International Journal of Women's Health

Dovepress
Taylor & Francis Group

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REVIEW

A Scoping Review of Nutritional Intake and Physical Activity in Adolescent Girls with Anemia

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Abstract: Anemia is a significant health concern in adolescents, linked to diminished physical stamina and productivity. Menstruation is a prevalent cause of iron deficiency anemia. If this persists until pregnancy, it may elevate the risk of having infants with low birth weight. Consequently, efficacious preventive interventions are necessary. This literature review investigates the correlation between dietary intake and physical activity with anemia in adolescent girls. The evaluation was per the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) standards. A thorough search was conducted across various databases, including PubMed (n = 59), Scopus (n = 103), and ScienceDirect (n = 5546), along with manual citation tracking (n = 6) and previously published reviews (n = 2), yielding a total of 5708 articles. Following the screening process, 157 articles were eliminated for irrelevance, four articles were deemed inaccessible, and 14 articles were added based on the eligibility assessment. The results emphasize that macronutrient and micronutrient consumption are essential for erythropoiesis and the prevention of anemia. Dietary diversity and sufficient energy intake were substantially correlated with enhanced anemia status. Furthermore, moderate to strenuous physical activity correlated favorably with hemoglobin and ferritin concentrations. Excessive body fat may impede iron absorption. Overall, sufficient dietary consumption and consistent physical exercise seem complementary to preventing anemia. This is important as an effort to prevent disease throughout the life span because anemia that persists into adulthood hurts pregnancy, childbirth, and the health outcomes of the newborn. However, we have not identified a certain frequency and duration of activity that affects anemia. Consequently, additional investigation is required regarding this matter.

Keywords: nutritional intake, physical activity, iron deficiency, female adolescents, anemia

Introduction

Anemia constitutes a significant global health issue. Globally, there are 1.9 billion instances of anemia, with 30% occurring in women aged 15 to 49.[1–3] Menstruation in women is a prevalent cause of iron deficiency anemia.[4] Mitigating anemia is a global health goal; nevertheless, not all nations have succeeded in attaining a 50% reduction in its prevalence.[5] Anemia can result in a decrease in body resistance and cognitive agility, which can lead to a decrease in the productivity of adolescents.[6] Anemia adversely affects physical development and jeopardizes the life cycle of women.[7,8] Chronic anemia in pregnancy correlates with elevated risks during childbirth and a greater probability of a low-birth-weight infant.[6,9]

A contributing factor to anemia is insufficient dietary intake.[3,10] The predominant causes of nutritional deficiency anemia encompass deficiencies in iron, vitamin A, vitamin B9 (folate), and vitamin B12 (cobalamin).[3] Impairment of DNA synthesis can result from deficiencies in folate and vitamin B12, which disrupts the erythropoiesis process and leads to the apoptosis of hematopoietic cells.[11,12] Conversely, those with iron deficient anemia exhibited a reduction in

Received: 7 May 2025
Accepted: 27 August 2025
Published: 6 September 2025

hemoglobin and MCV levels.[11] In 2021, iron deficiency anemia among women was a significant issue in Southeast Asian countries.[2] Iron deficiency is the predominant etiology of anemia, accounting for about 60% of cases.[13]

Individuals with insufficient dietary intake may suffer from malnutrition. Malnutrition arises from an imbalance in dietary consumption, nutritional status, body tissue mass, and levels of physical activity.[14] The nutritional status of teenagers can be assessed by measures such as body mass index (BMI) and mid-upper arm circumference (MUAC). Adolescents with either underweight or overweight status exhibit an increased propensity for developing anemia in comparison to their counterparts with a normal BMI. Furthermore, reduced MUAC measures correlate with a heightened risk of anemia in teenagers.[15] Globalization, urbanization, and swift economic development have led to significant alterations in Indonesia's dietary habits and physical activity levels. Individuals are progressively consuming energy-dense foods while engaging infrequently in physical activity, hence elevating the incidence of overweight and obesity.[16] Engaging in physical activity helps mitigate the risk of obesity.[17] Mid-upper arm circumference (MUAC) is one of the measures utilized to assess malnutrition,[18] which additionally indicates muscular and adipose reserves.[19,20] Excess adipose tissue may hinder vitamin absorption and affect erythropoiesis, thereby diminishing red blood cell synthesis.[21,22] Moreover, physical activity correlates with muscle mass, indicative of a metabolic state that facilitates erythrocyte production.[19,21,22]

According to the World Health Organization, 75% of adolescents do not adhere to the minimum physical activity guidelines.[23] Physical activity is recognized for its capacity to diminish the risk of obesity and enhance physical fitness and cognitive outcomes.[24] Consistent physical activity in children and adolescents correlates with enhanced physical fitness, bolstered immunological function, improved cardiometabolic health, stronger bones, better cognitive results, enhanced mental health, effective weight management, and decreased body fat.[25]

The World Health Organization (WHO) has implemented measures to mitigate anemia in teenagers by advocating for iron supplementation. This study examines the relationship between dietary intake, physical activity, and anemia in teenagers in light of this guideline. At present, there is a scarcity of research that investigates the combined impact of physical activity and nutritional intake on anemia in adolescent females.

Methods

This literature analysis utilizes the scoping review methodology, a technique that identifies and examines knowledge deficiencies and critical attributes or elements related to a concept. Furthermore, we employ this strategy to locate and delineate available evidence.[26] We adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) standards and utilized the PRISMA flowchart for search stages.[27]

Research Question

The objective of this review is to comprehend the significance of physical activity and nutritional intake in the context of anemia in adolescent females. Subsequently, the inquiry becomes, "Is there a correlation between anemia in adolescents, physical activity, and nutritional intake?"

