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RESEARCH

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Modifiable risk factors for anemia in pregnancy: an umbrella review of systematic reviews and meta-analyses

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Abstract

Background Anemia during pregnancy affects more than one-third of women globally, with the heaviest burden in low- and middle-income countries. It contributes substantially to maternal morbidity, adverse birth outcomes, and increased neonatal mortality. Despite extensive research, there remains a lack of comprehensive and up-to-date synthesis on modifiable determinants to guide effective, targeted interventions. This umbrella review aimed to consolidate evidence from systematic reviews and meta-analyses on modifiable risk factors associated with anemia in pregnancy.

Methods A systematic search was conducted across PubMed, Scopus, ScienceDirect, Epistemonikos, Hinari, Google Scholar, and the Cochrane Library. Search terms combined controlled vocabulary and free-text keywords including anemia, hemoglobin, iron deficiency, determinants, pregnant women, systematic review, and meta-analysis. Boolean operators (OR/AND) were applied, and the search was limited to English-language publications from 2014 to 2024. Eligible studies included systematic reviews and meta-analyses examining risk factors for anemia among pregnant women. Methodological quality was assessed using the Joanna Briggs Institute (JBI) critical appraisal tool, and synthesis followed JBI guidance to ensure rigor and transparency. Certainty of evidence assessed using GRADE.

Results Of 13,348 records identified, 10 systematic reviews and meta-analyses were included. The synthesis highlighted several modifiable risk factors. Nutritional determinants included low dietary diversity (RR = 2.38–3.59), poor dietary practices (AOR = 1.63–2.97), and inadequate iron/folic acid supplementation (AOR = 1.38–1.82). Maternal health conditions, particularly intestinal parasite infections (AOR = 2.18–4.34) and malaria (AOR = 1.94–11.19), showed strong associations. Sociodemographic risks included low maternal education (AOR = 1.34–2.04), short birth intervals (< 24 months; AOR = 1.27–2.84), adolescent pregnancy (AOR = 2.60), large family size (AOR = 1.58–1.95), and rural residence (RR = 1.56). Limited healthcare access, especially lack of antenatal care (AOR = 1.36–2.02), further increased

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risk. Considerable heterogeneity (I^2=0–94.5%) and low-to-moderate certainty ratings (GRADE) suggest variability across settings and highlight context dependence.

Conclusions Anemia during pregnancy arises from multiple modifiable factors, including poor nutrition, low dietary diversity, adolescent pregnancy, and infections like malaria and intestinal parasites. This umbrella review highlights the importance of developing context-specific interventions and implementing multisectoral policies that integrate nutrition and infection-control strategies to reduce the global burden of maternal anemia.

Keywords Anemia, Pregnancy, Modifiable risk factors, Umbrella review

Introduction

Anemia during pregnancy is a significant public health issue, affecting more than one-third of pregnant women globally, with the highest prevalence observed in low- and middle-income countries [1]. Anemia during pregnancy is defined by a reduction in hemoglobin level less than 11 gm/dl [2]. Maternal anemia can lead to a multitude of complications, including increased susceptibility to infections, preterm delivery, low birth weight, and even maternal mortality [3, 4]. The detrimental effects of anemia extend beyond the immediate health of the mother, potentially impacting the cognitive and physical development of the child [5, 6].

While the causes of anemia are diverse, half of the cases are due to iron deficiency [7]. Given this fact, it is critical to understand that this condition is influenced by a complex interplay of modifiable risk factors. Modifiable risk factors for anemia in pregnancy encompass dietary habits, socioeconomic status, maternal health conditions, and access to healthcare services even though their effects vary across settings [1, 8–12]. Among these, poor dietary diversity, reflecting insufficient intake of essential nutrients, remains one of the most consistent predictors of risk [13, 14]. These factors can be altered through appropriate interventions, thereby providing an 20opportunity for healthcare providers to implement targeted strategies aimed at reducing the incidence of anemia [15, 16].

Recognizing this, the United Nations Sustainable Development Goal 2 (SDG) set an ambitious target: to cut anemia among women of reproductive age by half, from 24.5% in 2020 to 15% by 2030 [17]. Yet, despite these commitments, anemia prevalence among pregnant women remains unacceptably high due to unresolved determining factors [1, 18, 19].

Therefore, synthesizing modifiable risk factors of anemia among pregnant women is central to accelerating SDG 2, particularly Target 2.2 which tracks anemia reduction as Indicator 2.2.3 [17]. Evidence shows that addressing modifiable risk factors can substantially reduce maternal anemia and improve birth outcomes and achieving SDG 2 targets [20].

Most existing systematic reviews are limited to specific countries, regions, or narrow domains such as nutrition, infections, healthcare access, or supplementation adherence, leaving a critical gap in comprehensive syntheses that integrate and prioritize modifiable risk factors on a global scale. Closing this gap is essential to guide the design of effective interventions and inform policy decisions aimed at reducing the burden of anemia in pregnancy. Therefore, this umbrella review systematically gathered and analyzed evidence from systematic reviews and meta-analyses published between 2014 and 2024 to identify the most pertinent modifiable risk factors. The period 2014–2024 was selected to capture the most recent decade of evidence, aligning with the SDGs and a surge in high-quality systematic reviews on maternal anemia followed by the development of the global targets.

The present review is informed by the social determinants of health framework, which emphasizes that health outcomes, including maternal anemia, are shaped not only by biological factors but also by socioeconomic conditions, environmental exposures, and healthcare access [21]. Within this framework, modifiable risk factors such as dietary diversity, maternal education, employment status, and healthcare utilization are viewed as interconnected determinants that either buffer or exacerbate the risk of anemia during pregnancy. This perspective is complemented by the health behavior model, which underscores the role of individual knowledge, perceptions, and practices in influencing dietary intake and adherence to supplementation [22]. Together, these frameworks provide a lens through which modifiable risk factors can be systematically organized, interpreted, and translated into actionable interventions aimed at reducing anemia prevalence and advancing global health targets such as the Sustainable Development Goals.

