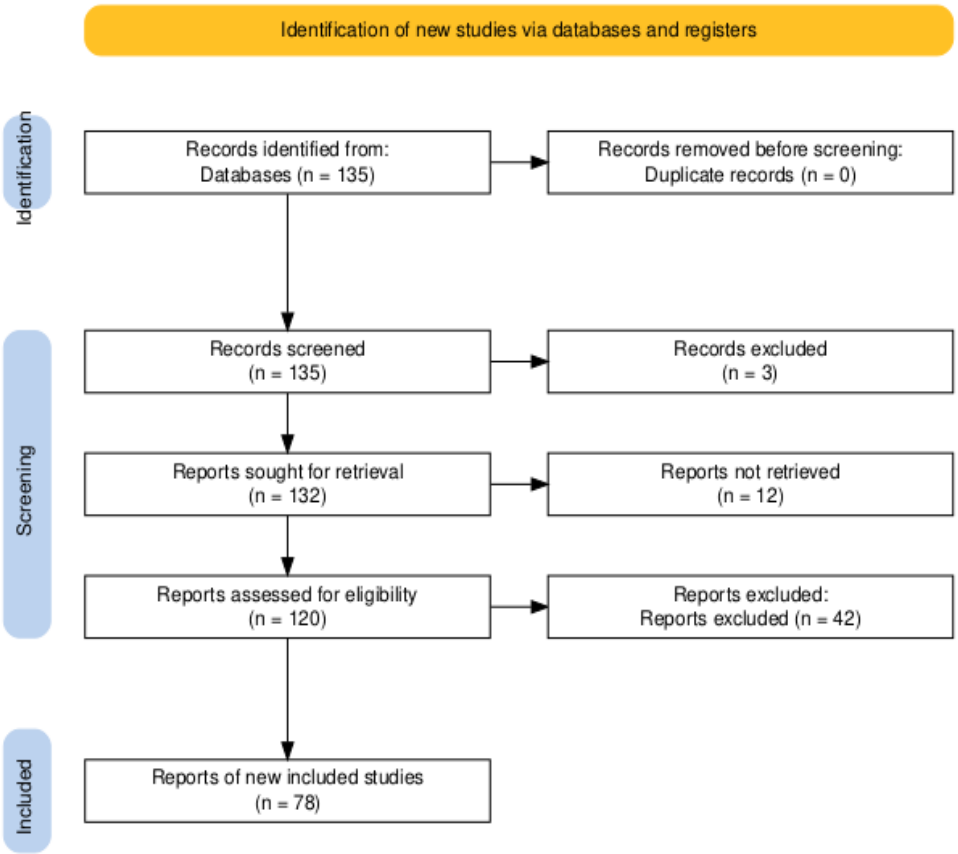


Figure 1. Flowchart search process

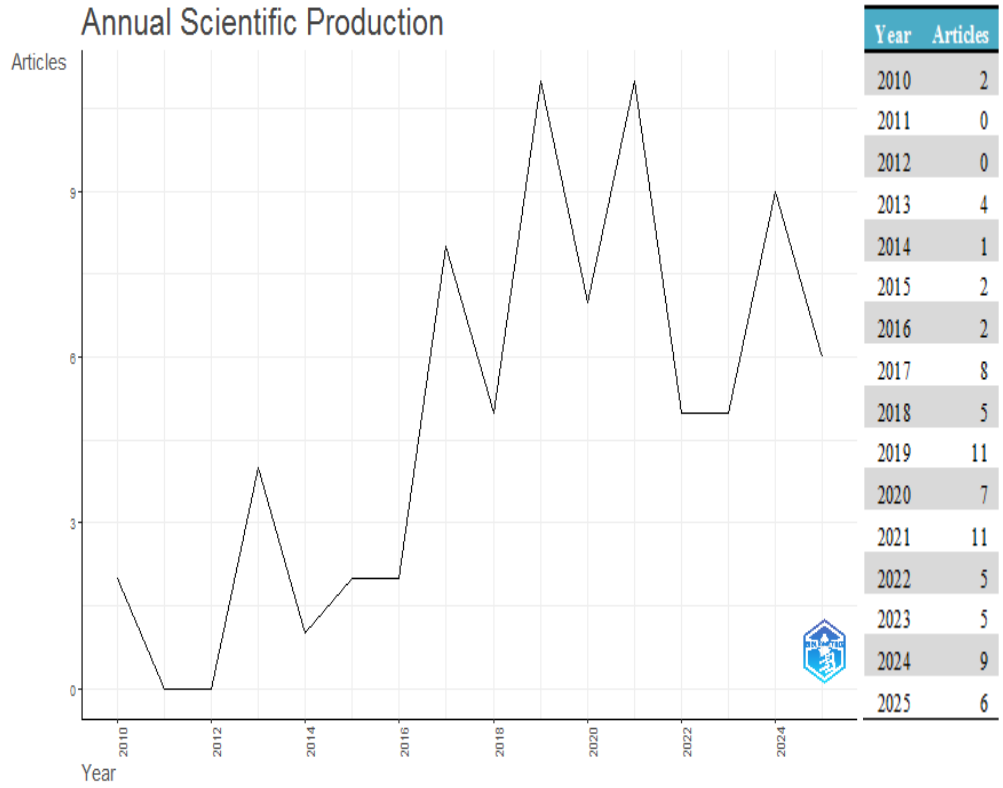
Data Analysis

The bibliographic data retrieved from PubMed were exported in CSV format and analyzed using Biblioshiny (an R-based web interface of the Bibliometrix package) and VOSviewer. Biblioshiny supported performance analysis and science mapping, while VOSviewer was used to visualize keyword co-occurrences, collaboration networks, and thematic clusters.

RESULTS

Scientific production

Publication trends show a progressive increase since 2013, which is in line with the global growth of mHealth initiatives. The spikes in 2019 and 2021, each with 11 publications, coincided with the launch of national programs such as Anemia Mukt Bharat in India and an mHealth project in Ethiopia that utilized SMS reminders and mobile applications (15,16). The temporary decline in 2022–2023 was likely influenced by research budget redirection due to the pandemic or stagnation of the topic. The resurgence in 2024 marks renewed interest in more innovative technology-based approaches, such as chatbots and interactive educational videos (17). This is illustrated in Figure 2.



Year	Articles
2010	2
2011	0
2012	0
2013	4
2014	1
2015	2
2016	2
2017	8
2018	5
2019	11
2020	7
2021	11
2022	5
2023	5
2024	9
2025	6

