Maternal anemia prevalence and effect of nutritional interventions during COVID-19: A systematic review and meta-analysis

Francis Muchiri Wambura[1], Jack Kelly Oluoch[2], Charles Korir Cheruiyot[3], Lucy Kathure Manyara[4], Christopher Cadillac Onyango[1], Peris Kipchumba Kibet[5], John Kyalo Muthuka[1,6]

[1]Department of Community Health & Health Promotion, Kenya Medical Training College, Nairobi, Kenya, [2]Department of Pharmacy, Kenya Medical Training College, Nairobi, Kenya, [3]Division of Health Promotion and Education Management, Ministry of Health, Nairobi, Kenya, [4]Department of Clinical Medicine, Kenya Medical Training College, Nairobi, Kenya, [5]Department of Nutrition & Dietetics, Kenya Medical Training College, Nairobi, Kenya, [6]College of Health Sciences, Graduate School, Kenya Medical Research Institute, Nairobi, Kenya

ABSTRACT

Introduction: The review sought to investigate the effect of nutritional maternal supplements as interventions on the risk of anemia during the Coronavirus Disease 2019 (COVID-19) pandemic via systematic review and meta-analysis. **Methods:** Studies from January 2020 to December 2022 were retrieved using MeSH (Medical Subject Headings) terms in PubMed, Embase, Cochrane Library, Clinical Trials, Scopus databases, and gray literature. These studies were reviewed, and their quality assessed using Cochrane risk of bias guidelines. Analyses were conducted with both random and fixed effect models in RevMan 5.4.1 software. Heterogeneity was evaluated using the Cochran Q statistic and Higgins test, while publication bias was assessed through funnel plots. The primary outcome was the overall effect of nutritional maternal supplements (n = 8) on anemia risk. Regional effects based on study location were analyzed as secondary outcomes. A total of 5,584 pregnant women of reproductive age were included in the studies. The risk ratio for maternal anemia, as influenced by these nutritional interventions, was estimated during the meta-analysis. This review is part of the registered PROSPERO: CRD42023410657. **Results:** Eight studies were included with a cumulative prevalence of maternal anemia estimated at 49% (2,753/5,584), 40% (1,371/3,396) in the African region, and 70% (1,265/1,801) in the Asian region. The findings suggested that nutritional interventions reduced maternal anemia risk by 36% during the COVID-19 pandemic [RR (95% CI) = 0.64 [0.45, 0.90]; Test for overall effect: Z = 2.56 (P = 0.01); Heterogeneity: $Tau^2 = 0.22$; $Chi^2 = 215.05$, df = 7 (P < 0.00001); $I^2 = 97\%$]. Nutritional interventions in African countries had the highest effect on risk reduction of maternal anemia by 51% [RR (95% CI) = 0.49 [0.27, 0.90]; P = 0.02], while those in Asia had an insignificant effect of 4% [RR 0.96 [95% CI = 0.70, 1.32]; P = 0.80]. **Conclusion:** Maternal nutritional interventions reduced the risk of anemia primarily in Africa. The current study suggests that Asian nations were highly affected by the COVID-19 pandemic, compromising key maternal nutritional interventions. The study had limitations, such as few studies and potential publication bias. These were addressed through subgroup analysis and a substantial population size, ensuring credible and reliable findings.

KEYWORDS: Maternal Anemia, COVID-19 Pandemic, Nutritional Interventions

&CORRESPONDING AUTHOR: John Kyalo Muthuka, Department of Community Health & Health Promotion, Kenya Medical Training College, Nairobi, Kenya. Email: ohnmuthuka@gmail.com,
ORCID: https://orcid.org/0000-0002-6207-5249

RECEIVED
17/02/2025

ACCEPTED
24/04/2025

PUBLISHED
29/04/2025

LINK

https://afenet-journal.org/maternal-anemia-prevalence-and-effect-of-nutritional-interventions-during-covid-19-a-systematic-review-and-meta-analysis/

CITATION
Francis Muchiri Wambura et al Maternal anaemia prevalence and effect of nutritional interventions during COVID-19: A systematic review and meta-analysis. Journal of Interventional Epidemiology and Public Health. 2025;8:27.
https://doi.org/10.37432/jieph-d-25-00051

Introduction

Maternal anemia is a condition characterized by low levels of hemoglobin during pregnancy, commonly defined as hemoglobin levels below 11 g/dL. It is often caused by nutritional deficiencies, infections, or chronic diseases [1]. Approximately 36.5% of pregnant women aged 15-49 years are estimated to be anemic translating to around 32 million pregnant women globally [2]. The prevalence of maternal anemia varies by region. The highest rates are found in Sub-Saharan Africa (around 60%) and South-East Asia (around 40%)[1], [3], [4]. It is associated with adverse health outcomes, including preterm delivery, low birth weight, and impaired cognitive and motor development in children [5].

Preconception nutrition supplements, such as iron and folic acid, have been shown to reduce maternal anemia and improve intrauterine growth [6], [7], and are crucial in managing maternal anemia. Daily oral iron and folic acid supplementation is recommended for pregnant women to prevent maternal anemia, puerperal sepsis, low birth weight, and preterm birth. The World Health Organization (WHO) recommends 30 mg to 60 mg of elemental iron and 400 μg (0.4 mg) of folic acid [8]. Providing pregnant women with dietary counseling on healthy eating and appropriate weight gain is essential. This includes education on increasing daily energy and protein intake, especially in undernourished populations [9].

COVID-19 was responsible for at least 3 million excess deaths with many indirectly attributable to the pandemic due to disruptions in health service delivery and routine immunizations. Health systems faced challenges due to the exhaustion and infection of health workers, leading to decreased capacity to provide essential services [10]. Further, it exacerbated existing inequalities, with vulnerable populations facing greater challenges in accessing healthcare. The disruptions have had long-term consequences on health outcomes, with many countries still struggling to recover and restore essential health services [11]. For instance, cancer screenings and HIV testing saw declines of up to 96% in some regions. Maternal health services were particularly affected, with reduced antenatal care attendance, fewer facility-based births, and increased reliance on untrained birth attendants[12]. In Kenya, lockdowns and curfews hindered access to maternity care, while economic constraints and fear of infection further limited service utilization[13], [14].

Decent studies have highlighted the effectiveness of various maternal anemia interventions globally, with significant regional variations. In low- and middle-income countries, interventions such as iron and folic acid supplementation, dietary counseling, and nutrition education have shown promising results in reducing maternal anemia [15]. The implementation and impact of these interventions show considerable variation across regions. For instance, in Sub-Saharan Africa, maternal anemia prevalence remains high despite ongoing efforts. Contributing factors include limited healthcare access, inadequate dietary diversity, and high rates of parasitic infections. Conversely, South-East Asian countries have achieved more success in reducing anemia rates due to comprehensive public health programs and better healthcare infrastructure. These disparities highlight the necessity for tailored approaches that consider local contexts and challenges to effectively address maternal anemia. [16], [17], [18]. This systematic review and meta-analysis was conducted to summarize the evidence on the effects of nutritional maternal interventions on the risk of maternal anemia during the COVID-19 pandemic using majorly, relative risk as the effect measure with random effects and fixed effect modelling.

Methods

Design

Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement were followed in conducting this meta-analysis [19]. Moreover, PRISMA standards were employed in the preparation of systematic reviews of research interventions [20]. The data were aggregated from a variety of RCTs, as well as observational studies including cohort, case-control, cross-sectional, and other relevant case studies. The protocol for this study was registered with PROSPERO (CRD-42023410657).

Search Strategy

Two independent investigators conducted searches in the PubMed, Embase, Cochrane Library, and Scopus databases to identify relevant publications in English from December 2019 to August 2022. The search terms used included combinations of: "maternal anemia," "anemic condition," "hemoglobin levels," "pregnancy anemia," "anemia in pregnant women," "gestation anemia," "hemoglobin concentration," "hemoglobin changes," "hemoglobin status," "nutritional treatment," "nutritional intervention," "pregnancy anemia management," "effect," "effectiveness," "impact," and "outcome." Titles and abstracts of the identified articles were screened, and duplicates were removed. Full texts of the selected articles were then retrieved, considering only those written in English. The review process checked for ethical approval and informed consent in the included studies.

Study selection

Inclusion criteria

To formulate the research question for this review, a structured approach was employed utilizing the Participants, Interventions, Comparisons, Outcomes, and Study Design Approach (PICOS)[21]. The components included:

Studies involving women of reproductive age undergoing any form of nutritional intervention, regardless of anemia status as defined by the World Health Organization (WHO), during the COVID-19 pandemic.
Research reporting the effects of any viable nutritional intervention on the risk of maternal anemia as either a primary or secondary outcome, without restrictions on gender, age, race, or geographical distribution of participants. Nutritional interventions included routine iron and folic acid (IFA) supplementation, micronutrient fortification of common foods, malaria control during pregnancy, and supplementation with iron, folate, vitamin B12, and other essential nutrients to prevent maternal anemia.

Study designs comprised randomized clinical trials (RCTs) and observational studies, such as cohort, cross-sectional, case-control studies, as well as quasi-experimental designs.