The findings of this umbrella review are expected to provide critical evidence for policymakers and healthcare practitioners, supporting the development of targeted, evidence-based interventions that are both culturally sensitive and context-specific. By addressing the identified modifiable risk factors, such interventions have the potential to improve maternal health outcomes and strengthen the quality of care for pregnant women globally.

Methods

This umbrella review was conducted based on the Joanna Briggs Institute (JBI) methodology for the synthesis of evidence using umbrella reviews [23] and reported based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 checklist [24]. JBI was selected over other appraisal tools as it provides a comprehensive and validated framework specifically designed for umbrella reviews of non-intervention studies.

Eligibility criteria

Systematic reviews and meta-analyses (SRs) published between January 2014 and January 2024 that examined determinants or associated factors of anemia among pregnant women were systematically searched and screened for eligibility. The eligibility of the SRs was assessed based on the following Population, Intervention or phenomenon of interest, Comparison, and Outcomes (PICOs): (a) Population: Pregnant women of reproductive age from any geographic setting. (b) Phenomenon of interest: Systematic reviews and meta-analyses that assessed anemia in pregnancy, specifically focusing on its prevalence and risk factors, determinants, or associated factors. (c) Outcomes: Reviews reporting quantitative associations (both significant and non-significant) between identified risk factors and anemia in pregnancy, including analytical measures such as adjusted odds ratios (AOR), relative risks (RR), or equivalent effect estimates. (d) Context: Systematic reviews synthesizing evidence from primary studies conducted globally, published in English between January 2014 and January 2024. (e) Types of studies: Only systematic reviews and meta-analyses of observational studies that performed meta-analysis and/or meta-regression were eligible.

Reviews based on non-human studies, narrative or scoping reviews, case reports, commentaries, and non–full-text articles were excluded.

Search strategy and data sources

Systematic searches were conducted in PubMed/Medline, Scopus, ScienceDirect, HINARI, Cochrane Library, Epistemonkos and Google Scholar for systematic reviews and meta-analyses published in English between January 1, 2014, and January 1, 2024. English-language restriction was applied for feasibility and because most indexed reviews are available in English. Each search string was screened using combinations of keywords related to "anemia," "pregnancy," "risk factors," "determinants," and "systematic review" or "meta-analysis." Searches were performed from March 15–30, 2024, supplemented by manual reference checking and direct author contact for articles not freely accessible. We have used Herzing's Publish or Perish open-source software to download google scholar search results.

Data base tailored search strategy combining MeSH terms (e.g., anemia, hemoglobin, iron deficiency, factors, determinants, pregnant women, pregnant mothers), keywords (systematic review, meta-analysis), and Boolean operators (AND, OR) was applied to the title and abstract fields of articles (supplementary file S1).

Study screening and selection

Two authors (WK and MS) independently conducted the literature search using EndNote for citation management. Following retrieval, three authors (WK, SG, and ZD) independently screened studies against the eligibility criteria in three stages: title, abstract, and full-text review. Discrepancies were resolved through discussion with a third author (MS). The screening process and number of studies included at each stage are presented in the PRISMA flow diagram (Fig. 1).

Assessment of methodological quality

The methodological quality of included systematic reviews was assessed using the JBI Critical Appraisal Checklist for Systematic Reviews [25], applied via the JBI SUMARI web application (https://app.jbisumari.org). The tool comprises 11 questions evaluating the rigor and transparency of review conduct. Two reviewers (WK and MS) independently performed the appraisal, with disagreements resolved through discussion with other reviewers (SG and MAR). Quality thresholds were set a priori: scores ≥ 70% were considered high quality, 50–70% medium quality, and < 50% low quality [26]. A minimum cut-off of 70% was required for inclusion in the synthesis. Most included reviews met this threshold, scoring 100% while two systematic reviews scored 90.9%. Detailed appraisal results are provided in Supplementary File S2.

Data extraction and summary

The JBI data extraction tool [23] was used to extract the required information for this umbrella review. Two reviewers (AJ and MG) extracted the data from the included reviews independently. The reviewers discussed on the extraction tool prior data extraction. Any discrepancies after extraction were resolved with a third reviewer (WK) and discussion. Information related with name of the authors and year of publication, total number of primary studies analyzed, total number of participants, range of year of publication of primary studies, primary studies' country of origin, associated risk factors identified, and heterogeneity between studies were collected (Table 1 of result section).

