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Systematic Review

Dietary factors influencing anemia prevalence across the life span: review

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ABSTRACT

Nutritional and dietetic determinants lie at the heart of anemia causation. Life cycle perspective emphasizes the need to tackle anemia at every stage from infancy to old age. This review includes 61 primary studies from PubMed, Google Scholar, and Web of Science. Low dietary diversity, poor meal frequency, food insecurity, reduced consumption of heme iron, fruits, and green leafy vegetables increase anemia risk. Among infants, suboptimal breastfeeding and complementary feeding are key contributors. Pregnant women are significantly impacted by low dietary diversity, worsening anemia risk. The review highlights the importance of life-stage-specific dietary policies and focused interventions in order to tackle anemia.

Keywords: Anemia, Dietary diversity, Iron deficiency, Nutritional factors, Diet quality, Life cycle

INTRODUCTION

Anemia continues to be an endemic global health issue that has a widespread reach across all ages and geographic areas. The World Health Organization (WHO) indicates that approximately one third of the entire world's population suffers from anemia, where preschool children, pregnant women, elderly individuals, and Women of Reproductive Age (WRA) (15–49 years) have the highest affected prevalence.[1]

Several reasons lead to anemia including genetic susceptibility, inflammation, infestation by worms, and chronic disease, but nutritional and dietary causes play a critical role.[2] Nutritional and dietary factors form part of the multifactorial pathogenesis of anemia. Specifically, micronutrient deficiencies such as iron, vitamin B12, folate, vitamin C and vitamin A have been widely established by several clinically reported studies as foremost causes of anemia development.[3-7] Moreover, poor food diversity, consumption of anti-nutritional factors, and socioeconomic or cultural factors affecting access to nutrient-rich foods have further elevated the risk for anemia among vulnerable populations.[8-11] The lifecycle approach to health highlights prevention and early intervention at each phase of life namely intrauterine, young childhood, adolescence, middle years, and advanced age. It is essential for avoiding health inequities and enhancing long-term health outcomes.[12] Anemia, particularly prevalent in vulnerable groups like pregnant women and children, exemplifies the inter-generational cycle of health issues, where anemic mothers are significantly more likely to give birth to low-birth-weight and anemic infants, perpetuating the condition across generations.[2,12]

As a result of the complex and diverse nature of anemia and its direct link with dietary and nutritional

components, there is a strong imperative for an integrative review of current evidence across all stages of life to inform evidence-based practice and policy-making. Additionally, eating habits are interrelated throughout the life cycle; negative eating patterns developed at an earlier age often persist and solidify as individuals age, contributing to an increased risk of anemia and associated morbidities.[13-15] The reason to carry out a comprehensive review on the nutritional and dietary determinants of anemia throughout the life cycle is that diet has such a fundamental effect on the occurrence, severity, and control of this worldwide health disorder at every point in life. Additionally, some stages in life are more vulnerable and significant to intervene compared to others. It is important to understand the intricate relationship between diet, such as nutrient consumption, frequency of meals (MF), and dietary variety (DD) in order to create evidence-based interventions and preventive measures.[16-20] Through a synthesis of primary study evidence, this review seeks to present a thorough overview of the role of diet and nutrition in anemia across different life stages, offering an abundance of evidence for healthcare providers, policymakers, and at-risk individuals.

METHODS

Search strategy

Databases namely PubMed, Web of Science (WoS), and Google Scholar were used for systematically searching the articles. Based on Boolean logic and truncation combinations, keywords including nutrition, diet, nutrient, micronutrient, dietary behaviour, anemia, anaemia, iron deficiency anemia, nutritional anemia, infants, children, adolescent, pregnant women, pregnancy, geriatric population, elderly, adults, and Women of Reproductive Age (WRA) were used. Search filters like publication date and year, language, source type, and document type were applied during research.

Inclusion and exclusion criteria

Research articles focusing on nutritional and dietary determinants of anemia, published between the year 2000 and May 2024, and available in open access were included. Only primary research articles on healthy human populations published in the English language were incorporated into the review. Articles published before the year 2000 were excluded. Experimental and intervention study designs were excluded. Researches focusing on specific disease populations (e.g., cancer, chronic kidney disease) were out of the scope of the review. Animal studies, narrative reviews, secondary research, commentaries, unpublished reports, and conference abstracts were not included.

PRISMA flowchart and selection process details

The detailed step-by-step screening and selection process is documented in Figure 1.

Identification: Initial database queries yielded 6,317 records (PubMed: n=2,004; Google scholar: n=4,089; Web of science: n=224).