Exclusion criteria

Excluded materials included editorials, case reports, letters to the editor, review articles, and studies involving animals. Studies (RCTs or observational) that did not assess hemoglobin levels, concentrations, changes, or status as either primary or secondary outcomes, or those lacking control or comparator intervention arms, were excluded. Any RCTs or observational studies that failed to report comparative events between intervention and control groups were not considered. Studies in languages other than English without full texts (unavailable or unpublished), those lacking a digital object identifier (DOI), and those with small sample sizes (fewer than 50 patients) due to low statistical power were also excluded.

Data Extraction

The data extraction process involved meticulously collecting both adjusted and non-adjusted data for pregnant women undergoing experimental interventions versus control groups using a standardized tool to capture variables like demographics, interventions, outcomes, and study quality. This dual approach was critical for identifying confounding factors that could influence the pooled analysis. Two researchers, JK and FM, worked independently to extract qualitative and quantitative data, ensuring a robust and unbiased process. In cases of disagreement regarding study inclusion or specific data points, a third researcher, KO, was consulted to mediate and reach a consensus. This multistep resolution approach minimized bias and maintained the integrity of the data extraction process. After extraction, the data was cross-verified with the original study reports, and any errors or omissions were corrected. Only studies that were agreed upon by all reviewers were included in the final analysis. The extracted data included the title, first author's name, data collection year, region, sample size, study design, study setting (single or multicenter), type of nutritional intervention, and the proportion of anemic cases as either primary or secondary outcomes. A p-value of <0.05 was considered statistically significant for all included studies.

To assess the quality and risk of bias in the included studies, the Cochrane risk of bias tool and the RoB 2 tool (7.0) [22] were utilized. The studies were evaluated across various domains: bias from the randomization process, deviations from intended interventions, missing outcome data, measurement of the outcome, and selection of the reported result, followed by an overall risk of bias assessment. Additionally, the methodological quality of observational studies was assessed using the National Institutes of Health (NIH) tool [22]. Two to three reviewers independently evaluated the quality of the studies, and the scores were included in the data extraction form to mitigate bias. Each of the 14 items was rated qualitatively as yes, no, or not applicable. An overall score was calculated by summing the "yes" responses (yes = 1, no/not applicable = 0), categorizing studies as poor (score 0–5), fair (score 6–9), or good (score 10–14). These quality assessment scores from the NIH tool were then used to evaluate the strength of evidence across studies, ensuring a robust interpretation of the findings. All data were cross-verified by independent reviewers who had not been involved in the initial scoring process to maintain objectivity and reliability. The NIH quality assessment scores were used to evaluate the strength of evidence, with "good" studies offering high-confidence findings and "fair" or "poor" studies highlighting potential biases. This ensured balanced interpretation and transparency in the analysis.

Statistical analysis

The analyses were conducted using RevMan 5.4.1 software, employing both random and fixed effect models. The random effect model was chosen for random variances, especially when the number of included studies was limited and there were differences in the number and characteristics of the participants (DerSimonian R, Laird N. Meta-analysis in clinical trials. Control Clin Trials). This model ensured that small and large sample sizes had the same impact on the final conclusion. Conversely, the fixed effect model was applied for studies with fixed parameters or non-random quantities. By focusing on the fixed-effect scenario, the model provided precise estimates applicable to a narrowly defined population under similar conditions. Thus, the complementary use of these models ensured methodological rigor and adaptability, allowing the analysis to address variability and provide accurate, context-specific interpretations of the effects of nutritional interventions on maternal anemia. Categorical data from the studies were extracted and aggregated, with variables analyzed to obtain overall relative risk (RR) with 95% confidence intervals (CIs) using the inverse variance method. The effects of nutritional interventions on anemia risk were compared between the intervention and control groups.

Heterogeneity was assessed using both the Cochran Q statistic and the Higgins I^2 test, which measure the variability in effect estimates across studies. A fixed-effects model was applied for heterogeneity levels below 50% ($I^2 < 50\%$), while a random-effects model was used for heterogeneity exceeding 50% ($I^2 > 50\%$), consistent with recommendations in the Cochrane Handbook for Systematic Reviews of Interventions. When heterogeneity was identified, sensitivity analyses and subgroup analyses were performed to explore potential sources and assess the robustness of the findings. To ensure interpretability, the rationale for applying these models was based on their ability to address varying degrees of study-level variation. Statistical significance was set at a p-value of <0.05. Publication bias was evaluated using the Cochrane Risk of Bias tool, which systematically assesses potential biases in study reporting and methodology.

Subgroup Analysis

Predetermined subgroup analyses were performed following Higgins[23] to assess the potential effects of nutritional interventions on anemia risk among pregnant women during the COVID-19 pandemic. This method explored studies according to the potential heterogeneity of inducer factors, with separate statistical analyses conducted for each study subgroup. A significant reduction in heterogeneity within each subgroup confirmed that the differences were based on various maternal anemia interventions.

Results

The PRISMA flow diagram illustrates the selection of included studies and screening process. Totally, 251 articles were found in the preliminary search, and 108 of these articles were removed studying the titles and abstracts where a nutritional supplement as an intervention was not captured. Further, possible double entries duplicates were expunged from the pool. After all this process, eight studies [24], [25], [26], [27], [28], [29], [30], [31] met the ultimate criteria for quantitative synthesis inclusion (Figure 1).

Characteristics of the included studies and subject nutritional and or dietary supplements

The eight studies had a blend of research designs and specific nutritional or dietary intervention; (Adeboye et al., 2022; Agyeman et al., 2021; Braithwaite et al., 2021; Hanley-Cook et al., 2022; Hansen et al., 2022; Oskovi-Kaplan et al., 2021; Pasricha et al., 2023; Saapiire et al., 2022) The studies were conducted between 2020 and 2021 with sample size ranging from 117[28] to 914[25]. Most studies were based in

Africa[24], [25], [26], [29], [30] with only one from Europe[27], Asia [28] and another at global level by WHO [28]. Majority of the studies' nutritional or dietary interventions were based on at least, a component of iron supplement (Table 1).

Outcome Measures

All the 8 studies reported and defined maternal anemia in terms of the number of women in whom a specific nutritional intervention worked reduced anemic condition in comparison with the comparator or group on an alternative supplement, here in taken as control. This was vested on relative risk as the effect measure with random effects model at 95% confidence interval. The highest effect of a nutritional intervention 78% [RR (95% CI) = 0.22 [0.10, 0.51] which was in form of a treatment approach [25].

Quality and risk of bias assessment

The quality of the included studies was assessed using a modified version of the Newcastle-Ottawa Scale (NOS), comprising eight items across three subscales, with a maximum total score of 9. In the absence of a universally accepted criterion for high-quality studies, a score of ≥7 was considered indicative of high quality. The included studies achieved a mean score of 7.25, suggesting that the overall quality was moderate (NOS score range: 5–8) (Table 2).

Meta-analyses Outcomes

Cumulative Effect of Nutritional Supplementation Interventions on Maternal Anemia

Pooled data from eight studies [24], [25], [26], [27], [28], [29], [30], [31] examined the cumulative effects of various maternal anemia interventions during the COVID-19 pandemic between intervention and comparator arms. The studies included a total of 5,584 participants, with 1,602 in the intervention group and 1,151 in the control group, resulting in an overall pooled prevalence of maternal anemia of 49% (2,753/5,584). Notably, pooled prevalence of maternal anemia in the intervention group was 50% (1,602/3,216) and 49% (1,151/2,368) in the comparator group, showing a similar baseline prevalence. Using a random-effects model with relative risk (M-H, Random, 95% C.I) as the effect measure, nutritional interventions reduced anemia by 36% (RR = 0.64, 95% CI [0.45, 0.90], Z = 2.56, p = 0.01). However, significant heterogeneity was observed ($Tau^2 = 0.22$, $Chi^2 = 215.05$, df = 7, $p < 0.00001$, $I^2 = 97\%$) (Figure 2).

A Comparison Based on Geographical Region and Study Year

Subgroup analysis with a random-effects model categorized data into three geographical regions. Interventions in African countries achieved the greatest reduction in anemia at 51% (RR = 0.49, 95% CI [-0.27, 0.90], Z = 2.32, p = 0.02, $I^2 = 98\%$). Asian countries showed a negligible, statistically insignificant effect of 4% (RR = 0.96, 95% CI [0.70, 1.32], Z = 0.26, p = 0.80, $I^2 = 92\%$), while European/other regions demonstrated a moderate reduction (RR = 0.82, 95%CI: 0.54, 1.25) (Figure 3).

Subgroup Sensitivity Analysis Using a Fixed-Effect Model

Applying a fixed-effect model assumed that regional characteristics were constant, revealing that all regions demonstrated some effect on reducing anemia overall (RR = 0.82, 95% CI [-0.77, 0.847], Z = 6.64, $p < 0.00001$, Test for subgroup differences: $Chi^2 = 5.23$, df = 2, p = 0.07, $I^2 = 61.7\%$). African countries maintained the highest impact, with a 22% reduction (RR = 0.78, 95% CI [-0.72, 0.84]). Maternal anemia prevalence was 40% (1,371/3,396) in Africa and 70% (1,265/1,801) in Asia, demonstrating the relatively lower impact of nutritional interventions in Asia during the COVID-19 pandemic (Figure 4).