Eligibility Criteria

This review centers on adolescents as the target demographic, examining dietary intake and physical activity as key exposures, with iron deficiency anemia as the significant outcome. The review is not limited by geographical constraints and encompasses papers published from 2011 to 2024. To be eligible for inclusion, articles had to satisfy the following criteria: (1) original research articles composed in English, (2) published in indexed journals, and (3) accessible in full text. Studies were omitted if they were duplicates, review articles, theses, dissertations, concentrated on pregnancy, or did not investigate the relationship between dietary intake, physical activity, and anemia.

Search Strategy

Upon formulating the study questions, we employed the PICO framework, utilizing customized MeSH terms to obtain search results congruent with the research aims. Following the conversion of MeSH terms into the Boolean format, keywords were produced in this sequence: "adolescent" AND "Nutrient Intake" OR "Dietary Intake" AND "Physical activity" OR "Exercise" AND "Anemia". Articles were searched from November to December 2024.

Selection Process

We searched the PubMed, Scopus, and ScienceDirect databases. The PRISMA flowchart (Figure 1) was modified to detect publications. This flowchart comprises three phases: identification, screening, and inclusion. In the identification phase (Stage I), the quantity of articles obtained from the database search and the count left after the elimination of duplicates were ascertained. At this step, automation tools were employed to filter articles according to criteria like language (English), full-text availability, classification as research papers, year of publication, and open access status. The screening process (Stage II) entailed categorizing papers based on the study topic and eligibility criteria, utilizing keywords, titles, and abstracts. During the inclusion step (Stage III), all the texts of the retrieved articles were assessed. At this level, authors evaluated papers for review eligibility. The selected literature sources were required to fulfill specific requirements, including publication in indexed journals and possessing a designated journal number and volume. Only papers that fulfilled these criteria were included in the final round of the review process.

Results

The results document data from studies investigating the correlation between nutritional consumption and physical activity with anemia. We identified articles according to their profiles, attributes, demographic data, and results from the statistical studies conducted inside the articles.

The Study Profile Counts

A total of 5708 publications were identified by an extensive search of various databases, including PubMed (n = 59), Scopus (n = 103), and ScienceDirect (n = 5546). Six supplementary papers were located through manual citation monitoring, and two articles were obtained from prior literature studies. After eliminating 95 duplicate entries, 5430 articles were discarded based on automated screening criteria, and one item was eliminated for failing to align with the designated keywords. Subsequent to the title and abstract screening, 157 publications were eliminated due to their lack of

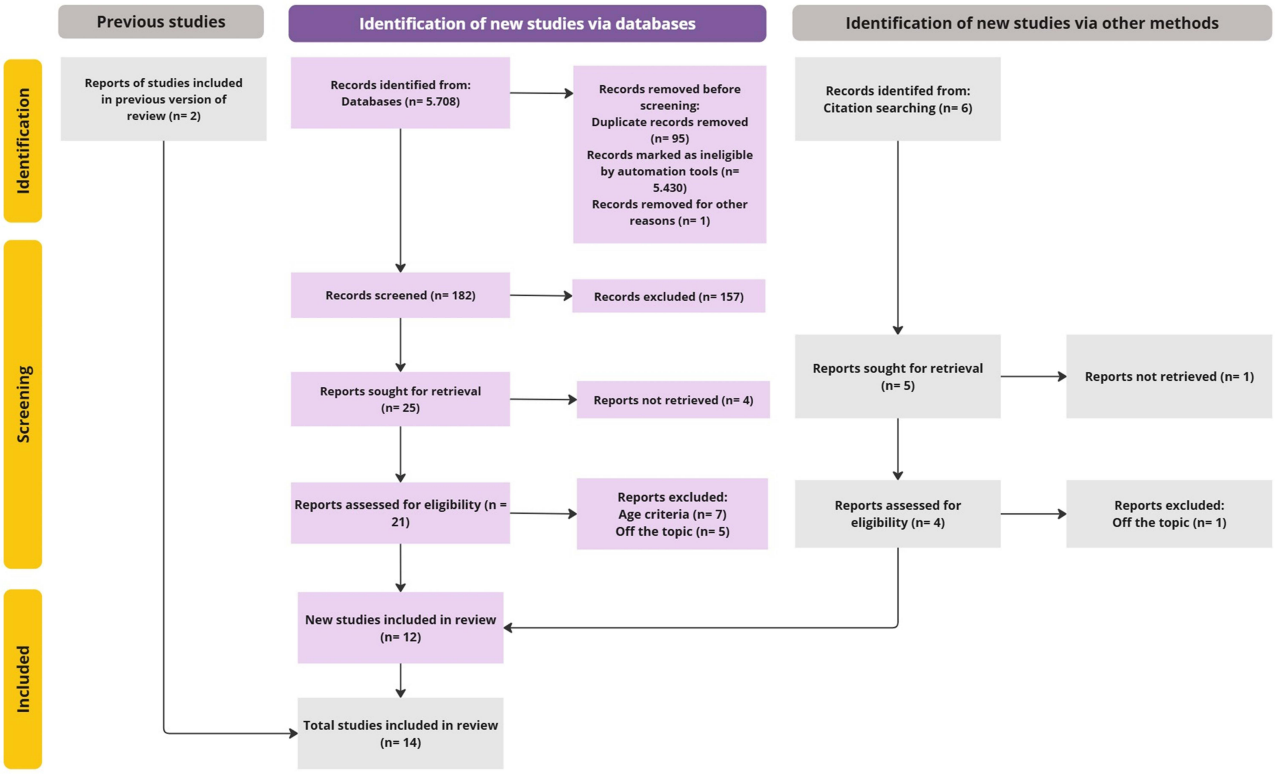

Figure 1 PRISMA flowchart of the article's selection process from 2011 to 2024.