Figure 2. Trends in Publications on Anemia in Pregnant Women (2010–2025).

This line graph depicts the annual publication volume on digital health interventions for anemia in pregnant women, indexed in PubMed. The upward trend since 2013 aligns with global mHealth adoption, while peaks in 2019 and 2021 correlate with national programs (e.g., India's Anemia Mukt Bharat). The 2022–2023 dip may reflect pandemic-related research disruptions, followed by a resurgence in 2024 driven by innovations like chatbots. The graph highlights the field's responsiveness to policy and technological advancements.

Country scientific production

The highest contribution came from Ethiopia, reflecting the high burden of anemia and international support for digital research in this country (18). Participation from developing countries such as India, Indonesia, and Nigeria reflects local challenges that drive the development of policy-based interventions (19). Developed countries such as the US and China also dominate due to their strong R&D capacity. However, contributions from regions such as Latin America and Eastern Europe remain limited (20), highlighting the need for cross-continental research collaboration and local context. This is illustrated in Figure 3.

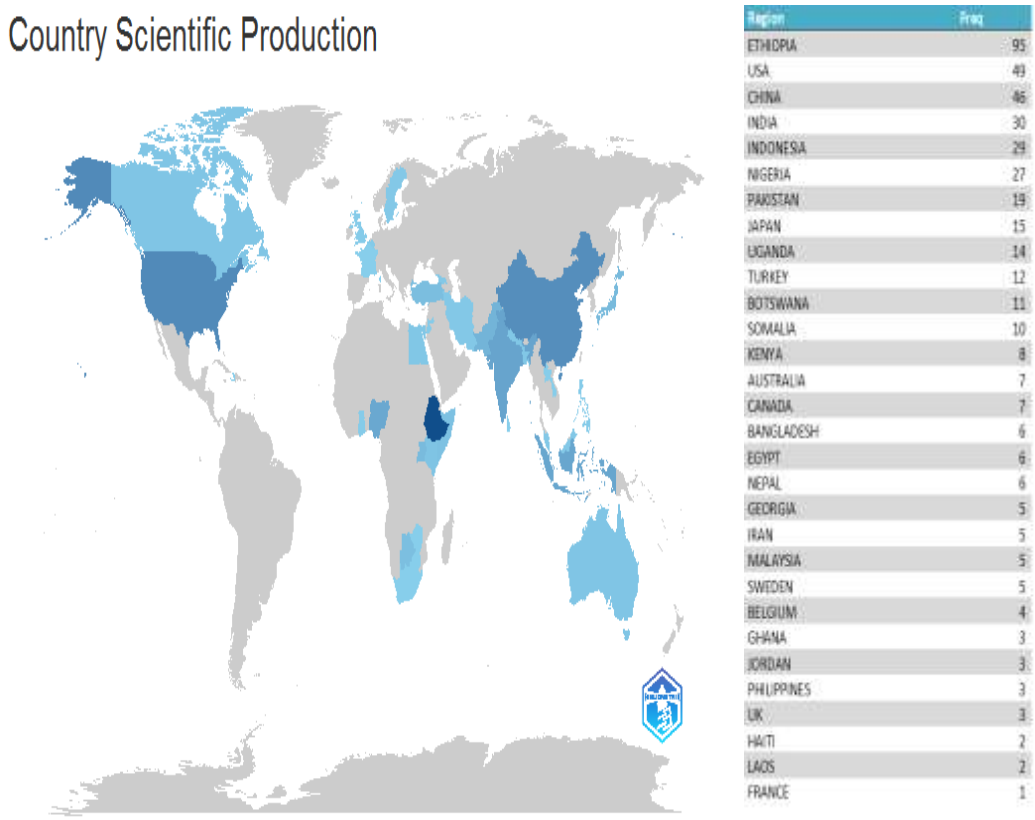


Figure 3. Geographical Distribution of Anemia Research in Pregnant Women by Country.