Sensitivity Analysis and Publication Bias

Sensitivity analysis using both random-effects and fixed-effect models via the leave-one-out method showed minimal changes in pooled effects. For example, removing study [25] reduced the effect to 30% (RR = 0.70, 95% CI [0.49, 0.99], $p < 0.00001$, $I^2 = 97\%$), and removing study[29]produced an effect of 32% (RR = 0.68, 95% CI [0.47, 0.97], p = 0.04, $I^2 = 97\%$). Notably, removing study [24] significantly reduced the effect to 21% (RR = 0.79, 95% CI [0.64, 0.98], p = 0.03, $I^2 = 89\%$) while eliminating heterogeneity in subgroup differences ($Chi^2 = 1.26$, df = 2, p = 0.53, $I^2 = 0\%$) (Figure 5).

A funnel plot indicated asymmetry, suggesting publication bias and heterogeneity likely due to variations in populations and interventions. The current evidence showed that specific maternal anemia interventions affected hemoglobin levels with indications of publication bias (Figure 6).

Discussion

Pregnant women are a vulnerable research population due to the physiological and psychological changes of pregnancy, which can increase their susceptibility to health risks. The COVID-19 pandemic further exacerbated these vulnerabilities by disrupting healthcare access and increasing stress levels, potentially heightening the risk of anemia. Nutritional supplementation during pregnancy is a critical intervention to mitigate these risks, especially in the context of pandemics. Ethical considerations are paramount when including pregnant women in research, ensuring informed consent and minimizing risks to both the mother and fetus. Research during the pandemic has highlighted the importance of maternal nutrition in improving outcomes for both mother and child[32], [33].

The current review included 8 studies with 5,584 participants from different countries. The pooled cumulative effect of the maternal nutritional interventions had an effect on by reducing maternal anemia in overall with a pooled cumulative prevalence of maternal anemia being estimated at 49% during COVID-19 period. Notably, both the intervention and control arms showed a similar prevalence as that of the entire cohort of pregnant women. Generally, the nutritional intervention reduced by 36%, the maternal anemia. African region showed a more plausible effect by nutritional interventions on maternal anemia. Generally, at least, with fixed effect modelling all the regions showed some impact of the nutritional interventions, however, with a reduced magnitude and African region, having the highest effect. The maternal anemia prevalence was lower in African region than in Asian region.

Regional disparities in nutritional intervention effectiveness highlight critical ethical issues of equity and access. Systemic inequalities, such as income, location, and cultural barriers, can limit resources, leaving vulnerable groups underserved. For example, rural and low-income areas often face infrastructural challenges, intensifying malnutrition and health disparities. Ethical principles call for prioritizing these populations, ensuring fairness and inclusivity. Addressing these gaps requires culturally sensitive and pro-equity approaches tailored to local needs [34]. To our knowledge, this is the only meta-analysis which has evaluated and investigated solely the nutritional interventions subject to maternal anemia with a focus on COVID-19 pandemic apart from World Health Organization (WHO) and UNICEF that have both highlighted the impact of COVID-19 on maternal nutrition and the importance of maintaining nutritional services during this time[35].

According to existing evidence like the current one demonstrates that, the prevalence of anemia in pregnant women aged 15-49 was already a significant concern before the pandemic. The pandemic likely exacerbated this issue due to disruptions in healthcare services and nutritional support [36]. Additionally, the prevalence of maternal anemia during the COVID-19 pandemic varied by region and the extent of healthcare disruptions. However, a general estimate from various reports suggests that the prevalence of anemia in pregnant women increased by approximately 10-20% during the pandemic.[35], [37], [38], [39]. Notably, there was a perceived increase of maternal anemia as it has been established across board implicating that, COVID-19 contributed to an increase in maternal anaemia [35], [40].

In Sub-Saharan Africa, the prevalence of anemia among pregnant women was around 35.6%, in low- and middle-Income countries reaching up to 60% in some regions with a global prevalence of anemia in pregnant women being estimated to be around 20-40% before the pandemic[4], [15]. This profile before the pandemic as per the current review clearly show the pandemic had a negative effect on maternal anemia mitigation with an upsurge to 40% in Africa and all the way to 70% in Asia. However, the analysis gave an output that showed, at global level, it was 49%. This is a clear demonstration that, African and Asian countries were highly compromised and maternal anemia rate went high. As proven by other existing evidence[15], [40].

The differing impact of nutritional interventions between Africa and Asia during the COVID-19 era can be attributed to lower COVID-19 infection rates in Africa that enabled better continuity of services, while community-driven approaches and integration of food fortification into public health strategies enhanced intervention effectiveness. Conversely, Asia experienced severe disruptions due to stricter lockdowns, overwhelmed healthcare systems, and reallocation of resources to manage the pandemic, leading to reduced access to antenatal care and nutritional programs[41]. Cultural and logistical barriers, coupled with disrupted supply chains, further hindered intervention uptake in Asia[42]. Asia's focus on managing the immediate effects of COVID-19 often could have come at the expense of maternal nutrition programs.

In existing literature and knowledge, a systematic review found that iron and folic acid supplementation during pregnancy can increase hemoglobin levels by an average of 0.88 g/dL and reduce the risk of anemia by 34% [43], an almost precise finding like the current one which established a risk reduction for maternal anemia by 36%. The finding illuminate that, despite the disparities in interventions' effect on maternal anemia, there was generally a felt impact at least among all the regions however, in a low magnitude as it has been established in other findings that, there was a reduced effect of nutritional interventions on maternal anemia during the COVID-19 pandemic[35], [44]. It is in literature that, maternal healthcare services in Asia were significantly disrupted during the COVID-19 pandemic, leading to an increased risk of maternal anemia[35], [45]. This is what the current finding has found out that, Asian region was highly compromised by increased rate of maternal anemia, a fact that is substantiated by another study that 63.2% of pregnant women were anemic during the pandemic[44], similar or close the current study's prevalence of 70%. Notably, it is crucial to consider that the COVID-19 pandemic severely disrupted large-scale maternal nutrition programs, likely contributing to the diminished outcomes and having originated from Asia (China), this could have been hit more compared to other regions. These disruptions may have stemmed from reduced healthcare access, limited availability of intervention supplies, or shifts in public health priorities during the pandemic. Further investigation is needed to explore whether differences in intervention types, baseline nutritional deficiencies, healthcare infrastructure, or pandemic-related socioeconomic challenges played a role. Such insights are essential for tailoring strategies to enhance the effectiveness of maternal nutrition interventions in regions with limited impact.

The Global Health Observatory data trends repository on maternal anemia [46], [47] shows maternal anemia as a major public health concern up to the year 2019 with Asian and African countries having seemingly higher prevalence in comparison to other regions. This has been implied by the current review findings as well in regards of the era of COVID-19. Despite all this, some limitations existed in this study as the number of included studies where few, eight in number and there was a feasible publication bias. This on the flip side was mitigated by having a sub-group analysis approach that consequently ensured ascertaining the degree of variability between studies which was actually low and thus, the current findings are well reliable and informative. The findings reveal how COVID-19 disrupted healthcare systems globally, with low-resource regions facing severe impacts like increased maternal mortality. More resilient systems adapted with measures like telemedicine, mitigating some effects. The generalizability of these results varies, emphasizing the need for tailored, context-specific solutions. Publication bias may have skewed the evidence in one direction, which may have resulted in overrepresentation of certain outcomes while underreporting others, potentially distorting the overall conclusions drawn from the data. However, recognizing this limitation was essential for ensuring balanced interpretations and encouraging transparency in research finding dissemination. The review and included studies faced limitations too, such as a small number of studies (fewer than ten), which might have limited the breadth of evidence but was somewhat mitigated by the substantial population size providing reliable findings. Diverse study designs introduced heterogeneity, complicating comparisons, while potential biases—like selection and reporting bias—along with the risk of publication bias, remained as concerns. Despite these issues, the included studies utilized well-defined effect measures, offering credible estimates of intervention effects, though future research should aim for more standardized designs and rigorous methodologies to strengthen the evidence base.

Conclusion

The findings highlight the critical need for region-specific and contextually adapted strategies to combat maternal anemia. In Africa, where interventions demonstrated the highest impact, scaling up successful nutritional programs, such as food fortification and supplementation, is vital. Policymakers should focus on embedding these interventions into routine antenatal care, while addressing barriers to accessibility in rural and underserved areas. In Asia, where the impact was minimal, redesigning interventions to address cultural and dietary practices, alongside logistical implementation challenges, is essential. Strengthening community-based education, engaging local leaders, and fostering culturally tailored solutions can improve adherence and outcomes. Additionally, it is crucial to invest in robust monitoring and evaluation systems to assess program effectiveness and facilitate course corrections.

Public health policies must prioritize stable funding, resource allocation, and contingency planning to ensure the continuity of maternal nutrition programs during crises such as the COVID-19 pandemic. Research to investigate disparities, including genetic and environmental factors, should be expanded to provide a nuanced understanding of regional differences. Global collaboration through partnerships, crop bio fortification, and digital innovations like mobile health platforms can enhance program delivery and scalability. Policymakers should strive to make maternal nutrition a cornerstone of public health initiatives, ensuring that interventions reach those most vulnerable to the burden of anemia. ensuring that interventions reach those most vulnerable to the burden of anemia. By implementing these evidence-driven strategies, maternal health outcomes can be significantly improved worldwide.