https://doi.org/10.2147/IJWH.S519269

relevance to the research topic. Additionally, five items were inaccessible owing to access limitations. Of the 27 papers evaluated for eligibility, 13 were rejected for failing to meet the inclusion criteria. In conclusion, 14 papers from databases and additional sources were incorporated into the final review.

The Study Demographic Profiles

Most of the selected papers regarding demographic aspects originated from the Asia-Pacific region (Figure 2). This pertains to undernourishment in the Asia and Pacific subregion. The Food and Agriculture Organization (FAO) reports that despite a reduction in undernourishment by 12 million individuals in 2021, the total number of undernourished people remained 55 million higher than in 2019.[28] Early malnutrition is recognized to impede skeletal development and menarche while extending the growth period in females.[29] Malnutrition is frequently linked to anemia.[30]

Characteristics of the Studies

We selected attributes based on author names, publication year, country of study, title, objectives, participant data, methodologies, and outcomes. The research characteristics incorporated in this scoping review are delineated in Table 1. The participant count ranged from 47 to 22,486. While the research recruited participants beyond adolescence, the literature specifically encompassed the cohort of adolescent girls. Most of the articles employed a cross-sectional design,[10,31–40] an article employing a cohort design[41] and two further articles employed retrospective studies.[42,43] Four research employed bivariate analysis,[32,35,36,38] Ten studies examined utilizing multivariate testing.[10,31,33,34,37,39–43] The particular analysis differs based on the data type (Table 2).

Synthesis of the Result

Table 3 presents the study's findings concerning the correlation between dietary intake, physical activity, and anemia. The analysis revealed that the results pertained to nutritional intake of macronutrients and micronutrients, dietary diversity, energy consumption, and frequency of food intake. The analysis pertains to physical activity through sports club membership, sports participation, standing board jumps, and several nutritional parameters, including participant socio-demographics and average monthly income. A statistical investigation of the correlation between these variables and anemia was conducted using bivariate and multivariate methods.

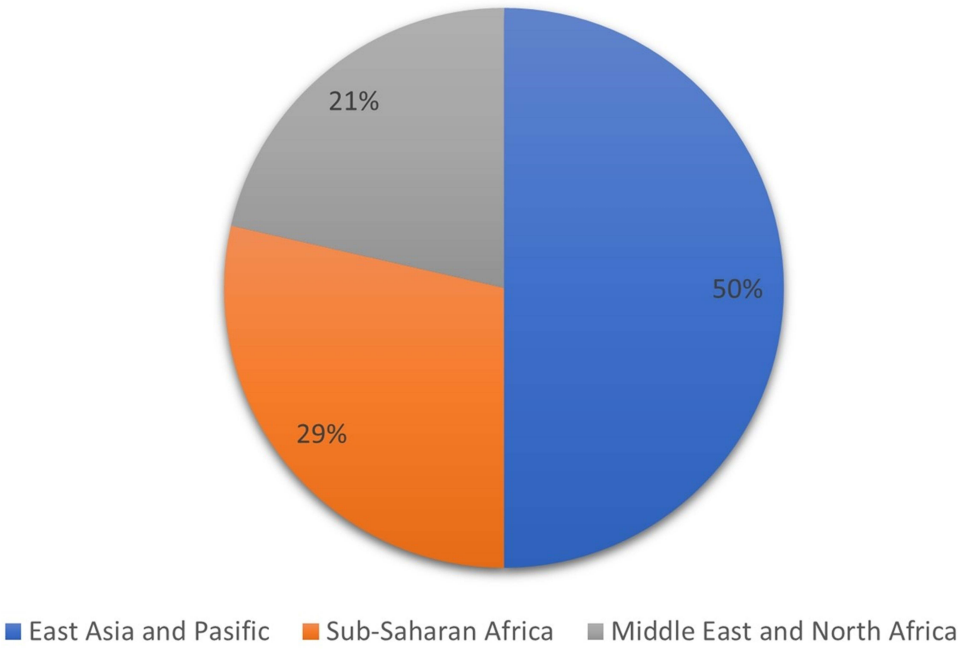

Figure 2 Characteristics of selected articles by continent (n = 14).