Deduplication and title screening: A total of 3,142 records were excluded during initial screening, including duplicates removed electronically and manually (n=879), full-text articles unavailable/inaccessible (n=732), and non-relevant titles (n=1,531), leaving 3,175 records.

Abstract screening: Abstracts of 3,175 records were assessed, of which 1,028 were excluded for not meeting the thematic scope, leaving 2,147 records.

Study design and population eligibility: Full texts and detailed descriptions of 2,147 records were evaluated; 2,044 were excluded due to non-eligible study designs (e.g., intervention trials, reviews, commentaries; n=1,046) and inclusion of participants with chronic comorbidities/clinical populations (n=998).

Final inclusion: Out of the remaining 103 full-text articles assessed for eligibility, 42 were excluded due to a lack of quantifiable diet-related outcome measures. A final total of 61 primary research studies met all inclusion criteria and were incorporated into the systematic synthesis.

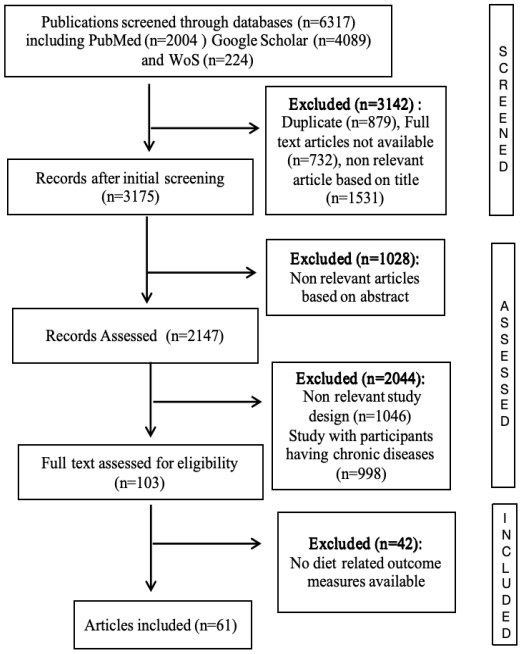


Figure 1: Article screening and selection process.

Data extraction and analysis

Data items including author(s), year, country, sample size, age (in years), evaluated nutritional and dietary components, and primary study outcomes were extracted from the 61 included articles and entered into Table 2.

RESULTS

A total of 6,317 relevant studies (2,004 from PubMed, 224 from Web of Science and 4,089 from Google Scholar) were obtained from the initial search. Only those articles were included (N=61) which met the scope of the study and inclusion criteria after full-text evaluation. Out of the 61 studies, the majority (26) were conducted in Ethiopia. Based on research designs, 51 were cross-sectional, 8 were case-control, and 2 were cohort studies.

Life stage classification

Using WHO classifications as a reference, age groups were categorized into: Infants and young children under 5 years, Children and adolescents (6-19 years), Adults (20-65 years), Geriatric population (>65 years), Pregnant women, and Women of Reproductive Age (WRA) (15–49 years). The distribution of nutritional and dietary determinants across life stages is summarized in Table 1.

Table 1: Life stage wise distribution of dietary and nutritional contributors of anemia.

Life cycle Stage / Category	Infants and young children (<5y)	Children and Adolescents (6-19y)	Adults (20-65y)	WRA (15-49y)	Pregnant Women	Elderly (≥65y)	Total
Nutritional factors							
Iron	3	4	1	1	-	1	10
Vitamin B1	-	-	1	-	-	1	2
Vitamin B2	-	-	1	-	-	1	2
Vitamin B6	1	-	-	-	-	-	1
Vitamin B12	1	-	-	-	-	-	1
Vitamin A	1	-	1	1	-	1	4
Vitamin C	3	-	-	-	-	1	4
Calcium	2	-	1	-	-	1	4
Copper	-	-	-	-	-	1	1
Manganese	-	-	-	-	-	1	1
Zinc	1	-	-	-	-	-	1
Energy	1	1	1	-	-	1	4
Proteins	1	1	1	-	-	1	4
Fats	1	-	-	-	-	-	1
Carbohydrate	-	-	1	-	-	1	2
Food groups							
Animal meat, poultry and fish	2	3	6	2	8	4	25
Milk and milk products	2	1	-	-	1	-	4
Fruits	1	2	1	1	3	1	9
Vegetables	2	-	4	3	4	3	17
Pulses	-	-	2	1	-	2	5
Tea/Coffee	1	-	1	-	7	-	9
Sugar and soft drinks	-	-	2	-	1	-	3
Fibre	1	1	-	-	-	-	2
Dietary factors							
Dietary diversity (DD)	7	-	1	2	11	-	21
Household food security	6	-	-	1	-	-	7
Meal frequency (MF)	1	1	-	1	2	-	5
IYCF practices	4	-	-	-	-	-	4
Fast food consumption	-	1	1	-	-	-	2
Skipping meals	-	2	-	-	-	-	2
Different diet patterns	-	1	1	-	-	-	2
Total determinants noted	42	17	29	12	38	22	160