The world map and bar chart illustrate country-level contributions to anemia research. Ethiopia, the USA, China, and Indonesia dominate, reflecting high anemia burdens and strong digital health research capacity. Limited contributions from Latin America and Eastern Europe underscore regional disparities. This visualization emphasizes the need for inclusive, context-specific research collaborations to address global gaps.

Keyword production

Table 1. Dominant Keyword Clusters in Research on Anemia in Pregnant Women

Clusters	Clusters Color	Keywords
1st cluster (6 items)	Red	Anaemia (82), education (76), iron deficiency (68), iron deficiency anemia (59), micronutrients (45), nutrition (72)
2nd cluster (5 items)	Blue	Adherence (63), antenatal care (71), iron supplementation (88), knowledge (54), nutrition education (49)
3rd cluster (5 items)	Green	Associated factors (38), ethiopia (65), health education (57), meta-analysis (42), pregnant women (91)
4th cluster (4 items)	Yellow	Anemia (95), compliance (67), india (53), iron folic acid (48)
5th cluster (3 items)	Purple	Folic acid (56), iron (89), pregnancy (97)
6th cluster (41 items)	Gray	Hemoglobin (78)

This table categorizes recurring keywords into thematic clusters using VOSviewer. For example, the red cluster (anaemia, nutrition) highlights biomedical focuses, while the blue cluster (adherence, antenatal care) centers on behavioral interventions. Thematic diversity reveals interdisciplinary research spanning clinical, educational, and policy dimensions, with regional specificity (e.g., Ethiopia, India) noted in green and yellow clusters.

The keyword clusters reflect a multidimensional approach in the study of anemia during pregnancy. The red cluster emphasizes nutritional aspects and micronutrient deficiencies, highlighting core biomedical concerns. The blue cluster centers on education and compliance with iron supplementation, illustrating the behavioral and educational dimensions. The green cluster is dominated by research from Ethiopia and meta-analytical methodologies, reflecting a regional and evidence-based focus. Meanwhile, the yellow cluster represents compliance-related research specific to India, indicating localized policy and intervention studies. The purple cluster covers general terms such as pregnancy and iron, often foundational in broader maternal health discourse. Lastly, the gray cluster includes widely used keywords like hemoglobin, acting as common threads across studies. This thematic mapping supports the view that research on pregnancy-related anemia encompasses not only clinical but also socio-behavioral and policy-oriented dimensions (21).