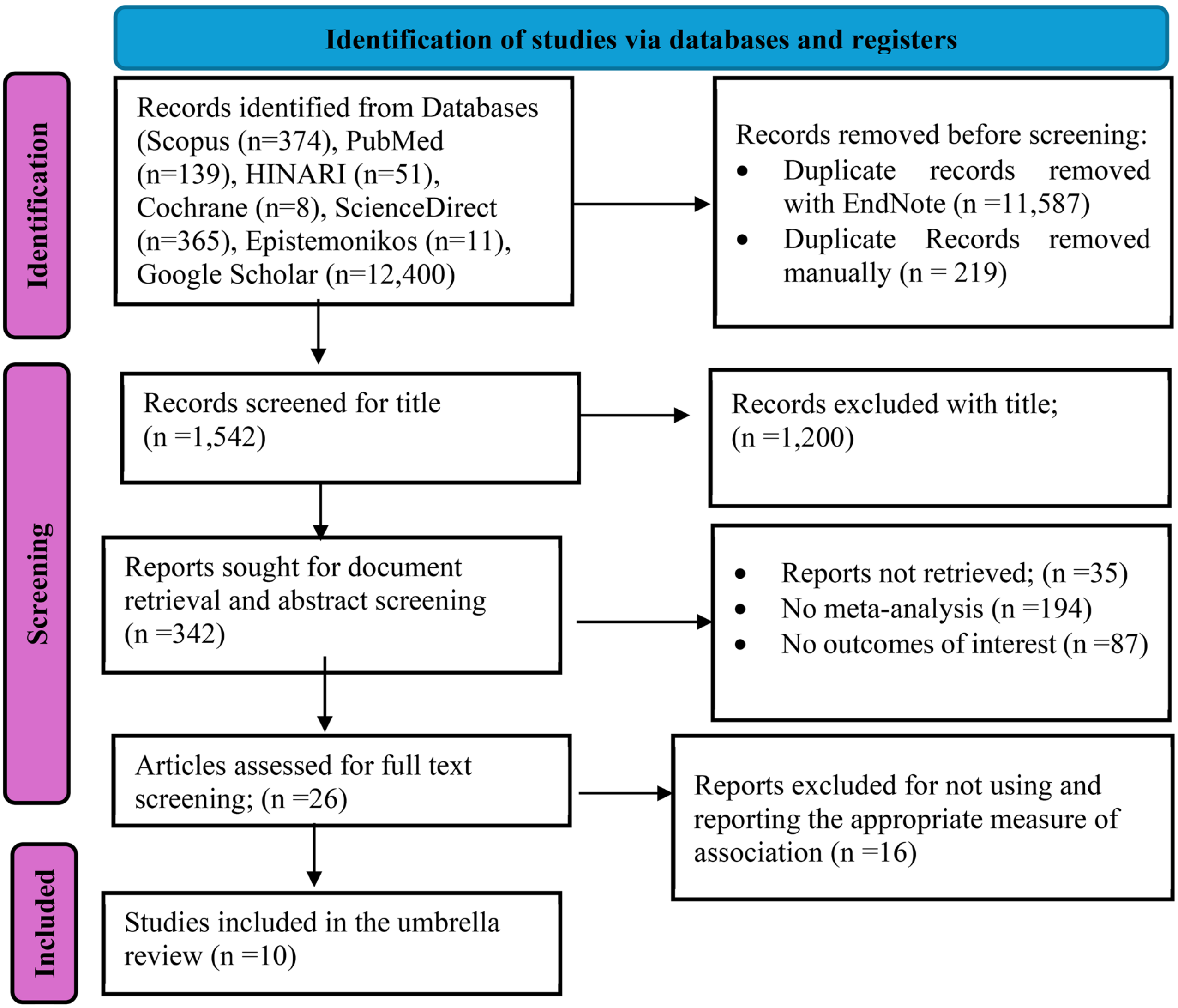

Fig. 1 PRISMA 2020 flow diagram for the process of study searching, retrieval and selection. (Source: Page MJ, et al. BMJ 2021;372:n71. doi: https://doi.org/10.1136/bmj.n71.)

Data analysis, assessment of certainty of evidence and interpretation

All extracted data were managed using Microsoft Excel 2024 and exported to R software (version 4.4.2) for statistical analysis. Determinants consistently reported across multiple systematic reviews with comparable effect estimates were summarized and synthesized narratively. The strength of evidence for each associated modifiable factor was graded using the GRADE tool [35] (https://gdt.gradepro.org/app/) which evaluates evidence based on study design, risk of bias, imprecision, inconsistency, indirectness, magnitude of effect, and publication bias [36]. Two independent reviewers (SG and AJ) conducted the evaluation at the outcome level, with disagreements resolved through discussion with a third reviewer (MG). The Summary of Findings table for effect estimates and the quality of evidence is presented in results section (Table 2). To assess the extent to which primary studies overlapped across systematic reviews and meta-analyses, the Corrected Covered Area (CCA) was calculated (Table 3).

Results

Search results

A total of 13,348 research articles were initially identified from the searched databases. After title screening, 342 articles were retained for abstract screening and full-text retrieval of which 26 articles were selected for full-text assessment, and 10 studies ([9, 11, 27–34], found fit for the umbrella review. The process was conducted as per the PRISMA 2020 flow diagram [24] (Fig. 1).

Characteristics of included studies

A total of 10 systematic reviews and meta-analyses, comprising 309,727 pregnant women, were included in this

Table 1 Characteristics of included reviews for the evidence synthesis (Umbrella review) of modifiable risk factors of anemia among pregnant women

S.N	First author (publication year)	Studies analyzed	Total sample size	Range (years) of included	Country of Origin	Associated/risk factors (AOR/RR)	Heterogeneity	Reference
1.	Geta et al. (2022)	60	31,266	2010 to 2020	Ethiopia	• Rural residence (RR = 1.56, 95% CI: 1.31, 1.86) • Low educational level (RR = 1.51, 95%CI: 1.36,1.68) • Family size greater than 5 (RR = 1.62, 95% CI: 1.33, 1.96) • Birth interval less than 24 months (RR = 1.55(95% CI; 1.31,1.83) • No history of ANC visit (RR = 1.36 (95% CI: 1.04,1.80) • No Iron and folic acid supplementation (RR = 1.53 (95% CI, 1.30, 1.81)) • Low dietary diversity (RR = 2.61, 95% CI: 1.97, 3.48) • Intestinal parasite infection (RR = 2.18, (95%CI: 1.66, 2.87) • Malaria infection (RR = 1.96(95%: 1.55, 2.48)	88.8, 69.7, 86, 76, 92.7, 85.7, 94.5, 93.3, 82.3	[11]
2.	Fite et al. (2021)	25	15,061	2010 to 2019	Sub-Saharan African countries	• Intestinal parasite infection (AOR = 3.59, 95% CI (2.44,5.28)) • No iron and folic-acid supplementation (AOR = 1.82, 95% CI (1.22,2.70)) • Low dietary diversity score (AOR = 3.59, 95% CI (2.44, 5.28))	58%, 68%, 68%	[27]
3.	Adam et al. (2021)	32	21,024	From inception to 2020	Sub-Saharan African countries	Intestinal parasite infection (Schistosomiasis) (OR = 3.02 (95%CI: 1.25,7.28))	72.7%	[28]
4.	Ali et al. (2020)	15	100,168	2000 to 2015	South Asia and African countries	• Birth interval of < 24 months: (AOR = 1.27 (95% CI 1.06, 1.71)) • Household food insecurity: (AOR = 1.42 (95% CI 1.23, 1.63)) • No iron or folate supplementation (AOR = 1.54 (95% CI 1.04–2.27)) • Having three to five children: (AOR = 1.95 (95% CI; 1.19–3.19)) • Malaria-infection (AOR = 11.19 (95% CI 3.31–37.7)) • Intestinal parasite infection (Hookworm) (RR = 2.37 (95% CI 1.44, 3.91)) • Low educational level (AOR = 2.04 (95% CI:1.49–2.80)) • Intestinal parasite infections (AOR = 1.82, 95% CI:1.16–2.87))	Not indicated	[29]
5.	Alvarado-Gonzalez et al. (2022)	38	19,169	2000 to 2021	Low and Middle income	• Intestinal parasite infection (AOR = 4.34(95%CI:2.66,7.10)) • Malaria infection (AOR = 2.98(95%CI:1.98,4.48))	84 71	[30]
6.	Kassa et al. (2017)	20	10,281	Inception to 2017	Ethiopia	• Pregnancy interval less than 24 months (RR: 2.14 (95% CI: 1.67, 2.74)) • Malaria infection during pregnancy (RR: 1.94 (95% CI: 1.33, 2.82))	89.1%	[31]
7.	Lima et al. (2021)	17	6,530	2010 to 2021	Global	• Vitamin D Deficiency (OR = 1.61(95%CI:1.41:1.83)	48%	[32]