Infants and young children below 5 years

Numerous studies have consistently shown that poor dietary diversity (DDS <4) and household food insecurity negatively affect the prevalence of anemia in children under five years old.[8,9,11,21-24] Research indicates that sufficient intake of iron, zinc, calcium, Vitamin B complex, Vitamin A and Vitamin C is crucial for preventing anemia, with non-anemic children exhibiting higher levels of these nutrients in their diets.[7] Specific foods such as meat, vegetables, fruits, milk and certain root-based vegetables like pumpkin and sweet potato have been associated with protection against anemia.[25,26] Whereas, consumption of white potatoes, white yams, manioc, cassava, and other root-based foods increases risk of anemia.[26] Optimal IYCF practices like early initiation of complementary feeding practices also impact anemia prevalence, with timely introduction of solid foods and sustained breastfeeding reducing anemia risk.[8,11]

Children and adolescents (6–19 years)

Iron intake is an essential factor with respect to anemia prevalence among children and adolescents. Consumption of fruits, high protein diet, animal meat, and poultry has been positively associated with anemia reduction.[27,28] Consuming heme-iron rich foods and frequent egg consumption were protective against anemia among adolescents and children of both genders.[15,29-31] Skipping meals was also identified as a determinant of anemia among children and adolescents.[13,14]

Gender-specific findings indicated that adolescent girls were particularly at risk of anemia when consuming a vegetarian diet and had higher odds of anemia associated with poor diet quality.[13,32,33] Furthermore, dietary patterns such as fast-food consumption were positively associated with anemia risk in Chinese adolescents, particularly girls post-menarche.[15] In boys, higher intake of vitamin A-rich fruits and vegetables was associated with a reduced risk of anemia.[28]

Adults (20–65 years)

Higher consumption of green leafy vegetables (GLV) was observed among non-anemic individuals compared to anemic ones in India.[34] Associations between dietary factors such as refined grains, meat, egg, and sugar consumption with anemia prevalence were found in different demographic groups in India.[35] Additionally, specific dietary habits negatively correlated with anemia, such as red meat consumption for women and fruit consumption for men in China.[36] A Chinese study looked at association of different dietary patterns with anemia prevalence.[37] They found a positive association of 'Traditional diet' (rice, vegetable, wheat flour) and 'sweet tooth diet' (drinks, cake) with anaemia.[37] Negative association with anemia was seen in people having a 'healthy diet' pattern (whole grains, fruits, vegetables), whereas no association was found between the 'macho' pattern (meat and alcohol) and anemia prevalence.[37] Low intake of iron-rich foods was a consistent predictor of anemia in India, with specific findings indicating that diets lacking meat, fish, eggs, and GLV were significantly associated with higher anemia prevalence.[18,38-41,42] Furthermore, poor DD and low MF were also linked to anemia.[18] Additionally, food insecurity was one of the notable contributors to anemia risk.[43]

Pregnant women

Low DDS (<3) emerged as a consistent predictor of anemia across several studies.[16,20,44] Specific dietary patterns, such as low intake of meat, fruits, GLVs, eggs, and frequent consumption of tea/coffee were highlighted as risk factors for anemia.[10,45-51] Furthermore, MF and additional dietary intake during pregnancy were also critical, with less frequent meals and lack of additional diet being associated with higher anemia prevalence.[17,49]

Table 2: Research studies analyzed for review.