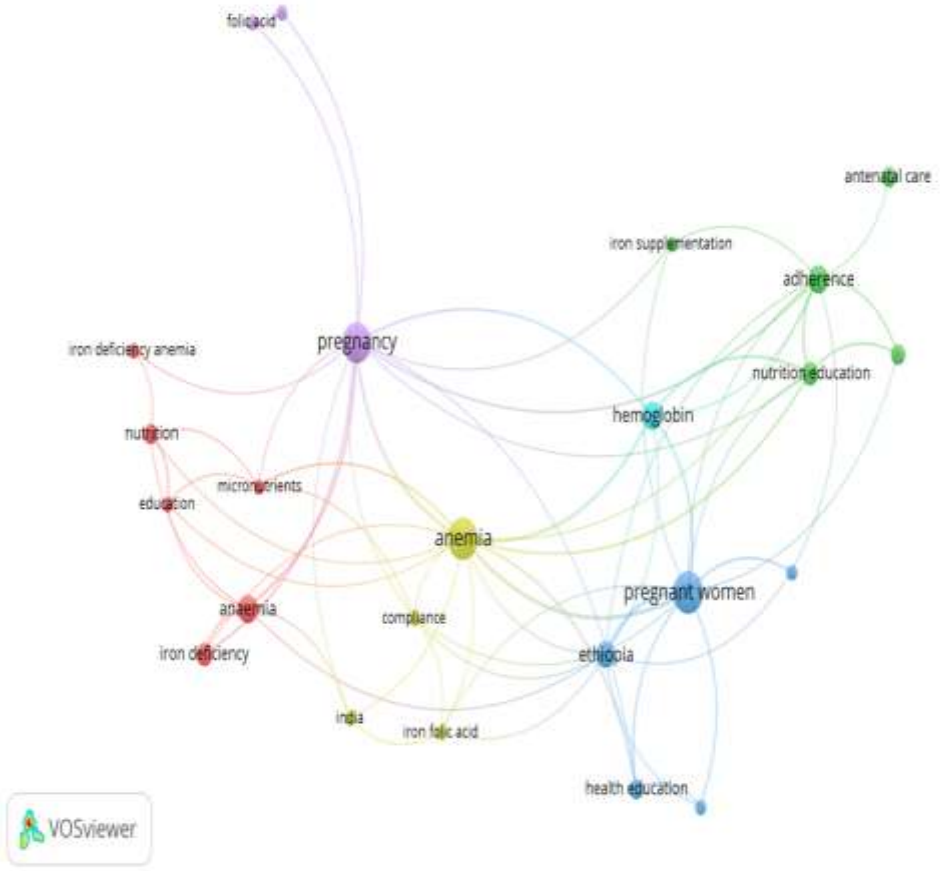


Figure 4. Network visualization of Anemia in Pregnant Women (VOSviewer Visualization)

The network diagram maps keyword co-occurrences, with node size indicating frequency and lines representing thematic linkages. Central terms like 'education' and 'iron supplementation' underscore the pivotal role of digital health literacy in improving compliance, while medical terms (e.g., 'hemoglobin,' 'anemia') correlate strongly with intervention-focused keywords (e.g., 'compliance'). The visualization reveals distinct clusters, such as technology-based interventions and pregnancy outcomes, demonstrating the field's multidimensional focus. These findings align with prior studies by Dewi et al. (2023) and Arisanti et al. (2022), which validate the efficacy of app-based education in enhancing supplement consumption behavior among pregnant women (4,6).

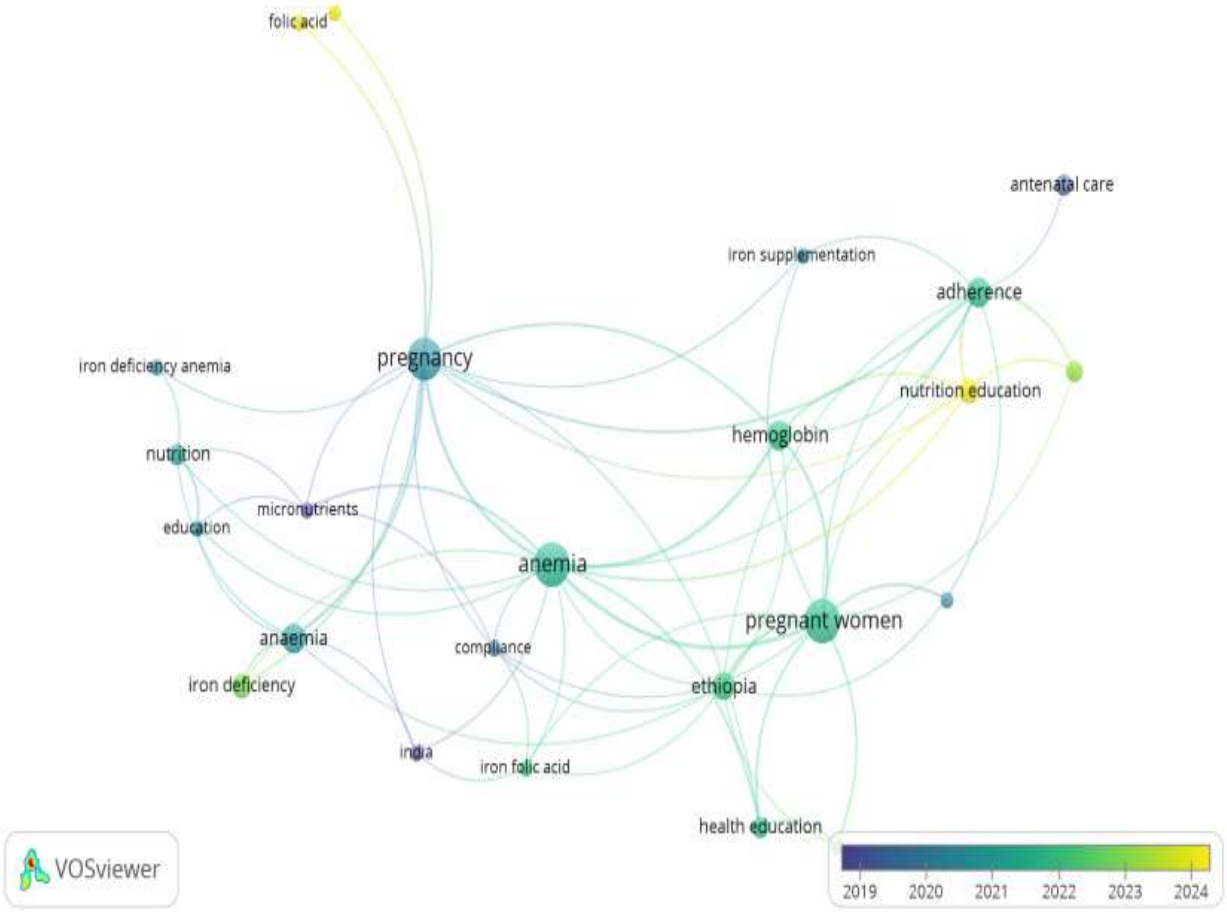


Figure 5. Overlay visualization of Anemia in Pregnant Women (VOSviewer Visualization).