Table 1 The Characteristics of Selected Studies (n = 14)

No.	Author(s)/Year	Country	Title	Objectives	Participant	Methods	Findings
1.	Jalambo et al (2018)[31]	Palestine	Prevalence and risk factor analysis of iron deficiency and iron-deficiency anaemia among female adolescents in the Gaza Strip, Palestine	To assess the prevalence of anemia, iron deficiency (ID), and iron deficiency anemia (IDA), along with associated risk factors among adolescent females in the Gaza Strip.	330 female adolescents aged 15 to 19 years	Descriptive cross-sectional study	A significant association (P<0.05) occurs between iron deficiency (ID), anemia, and iron deficiency anemia (IDA) and dietary habits, notably the exclusion of breakfast (OR=0.95, 95% CI 0.92, 0.96, P <0.001). The results of this study indicate no link between iron deficiency and anemia in relation to physical activity (P>0.05)
2.	Qasrawi et al (2024)[32]	Palestine	Identification and prediction of association patterns between nutrient intake and anemia using machine learning techniques: results from a cross-sectional study with university female students from Palestine	To identify new patterns and classifications of the relationship between nutritional intake and anemia	775 females aged 18–30 years	Cross-sectional study	Anemia is markedly correlated with the intake of energy, protein, fat, vitamins B1, B5, B6, C, magnesium, copper, and zinc. In contrast, anemic persons exhibit a significant reduction in the intake of protein, vitamins B2, B5, B6, C, E, choline, folate, phosphorus, manganese, and zinc compared to non-anemic individuals. A significant association appears between Vitamin B12 intake and anemia (X2 = 50.8, P < 0.001). The anemia prevalence is significantly higher in individuals with severely low Vitamin B12 intake compared to those with lower intake levels (45.9% vs 21.1%, respectively).
3.	Mchau et al (2024)[33]	Tanzania	Co-occurrence of Overweight, Stunting, and Anemia among Adolescents (10–19 Years) in Tanzania Mainland: A School-Based Cross-Sectional Study	To assess the coexistence of malnutrition (overweight, stunting, and anemia) among adolescents (10–19 years) in mainland Tanzania	Total 44.120 participants. 22.486 females and 21.634 males adolescents aged 10–19 years	Cross-sectional study	The data reveal that individuals with anemia demonstrate reduced vitamin intake compared to those without anemia. Studies demonstrate that women have a higher likelihood of being overweight compared to men (relative risk [RR]: 1.33; 95% confidence interval [CI]: 1.21, 1.45).

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Table 1 (Continued).

No.	Author(s)/Year	Country	Title	Objectives	Participant	Methods	Findings
4.	Sigit et al (2024)[34]	Indonesia	Factors influencing the prevalence of anaemia in female adolescents: A population-based study of rural setting in Karanganyar, Indonesia	To investigate the prevalence of anemia and its relationship with anthropometric indices, dietary habits, and menstrual status among adolescent girls in Karanganyar.	730 females aged 15–49 years	Cross-sectional study	BMI and Upper Arm Circumference demonstrate an inverse relationship with anemia [AOR (95% CI): 0.87 (0.79–0.95) and 0.89 (0.81–0.99)]. Individuals with a BMI-for-age Z-Score (BAZ) < −2 SD have more than double the risk of anemia compared to those with a BAZ > −2 SD [2.43 (0.94–6.29)].
5.	Nabeyama et al (2023)[41]	Japan	Prevalence of iron-deficient but non-anemic university athletes in Japan: an observational cohort study	This study aims to investigate the prevalence of ID and IDA among athletes participating in kendo, badminton, baseball, and handball at the University of Tsukuba. (Tsukuba, Prefektur Ibaraki, Japan)	A total of 126 participants. 47 females aged 19 years and 79 males aged 20 years	Observational cohort study	A shorter duration of athletic experience (adjusted odds ratio [95% confidence interval]: 0.62 [0.43–0.90]), decreased calorie intake (0.994 [0.989–0.999]), and increased dietary iron intake (4.40 [1.12–17.26]) are associated with hypoferritinemia.
6.	Yamamoto et al (2022)[42]	Japan	Profiles of anemia in adolescent students with sports club membership in an outpatient clinic setting: a retrospective study	This study aims to explain the clinical characteristics of anemia in adolescent athletes.	A total of 485 participants. 254 females, 231 males aged 13–22 years	Retrospective study	Anemic women demonstrated a significantly higher prevalence of folate deficiency compared to non-anemic women ($p = 0.006$). Significantly reduced levels of Hb, MCV, and MCH were noted in the IDA cohort compared to the non-IDA cohort in both sexes ($p = 0.007$, 0.03, and 0.003 for males, and 0.001, 0.003, and 0.001 for females, respectively).

7.	Oy et al (2019)[35]	Indonesia	Problem Nutrients in Adolescent Girls with Anemia Versus Nonanemic Adolescent Girls and the Optimized Food-Based Recommendations to Meet Adequacy of These Nutrients in Adolescent School Girls in East Java, Indonesia	To compare nutritional issues in the diets of adolescent girls with anemia and those without anemia, and to develop food-based recommendations (FBR) to prevent anemia and micronutrient deficiencies.	355 females aged 15–18 years	Cross-sectional study.	The weekly consumption frequency of food groups is the same for both the anemia and non-anemia groups. The FBR is sufficient to prevent anemia in non-anemic adolescents and improve nutritional status in anemic adolescents, except for absolute mineral deficits (iron and calcium) that remain below the EAR (65% RNI) in the most unfavorable conditions.
8.	Ganpule-Rao et al (2020)[43]	India	Dietary diversity scores, nutrient intakes and biomarkers vitamin B 12, folate and Hb in rural youth from the Pune Maternal Nutrition Study	This study examines the validity of DDS to measure deficiencies in vitamin B12, folate, and Hb.	A total of 656 participants. 303 males and 353 females aged 17 years old	Retrospective study	Adolescents with the lowest concentrations of vitamin B12 and hemoglobin (Hb) predominantly ingested starchy staples, legumes, and certain fruits and vegetables, yielding an Individual Dietary Diversity Score (IDDS) of ≤3 (n = 240). In contrast, individuals with heightened micronutrient levels incorporated meat or eggs into their diet (n = 51, consisting of 13 females and 38 males), revealing a significant disparity in vitamin B12 of –19.2 pmol/l (95% CI –53.96, 15.59, P = 0.03) and a difference in hemoglobin of –7.0 g/l (95% CI –12.8, –1.2, P = 0.01).