S. no.	Author, year and country	Study design population (Sample size)	Nutritional and dietary components: nutrients	Nutritional and dietary components: Foods/Food groups	Nutritional and dietary components: Dietary factors	Outcomes
1.	Vitolo and Bortolini, 2007[7] Brazil	Cohort, Infants aged 12-16 months (n=369)	Iron Vitamin C Energy			Non anemic had a greater intake of Iron, Vitamin C, Energy density at dinner
2.	Sunardi et al 2021[6] Indonesia	Cross sectional, Infants aged 6-26 months (n=185)	Fat, Protein, Calcium, Zinc, Iron, Vitamin A, Vitamin C, Vitamin B6, Vitamin B12	Milk		Significant associations of anemic status and inadequate dietary intake: fats, protein, calcium, iron, zinc, vitamin A, vitamin C, vitamin B6, vitamin B12 and not consuming cow's milk formula
3.	Malako et al 2018[11] Ethiopia	Cross sectional, Infants aged 6-23 months (n=485)			DD, IYCF Practices, HH Food Security	Significantly associated with anemia: HH food insecurity, low DD, early or late initiation of complementary feed, suboptimal breastfeeding practice

Continued.

S. no.	Author, year and country	Study design population (Sample size)	Nutritional and dietary components: nutrients	Nutritional and dietary components: Foods/Food groups	Nutritional and dietary components: Dietary factors	Outcomes
4.	Woldie et al 2015[21] Ethiopia	Cross sectional, Infants aged 6-23 months (n=347)			DD, IYCF Practices	Significantly associated with anemia: poor DD, early initiation of complementary food
5.	Kathuria et al 2023[9] India	Cross sectional, Infants and Young Children 6-59 months (n=266)			DD	Low DD associated with: - Prevalence of moderate anaemia - Prevalence of severe anaemia
6.	Fentaw et al 2023[8] Ethiopia	Cross sectional, Infants and Young Children 6-59 months (n=409)			IYCF Practices, DD	Negatively associated with anemia: exclusive breastfeeding until six months Positively associated with anemia: low DDS (≤ 3)
7.	Kejo et al 2018[25] Tanzania	Cross sectional, Infants and Young Children aged 6–59 months (n=436)		Meat, vegetables, milk, tea		Predictors of anemia: Not eating meat, Not eating vegetables, Consuming milk, Consuming tea
8.	Jembere et al 2020[22] Ethiopia	Case Control, infants and Young Children aged 6 to 59 months (n=413; 137 anemic cases and 276 non anemic controls)			Food security	Determinant of anemia: household food insecurity
9.	Shourove et al 2022[26] Nigeria	Cross sectional, infant and young children aged 6-59 months (n=6338)		Vegetables		Reduction of anemia by 17%: Pumpkin, carrot, squash, sweet potato Increase in anemia by 14%: White potatoes, white yams, manioc, cassava, and other root-based foods
10.	Park et al 2009[24] USA	Cross-sectional, Young Children >36 months (n=2853)			HH Food Security	HH with very low food security: almost twice as likely to have IDA vs those from HH with high or marginal food security
11.	Soh et al 2002[64] New Zealand	Cross sectional, Infants, non-breastfeeding 6-24 months (n=226)	Iron, Vitamin C, Dietary fiber, calcium			Positively associated with serum ferritin: intakes of iron and vitamin C Negatively associated with serum ferritin: intakes of calcium and dietary fiber
12.	Alamneh et al 2021[58] Ethiopia	Cross sectional, Infant and Young children (6-59 months) (n=310)			DD, IYCF Practices, HH Food Security	Factors significantly associated with anemia: poor DDS (< 4), food-insecure HH, complementary feeding initiation time
13.	Alemayehu et al 2019[23] Ethiopia	Cross sectional, infants and young children 6-23 months (n=993)			DD, HH food security	Factors associated with anemia: - Poor DDS (< 4) - HH food insecurity
14.	Molla et al 2020[19] Ethiopia	Cross sectional, Children aged 6-23 months (n=531)			DD, HH Food Security, MF	Positively associated with anemia: HH food insecurity, DDS < 4. Met Minimal Meal Frequency had a protective effect against anemia
15.	Tahir et al 2020[52] Canada	Cross sectional, Children and Adolescent aged 3-19 years (n=198)		Meat, Fruits		Positively associated with serum ferritin: traditional meat, fruit and fruit juice (natural and powdered)
16.	Desalegn et al 2014[27] Ethiopia	Cross sectional, Children aged 6-12 years (n=616)		Milk and Milk Products, Protein, Energy rich foods		Predictors of anemia: not-eating protein source foods, not-eating dairy products, not eating discretionary calories

Continued.