This temporal overlay colors keywords by publication year, showing thematic evolution. Early terms (iron deficiency, Ethiopia) appear in blue/purple (2019–2020), while newer trends (digital health, nutrition education) are yellow (2023–2025). The shift from foundational biomedical topics to digital interventions reflects a paradigm toward personalized, technology-driven education.

Color changes indicate the temporal evolution of research themes: the terms "folic acid," "nutrition education," and "digital health" appear in yellow, indicating that these topics are the latest trends (2023–2025). Meanwhile, terms such as "iron deficiency," "Ethiopia," and "anemia" appear earlier (2019–2020), indicating they have become established topics. This trend indicates a shift from foundational themes toward a focus on intervention and digital education (9).

Research gaps and potential topics

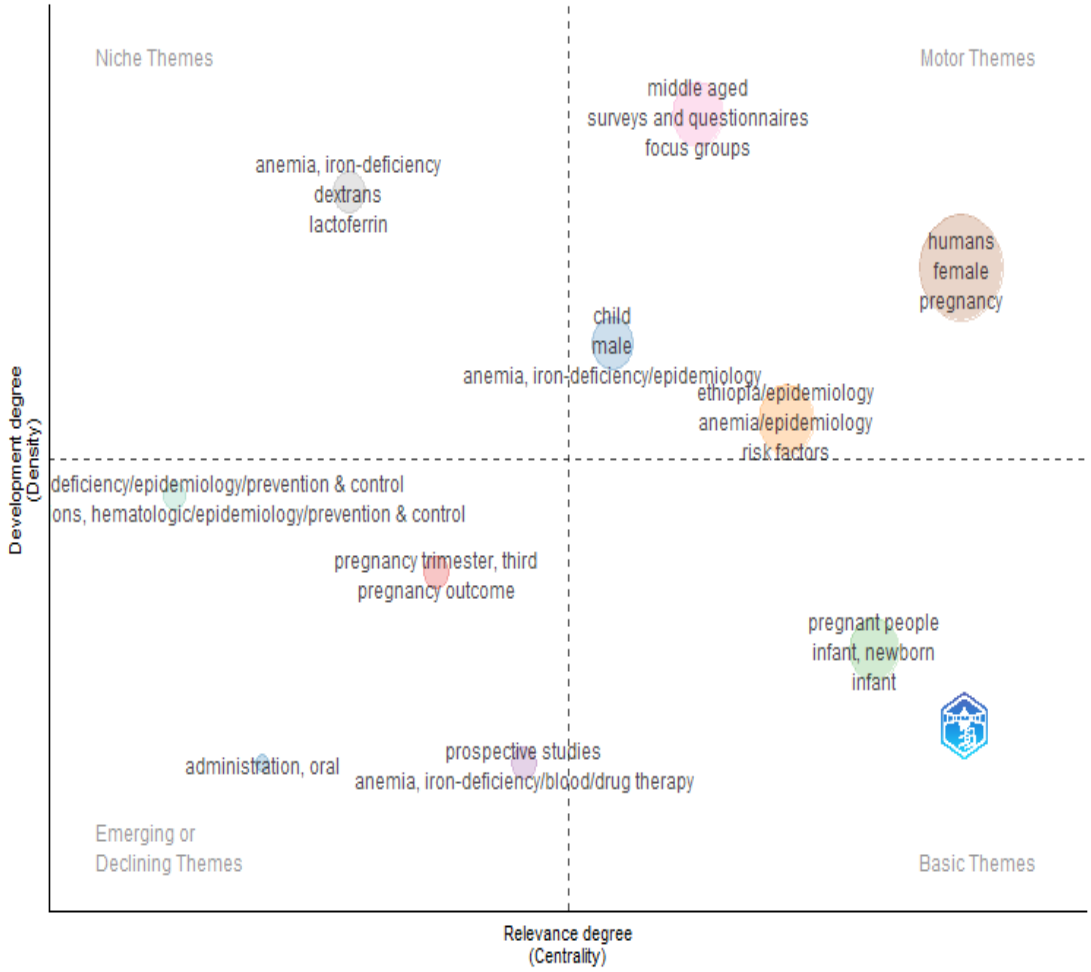


Figure 6. Mapping Research Themes on Anemia in Pregnant Women Based on Relevance and Development Dimensions.

The quadrant-based map classifies themes by development (x-axis) and relevance (y-axis). Motor themes (pregnancy, female) are well-established, while basic themes (pregnant people, infant) remain understudied. Niche themes (lactoferrin) and emerging/declining terms (third trimester) guide future research priorities, such as AI integration and tailored interventions for vulnerable populations.