Table 1 (continued)

S.N	First author (publication year)	Studies analyzed	Total sample size	Range (years) of included	Country of Origin	Associated/risk factors (AOR/RR)	Heterogeneity	Reference
8.	Ness et al. (2020)	13	18,885	2010–2020	Global	• Intestinal parasite Infection (Hookworm) (OR = 2.55 (95% CI; 2.20, 2.96)	89	[33]
9.	Zhang et al. (2022)	51	73,919	inception to June 27, 20,222	Global	• Tea/coffee after meals (AOR = 1.63 (1.21, 2.04)) • Meal frequency ≤ 2 times per day (AOR = 2.29 (95% CI; 1.61, 2.96) • Frequency of eating meat ≤ 1 time per week (AOR = 2.02 (95% CI; 1.55, 2.50) • Dietary diversity score ≤ 3 (AOR = 2.38 (95% CI; 1.55, 3.21) • Frequency of eating vegetables ≤ 3 times per week (AOR = 2.97 (95% CI; 1.59, 4.34) • No iron supplementation (AOR = 1.38 (95% CI; 0.77, 1.99) • Lack of understanding of anemia (AOR = 1.31 (95% CI; 0.95, 1.66) • No antenatal care (AOR = 2.02(95% CI; 1.81, 2.22) • Have more than 3 children (AOR = 1.58 (95% CI; 1.28, 1.89) • Birth interval ≤ 2 year 2.84 (AOR= (95% CI; 1.59, 4.09) • Low educational level (AOR = 1.34 (95% CI; 0.92, 1.76))	49.8,0,44,7,42.3,77.5,74.9,0,0, 28.1,87.9, 66.6	[9]
10.	Karaçam et al. 2021	10	13,424	2008 to 2020	Türkiye	• Pregnancy during adolescence (AOR = 2.60 (95% CI; 1.56–4.32))	86%	[34]

umbrella review. The studies originated globally, with most conducted in low- and middle-income countries (Fig. 2). The reviews have identified different modifiable risk factors/determinants of anemia during pregnancy. The main risk factors identified were related to nutrition and infection (Table 1).

Summary of findings

The umbrella review identified multiple modifiable risk factors for anemia during pregnancy, which were categorized into four broad categories: nutritional factors, maternal health conditions, sociodemographic characteristics, and healthcare access. Among nutritional factors, low dietary diversity (RR = 2.38–3.59), poor dietary practices including low meal frequency, inadequate vegetable and meat intake were consistently reported across multiple systematic reviews, indicating a substantial impact on anemia risk. Maternal health conditions, particularly intestinal parasite infections (RR/AOR = 2.18–4.34) and malaria infection (RR/AOR = 1.94–11.19), were strongly associated with increased anemia risk, though effect estimates showed notable heterogeneity across studies. Sociodemographic factors such as low maternal education (RR/AOR = 1.34–2.04), short birth/pregnancy intervals (< 24 months; RR/AOR = 1.27–2.84), and adolescent pregnancy (AOR = 2.60) were also identified, generally showing moderate effects. Finally, limited access to healthcare, as reflected by no antenatal care visits (RR/AOR = 1.36–2.02) and insufficient iron/folate supplementation (AOR = 1.38–1.82), contributed to anemia, though evidence was less robust for these factors. The integration of heterogeneity (I^2 ranging from 0% to 94.5%) into the assessment highlighted that while many factors consistently increased anemia risk, the certainty of evidence varied across variables and study settings, emphasizing the need for targeted, context-specific interventions (Table 2).

Certainty of evidence

All evidence was derived from observational studies, thus certainty of evidence started at a low level according to GRADE. Risk of bias was generally judged low to moderate across primary studies included in the systematic reviews, so no further downgrading was applied. Inconsistency was a frequent concern: several pooled analyses demonstrated substantial to considerable heterogeneity (I < 25 means low, 26–50 moderate, 51–75 substantial heterogeneity and > 75 is considerably high heterogeneity), particularly for dietary diversity, intestinal parasite infection, malaria, short birth interval, and maternal

Table 2 Summary of evidence for modifiable risk factors of anemia among pregnant women