What is already known about the topic

- Maternal anemia is a significant global health issue, particularly in low- and middle-income countries, with prevalence rates often exceeding 40%
- Nutritional interventions, such as iron and folic acid supplementation, have been shown to effectively reduce maternal anemia
- The COVID-19 pandemic disrupted healthcare services and supply chains, potentially affecting the delivery and effectiveness of nutritional interventions for maternal anemia.

What this study adds

- It highlights the exacerbation of maternal anemia due to the pandemic and the role of nutritional interventions in mitigating this effect.
- The study provides a detailed comparison of the effectiveness of nutritional interventions across different regions, with a notable emphasis on the African and Asian regions.
- It demonstrates that while interventions were effective in reducing maternal anemia overall, the impact was more substantial in Africa compared to Asia.
- It adds precise quantitative data on the prevalence and reduction rates of maternal anemia due to nutritional interventions during the pandemic. For instance, it shows a 36% reduction in maternal anemia and provides a pooled prevalence estimate of 49%.
- The study uniquely focuses on the period during the COVID-19 pandemic, providing insights into how the pandemic disrupted maternal healthcare services and increased maternal anemia rates. It aligns these findings with global health data and previous research, adding a contemporary context to the existing knowledge.

Competing Interest

The authors of this work declare no competing interest

Authors´ contributions

FMW led the research work, including conceptualization, design, data collection, analysis, and manuscript writing. JKO contributed significantly to data analysis and interpretation. CKC assisted with the research design and provided valuable insights during the manuscript preparation. LKM supported data collection and contributed to the review. CCO helped with data collection and participated in discussions about the findings. PKK assisted with manuscript editing and proofreading. JKM offered guidance on the overall project and contributed to the final review and approval of the manuscript.

References

1. Stanley AY, Wallace JB, Hernandez AM, Spell JL. Anemia in pregnancy: screening and clinical management strategies. MCN Am J Matern Child Nurs [Internet]. 2022 Jan-Feb [cited 2025 Apr 28];47(1):25–32. Available from: https://journals.lww.com/10.1097/NMC.0000000000000787. https://doi.org/

10.1097/nmc.0000000000000787. Subscription or purchase required to view full text.
2. WHO, Global Health Observatory. Anemia in women and children: WHO global anaemia estimates, 2021 edition [Internet]. Geneva (Switzerland): WHO; c2025 [cited 2025 Apr 28]; [about 10 screens]. Available from: https://www.who.int/data/gho/data/themes/topics/anaemia_in_women_and_children.
3. Sunguya BF, Zhu S, Paulo LS, Ntoga B, Abdallah F, Assey V, Mpembeni R, Huang J. Regional disparities in the decline of anemia and remaining challenges among children in Tanzania: analyses of the Tanzania demographic and health survey 2004–2015. Int J Environ Res Public Health [Internet]. 2020 May 17 [cited 2025 Apr 28];17(10):3492. Available from: https://www.mdpi.com/1660-4601/17/10/3492. https://doi.org/10.3390/ijerph17103492. Subscription or purchase required to view full text.
4. Araujo Costa E, De Paula Ayres-Silva J. Global profile of anemia during pregnancy versus country income overview: 19 years estimative (2000–2019). Ann Hematol [Internet]. 2023 May 26 [cited 2025 Apr 28];102(8):2025–31. Available from: https://link.springer.com/10.1007/s00277-023-05279-2. https://doi.org/10.1007/s00277-023-05279-2.
5. Bellad A, Kapil R, Gupta A. National guidelines for prevention and control of iron deficiency anemia in India. Indian J Community Health [Internet]. 2018 Apr 25 [cited 2025 Apr 28];30(1 Suppl):89–94. Available from: https://www.iapsmupuk.org/journal/index.php/IJCH/article/view/819. https://doi.org/10.47203/IJCH.2018.v30i01SUPP.013.
6. Gonzalez-Casanova I, Nguyen PH, Young MF, Harding KB, Reinhart G, Nguyen H, Nechitillo M, Truong TV, Pham H, Nguyen S, Neufeld LM, Martorell R, Ramakrishnan U. Predictors of adherence to micronutrient supplementation before and during pregnancy in Vietnam. BMC Public Health [Internet]. 2017 May 16 [cited 2025 Apr 28];17(1):452. Available from: http://bmcpublichealth.biomedcentral.com/articles/10.1186/s12889-017-4379-4. https://doi.org/10.1186/s12889-017-4379-4.
7. Nguyen PH, Young M, Gonzalez-Casanova I, Pham HQ, Nguyen H, Truong TV, Nguyen SV, Harding KB, Reinhart GA, Martorell R, Ramakrishnan U. Impact of preconception micronutrient supplementation on anemia and iron status during pregnancy and postpartum: a randomized controlled trial in rural Vietnam. Hwang SJ, editor. PLoS One [Internet]. 2016 Dec 5 [cited 2025 Apr 28];11(12):e0167416. Available from: https://dx.plos.org/10.1371/journal.pone.0167416. https://doi.org/10.1371/journal.pone.0167416.
8. WHO e-Library of Evidence for Nutrition Actions (eLENA). Exclusive breastfeeding for optimal growth, development and health of infants [Internet]. Geneva (Switzerland): WHO; 2023 Aug 9 [cited 2025 Apr 28]; [about 10 screens]. Available from: https://www.who.int/tools/elena/interventions/exclusive-breastfeeding.
9. Akseer N, Kandru G, Keats EC, Bhutta ZA. COVID-19 pandemic and mitigation strategies: implications for maternal and child health and nutrition. Am J Clin Nutr [Internet]. 2020 Jun 19 [cited 2025 Apr 28];112(2):251–6. Available from: https://linkinghub.elsevier.com/retrieve/pii/S0002916522007961. https://doi.org/10.1093/ajcn/nqaa171.
10. WHO. The impact of COVID-19 on global health goals [Internet]. Geneva (Switzerland): WHO; 2021 May 21 [cited 2025 Apr 28]; [about 26 screens]. Available from: https://www.who.int/news-room/spotlight/the-impact-of-covid-19-on-global-health-goals.
11. WHO. Third round of the global pulse survey on continuity of essential health services during the COVID-19 pandemic: November–December 2021: interim report [Internet]. Geneva (Switzerland): WHO; 2022 Feb 7 [cited 2025 Apr 28]; 50 p. Available from: https://iris.who.int/bitstream/handle/10665/351527/WHO-2019-nCoV-EHS-

continuity-survey-2022.1-eng.pdf?sequence=1. Download PDF to view full text.
12. Senkyire EK, Ewetan O, Azuh D, Asiedua E, White R, Dunlea M, Barger M, Ohaja M. An integrative literature review on the impact of COVID-19 on maternal and child health in Africa. BMC Pregnancy Childbirth [Internet]. 2023 Jan 4 [cited 2025 Apr 28];23(1):6. Available from: https://bmcpregnancychildbirth.biomedcentral.com/articles/10.1186/s12884-022-05339-x. https://doi.org/10.1186/s12884-022-05339-x.
13. Oluoch-Aridi J, Chelagat T, Nyikuri MM, Onyango J, Guzman D, Makanga C, Miller-Graff L, Dowd R. Covid-19 effect on access to maternal health services in Kenya. Front Glob Womens Health [Internet]. 2020 Nov 26 [cited 2025 Apr 28];1:599267. Available from: https://www.frontiersin.org/articles/10.3389/fgwh.2020.599267/full. https://doi.org/10.3389/fgwh.2020.599267.
14. Ombere SO, Nyabundi AA. Effects of covid-19 on Kenya's healthcare system: healthcare providers' experiences with maternal health services utilization in coastal Kenya. World [Internet]. 2023 Feb 28 [cited 2025 Apr 28];4(1):140–52. Available from: https://www.mdpi.com/2673-4060/4/1/10. https://doi.org/10.3390/world4010010.
15. Fite MB, Assefa N, Mengiste B. Prevalence and determinants of anemia among pregnant women in sub-Saharan Africa: a systematic review and meta-analysis. Arch Public Health [Internet]. 2021 Dec 3 [cited 2025 Apr 28];79(1):219. Available from: https://archpublichealth.biomedcentral.com/articles/10.1186/s13690-021-00711-3. https://doi.org/10.1186/s13690-021-00711-3.
16. Dossa RAM. Micronutrient supplementation of young stunted Beninese children: effects on appetite and growth performance [dissertation]. Wageningen (Netherlands): Wageningen University; 2001 May 16. 104 p. Available from: https://research.wur.nl/en/publications/1dfef932-2c4a-4692-9cbf-accd5d192bd5.
17. Rao S, Lee GM, Razzaghi H, Lorman V, Mejias A, Pajor NM, Thacker D, Webb R, Dickinson K, Bailey LC, Jhaveri R, Christakis DA, Bennett TD, Chen Y, Forrest CB. Clinical features and burden of postacute sequelae of sars-cov-2 infection in children and adolescents. JAMA Pediatr [Internet]. 2022 Aug 22 [cited 2025 Apr 28];176(10):1000. Available from: https://jamanetwork.com/journals/jamapediatrics/fullarticle/2795569. https://doi.org/10.1001/jamapediatrics.2022.2800.
18. Ali SA, Razzaq S, Aziz S, Allana A, Ali AA, Naeem S, Khowaja N, Ur Rehman F. Role of iron in the reduction of anemia among women of reproductive age in low-middle income countries: insights from systematic review and meta-analysis. BMC Womens Health [Internet]. 2023 Apr 17 [cited 2025 Apr 28];23(1):184. Available from: https://bmcwomenshealth.biomedcentral.com/articles/10.1186/s12905-023-02291-6. https://doi.org/10.1186/s12905-023-02291-6.
19. PRISMA-P Group, Moher D, Shamseer L, Clarke M, Ghersi D, Liberati A, Petticrew M, Shekelle P, Stewart LA. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. Syst Rev [Internet]. 2015 Jan 1 [cited 2025 Apr 28];4(1):1. Available from: https://systematicreviewsjournal.biomedcentral.com/articles/10.1186/2046-4053-4-1. https://doi.org/10.1186/2046-4053-4-1.
20. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, Shamseer L, Tetzlaff JM, Akl EA, Brennan SE, Chou R, Glanville J, Grimshaw JM, Hróbjartsson A, Lalu MM, Li T, Loder EW, Mayo-Wilson E, McDonald S, McGuinness LA, Stewart LA, Thomas J, Tricco AC, Welch VA, Whiting P, Moher D. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ [Internet]. 2021 Mar 29 [cited 2025 Apr 28];372:n71. Available from: https://www.bmj.com/lookup/doi/10.1136/bmj.n71. https://doi.org/10.1136/bmj.n71.
21. Wang Q, Liao J, Lapata M, Macleod M. PICO entity extraction for preclinical animal