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Table 1 (Continued).

No.	Author(s)/Year	Country	Title	Objectives	Participant	Methods	Findings
9.	Al Sabbah et al (2020)[36]	Dubai	Prevalence of overweight/obesity, anaemia and their associations among female university students in Dubai, United Arab Emirates: a cross-sectional study	To assess the prevalence of overweight, obesity, anemia, and their relationship with eating habits, physical activity, and total body fat among female students	A total of 251 college students	Cross-sectional study	Students with overweight or obesity reported a greater frequency of activity compared to their normal-weight counterparts (P = 0.05). Students with anemia demonstrated diminished exercise levels relative to their non-anemic peers (P = 0.05). The body fat percentage was highest (38.9%) among students with anemia (P < 0.05). Seventy-two-point one percent of anemic students expressed a preference for fast food, in contrast to fifty-seven-point four percent of non-anemic students (P = 0.053).
10.	Sari et al (2022)[10]	Indonesia	Iron Deficiency Anemia and Associated Factors Among Adolescent Girls and Women in a Rural Area of Jatinangor, Indonesia	To explore iron deficiency anemia and related factors in adolescent girls and women in the rural area of Jatinangor, Indonesia.	A total of 180 participants. 95 aged 10–19 years old and 85 aged 20–35 years old	Cross-sectional.	Protein consumption (OR=0.25; 95% CI 0.11–0.58) is positively connected with anemia. A notable disparity existed in the frequency of anemia and weight classification between adolescent females and adult women (P<0.005). Hematological indices, including hemoglobin, hematocrit, platelets, MCV, MCH, and MCHC levels, demonstrate substantial disparities between anemic and non-anemic adolescent females, with p<0.05.

11.	Mengistu et al (2019)[37]	Ethiopia	Iron Deficiency Anemia among In-School Adolescent Girls in Rural Area of Bahir Dar City Administration, North West Ethiopia	To assess the prevalence of anemia and associated factors among schoolgirls in the rural areas of the Bahir Dar City Administration, Northwest Ethiopia.	Total 443 adolescent females aged 10–19 years old	Cross-sectional study	The prevalence of anemia is 11.1%. Household size [AOR=3.2, 95% CI (1.29–7.89)], history of intestinal parasite infection [AOR=2.7; 95% CI (1.19–6.21)], duration of menstrual flow [AOR=2.4; 95% CI (1.08–5.44)], and BMI for age [AOR=3.2; 95% CI (1.43–7.05)] are identified as predictors of anemia. Adolescent girls with a BMI for age below −2 SD are 3.2 times more susceptible to anemia than those with a BMI for age of −2 SD or higher [AOR=3.2, 95% CI (1.43, 7.05)].
12.	Monyeki et al (2024)[38]	South Africa	Relationships between Iron Status and Selected Physical Fitness Components of South African Adolescents: The PAHL-Study	To determine the relationship between iron status and certain components of physical fitness in South African adolescents	A total of 178 participants. 76 males and 102 adolescent females aged 13–16 years old	cross-sectional	A positive association was seen between ferritin levels in females ($r = 0.25$, $p = 0.04$) and standing broad jump (SBJ), as well as between hemoglobin (Hb) and SBJ ($r = 0.21$, $p = 0.03$) and V˙O2max ($r = 0.32$, $p = 0.001$). The results concerning iron status and certain physical fitness indicators demonstrate that people with iron deficiency, without anemia and low hemoglobin, show significantly poorer performance ($p < 0.001$). Within the overall cohort, hemoglobin levels shown a little positive connection with both outcomes in female adolescents, but only with the standing broad jump in male adolescents. Ferritin had a moderate positive connection with VO˙2max and SBJ in both the general population and specifically among adolescent girls.

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Table 1 (Continued).

No.	Author(s)/Year	Country	Title	Objectives	Participant	Methods	Findings
13.	Ayogu et al (2016)[39]	Nigeria	Prevalence and factors associated with anthropometric failure, vitamin A and iron deficiency among adolescents in a Nigerian urban community	To determine the prevalence of stunting, underweight, vitamin A, and iron deficiency among urban Nsukka, Nigeria adolescent students, and to identify factors associated with nutritional problems.	Total 400 Participants. 225 males and 175 adolescent females aged 12–18 years old	Descriptive cross-sectional study	Serum retinol (28.5 and 30.9 μg/dl), packed cell volume (34.6 and 35.4%), and hemoglobin levels (11.5 and 11.5 g/dl) did not exhibit any significant changes (P>0.05). Even after accounting for other covariates, multivariate analysis demonstrates that household income has a substantial impact on serum retinol levels (AOR=0.14; 95% CI=0.031, 0.607; P=0.009) and height-for-age status (AOR=0.12; 95% CI=0.021, 0.671; P=0.016).
14.	Ford et al (2022)[40]	Nepal	Factors associated with anaemia among adolescent boys and girls 10–19 years old in Nepal	This study aims to evaluate the factors associated with anemia.	A total of 2.647 participants. 1.680 females and 967 males aged 10–19 years old	Cross-sectional study	Women living in the Mountain and Hill ecological zones, compared to those in the Terai, demonstrate a lower probability of anemia, with adjusted odds ratios (AOR) of 0.28 (95% CI [0.15, 0.52]) and 0.42 (95% CI [0.25, 0.73]), respectively. Furthermore, ln ferritin (μg/L) exhibits an adjusted odds ratio (AOR) of 0.53 (95% confidence interval [0.42, 0.68]), while ln retinol-binding protein (RBP) (μmol/L) presents an AOR of 0.08 (95% confidence interval [0.04, 0.16]). One-third of women with anemia (33.2%, 95% CI [26.7, 39.7]) demonstrated iron deficiency as assessed by ferritin levels.