Determinant (modifiable risk factor)	Effect size (all reported estimates)	Reviews reporting	Heterogeneity range (I^2%)	GRADE certainty (Risk of Bias/Inconsistency/Indirectness/Imprecision/Publication Bias/Overall)
Low dietary diversity	RR = 2.61 (1.97–3.48); AOR = 3.59 (2.44–5.28); AOR = 2.38 (1.55–3.21)	Geta 2022 [11]; Fite 2021 [27]; Zhang 2022 [9]	44.7–94.5	Low/Serious/Not serious/Not serious/**Not detected**[a]/**Moderate**[a]
Poor dietary practices*	AOR = 1.63 (1.21, 2.04)), (AOR = 2.29 (95% CI; 1.61, 2.96), (AOR = 2.02 (95% CI; 1.55, 2.50), (AOR = 2.97 (95% CI; 1.59, 4.34)	Zhang 2022 [9]	0–49.8.8	Low/Not serious/Not serious/Not serious/**Not detected/High**
No iron/folic acid supplementation	RR = 1.53 (1.30–1.81); AOR = 1.82 (1.22–2.70); AOR = 1.38 (0.77–1.99); AOR = 1.54 (1.04–2.27)	Geta 2022 [11]; Fite 2021 [27]; Ali 2020 [29]; Zhang 2022 [9]	0–85.7	Low/Serious/Not serious/Serious/**Mixed**[b]/**Moderate**[b]
Intestinal parasite infection	RR = 2.18 (1.66–2.87); OR = 2.55 (2.20–2.96); AOR = 3.59 (2.44–5.28); AOR = 4.34 (2.66–7.10); OR = 3.02 (1.25–7.28); RR = 2.37 (1.44–3.91)	Geta 2022 [11]; Fite 2021 [27]; Adam 2021 [28]; Ali 2020 [29]; Alvarado-González 2022 [30]; Ness 2020 [33]	72.7–93.3	Low/Serious/Not serious/Not serious/**Detected**[c]/**Low**[c]
Malaria infection	RR = 1.94 (1.33–2.82); RR = 1.96 (1.55–2.48); AOR = 2.98 (1.98–4.48); AOR = 11.19 (3.31–37.7)	Geta 2022 [11]; Ali 2020 [29]; Alvarado-González 2022 [30]; Kassa 2017 [31]	71–89.1	Low/Serious/Not serious/Serious/**Not Detected1/Moderate**
Short birth interval (< 24 months)	RR = 1.55 (1.31–1.83); AOR = 1.27 (1.06–1.71); RR = 2.14 (1.67–2.74); AOR = 2.84 (1.59–4.09)	Geta 2022 [11]; Ali 2020 [29]; Kassa 2017 [31]; Zhang 2022 [9]	76–89.1	Low/Serious/Not serious/Not serious/**Mixed**[e]/**Moderate**[e]
Low maternal education	RR = 1.51 (1.36–1.68); AOR = 2.04 (1.49–2.80); AOR = 1.34 (0.92–1.76)	Geta 2022 [11]; Ali 2020 [29]; Zhang 2022 [9]	66.6–85.7	Low/Serious/Not serious/Serious/**Mixed**[f]/**Low**[f]
Large family size (> 5)	RR = 1.62 (1.33–1.96); AOR = 1.95 (1.19–3.19); AOR = 1.58 (1.28–1.89)	Geta 2022 [11]; Ali 2020 [29]; Zhang 2022 [9]	66.6–87.9	Low/Serious/Not serious/Serious/**Mixed**[f]/**Low**[f]
Lack of ANC visits	RR = 1.36 (1.04–1.80); AOR = 2.02 (1.81–2.22)	Geta 2022 [11]; Zhang 2022 [9]	0–28.1	Low/Not serious/Not serious/Not serious/**Not detected**[a]/**Moderate**[a]
Household food insecurity	AOR = 1.42 (1.23–1.63)	Ali 2020 [29]	NA	Low/Not serious/Serious/Serious/**Not reported**[b]/**Low**[b]
Vitamin D deficiency	OR = 1.61 (1.41–1.83)	Lima 2021 [32]	48	Low/Not serious/Not serious/Not serious/**Mixed**[d]/**Low**
Adolescent pregnancy	AOR = 2.60 (1.56–4.32)	Karaçam 2021 [34]	86	Low/Serious/Serious/Not serious/**Not detected**[a]/**Low**[a]

[a]Not detected → Egger's/Begg's test showed no publication bias: Geta 2022 [11], Fite 2021 [27], Zhang 2022 [9], Lima 2021 [32], Karaçam 2021 [34]

[b]Mixed/Not reported → Some SRs didn't test for bias: Ali 2020 [29]

[c]Detected → Egger's test significant ($p = 0.005$) (Adam 2021 [28]). Thus, downgraded overall certainty for *intestinal parasite infection*

[d]Malaria infection → No publication (Kassa 2017 [31]: Egger's $p = 0.543$, Begg's > 0.05, Geta 2022 [11]: no bias) while Alvarado-Gonzalez 2022 [30] reported funnel plot asymmetry suggesting publication bias

[e]Short birth interval → No bias (Geta 2022 [11], Zhang 2022 [9], Kassa 2017 [31]) while Ali 2020 [29] did not report

[f]Low maternal education & Large family size → No bias (Geta 2022 [11], Zhang 2022 [9]) while Ali 2020 [29] did not report

*Tea/coffee after meals, Meal frequency ≤ 2 times per day, Frequency of eating meat ≤ 1 time per week, Frequency of eating vegetables ≤ 3 times per week

education, leading to downgrading. Indirectness was considered serious when the evidence was drawn from mixed populations (e.g., women of reproductive age, not limited to pregnancy) or context-specific reviews with limited generalizability (e.g., adolescent pregnancy in Turkey). Imprecision contributed to further downgrading when confidence intervals were wide or crossed the line of no effect, as observed for iron/folic acid supplementation, malaria, and maternal education. Publication bias was assessed in most meta-analyses, with no evidence detected in reviews by Geta, Fite, Zhang, Kassa, Lima, Karaçam, and Ness. However, Adam reported significant publication bias (Egger's $p = 0.005$) for intestinal parasites, which reduced certainty for this determinant, while Ali and Alvarado-González did not report bias assessment. Taken together, determinants such as lack of antenatal care and vitamin D deficiency, which showed consistent and precise effects without major concerns in other domains, were graded as moderate certainty, whereas factors affected by substantial heterogeneity, imprecision, or publication bias were graded as low certainty (Table 2).