literature. Syst Rev [Internet]. 2022 Sep 30 [cited 2025 Apr 28];11(1):209. Available from: https://systematicreviewsjournal.biomedcentral.com/articles/10.1186/s13643-022-02074-4. https://doi.org/10.1186/s13643-022-02074-4.
22. Zeng X, Zhang Y, Kwong JSW, Zhang C, Li S, Sun F, Niu Y, Du L. The methodological quality assessment tools for preclinical and clinical studies, systematic review and meta-analysis, and clinical practice guideline: a systematic review. J Evid Based Med [Internet]. 2015 Jan 16 [cited 2025 Apr 28];8(1):2–10. Available from: https://onlinelibrary.wiley.com/doi/10.1111/jebm.12141. https://doi.org/10.1111/jebm.12141. Subscription or purchase required to view full text.
23. Borenstein M, Higgins JPT. Meta-analysis and subgroups. Prev Sci [Internet]. 2013 Mar 13 [cited 2025 Apr 28];14(2):134–43. Available from: http://link.springer.com/10.1007/s11121-013-0377-7. https://doi.org/10.1007/s11121-013-0377-7.
24. Adeboye TE, Bodunde IO, Okekunle AP. Dietary iron intakes and odds of iron deficiency anaemia among pregnant women in Ifako-Ijaiye, Lagos, Nigeria: a cross-sectional study. Pan Afr Med J [Internet]. 2022 May 11 [cited 2025 Apr 28];42:23. Available from: https://www.panafrican-med-journal.com/content/article/42/23/full. https://doi.org/10.11604/pamj.2022.42.23.29965.
25. Agyeman YN, Newton S, Annor RB, Owusu-Dabo E. Intermittent preventive treatment comparing two versus three doses of sulphadoxine pyrimethamine (IPTP-SP) in the prevention of anaemia in pregnancy in Ghana: a cross-sectional study. Luty AJF, editor. PLoS One [Internet]. 2021 Apr 20 [cited 2025 Apr 28];16(4):e0250350. Available from: https://dx.plos.org/10.1371/journal.pone.0250350. https://doi.org/10.1371/journal.pone.0250350.
26. Hanley-Cook G, Toe LC, Tesfamariam K, De Kok B, Argaw A, Compaoré A, Ouédraogo M, Dailey-Chwalibóg T, Kolsteren P, Lachat C, Huybregts L. Fortified balanced energy-protein supplementation, maternal anemia, and gestational weight gain: a randomized controlled efficacy trial among pregnant women in rural Burkina Faso. J Nutr [Internet]. 2022 Jul 30 [cited 2025 Apr 28];152(10):2277–86. Available from: https://linkinghub.elsevier.com/retrieve/pii/S0022316623086042. https://doi.org/10.1093/jn/nxac171.
27. Hansen R, Sommer VM, Pinborg A, Krebs L, Thomsen LL, Moos T, Holm C. Intravenous ferric derisomaltose versus oral iron for persistent iron deficient pregnant women: a randomised controlled trial. Arch Gynecol Obstet [Internet]. 2022 Sep 15 [cited 2025 Apr 29];308(4):1165–73. Available from: https://link.springer.com/10.1007/s00404-022-06768-x. https://doi.org/10.1007/s00404-022-06768-x.
28. Oskovi-Kaplan ZA, Kilickiran H, Buyuk GN, Ozyer S, Keskin HL, Engin-Ustun Y. Comparison of the maternal and neonatal outcomes of pregnant women whose anemia was not corrected before delivery and pregnant women who were treated with intravenous iron in the third trimester. Arch Gynecol Obstet [Internet]. 2020 Sep 29 [cited 2025 Apr 29];303(3):715–9. Available from: https://link.springer.com/10.1007/s00404-020-05817-7. https://doi.org/10.1007/s00404-020-05817-7. Subscription or purchase required to view full text.
29. Braithwaite VS, Mwangi MN, Jones KS, Demir AY, Prentice A, Prentice AM, Andang'o PE, Verhoef H. Antenatal iron supplementation, FGF23, and bone metabolism in Kenyan women and their offspring: secondary analysis of a randomized controlled trial. Am J Clin Nutr [Internet]. 2021 Mar 1 [cited 2025 Apr 29];113(5):1104–14. Available from: https://linkinghub.elsevier.com/retrieve/pii/S0002916522006864. https://doi.org/10.1093/ajcn/nqaa417.
30. Pasricha SR, Mwangi MN, Moya E, Ataide R, Mzembe G, Harding R, Zinenani T, Larson LM, Demir AY, Nkhono W,

Chinkhumba J, Simpson JA, Clucas D, Stones W, Braat S, Phiri KS. Ferric carboxymaltose versus standard-of-care oral iron to treat second-trimester anaemia in Malawian pregnant women: a randomised controlled trial. Lancet [Internet]. 2023 May 13 [cited 2025 Apr 29];401(10388):1595–609. Available from: https://linkinghub.elsevier.com/retrieve/pii/S0140673623002787. https://doi.org/10.1016/s0140-6736(23)00278-7.
31. Tuncalp Ö, Rogers LM, Lawrie TA, Barreix M, Peña-Rosas JP, Bucagu M, Neilson J, Oladapo OT. WHO recommendations on antenatal nutrition: an update on multiple micronutrient supplements. BMJ Glob Health [Internet]. 2020 Jul 30 [cited 2025 Apr 29];5(7):e003375. Available from: https://gh.bmj.com/lookup/doi/10.1136/bmjgh-2020-003375. https://doi.org/10.1136/bmjgh-2020-003375.
32. Lyerly AD, Beigi R, Bekker L, Chi BH, Cohn SE, Diallo DD, Eron J, Faden R, Jaffe E, Kashuba A, Kasule M, Krubiner C, Little M, Mfustso-Bengo J, Mofenson L, Mwapasa V, Mworeko L, Myer L, Penazzato M, Rid A, Shapiro R, Singh JA, Sullivan K, Vicari M, Wambui J, White A, Wickremsinhe M, Wolf L. Ending the evidence gap for pregnancy, HIV and co-infections: ethics guidance from the PHASES project. J Int AIDS Soc [Internet]. 2021 Dec 15 [cited 2025 Apr 29];24(12):e25846. Available from: https://onlinelibrary.wiley.com/doi/10.1002/jia2.25846. https://doi.org/10.1002/jia2.25846.
33. Agostoni C, Baglioni M, La Vecchia A, Molari G, Berti C. Interlinkages between climate change and food systems: the impact on child malnutrition—narrative review. Nutrients [Internet]. 2023 Jan 13 [cited 2025 Apr 29];15(2):416. Available from: https://www.mdpi.com/2072-6643/15/2/416. https://doi.org/10.3390/nu15020416.
34. Development Initiatives. 2018 Global Nutrition Report Chapter 2: the burden of malnutrition [Internet]. Bristol (United Kingdom): Development Initiatives; 2018 [cited 2025 Apr 29]; p. 28-51. Available from: https://globalnutritionreport.org/reports/global-nutrition-report-2018/burden-malnutrition/. Download PDF to view full text.
35. Abu-Ismail L, Taha MJJ, Abuawwad MT, Al-Bustanji Y, Al-Shami K, Nashwan A, Yassin M. Covid-19 and anemia: what do we know so far? Hemoglobin [Internet]. 2023 Jul 31 [cited 2025 Apr 29];47(3):122–9. Available from: https://www.tandfonline.com/doi/full/10.1080/03630269.2023.2236546. https://doi.org/10.1080/03630269.2023.2236546.
36. The Global Health Observatory. Anaemia in pregnant women: prevalence of anaemia in pregnant women (aged 15-49) (%) [Internet]. Geneva (Switzerland): WHO; 2019 [cited 2025 Apr 29]; [about 4 screens]. Available from: https://www.who.int/data/gho/data/indicators/indicator-details/GHO/prevalence-of-anaemia-in-pregnant-women-(-).
37. Wakwoya EB, Belachew T, Girma T. Effect of intensive nutrition education and counseling on hemoglobin level of pregnant women in East Shoa zone, Ethiopia: randomized controlled trial. BMC Pregnancy Childbirth [Internet]. 2023 Sep 19 [cited 2025 Apr 29];23(1):676. Available from: https://bmcpregnancychildbirth.biomedcentral.com/articles/10.1186/s12884-023-05992-w. https://doi.org/10.1186/s12884-023-05992-w.
38. Young MF, Oaks BM, Rogers HP, Tandon S, Martorell R, Dewey KG, Wendt AS. Maternal low and high hemoglobin concentrations and associations with adverse maternal and infant health outcomes: an updated global systematic review and meta-analysis. BMC Pregnancy Childbirth [Internet]. 2023 Apr 19 [cited 2025 Apr 29];23(1):264. Available from: https://bmcpregnancychildbirth.biomedcentral.com/articles/10.1186/s12884-023-05489-6. https://doi.org/10.1186/s12884-023-05489-6.
39. Hassan H, Manaf RA, Said SM, Appannah G. The effectiveness of theory-based intervention to improve haemoglobin levels