S. no.	Author, year and country	Study design population (Sample size)	Nutritional and dietary components: nutrients	Nutritional and dietary components: Foods/Food groups	Nutritional and dietary components: Dietary factors	Outcomes
17.	Ayogu et al 2015[14] Nigeria	Cross sectional, Children aged 5-15 years (n=450)			Skipping meals	Frequency of skipping breakfast associated with anemia
18.	Ma et al 2023[15] China	Cross sectional, Children aged 9–16 years (n=1476)		Meat, egg	Fast food diet	Positively associated with risk of anemia in children entering puberty: fast food pattern especially in girls after menarche Negatively associated with risk of anemia: meat and egg pattern, especially in boys after spermatorrhea
19.	Agustina et al 2020[13] Indonesia	Cross sectional, Adolescents girls (n=355)			Skipping meal, MF	Negatively associated with anemia: skipping dinner Positively associated with anemia: MF 3–4 times, MF >4 times
20.	Knijff et al 2021[28] Indonesia	Cross sectional, Adolescents (n=2150)	Iron	Meat, Fruits and Vegetables		Significantly associated with a lower risk of anemia: Animal-based iron-rich foods among adolescent girls; and Higher intake of vitamin A-rich fruits and vegetables among adolescent boys
21.	Zeleke et al 2020[59] Ethiopia	Cross sectional, Adolescents (n=742)		Fibre		Consumption of fibre-rich foods daily: less likely to be anemic among males
22.	Hassan et al 2017[30] Pakistan	Cross sectional, Adolescent girls (n=116)	Iron	Heme iron rich foods		Significantly associated with IDA: frequency of heme iron consumption
23.	Kaur et al 2006[32] India	Cross sectional, Adolescent girls (n=600)	Iron		Vegetarian diet	Predictors of anemia: vegetarian diet and iron intake <14 mg
24.	Olumakaiye, 2013[33] Nigeria	Cross sectional, Adolescent Girls (n=120)	Iron	Heme-iron rich food	DD	Heme iron source was consumed less than non-heme iron by anemic girls Significantly higher risk for anemia: low DDS (≤2)
25.	Engidaw et al 2018[31] Ethiopia	Cross sectional, Adolescent girls (n=437)		Egg, Heme-iron rich food		Less heme iron-rich foods consuming population (<1 time/month): 11 times more likely to develop anemia vs those who >twice/week Egg consuming population (>twice/week): 68% less likely to develop anemia vs consuming once/month
26.	Ghosh et al 2020[18] India	Cross sectional, WRA, 15-49 years (n=120)	Iron		DD	Diet lacking in iron-rich food was associated with moderate anemia and mild anemia Low MDDW score (<5) associated with moderate and severe anemia
27.	Khokhar et al 2022[39] Pakistan	Cross sectional, WRA (n=1541)		Meat, pulse		Low intake of meat, beans & pulses significantly influence rate of anemia prevalence
28.	Kankanamge et al 2017[42] Sri Lanka	Cross sectional, WRA (n=152)		Fish, meat, egg, GLV		Significant difference with Hb level among anemics and non-anemics: consumption of fish, white meat, egg and GLV
29.	Ali et al 2020[40] Pakistan	Cross sectional, WRA (n=150)		Meat		Significantly associated with anemia: not consuming meat
30.	Panigrahi and Sahoo 2011[38] India	Cross sectional, WRA aged between 15 and 49 years (n=240)		GLV, Pulse		Statistically significant with anemia: inadequate consumption of GLV and pulses

Continued.