Table 2 The Analytical Methods of Selected Studies (n = 14)

Analytical Methods	n	%	References	Participants	Findings	
					Significance	Insignificance
Multivariat logistic regression	8	57.14%	Jalambo et al (2018)[31]	330	Nutritional intake Macronutrient	Physical activity
			Sigit et al (2024)[34]	730	–	Nutritional intake
			Nabeyama et al (2023)[41]	126	Dietary energy Exercise	– –
			Yamamoto et al (2022)[42]	485	Micronutrient	Club sport activity
			Sari et al (2022)[10]	180	Macronutrient	–
			Mengistu et al (2019)[37]	443	Average income	–
			Ayogu et al (2016)[39]	400	–	Macronutrient
			Ford et al (2022)[40]	2.647	Macronutrient	–
Multivariabel log-binomial models	1	7.14%	Mchau et al (2024)[33]	44.120	Social Demography	–
Binary logistic regression	1	7.14%	Ganpule-Rao et al (2020)[43]	656	Dietary diversity	–
Chi-square test	1*	7.14%	Qasrawi et al (2024)[32]	775	Macronutrient Micronutrient	
Mann–Whitney	1*	7.14%	Oy et al (2019)[35]	355	–	Frequency of food consumption
X^2 test	1*	7.14%	Al Sabbah et al (2020)[30]	251	Exercise	–
Spearman correlation	1*	7.14%	Monyeki et al (2024)[38]	178	Standing broad jump	–
Total	14	100%				

Notes: *Bivariate analysis. The majority of studies that reported significant findings utilized multivariate logistic regression analysis, particularly in the examination of associations with nutritional intake (both macro- and micronutrients), physical activity, average income, and sociodemographic factors. This emphasizes the method's perceived reliability and pervasive use in the assessment of multivariable relationships.

Table 3 Summary of the Findings (n = 14)

Indicator	Statistical Result			
	Significance		Insignificance	
Nutritional Intake or Physical Activity	Articles (n)	References	Articles (n)	References
Nutritional intake	1	Jalambo et al (2018)[31]	1	Sigit et al (2024)[34]
Macronutrient	4	Qasrawi et al (2024)[32] Jalambo et al (2018)[31] Sari et al (2022)[10] Ford et al (2022)[40]	1	Ayogu et al (2016)[39]

(*Continued*)

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Table 3 (Continued).

Indicator	Statistical Result			
	Significance		Insignificance	
Nutritional Intake or Physical Activity	**Articles (n)**	**References**	**Articles (n)**	**References**
Micronutrient	2	Qasrawi et al (2024)[32] Yamamoto et al (2022)[42]		
Dietary diversity	1	Ganpule-Rao et al (2020)[43]		
Dietary energy	1	Nabeyama et al (2023)[41]		
Frequency of food consumption			1	Oy et al (2019)[35]
Physical activity			1	Jalambo et al (2018)[31]
Club sport activity			1	Yamamoto et al (2022)[42]
Exercise	2	Al Sabbah et al (2020)[36] Nabeyama et al (2023)[41]		
Standing broad jump (SBJ)	1	Monyeki et al (2024)[38]		
Social Demography	1	Mchau et al (2024)[33]		
Average household monthly income	1	Mengistu et al (2019)[37]		

Figure 3 shows a network visualization of keywords based on the selected studies. A label and a circle indicate each item. The weight of the item determines the size of the label and circle—the higher the weight, the larger the label and circle. The color of each item indicates the cluster in which the item is located. The lines connecting the items indicate the relationship or association between the items.[44] The blue signifies the correlation between iron deficiency anemia and teenage females; the green denotes food consumption in relation to anemia; whilst the red illustrates the association between physical activity and anemia. The map lacks terms about muscle mass and fat mass.

Discussion

Anemia is a nutritional issue that adversely affects the growth and development of adolescent females and is closely linked to their nutritional status.[13] A multitude of studies have examined the relationship between adolescent food consumption, physical activity, and anemia; however, only fourteen papers fulfilled the review requirements. The analysis indicated insufficient information about the correlation between nutritional intake, physical activity, and anemia globally (Table 3).

The examined studies assessed macronutrient intake, micronutrient intake, dietary diversity, energy intake, and frequency of food consumption. The physical exercise included sports club membership, various sports, and standing board jumps. We also incorporated additional characteristics about nutrition, including participant socio-demographics and average monthly income. Seven articles indicated a correlation between nutritional intake.[10,31,32,40–43] Nonetheless, three investigations indicated that nutritional intake was not substantially associated with anemia.[34,35,39] Three studies indicated a strong link in physical activity,[36,38,41] two studies revealed no significant link.[31,42] Two studies addressed both topics but yielded insignificant analytical results for the physical activity component.[31,42]

Only one study examined the relationship between dietary consumption, physical activity, and anemia, yielding significant analytical data.[41] The results of this review are, however, corroborated by a number of studies. According to a systematic review, motor competence is an indispensable component of a healthy lifestyle, and both a balanced diet and physical activity are beneficial for the health of adolescents.[45] This aligns with a study conducted in Portugal, which discovered that physical activity positively corresponds with body–food choice congruence, indicating a propensity to