among women with anaemia in pregnancy. Med J Malaysia. 2020 Nov 6;75(6):615–23.
40. Surekha MV, Suneetha N, Balakrishna N, Putcha UK, Satyanarayana K, Geddam JJB, Sreenu P, Tulja B, Mamidi RS, Rutter GA, Meur G. Impact of COVID-19 during pregnancy on placental pathology, maternal and neonatal outcome – a cross-sectional study on anemic term pregnant women from a tertiary care hospital in southern India. Front Endocrinol [Internet]. 2023 Mar 21 [cited 2025 Apr 29];14:1092104. Available from: https://www.frontiersin.org/articles/10.3389/fendo.2023.1092104/full. https://doi.org/10.3389/fendo.2023.1092104.
41. Han E, Tan MMJ, Turk E, Sridhar D, Leung GM, Shibuya K, Asgari N, Oh J, García-Basteiro AL, Hanefeld J, Cook AR, Hsu LY, Teo YY, Heymann D, Clark H, McKee M, Legido-Quigley H. Lessons learnt from easing COVID-19 restrictions: an analysis of countries and regions in Asia Pacific and Europe. Lancet [Internet]. 2020 Sep 24 [cited 2025 Apr 29];396(10261):1525–34. Available from: https://linkinghub.elsevier.com/retrieve/pii/S0140673620320079. https://doi.org/10.1016/S0140-6736(20)32007-9.
42. Anderson JD, Mitchell JL, Maples JG. Invited review: lessons from the COVID-19 pandemic for food supply chains. Appl Anim Sci [Internet]. 2021 Nov 23 [cited 2025 Apr 29];37(6):738–47. Available from: https://linkinghub.elsevier.com/retrieve/pii/S2590286521001464. https://doi.org/10.15232/aas.2021-02223.
43. Abdisa DK, Jaleta DD, Tsegaye D, Jarso MH, Jaleta GD, Tolesa GF, Kitila KM. Effect of community based nutritional education on knowledge, attitude and compliance to IFA supplementation among pregnant women in rural areas of southwest Ethiopia: a quasi experimental study. BMC Public Health [Internet]. 2023 Oct 5 [cited 2025 Apr 29];23(1):1923. Available from: https://bmcpublichealth.biomedcentral.com/articles/10.1186/s12889-023-16798-y. https://doi.org/10.1186/s12889-023-16798-y.
44. Diamond-Smith N, Gopalakrishnan L, Gutierrez S, Francis S, Saikia N, Patil S. Barriers to maternal and reproductive health care in India due to COVID-19. Adv Glob Health [Internet]. 2022 Jul 4 [cited 2025 Apr 29];1(1):1713935. Available from: https://online.ucpress.edu/agh/article/1/1/1713935/185895/Barriers-to-maternal-and-reproductive-health-care. https://doi.org/10.1525/agh.2022.1713935.
45. Gadsden T, Sood T, Purwar P, Peiris D, Nambiar D, Downey LE. Impact of COVID-19 on essential service provision for reproductive, maternal, neonatal, and child health in the Southeast Asia region: a systematic review. Lancet Reg Health Southeast Asia [Internet]. 2024 Feb 12 [cited 2025 Apr 29];25:100357. Available from: https://linkinghub.elsevier.com/retrieve/pii/S2772368224000076. https://doi.org/10.1016/j.lansea.2024.100357.
46. World Health Organization. World Health Organization Global Health Observatory [Internet]. Geneva (Switzerland): World Health Organization; 2020 Jan [cited 2025 Apr 29]; [about 5 screens]. Available from: https://www.who.int/data/gho/data/themes/oral-health-data-portal.
47. Vardell E. Global health observatory data repository. Med Ref Serv Q [Internet]. 2020 Feb 18 [cited 2025 Apr 29];39(1):67–74. Available from: https://www.tandfonline.com/doi/full/10.1080/02763869.2019.1693231. https://doi.org/10.1080/02763869.2019.1693231.

Table 1: Studies on nutritional and dietary interventions effect on maternal anemia							
Study	**Region**	**Study Design & Setting**	**Intervention**	**Comparator**	**Year**	**Proportion – Intervention Arm**	**Proportion – Comparator Arm**
[24]	Africa	gCS, bMC	Dietary iron intakes	Varied iron dietary profile	2020	86/363	67/70
[25]	Africa	aCS, bMC	Different SP dosage regimen (>3 doses as per new policy)	Regimen with fewer SP doses	2020	263/486	285/428
[26]	Africa	fP, bMC	IFA + micronutrient-fortified BEP supplement	Routine supplementation without fortified BEP	2021	333/854	336/890
[50]	Europe	fP, gSC	Intervention targeting iron-deficiency anemia	Standard care	2020	670/818	50/69
[28]	Asia	cRCC, hSC	Intravenous ferric carboxy-maltose treatment	Oral or alternative non-intravenous iron treatments	2020	6/66	21/51
[30]	Africa	cRCT, bMC	Ferric carboxy-maltose	Standard anemia care	2018-2021	179/341	189/333

Table 2: Risk of bias assessment							
Study	**Region**	**Study Design & Setting**	**Intervention**	**Comparator**	**Year**	**Proportion – Intervention Arm**	**Proportion – Comparator Arm**
[24]	Africa	gCS, bMC	Dietary iron intakes	Varied iron dietary profile	2020	86/363	67/70
[25]	Africa	aCS, bMC	Different SP dosage regimen (>3 doses as per new policy)	Regimen with fewer SP doses	2020	263/486	285/428
[26]	Africa	fP, bMC	IFA + micronutrient-fortified BEP supplement	Routine supplementation without fortified BEP	2021	333/854	336/890
[50]	Europe	fP, gSC	Intervention targeting iron-deficiency anemia	Standard care	2020	670/818	50/69
[28]	Asia	cRCC, hSC	Intravenous ferric carboxy-maltose treatment	Oral or alternative non-intravenous iron treatments	2020	6/66	21/51
[30]	Africa	cRCT, bMC	Ferric carboxy-maltose	Standard anemia care	2018-2021	179/341	189/333
[31]	Asia	CS-MC	Several nutritional interventions (specifics unclear from the data)	Standard care or alternative interventions	2020	Not provided	Not provided
[29]	Africa	hCS, bMC	Antenatal oral iron supplementatio n	No antenatal iron supplementation	2020	46/215	108/214
aRCC: retrospective case-control. bMC: multicenter. cRCT: random clinical trial. dR: retrospective. eO: observational. fP: prospective. gCS: cross-sectional. hSC: single-center.							