S. no.	Author, year and country	Study design population (Sample size)	Nutritional and dietary components: nutrients	Nutritional and dietary components: Foods/Food groups	Nutritional and dietary components: Dietary factors	Outcomes
31.	Habib et al 2019[43] Pakistan	Cross sectional, WRA (n=749)	Vitamin-A		HH Food security	Associated with increased odds of anemia: serum vitamin A deficiency, HH food insecurity
32.	Alaofè et al 2017[54] Benin	Cross sectional, WRA (n=767)		Fruits and vegetables	DD	Greater risk of ID due to low DDS, low fruits and vegetables consumption
33.	Abay et al 2017[46] Ethiopia	Cross sectional, Pregnant women (n=762)		Meat, soft drink, fruits	DD	Factors associated with anemia: low DD, no meat consumption, not drinking soft beverages, not eating fruits
34.	Obse et al 2013[10] Ethiopia	Cross sectional, Pregnant women (n=374)		Meat, fruits, vegetables, tea		Factors associated with anemia: meat consumption <1/week, intake of vegetables and fruits <1/day, intake of tea always after meal
35.	Gebre & Mulugeta, 2015[17] Ethiopia	Cross sectional, Pregnant women (n=714)			MF	MF < 2/day: predictor of anemia
36.	Tadesse et al 2017[47] Ethiopia	Case control, Pregnant women (n=448; 112 anemic cases and 336 non anemic controls)		Meat, GLV		Positively associated with anemia: not consuming dark GLVs per 2 weeks, not consuming chicken per 2 weeks
37.	Baig-Ansari et al 2008[48] Pakistan	Cross sectional, pregnant women (n=1369)		Tea, eggs, Meat		Significantly associated with anemia: - Consuming tea > 3 cups/day before pregnancy - Consumption of clay or dirt during pregnancy - Never consuming eggs/consuming eggs < 2/week during pregnancy - Consumption of red meat < 2/week prior to pregnancy: marginally associated with anemia but significantly associated with lower mean Hb
38.	Aikawa et al 2006[65] Vietnam	Cross sectional, Pregnant women (n=439)		Egg		Consumption of eggs: positively correlated with Hb concentration
39.	Tulu et al 2019[44] Ethiopia	Case control, Pregnant women (n=573; 191 Anemic cases and 382 non anemic controls)			DD	Significantly associated with anemia: low DDS (≤ 3), medium DDS (4-6)
40.	Ebuy et al 2017[62] Ethiopia	Case control, Pregnant women (n=264; 88 severe anemic cases and 176 non anemic controls)			DD	DDS: strong predictor of severe anemia
41.	Weldekidan et al 2018[49] Ethiopia	Case control, Pregnant women (n=333; 111 cases and 222 controls)		Tea/Coffee, Meat	Additional diet	Major determinants of anemia: - Not taking additional diet during pregnancy - Consuming tea/coffee immediately after food - Not eating meat

Continued.

S. no.	Author, year and country	Study design population (Sample size)	Nutritional and dietary components: nutrients	Nutritional and dietary components: Foods/Food groups	Nutritional and dietary components: Dietary factors	Outcomes
42.	Teshome et al 2020[51] Ethiopia	Case control, Pregnant women (n=344; 117 anemic cases, 227 non anemic controls)		Tea/coffee		Significant association between tea/coffee after meals and anemia
43.	Berhe et al 2019[56] Ethiopia	Case-control, Pregnant women (n=600; 150 anemic cases and 450 non anemic controls)		Tea/coffee	DD	Drinking coffee/tea with or immediately after meal daily and DDS < 3 were statistically significant for anemia
44.	Weldemariam 2018[50] Ethiopia	Cross sectional, Pregnant women (n=374)		Vegetables, tea/coffee		Intake of vegetables < 1 per day, taking tea always after meal independently influencing occurrence of anemia
45.	Ayensu et al 2020[61] Ghana	Cross sectional, Pregnant women (n=379)			DD	DDS: Predictor of Hb concentration (Mean DDS: 3.81 ± 0.7). Those with low DDS were more likely to be anemic vs those with high DDS
46.	Jugha et al 2021[66] Cameroon	Cross sectional, Pregnant women (n=1014)		Milk and milk products, meat, fruits and vegetables		Significant lower prevalence of anemia was associated with intake of dairy, animal protein, vitamin A-rich fruits and vegetables. Mean Hb levels were higher with diverse diets vs less diverse diets
47.	Delil et al 2018[45] Ethiopia	Cross sectional, Pregnant women (n=314)			DD	Low DDS intake was positively associated with Anemia
48.	Samuel et al 2020[67] Ethiopia	Cross sectional, Pregnant women (n=423)		Coffee	DD	Prevalence of anemia amongst lowest DDS (≤ 3) was 3.66 times vs those with higher DDS (≥ 6). Prevalence of anemia: not statistically different in case of frequency of coffee intake
49.	Zerfu et al 2016[20] Ethiopia	Cohort, Pregnant women (n=432)			DD	Inadequate DD group (WDDS < 4) had a higher risk of anemia than women in the adequate DD group (WDDS > 4)
50.	Lebso et al 2017[63] Ethiopia	Cross sectional, Pregnant women (n=507)			DD	Mean DDS: 3.6 ± 2.27. Low DDS associated with anemia
51.	Abriha et al 2014[16] Ethiopia	Cross sectional, Pregnant women, 16-40 years (n=619)		Meat	MF, DD	Association with anemia: MF < 2/day, Low (DDS ≤ 3), Medium (DDS = 4 or 5), Meat consumption < 1/week
52.	Deriba et al 2020[41] Ethiopia	Case Control, Pregnant women (n=376; 92 anemic Cases and 284 non-anemic Controls)		Tea/coffee, Fruits	DD	Determinants of anemia: taking tea/coffee immediately after food, not eating fruit, Low DDS (≤ 3), Medium DDS (4-6)
53.	Shill et al 2014[60] Bangladesh	Cross sectional, Adults aged 20-22 years (n=300)	Iron	Meat, fish, egg, junk food	Regular breakfast consumption	Regular breakfast-taking habit showed significant influence on IDA. Determinants of IDA: iron/iron-rich food intake frequency (insignificant in anemic; significant in non-anemic). Regular consumption of meat, fish, poultry, eggs (significant in non-anemic). Junk food consumption had no statistically significant influence

Continued.