Table 3 Corrected covered area (CCA) and pair-wise overlap per systematic review and meta-analyses

Review	Zhang et al. 2022 [9]	Ness et al. 2020 [33]	Kassa et al. 2017 [31]	Alvarado-Gonzalez et al. 2022 [30]	Adam et al. 2021 [28]	Fite et al. 2021 [27]	Geta et al. 2022 [11]	Karaçam et al. 2021 [34]	Ali et al. 2020 [29]	Lima et al. 2021 [32]
Zhang et al. 2022 [9]	1.000	0.042	0.077	0.072	0.012	0.134	0.264	0	0.031	0
Ness et al. 2020 [33]	0.042	1.000	0.050	0.220	0.078	0.091	0.108	0	0.027	0
Kassa et al. 2017 [31]	0.077	0.050	1.000	0.056	0.041	0.128	0.200	0	0.097	0
Alvarado Gonzalez et al. 2022 [30]	0.072	0.220	0.056	1.000	0.129	0.125	0.141	0	0.019	0
Adam et al. 2021 [28]	0.012	0.078	0.041	0.129	1.000	0.056	0.058	0	0.000	0
Fite et al. 2021 [27]	0.134	0.091	0.128	0.125	0.056	1.000	0.183	0	0.081	0
Geta et al. 2022 [11]	0.264	0.108	0.200	0.141	0.058	0.183	1.000	0	0.042	0
Karaçam et al. 2021 [34]	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1	0.000	0
Ali et al. 2020 [29]	0.031	0.027	0.097	0.019	0.000	0.081	0.042	0	1.000	0
Lima et al. 2021 [32]	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0	0.000	1
Total Studies	51	23	19	38	32	25	59	38	15	17

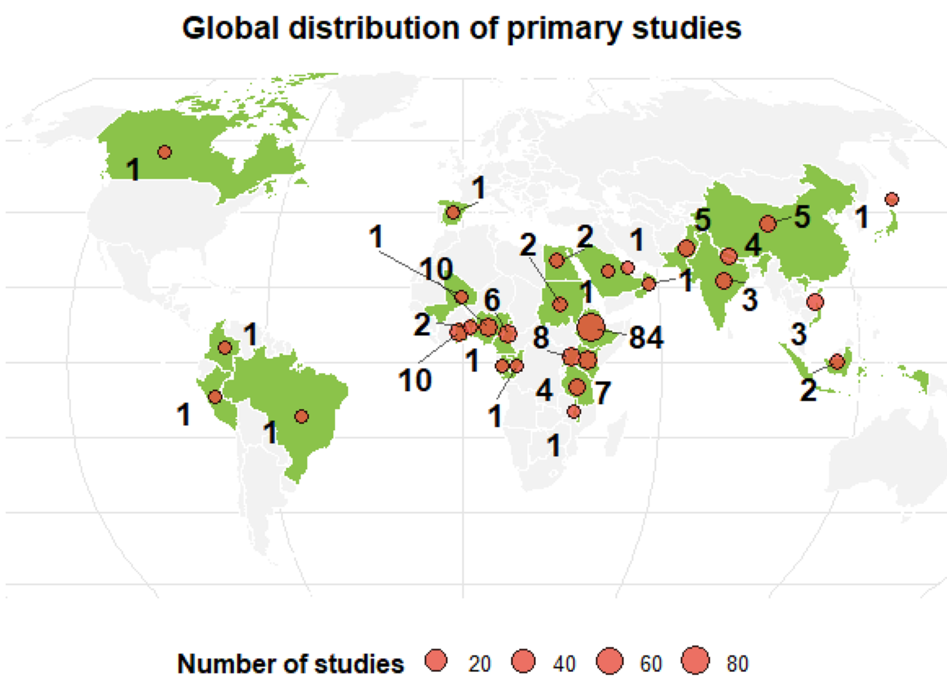

Fig. 2 Global distribution of original studies included in the umbrella review

Corrected covered area assessment

Corrected Covered Area (CCA) was calculated to investigate the magnitude of double-counting and overlapping of primary studies among the included systematic reviews and meta-analyses. The overall CCA across the 10 included systematic reviews was 0.045 (4.5%), indicating slight overlap in primary studies. Pairwise analysis showed that most reviews shared very few studies, although moderate overlap was observed between some reviews (Geta et al. [11] and Zhang et al. [9], 26.4%; Alvarado-Gonzalez et al. 2022 [30] and Ness et al. [33], 22%), suggesting partial redundancy in certain areas. Several reviews, including Karaçam et al. [34] and Lima et al. [32], did not overlap with any others, highlighting unique contributions of evidence. The number of primary studies per review varied from 15 to 59, reflecting differences in review size and scope. Overall, these findings indicate that the umbrella review synthesizes a broad, largely non-redundant evidence base, minimizing duplication and enhancing the comprehensiveness of the conclusions (Table 3).

Discussion

This umbrella review synthesized evidence from systematic reviews and meta-analyses to identify modifiable risk factors for anemia during pregnancy. The risk factors identified encompassed nutritional factors, maternal health conditions, sociodemographic characteristics, and healthcare access.

Low dietary diversity was one of the most consistent predictors of anemia in pregnancy across systematic reviews. Women consuming monotonous diets had more than twice the risk of developing anemia compared with those meeting minimum dietary diversity, with pooled estimates from Geta et al. [11], Fite et al. [37], and Zhang et al. [9] all showing significant effects. The consistency of these findings is supported by the biological plausibility, since monotonous diets limit intake of iron-rich foods and essential hematopoietic micronutrients such as folate, vitamin B12, and vitamin A [38–40]. Although heterogeneity was moderate to high, the direction of association was uniform, suggesting that interventions promoting food diversity could yield substantial reductions in anemia burden. These results align with evidence from different parts of the world that report inadequate dietary intake as a leading cause of gestational anemia, though variability in measurement of dietary diversity scores may partly explain the observed heterogeneity [13, 38, 41].