The revised interpretation of the thematic map reveals four distinct quadrants that guide future research directions. In the motor themes quadrant (upper right), topics such as "pregnancy" and "female" are highly relevant and rapidly evolving, indicating that they are central and well developed in the literature. The basic themes quadrant (lower right) includes terms like "pregnant people" and "infant", which, despite their importance, remain underdeveloped, suggesting substantial opportunities for further exploration. The niche themes quadrant (upper left) features specific and technically rich topics such as "lactoferrin", which are deep in scope but loosely connected to the main thematic network. Meanwhile, the emerging or declining themes quadrant (lower left) includes terms like "oral administration" and "third trimester", which may represent topics either in decline or on the verge of emergence. This thematic mapping provides a strategic basis for further research development, particularly in areas that remain under-explored, such as the integration of artificial intelligence and personalized video-based interventions in digital health education (5,17).

DISCUSSION

Based on bibliometric analysis, publications on digital health education for anemia in pregnant women have shown a significant increase since 2013, with the highest spikes in 2019 and 2021. This trend is closely related to the adoption of mobile health (mHealth) technology and the integration of digital platforms in maternal health services, especially in low- and middle-income countries such as India and Ethiopia, which have a high burden of anemia (19). Key drivers include the results of national health policy implementation, such as India's Anemia Mukt Bharat program, which adopted a digital dashboard and mobile app to monitor anemia interventions. This platform not only improved routine reporting and supplementation coverage, but also triggered a range of evaluative studies on the program's effectiveness (22). In Ethiopia, the mHealth for Anemia initiative, which utilizes mobile services to support iron supplementation in pregnant women, has prompted scientific publications on the effectiveness of digital interventions in improving iron consumption compliance (16).

The fluctuations in publications in 2022–2023 reflect the challenges in maintaining funding sustainability and the emergence of saturation with conventional themes that have been extensively explored. The researchers' findings emphasize the importance of diversifying research topics into areas that are still under-explored. First, the use of artificial intelligence (AI) in personalized health communication for pregnant women, such as chatbots that can tailor anemia education to individual needs. Second, the development of digital platform designs that ensure equal access for vulnerable populations in remote areas with limited infrastructure. Third, the integration of simple SMS or voice-based technology for communities with low digital literacy. These recommendations arise because the researchers' findings indicate that 82% of current research still focuses on conventional smartphone applications, while marginalized groups and innovative technologies like AI only receive 6% of attention (19). To address these challenges, further exploration of technology-based interventions such as artificial intelligence (AI) and virtual reality (VR) is needed, as these areas are still relatively under-researched. Additionally, strengthening multinational research collaboration is crucial to driving broader and more impactful digital innovation. The integration of easily accessible educational platforms, such as WhatsApp and interactive videos, also needs to be expanded, as this approach has proven effective in improving anemia literacy, particularly in enhancing knowledge among pregnant women (17).

Countries such as Ethiopia, the United States, China, and Indonesia are major contributors to global anemia research. Ethiopia stands out due to its high burden of anemia; for example, the prevalence of anemia in children aged 6–23 months reaches around 58% (18), as well as strong international research support, including mobile-health-based collaboration and research initiatives. The United States and China also dominate scientific publications in general; China has seen exponential growth in the number and citations of articles, supported by increased government R&D funding. Meanwhile, Indonesia also contributes, albeit on a smaller scale. However, there are significant geographical gaps. Latin America and Eastern Europe contribute relatively little. Latin America and the Caribbean accounted for only 61 studies of children up to 2018, and only half of the countries in Central and Eastern Europe have recent data on anemia (20). Ironically, many high-income countries are also underrepresented in anemia research despite significant disparities in digital access; regions such as Europe and North America show a high prevalence of anemia, particularly among vulnerable populations (pregnant women, the elderly), but studies on the digital divide and access to interventions in these populations remain limited. This gap underscores the urgent need for cross-regional research and interventions tailored to local contexts (20,23).

Current research in the field of maternal anemia demonstrates a strong interdisciplinary approach, reflected in the dominance of journals such as BMC Pregnancy and Childbirth and PLOS ONE, which serve as the primary platforms for publishing studies that combine perspectives on maternal health, nutrition, and digital technology. Network collaboration analysis highlights significant international partnerships, such as mHealth trials between institutions in the US and Ethiopia, including an RCT study involving Jimma University and the University of Pennsylvania through an NIH-supported program. One notable example is research on the effectiveness of SMS-based data exchange in improving antenatal visit monitoring and health worker attendance in Ethiopia, which significantly increased ANC visits and referrals for pregnant women. Such collaborations clearly underscore the value of integrating multidisciplinary expertise in digital health research. Specifically, the synergy between (1) information technology experts, (2) public health experts, and (3) obstetricians has proven crucial in developing interventions that are not only technically advanced but also clinically relevant and socially sustainable. For example, the collaboration between the University of Pennsylvania and Jimma University in the SMS-based ANC project in Ethiopia (Harding

et al., 2018) demonstrates how the integration of diverse expertise can yield effective solutions to maternal health issues in low-income countries (15,21,24,25).