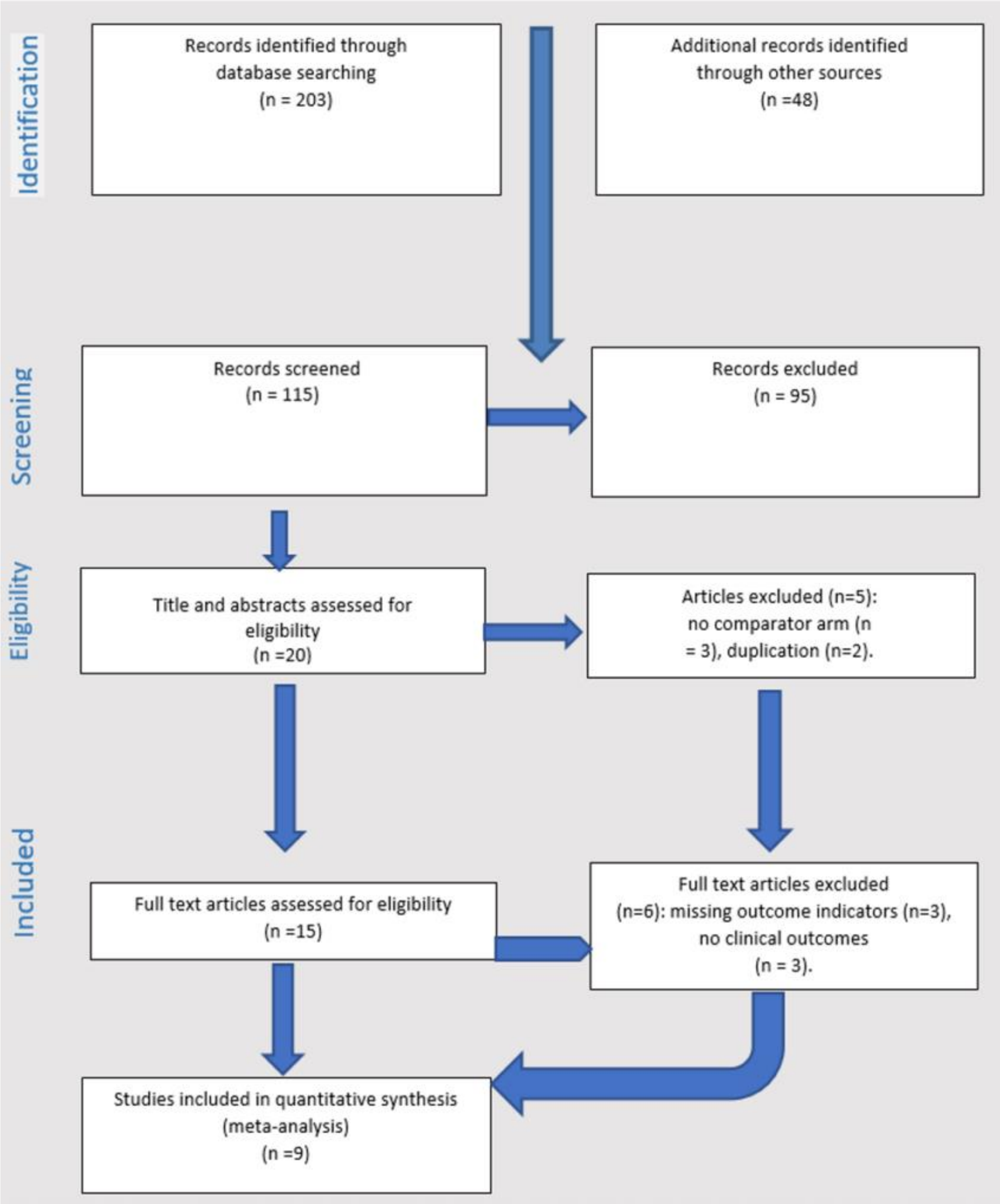

Figure 1: PRISMA flow-diagram of the study selection process

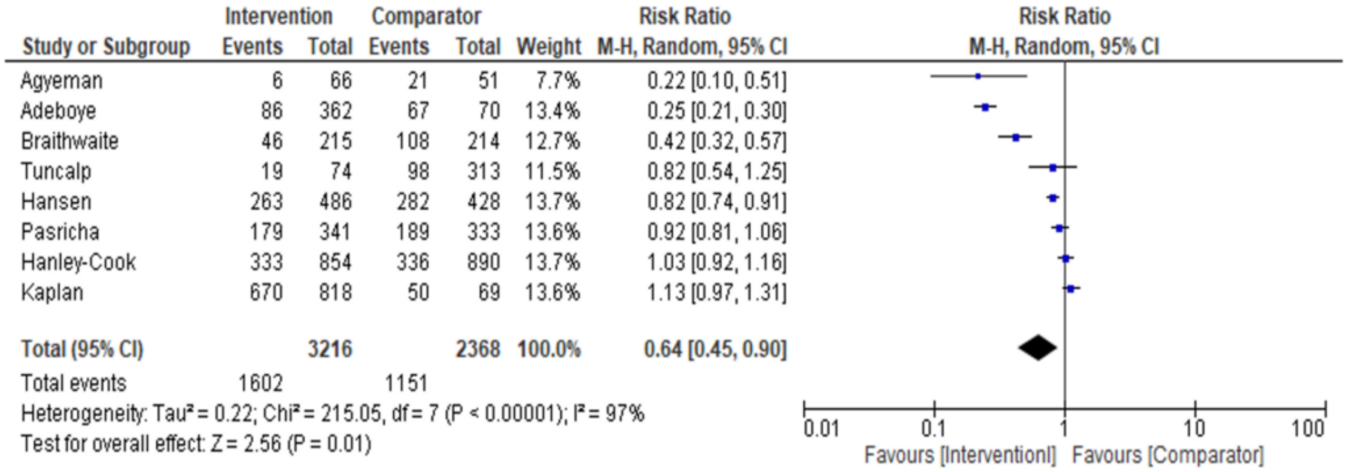

Figure 2: Forest plot showing results of a meta-analysis on the effects of nutritional maternal interventions on anemia. Data were reported as RR ((M-H, Random, 95% C.I) to compare the effect sizes across different studies to control for variability within the data

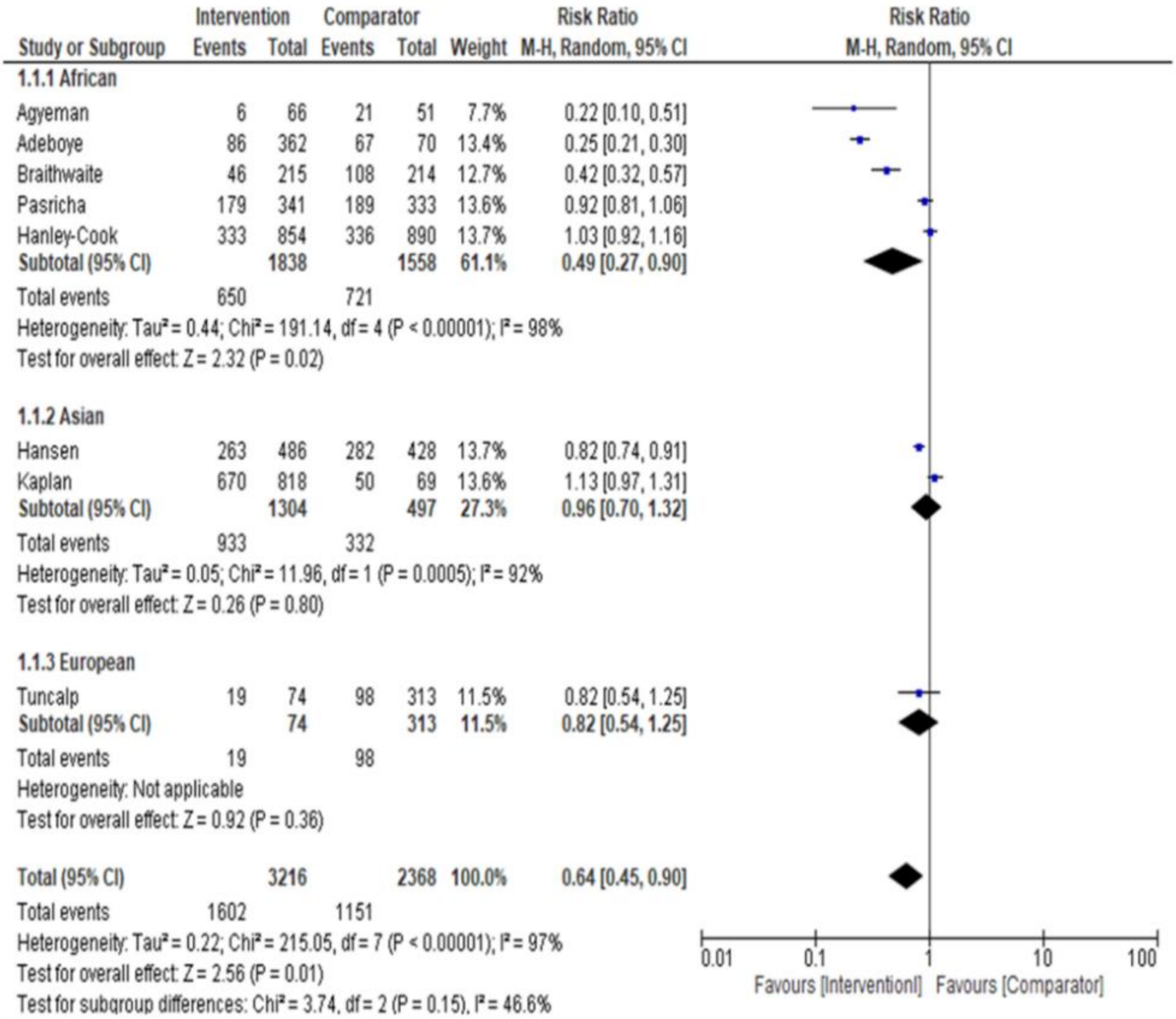

Figure 3: Forest plot showing results of a sub-group meta-analysis on the effects of nutritional maternal interventions on anemia as per the geographical region. Data were reported as RR ((M-H, Random, 95% C.I) to compare the effect sizes across different studies to control for variability within the data