Closely related to dietary intake, the absence of iron and folic acid supplementation further increases anemia risk. Reviews by Geta et al. [11], Ali et al. [29], and Zhang et al. [9] indicated that women not receiving supplementation had 1.4–1.8 times higher odds of anemia. Physiologically, pregnancy increases maternal iron requirements exponentially due to expanded red cell mass, fetal-placental demands, and blood loss at delivery [42]. That makes IFA supplementation imperative. These findings are in line with randomized trials showing that daily iron–folic acid reduces maternal anemia prevalence at term [43–45]. However, one adjusted estimate (AOR = 1.38, 95% CI: 0.77–1.99) was not statistically significant, reflecting the challenges of adherence, dosage variation, and differences in health system delivery. Thus, while the protective effect of supplementation is well established, its effectiveness in real-world settings depends heavily on consistent utilization and program quality [46].

Beyond nutritional determinants, infectious diseases remain major drivers of anemia during pregnancy. Systematic reviews reported that intestinal parasite infections, especially hookworm, increased anemia risk two- to fourfold [11, 28, 30]. These results are supported by biological plausibility, given that chronic intestinal blood loss and impaired absorption compromise iron balance. Malaria infection, likewise, was associated with approximately a twofold higher risk of anemia [29, 31]. Mechanistically, malaria contributes through hemolysis of parasitized red blood cells, bone marrow suppression, and sequestration of infected erythrocytes in the placenta, impairing nutrient and oxygen transfer [47–49]. Interestingly, the strength of association for malaria was more variable, with one review [29] reporting extremely high adjusted odds (AOR = 11.19), suggesting contextual differences in malaria transmission, diagnostic methods, and severity of infection. Despite high heterogeneity, the evidence for both infections consistently point toward integrated deworming and malaria control as crucial strategies in endemic areas.

Reproductive factors also play an important role. Short birth intervals (< 24 months) were found to significantly increase anemia risk, with relative risks ranging between 1.55 and 2.14 [9, 29]. This supports the "maternal depletion syndrome" hypothesis, in which insufficient recovery time between pregnancies depletes iron and folate stores [50]. Similar trends were noted in studies, reinforcing the global relevance of birth spacing as a determinant of maternal anemia [51, 52]. Adolescent pregnancy was also strongly associated with anemia, with Karaçam et al. [34] reporting over a twofold higher odd compared to older women. While both factors reflect reproductive vulnerability, adolescent pregnancy uniquely combines biological immaturity with social disadvantage, whereas short intervals mainly reflect physiological depletion [51–54]. Both findings underscore the need for family planning and adolescent reproductive health services as anemia prevention measures.

Social determinants further modify anemia risk. Low maternal education was associated with 1.5–2 times higher odds of anemia [9, 29], though one review reported a non-significant adjusted estimate (AOR = 1.34, 95% CI: 0.92–1.76), suggesting possible residual confounding. The association likely operates through health literacy, empowerment, and care-seeking behaviors. Similarly, larger household size (>5) was linked to higher anemia risk [11], probably reflecting competition for limited food and healthcare resources. Food insecurity, reported by Ali et al. [29], further compounds nutritional deficiencies, though evidence is limited to a single review. While these factors highlight socioeconomic vulnerability, their high heterogeneity and lower certainty suggest the need for more targeted, context-specific studies.

Access to health services was a consistent protective factor. Lack of antenatal care (ANC) attendance nearly doubled the risk of anemia in pregnancy [9, 11], and unlike other determinants, this association showed low heterogeneity, increasing confidence in the finding. ANC represents a delivery platform for nearly all other preventive measures; iron and folic acid supplementation, deworming, malaria prophylaxis, and dietary counseling, making it a critical point of intervention [55–57]. Compared with dietary and infection-related factors, ANC access emerges as the most proximal and actionable determinant, with the strongest programmatic implications.

Finally, emerging evidence points to vitamin D deficiency as an additional risk factor, with Lima et al. [32] reporting a pooled odds ratio of 1.61 (95% CI: 1.41–1.83). Unlike iron or folate deficiency, the causal link between vitamin D and anemia is less established, operating potentially through immune modulation and erythropoiesis [58]. While promising, this evidence comes from fewer studies with moderate heterogeneity. The relationship between hemoglobin level and vitamin D was also noted among female blood donors who were differed from donation [59]. Pregnant women at their 2nd and 3rd trimesters also showed vitamin D deficiency even though not significantly associated with anemia [60]. Therefore, it should be kept under consideration for further trials.

The findings support the social determinants of health framework, indicating that anemia in pregnancy arises from intertwined biological, behavioral, and structural factors. Nutritional deficits, inadequate supplementation, infections, and short birth intervals reflect proximal risks, while low education, food insecurity, and poor service access represent broader structural vulnerabilities. These results highlight that most risk factors are preventable and call for integrated, multilevel interventions. Together, these findings show that anemia in pregnancy is driven by a multifactorial interplay of inadequate diet, poor IFA supplementation, infections, reproductive vulnerabilities, social disadvantages, and missed health services. The consistency across reviews underscores the preventable nature of most modifiable risk factors, though heterogeneity and generally low-to-moderate certainty call for cautious interpretation. Addressing anemia in pregnancy therefore requires integrated approaches, strengthening ANC, improving dietary diversity and supplementation adherence, controlling infections, promoting family planning, and tackling broader social determinants.

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Interpretation within theoretical frameworks

- Social Determinants of Health (SDH): The findings align strongly with the SDH framework, illustrating how structural and contextual factors, such as low maternal education, poverty, food insecurity, and limited healthcare access, shape exposure to proximal risks like inadequate diet, poor supplement adherence, and infection. These determinants interact to perpetuate health inequities among pregnant women, especially in low- and middle-income settings.
- Health Belief Model (HBM): Behavioral aspects such as iron–folic acid adherence and ANC attendance reflect key HBM constructs. Women with low perceived susceptibility, limited health literacy, or fewer perceived benefits of supplementation are less likely to engage in preventive behaviors. Conversely, improving awareness, self-efficacy, and access to health information can strengthen adherence and preventive action, especially among women with lower education levels.