S. no.	Author, year and country	Study design population (Sample size)	Nutritional and dietary components: nutrients	Nutritional and dietary components: Foods/Food groups	Nutritional and dietary components: Dietary factors	Outcomes
54.	Shi et al 2006[37] China	Cross sectional, Adults >20 years (n=2849)			Traditional diet, healthy diet, macho diet	Positive association of 'Traditional' (rice, vegetable, wheat flour) and 'sweet tooth' (drinks, cake) with anaemia. Negative association with 'healthy' (whole grains, fruits, vegetables) and anemia. No association between 'macho' pattern (meat and alcohol) and anaemia
55.	Mishra et al 2021[34] India	Cross sectional, Children and Adults aged 0-60 years (n=520)		GLV, Tea		Consumption of GLV higher among non-anemic vs anemic. Those who never or rarely consumed GLV were more anemic vs non-anemic. Non-anemic had tea daily vs anemic
56.	Little et al 2018[35] India	Cross sectional, adults aged >20 years mean age 47.1 years (n=753; 412 women and 341 men)		Refined grains, meat, egg, sugar		Non-Pregnant Women: increased mild anemia with refined grains; reduced mild anemia with meat. Men: increased mild anemia with sugar; reduced mild anemia with eggs
57.	Wen et al 2023[36] China	Cross sectional, Adults and elderly aged 24-82 years (n=13465)		Meat, Vegetables, fruit		For women (negatively associated with anemia): red meat consumption, corn/sweet potato consumption. For men (negatively correlated with anemia): fruit consumption, corn/sweet potato consumption
58.	Broderstad et al 2011[68] Norway	Cross sectional, Adults and elderly aged 26-79 years (n=16323)		Meat		Intake of reindeer meat was associated with higher levels of serum ferritin
59.	Zhang et al 2018[55] China	Cross sectional, Adults and Elderly aged 50-77 years (n=738)		Vegetables, pulses		Positive correlations between Hb level and the intakes of vegetables and soybean
60.	Meng et al 2009[4] China	Case Control, Adults and Elderly women aged 50-75 years (n=853; 420 anemic cases and 433 non anemic controls)	Energy, protein, carbohydrate, vitamin A, vitamin B1, riboflavin, Iron and Calcium	Animal foods, egg		Intakes of energy, protein, carbohydrate, vitamin A (RE), vitamin B1, riboflavin and Calcium: significantly lower in cases vs controls. No significant difference in iron intake between the two groups. Animal foods and egg consumption for cases significantly lower vs controls
61.	Gupta et al 2020[3] India	Cross sectional, Elderly population mean age 69.3±7.4 years (males) and 67.9±7.2 years (females) (n=958)	Iron, vitamin C, copper, and manganese			Subjects with moderate and severe anemia had a significantly lower nutrient intake adequacy for iron, vitamin C, copper, and manganese vs those with no anemia and mild anemia

Geriatric population (65 years and above)

Anemic elderly women exhibited lower intake of energy, protein, carbohydrate, vitamin A, vitamin B1, riboflavin, and calcium with lower consumption of animal foods and eggs as compared to their non-anemic counterparts.[4] Elderly population with moderate and severe anemia had significantly lower intake of iron, vitamin C, copper, and manganese compared to those with no anemia and mild anemia.[3]

DISCUSSION

Across all life stages, the synthesis of primary evidence highlights the indispensable role of animal-source foods including meat, poultry, fish, and eggs in lowering the

risk of anemia.[27,28,34,42,52] This protective effect is physiologically driven by the high bioavailability of heme iron, which is absorbed intact via heme carrier proteins independently of dietary chelators and concurrently promotes the absorption of non-heme iron.[53] In contrast, plant-based diets, while rich in non-heme iron, contain substantial concentrations of phytates, polyphenols, and fiber that inhibit divalent metal transporter-1 (DMT1) intestinal uptake.[53] This explains why strict vegetarian diets and low intakes of animal protein among adolescent girls and women were frequently associated with significantly elevated odds of anemia unless systematically paired with ascorbic acid or micronutrient-dense items.[32,39] Concurrently, regular consumption of plant-based foods such as fruits and green leafy vegetables (GLVs) conferred substantial protection across populations.[26,34,36,54,55] This benefit arises because fresh produce supplies provitamin A carotenoids, folate, and ascorbic acid; vitamin C reduces ferric iron (Fe3+) to the more soluble ferrous state (Fe2+) at the brush border, mitigating the inhibitory effects of luminal phytates.[7,53]