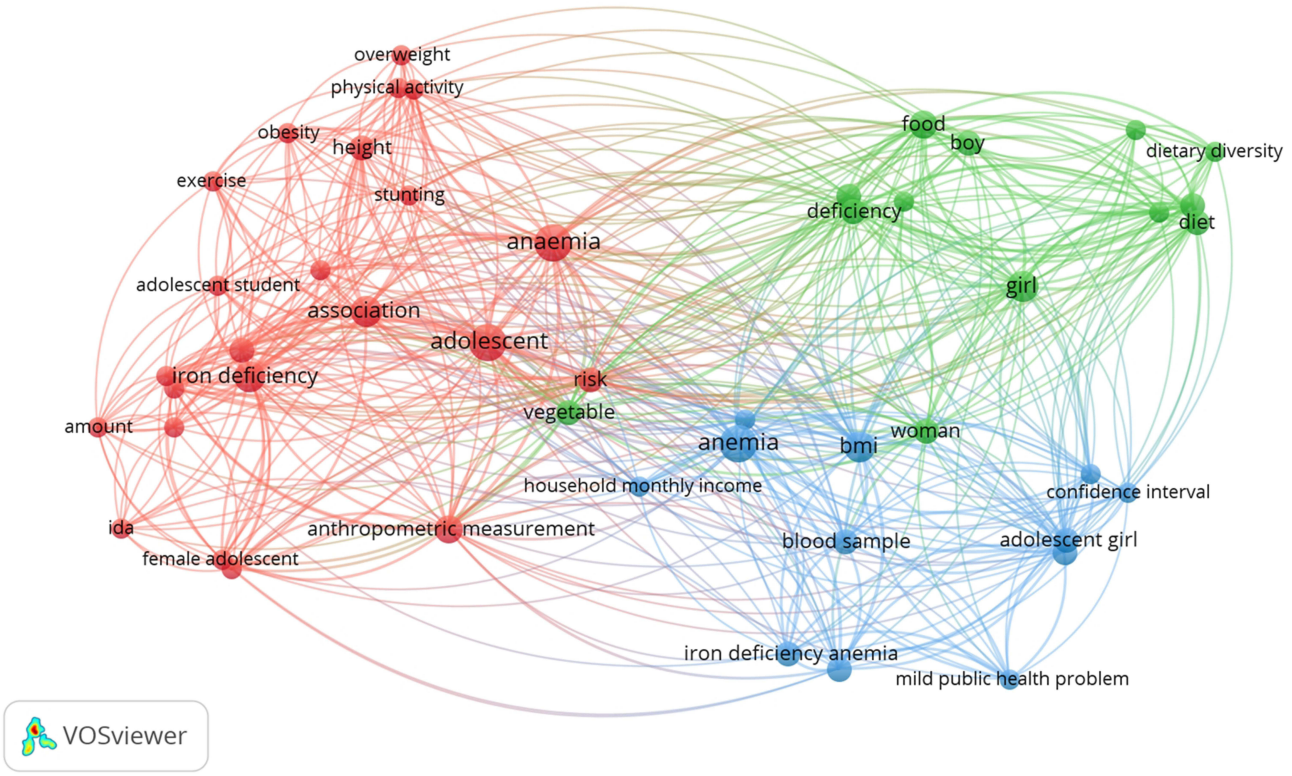

Figure 3 Map of Keywords Based on Selected Studies. Blue indicates the link between iron deficiency anemia and adolescent girls; green shows dietary intake; red reflects physical activity in relation to anemia.

select foods that enhance bodily health and function, such as those that supply energy and stamina.[46] Moreover, elevated levels of physical activity correlate with more autonomous eating behaviors, resulting in healthier dietary selections.[47]

The review indicated a correlation between the intake of both micronutrients and macronutrients and anemia.[10,31,32,40,42] Two investigations showed a substantial correlation between the intake of vitamin B12 and folate and the incidence of anemia. Women with anemia had a markedly greater frequency of folate insufficiency than their non-anemic counterparts.[32,42] Folate and vitamin B12 collaborate synergistically in creating red blood cells. A shortage in either folate or vitamin B12 impairs DNA synthesis and the erythropoiesis process.[12] This aligns with research in India, indicating that anemia is prevalent among adolescent girls with vitamin B12 deficiency.[48] A study in Palestine indicated that vitamin C is essential for the metabolism and absorption of iron.[32] Iron is crucial for numerous cellular operations, encompassing enzyme activities, DNA synthesis, oxygen transport, and mitochondrial energy generation.[4] Ascorbic acid, or vitamin C, facilitates the retention of iron in its reduced state, enhancing its bioavailability for absorption by the body.[49] Ascorbic acid significantly improves the absorption of both ferric (Fe3+) and ferrous (Fe2+) iron ions. This results from the reducing characteristics of vitamin C, which maintains iron's solubility across different pH levels, therefore enhancing its absorption via iron transporters in the small intestine.[50]

Four studies demonstrated that the intake of protein- and fat-dense meals, such as meat, correlates with a diminished risk of anemia.[10,31,32,40] A study in Vietnam indicated a notable rise in hemoglobin and iron levels among participants who received animal-based diets compared to the control group.[51] This indicates that meat-based diets assist in averting the reduction of iron levels. One study indicated that a high overall body fat percentage correlates with anemia.[36] Excess body fat may hinder vitamin absorption and the erythropoiesis process, thereby affecting red blood cell production,[21,22] increased body fat triggers an inflammatory response that elevates hepcidin levels, thereby impairing iron absorption in the gastrointestinal tract.[22] Conversely, protein is crucial for the synthesis of hemoglobin and myoglobin. When amino acids for protein synthesis are scarce, the body degrades muscle protein to fulfill amino acid needs. Extended protein shortage results in a reduction in skeletal muscle mass.[52] No studies about muscle mass were identified in this review.