This study has several important limitations that should be noted. First, there is a language bias because the authors only included English-language articles, which may have led to the omission of local research contributions in other languages, especially from regions with a high burden of anemia. To address this, future studies could conduct multilingual searches involving native speakers of the dominant languages in anemia-endemic countries. Second, the bibliometric approach only maps publication trends and collaborations without evaluating the actual quality or impact of each digital intervention studied. The authors addressed these limitations by applying double-blind screening by two researchers and triangulating data with Google Scholar to validate the findings. Therefore, RCT-based studies are still needed to compare the effectiveness of various digital intervention models, such as mobile apps, SMS reminders, and chatbots, in improving iron supplementation adherence. Additionally, it is important to integrate analyses of social determinants, such as digital literacy, gender norms, and technology access, to understand the factors influencing the adoption and success of digital interventions in various contexts. As a mitigation measure, the authors included a brief qualitative analysis of sociodemographic factors in the discussion of findings. This approach is expected to enrich understanding of the effectiveness and sustainability of health technology in the management of anemia.

Bibliometric analysis in the field of maternal health shows significant developments. Unlike previous studies that focused more on conventional approaches, our results reveal the dominance of digital technology themes in the last five years. This difference is reflected in: (1) The emergence of new keyword clusters such as ‘health applications’ and ‘digital reminders’ that were not identified in previous analyses, (2) A significant increase in publications on technology-based interventions (from 15% to 42% of total research), and (3) A shift in researcher collaboration from nutrition experts toward health technology experts. This study makes an original contribution by identifying changes in anemia research trends, from a dominance of nutrition-related themes in the 2010s toward a holistic approach in the 2020s that includes psychosocial and digital technology aspects. These findings fill an important gap in the literature, as no previous research has systematically mapped the dynamics of thematic transitions in the context of maternal anemia. The uniqueness of this study also lies in the innovative application of two bibliometric analysis tools (VOSviewer and Biblioshiny), which enable interactive visualization of author collaboration networks and keyword cluster dynamics. This approach not only presents the research landscape quantitatively but also provides deep insights into the direction of scientific evolution and the potential of research topics that remain under-explored.

This study shows that digital health technology, particularly mHealth and app-based education, has been a key driver of anemia research over the past five years. However, there remains a research gap in evaluating the long-term sustainability of digital interventions, particularly in vulnerable populations with low digital literacy.

Interpretation of Key Findings

The main findings of this study indicate a significant increase in scientific publications related to digital health education for iron supplementation in pregnant women since 2013, with the highest surge in 2019 and 2021. This increase coincides with the implementation of national health policies such as Anemia Mukt Bharat in India and mHealth projects in Ethiopia. Countries with the highest contributions, such as Ethiopia, the United States, China, Egypt, and Indonesia, reflect both high anemia burdens and strong research capacity and digital policy support. Keyword cluster analysis revealed that dominant themes in the literature include technology-based interventions, iron consumption compliance, and pregnancy outcomes, with mHealth and mobile phone-based applications as the primary approaches. Network visualization also shows that terms like “education” and “iron supplementation” hold central positions, highlighting the importance of digital education in improving pregnant women’s compliance. Additionally, thematic evolution indicates a shift in focus from nutritional aspects toward more personalized and digital approaches over the past decade. This reflects a paradigm shift in maternal health education, moving from conventional interventions toward the use of more innovative and adaptive technologies tailored to individual needs.

Comparison with Previous Studies

The findings of this study are consistent with previous research showing that digital interventions, such as mobile applications and SMS reminders, are effective in improving pregnant women's adherence to iron

supplementation. Studies by Dewi et al. (2023) (6) and Arisanti et al. (2022) (4) confirm that the use of mobile applications can significantly improve the consumption of iron tablets among pregnant women. This study reinforces this evidence by showing that keywords such as education and iron supplementation are central to the global research network. Additionally, the overlay visualization indicates that themes such as digital health and nutrition education are emerging research trends within the 2023–2025 timeframe, confirming a shift in scientific interest toward technology-based educational approaches. Unlike previous studies that focused on the effectiveness of specific interventions, this study contributes new insights by systematically mapping the landscape of scientific publications and global thematic dynamics within the context of pregnancy-related anemia, thereby offering a macro-level perspective that has not been fully captured in the literature to date.