During pregnancy, physiological plasma volume expansion increases maternal iron requirements by two- to three-fold, rendering pregnant women exceptionally vulnerable to dietary inhibitors.[2] Our findings demonstrated that routine consumption of tea and coffee, particularly when taken during or immediately after meals, was a dominant predictor of gestational anemia.[10,16,17,45,47-51,56] The polyphenolic compounds, tannins, and chlorogenic acids present in tea and coffee form stable, insoluble iron-tannate complexes within the intestinal lumen that drastically diminish non-heme iron absorption by up to 60% to 90%.[53] These observations are consistent with previous maternal cohort investigations indicating that nutrient timing, particularly the separation of beverage consumption from main meals, is as critical as absolute iron intake in low-resource settings.[49,57]

Among children under five years of age, suboptimal infant and young child feeding (IYCF) practices, especially with respect to the timing of complementary feeding and breastfeeding duration increased the risk of developing anemia.[8,11,21,58] Breast milk iron possesses high bio-efficacy (~50%), yet absolute concentrations are insufficient to sustain physiological erythropoiesis beyond six months of life, necessitating the timely introduction of iron-rich complementary foods.[2,8]

In adolescent populations, meal patterns showed nuanced, age and sex-dependent associations with hematologic status. While it was observed that higher meal frequency (consuming three or more meals daily) was positively associated with anemia among adolescent girls, this finding reflects calorie-dense but micronutrient-poor food choices, demonstrating that meal quality and nutrient density outweigh mere caloric frequency.[13,33] In contrast, meal skipping specifically skipping breakfast deprives adolescents of essential daily micronutrients (iron, riboflavin, folate) that are rarely compensated in later meals, directly predisposing school-aged children to iron deficiency.[14] Furthermore, dietary patterns such as daily consumption of fiber-rich plant foods were protective against anemia in adolescent males, likely because whole-plant foods simultaneously serve as major vehicles for vitamin A, vitamin C, and essential minerals in rural diets.[59,28] An interesting divergence was observed regarding ultra-processed and fast foods: fast food consumption showed no statistically significant association with anemia among young university-aged adults, but emerged as an independent risk factor among pubertal children and post-menarcheal girls.[60,15] During rapid adolescent growth spurts, the displacement of traditional, iron-rich staples by ultra-processed snacks that lack bioavailable micronutrients creates an acute micronutrient deficit relative to increased physiological demands.[15]

Diets lacking variety, characterized by low dietary diversity scores (DDS), were consistently associated with higher anemia rates across nearly all studied populations.[8,9,16,18,20,44,46,50,58,61-63] Dietary diversity acts as a robust proxy for micronutrient adequacy; consuming varied food groups ensures concurrent intake of trace elements and vitamins necessary for hemoglobin synthesis, immune function, and epithelial integrity.[2,20] Compounding this, household food insecurity was uniformly identified as an upstream socio-economic driver of anemia across children, adolescent girls, and women of reproductive age.[11,19,22,24,43] Food-insecure households are frequently forced to rely on low-cost, starchy staple foods with minimal dietary diversity, directly exacerbating chronic micronutrient starvation.[24,43] Finally, while data remain comparatively scarce for older demographics, evidence from geriatric populations identified a distinct multi-nutrient deficiency profile.[3,4]

CONCLUSION

Nutritional and dietary factors are paramount in determining the prevalence and severity of anemia across the life span from infancy and childhood through adolescence, pregnancy, adulthood, and advanced age. Findings underscore that addressing anemia requires moving beyond isolated single-nutrient supplementation to embrace comprehensive dietary quality frameworks. Targeted interventions at biologically vulnerable stages (specifically early childhood and pregnancy) are crucial to meet escalated physiological iron demands and interrupt the inter-generational cycle of undernutrition. Essential strategies must focus on enhancing dietary diversity, optimizing meal timing relative to inhibitory beverages, promoting adherence to age-appropriate complementary feeding, improving household food security, and supporting balanced diets rich in bioavailable micronutrients.

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