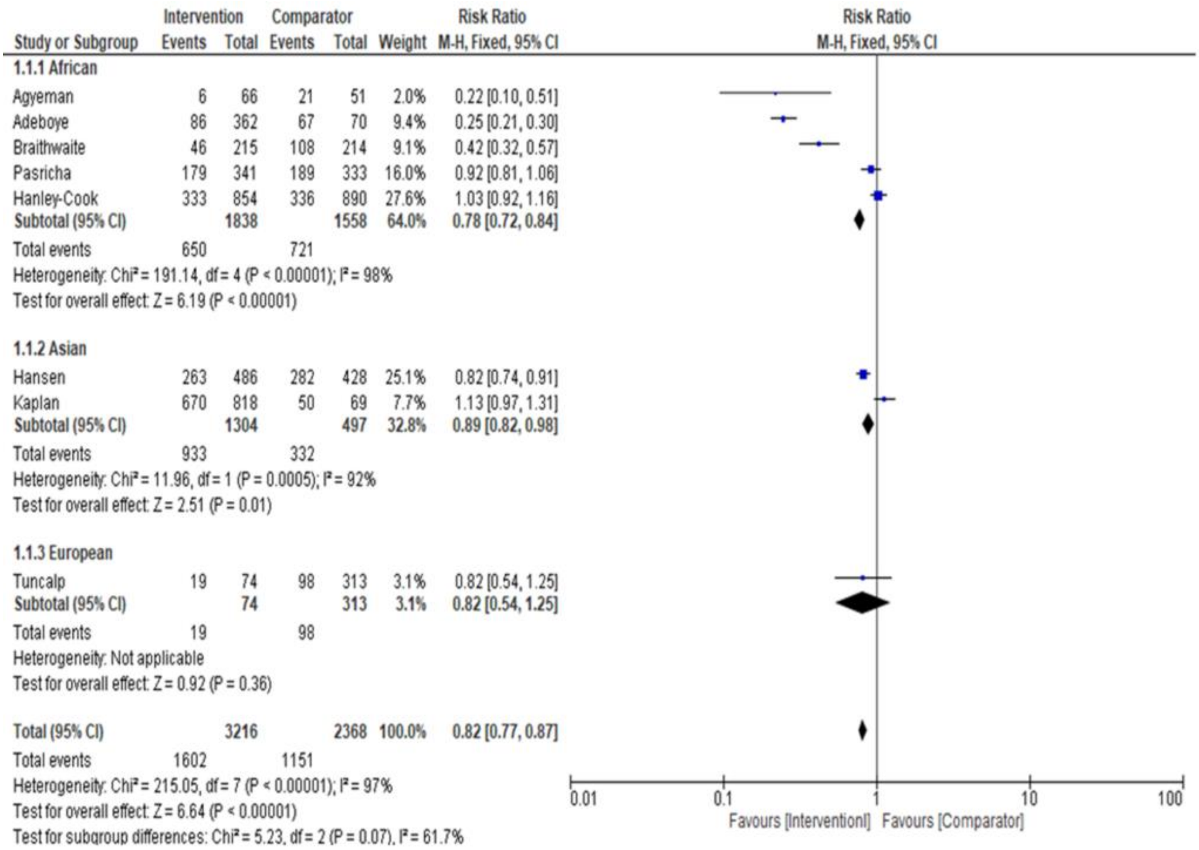

Figure 4: Forest plot showing results of a sub-group meta-analysis on the effects of nutritional maternal interventions on anemia as per the geographical region. Data were reported as RR ((M-H, Fixed, 95% C.I) to compare the effect sizes across different studies to control for variability within the data

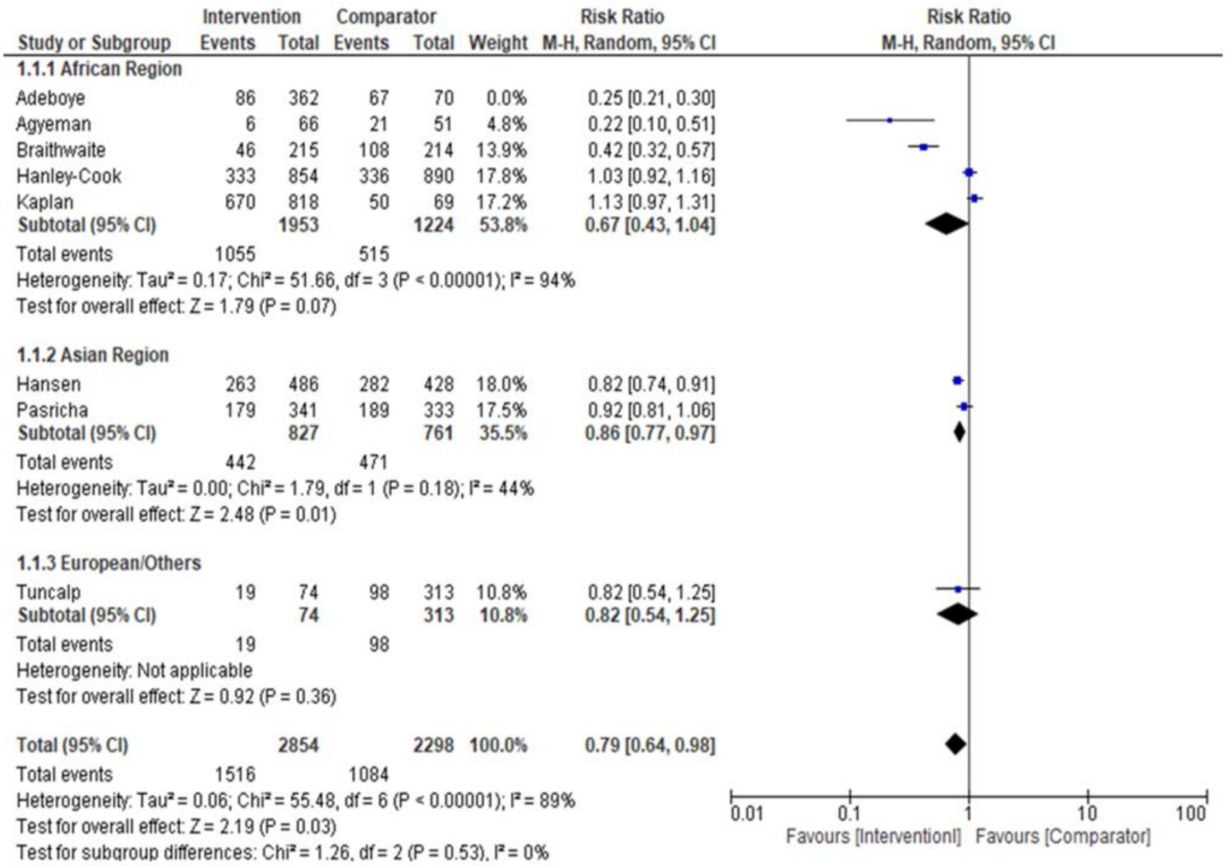

Figure 5: Forest plot showing results of a sensitivity sub-group meta-analysis with one study [24] removed on the effects of nutritional maternal interventions on anemia as per the geographical region. Data were reported as RR ((M-H, Random, 95% C.I) to compare the effect sizes across different studies to control for variability within the data.

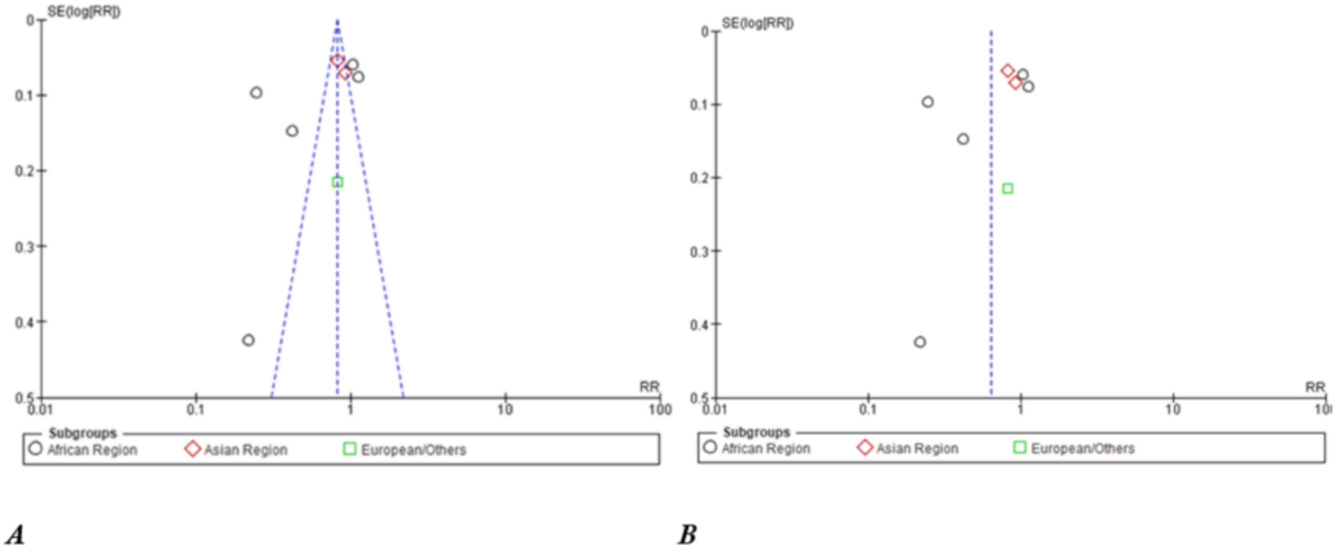

Figure 6: A funnel plots showing results of meta-analysis on the effects of nutritional maternal interventions on anaemia. Data were reported as RRs with both fixed effect (A)and random effects (B)models with 95% CIs