A study conducted in India revealed that teenagers suffering from anemia exhibited a higher propensity for poor individual dietary diversity. Dietary diversity and trends are shaped by dietary variety as geographic, cultural, and economic limitations.[43] A study in Tanzania indicated that adolescents with suboptimal diet quality exhibited elevated rates of overweight and anemia compared to their counterparts with superior diets. The study revealed that teenagers residing in urban regions exhibited a greater risk of overweight and anemia in comparison to those in rural settings.[33] A study in Ethiopia revealed that adolescent females from households with low monthly income were ten times more likely to be anemic.[37] This monthly income pertains to energy use. A study conducted in Japan revealed that reduced calorie consumption was inversely correlated with low ferritin levels.[41]

Physical activity is essential for teenage nutrition.[53] Physical activity is recognized to enhance calorie expenditure, aiding in the prevention of obesity,[17] reduces body fat,[25] and enhances red blood cell volume during youth.[53] This study discovered that low to moderate-intensity physical activity correlates with a reduced risk of being overweight compared to a sedentary lifestyle.[33] A study conducted in China indicates that moderate to high-intensity physical activity can diminish fat mass.[54] Excess adipose tissue can impede vitamin absorption and erythropoiesis, affecting red blood cell synthesis.[21] Physical exercise is correlated with muscle mass. Increased muscle mass signifies favorable metabolic health and facilitates the production of healthy erythrocytes.[21] In individuals with low exercise intensity, there is a reduction in muscle mass and oxidative capability of the muscles.[55] Muscle oxidative capability pertains to mitochondrial oxidative phosphorylation, a mechanism via which the body transforms nutrients into ATP utilizing oxygen.[56] In mitochondria, proteins engage with enzymes that facilitate energy production and contribute to the regulation of energy metabolism and erythropoiesis.[57]

A significant correlation between ferritin and hemoglobin levels and fitness has been seen in females.[38] A study indicated a shorter exercise experience correlated with reduced ferritin levels.[41] A study in Dubai revealed analogous findings, indicating that students with anemia engaged in less physical activity than their non-anemic counterparts. This study identified a correlation among anemia, insufficient physical activity, and total body fat percentage. This may be associated with a nutritionally deficient diet and a predilection for fast food.[36] A study conducted in Palestine revealed no correlation between anemia and physical activity.[31] This aligns with a study conducted in Japan, which indicated that the contributor to anemia in long-distance runners is the hepcidin response, which diminishes iron absorption in the gastrointestinal tract.[42] This study demonstrated that excessive physical activity may elevate hepcidin levels.

Based on the review, we suspect that adequate food consumption and consistent exercise complement each other in preventing anemia. It is known that adequate nutritional intake by doing exercise is a combination that increases oxidation and restores muscle mass.[55,58,59] Physical activity is related to muscle mass, which indicates a metabolic condition that supports erythrocyte formation.[21,53,55] We concluded that adequate nutrition and consistent physical activity are crucial in preventing anemia in young women, thereby contributing to optimal quality of life, particularly in preparing for future pregnancy and childbirth.

However, considering the discrepancies in findings on the association between physical activity and anemia, we deduce that specific limitations about the frequency of physical exercise may influence anemia. Additional research is required on this subject. The interplay of adequate energy consumption and physical activity influences the body's capacity to absorb, retain, and utilize iron effectively. This indicates that a comprehensive approach is essential in preventing anemia. Preventing anemia involves a multifaceted approach rather than concentrating on a singular issue.

This study is advantageous due to the existing paucity of studies on dietary intake and physical activity concerning anemia in adolescent girls. This study possesses multiple drawbacks. We incorporated research including adolescent samples without accounting for their menstrual health and erythrocyte genetics.

Conclusion

Anemia in teenagers is affected by various factors, including nutritional consumption, physical activity, and socioeconomic conditions. Intake of both macronutrients and micronutrients, especially iron, vitamin B12, folate, and vitamin C, is essential for red blood cell production and preventing anemia. Diversity in dietary intake and energy adequacy substantially influence anemic status. Moderate to high-intensity physical activity is favorably correlated with hemoglobin and ferritin levels. Conversely, excessive adiposity and diminished muscular mass can adversely impact erythropoiesis and iron absorption mechanisms. This review indicates that nutritional intake and physical exercise are interconnected and positively affect

anemia prevention. Nonetheless, additional research is required to ascertain the precise frequency and duration of physical exercise that affects anemia. Preventing anemia should not depend on isolated interventions. A holistic strategy is required, encompassing sufficient nutritional education, monitoring of nutritional status, provision of iron supplements, and programs promoting physical activity among adolescents. Moreover, governmental measures are essential to guarantee justice, sustainability, and the enduring effects of anemia prevention a single intervention.

Acknowledgments

The Academic Leadership Grant Universitas Padjadjaran funded the APC.

Disclosure

The authors declare that there are no conflicts of interest in the writing or publishing of this article.

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