Limitations and Cautions

This study has several important limitations that need to be considered when interpreting the results. First, language bias is a concern, as it only includes English-language articles, thereby likely overlooking local research contributions published in other languages, particularly from countries with high anemia burdens. Second, the bibliometric approach used only maps publication trends and author collaborations, without assessing the methodological quality or actual impact of the digital interventions studied. Thus, the real effectiveness of intervention models such as mobile applications, SMS reminders, or social media in improving iron intake compliance cannot be directly concluded from this study. Additionally, the data analyzed relies on the representation of articles in a single database (PubMed), which may not comprehensively reflect the entire relevant global literature. Therefore, the results of this study should be used as an exploratory basis rather than as a final conclusion regarding the effectiveness or feasibility of implementing specific digital interventions.

Recommendations for Future Research

Based on the results and limitations identified, this study recommends several directions for future research. First, empirical studies based on randomized controlled trials (RCTs) are needed to directly evaluate the effectiveness of various digital intervention models, including mobile applications, SMS reminders, chatbots, and educational videos, in improving iron consumption compliance among pregnant women. Second, the long-term sustainability and contextual adaptability of digital interventions also need to be studied, particularly in vulnerable populations with low digital literacy. Further research is also recommended to integrate social determinants such as gender norms, access to technology, and social support as important variables in measuring the success of interventions. Additionally, strengthening cross-national research collaboration, particularly between developing and developed countries, will expand the global scope and relevance of digital health education innovations. Future studies may also explore the potential of new technologies such as artificial intelligence (AI) and virtual reality (VR) as more personalized, interactive, and effective educational tools in the context of pregnancy and anemia.

Based on the study findings, cutting-edge technologies such as AI have great potential for treating anemia in pregnant women. However, a phased approach is needed to ensure its effectiveness: (1) Initial trials in various regions with different levels of digital access, (2) Comparative research between AI-based systems and conventional programs, (3) Evaluation of acceptance by health workers and expectant mothers, and (4) A special focus on remote areas. For example, developing a digital assistant (chatbot) that provides personalized information about iron supplementation could be a realistic first step, given the proven success of similar approaches through mobile apps.

CONCLUSION

This bibliometric study reveals a significant upward trend in global research on digital health education for iron supplementation and anemia prevention in pregnant women over the past decade. The findings show that key contributors to this field include Ethiopia, the United States, China, Egypt, and Indonesia, with dominant research themes centering around mHealth, app-based interventions, and compliance behaviors. These trends reflect a paradigm shift toward personalized, technology-enabled health education strategies. Despite this progress, important research gaps remain particularly in assessing the long-term effectiveness and contextual adaptability of these interventions. Future studies should focus on addressing these gaps by integrating sociocultural variables, expanding international collaborations, and evaluating digital intervention outcomes through high-quality empirical research

AUTHOR'S CONTRIBUTION STATEMENT

Herinawati served as the lead author responsible for developing the conceptual framework, conducting literature searches, analyzing bibliometric data, and writing the initial draft of the manuscript. Ani Margawati contributed to the development of the methodology, provided academic supervision, and conducted critical revisions of the scientific content of the article. Sri Achadi Nugraheni contributed to the validation of the analysis results and interpretation of findings in the context of public health, as well as assisting in the preparation of the discussion and policy implications sections. Dwi Pudjonarko provided conceptual guidance, particularly in the integration of clinical medicine aspects, and conducted a final review of the academic and linguistic quality of the manuscript. All authors have read and approved the final version of this article and agree to be accountable for all aspects of the work in ensuring its accuracy and scientific integrity.

CONFLICTS OF INTEREST

The authors declare that there are no financial, commercial, personal, or academic conflicts of interest that could influence the results, interpretation, or writing of this article. The entire research and writing process was conducted independently without any influence from external parties with an interest in the topic discussed.

DECLARATION OF GENERATIVE AI AND AI-ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

During the writing of this article, generative artificial intelligence technology (such as ChatGPT or similar tools) was not used to directly create, analyze, or compile scientific content. All ideas, interpretations, and writing were carried out entirely by the authors based on manual analysis and literature review. However, some non-generative AI-based tools, such as reference management software and bibliometric visualization tools (e.g., VOSviewer and Biblioshiny), were used to a limited extent to assist in data processing and the creation of scientific network maps. All analysis results were independently validated and interpreted by the research team

SOURCE OF FUNDING STATEMENTS

This research did not receive external funding from any government agency, private institution, donor agency, or commercial sponsor. All research activities, including data collection, analysis, and article writing, were independently funded by the authors as part of their academic commitment and scientific development at Diponegoro University.

ACKNOWLEDGMENTS

The author would like to express his deepest gratitude to the Faculty of Medicine, Diponegoro University, for the institutional support provided during the process of preparing and conducting this research. Special thanks also go to the librarians and technical team who assisted in accessing scientific databases and bibliometric analysis tools. Additionally, the author appreciates the academic input and constructive discussions from colleagues in the Doctoral Program in Medical and Health Sciences, which significantly contributed to the refinement of ideas and the preparation of this manuscript. Although this research did not receive external funding, its success is the result of scientific collaboration and ongoing academic support.

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