Policy implications

This umbrella review shows that anemia in pregnancy is largely driven by modifiable factors such as poor dietary diversity, inadequate supplementation, parasitic and malaria infections, short birth intervals, adolescent pregnancy, low maternal education, food insecurity, and limited antenatal care. Addressing these determinants requires integrated policies spanning nutrition, infection control, reproductive health, and health system strengthening.

High-quality antenatal care (ANC) offers a practical entry point to tackle many of these risk factors simultaneously [61–64]. Evidence shows that good ANC improves maternal nutrition through iron–folic acid supplementation and dietary counseling, reduces exposure to infections through deworming and malaria prevention, and promotes healthy birth spacing and adolescent pregnancy prevention through family planning counseling. ANC platforms are also effective for health education, which can mitigate the impacts of low maternal education, large family size, and food insecurity by linking women to social protection and nutrition-sensitive interventions. These, interventions that target multisectoral approaches should be implemented.

Feasible models that integrate ANC with multi-sectoral approaches already exist. India's *Anemia Mukt Bharat* [65]demonstrates how iron–folic acid supplementation, deworming, and community mobilization can be scaled nationally. Ethiopia's Health Extension Program [66] illustrates how community health workers can expand supplementation and infection control. Conditional cash transfers in Mexico (*Oportunidades*) [67] show that social protection can improve dietary intake and care-seeking among food-insecure households.

Implementation, however, faces barriers including weak supply chains, poor adherence to supplements, sociocultural norms around pregnancy and contraception, and resource limitations in remote settings. Overcoming these challenges requires sustained investments in women's education and empowerment, agricultural diversification, and fortified food programs.

Broader investments in women's education and empowerment are essential to sustain behavioral change and improve care-seeking practices. Embedding anemia prevention into maternal health and nutrition strategies, while leveraging successful country models, offers a pragmatic pathway toward Sustainable Development Goal (SDG) 2, Target 2.2, which aims to reduce by half the prevalence of anemia among women of reproductive age by 2030.

Considerable variability in anemia prevalence and associated factors likely exists within countries due to regional differences in diet, infection burden, socioeconomic status, and healthcare access. National averages may therefore mask substantial local disparities. Future research should prioritize regional or subnational meta-analyses to capture these geographic nuances, enabling more targeted, context-specific interventions and policies.

Strengths of the study

This umbrella review has several notable strengths. First, it synthesizes evidence from recent systematic reviews and meta-analyses, thereby providing the highest level of evidence on the modifiable determinants of anemia in pregnancy. Second, by focusing specifically on modifiable risk factors; including nutritional, infection-related, reproductive, sociodemographic, and healthcare determinants, it provides actionable insights for policymakers and program planners. Fourth, the review highlights evidence from diverse low- and middle-income countries where the burden of anemia is highest, making its findings particularly relevant to settings most affected. Finally, the integration of policy implications, feasibility considerations, and examples of successful interventions strengthens the translational value of the review, bridging the gap between research and practice.

Limitations and future directions

While this review provides valuable insights, it is important to recognize its limitations. The findings of this synthesis are based on observational studies which will prevent to establish causal relationships with determining variables. In addition, most of the effect estimates have low to moderate quality of evidence and had substantial heterogeneity, which may pose a careful interpretation of this finding. In addition, despite conducting an overlap assessment, the potential for double-counting of primary studies across reviews cannot be fully excluded, which may have influenced the pooled evidence. Therefore, interventions should be planned with careful design and consideration of further research supports. Future research should also aim to explore localized interventions and assess the effectiveness of tailored intervention programs, considering the unique needs of different populations.

Conclusion

This umbrella review shows that anemia in pregnancy is driven primarily by modifiable factors, including poor dietary diversity, lack of iron–folic acid supplementation, intestinal parasitic and malaria infections, short birth intervals, adolescent pregnancy, food insecurity, low maternal education, large family size, and inadequate antenatal care. These determinants operate through biologically and physiologically plausible pathways ranging from nutrient deficiencies and increased physiological demands to infection-induced hemolysis and chronic blood loss. The evidence underscores that maternal anemia is not an inevitable condition but a preventable one, provided that effective, integrated interventions are prioritized.

Recommendations

To accelerate progress toward achieving SDG Target 2.2.3 and the global nutrition goal of reducing anemia among women of reproductive age by 2030, urgent, coordinated, and multisectoral action is essential to reduce the burden of maternal anemia, safeguard maternal and neonatal health, and ensure timely progress toward global nutrition and health targets. Governments and global health partners should leverage antenatal care as a central platform for preventive interventions, including iron–folic acid supplementation, deworming, malaria prophylaxis, and nutrition counseling. Broader strategies must also address the underlying determinants of anemia by improving dietary diversity through agricultural diversification, food fortification, and social protection for food-insecure households. Equally important is the integration of infection control measures with maternal health services, alongside the promotion of reproductive health through family planning, delayed adolescent pregnancies, and optimal birth spacing. Moreover, investing in women's education and empowerment can strengthen health literacy, enhance care-seeking behaviors, and improve adherence to preventive practices. Finally, sustained support for research on additional micronutrients, such as vitamin D, may provide further insights to guide future strategies.

Supplementary Information

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Supplementary Material 1.

Supplementary Material 2.

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Authors' contributions
WKD and MS developed the protocol(conception), designed the study, and drafted the manuscript. WKD, SG, AJ, MG and ZD contributed for data acquisition and screening. WKD, MS and SG analyzed the data and interpretation. WKD, AB, MN and AS developed the drafted manuscript. MAR, GK, AA, TM, BBA, ET, BK, ZT, ZA, EG, YG and WA revised the manuscript. All authors have reviewed the final version of the manuscript and approved for publication. All authors agreed to take any responsibilities related with the article.

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