

SYSTEMATIC REVIEW

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# The global prevalence of anemia in patients with anorexia nervosa: a systematic review and meta-analysis

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## Abstract

**Background** Anorexia nervosa (AN) is a mental disorder characterized by severe loss of appetite and low nutrient intake. Along with many complications, the anorexia nervosa eventually disrupts hematogenesis and the occurrence of anemia. Thus, the present study aimed to investigate the global prevalence of anemia in anorexia nervosa patient.

**Methods** Systematic searching was applied (by August 10, 2024) in databases of PubMed, Scopus, WoS, ScienceDirect, Embase, and the Google Scholar search engine. Selected investigations were imported to the EndNote Citation Management Software and duplicate papers were merged. Following consideration of inclusion and exclusion criteria (during primary and secondary screening) relevant papers were selected and underwent validation. Finally, eligible papers were selected for data extraction and meta-analysis (CMA v.2). The I2 index was used for heterogeneity assessment, and the Random Effect Model was used for meta-analysis. The results were categorized based on hematocrit and hemoglobin levels, and study type, and meta-regression was also applied for sample size and year of paper publication.

**Results** In the review of 9 eligible studies, the global prevalence of anemia in anorexia nervosa patient was found to be 44.8% (95%CI:25.7–65.7). Also, this value was detected in 48% (95%CI:19.9–77.4) and 43.4% (95%CI:18.6–72) based on hematocrit and hemoglobin levels, respectively. Meta-regression analysis showed that following the increase in sample size and year of paper publication, the global prevalence of anemia in Anorexia nervosa patient decreased and increased, respectively.

**Conclusion** A relatively high prevalence of anemia in individuals with anorexia nervosa requires proper attention to the regular blood monitoring and laboratory evaluations of the patients.

**Keywords** Prevalence, Anemia, Anorexia, Meta-analysis, Systematic review

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## Background

Anorexia nervosa is known as a mental disorder caused by reduced food intake, weight loss, and malnutrition due to the fear of weight gain [1]. Along with genetic basis, the anorexia nervosa appears through many risk factors [2] including anxiety, perfectionism, and social or cultural traditions [3].

In recent years, the prevalence of anorexia nervosa has increased dramatically, especially among youngers [4]. In a study, the prevalence of anorexia nervosa was reported at 0.16% [5], and other investigations reported different statistics of anorexia nervosa prevalence in different geographical areas [6–8]. The prevalence of anemia among Iranians anorexia nervosa was calculated at 1% [6], 0.8% in Malaysia, and 0.36% in Spain [7, 8].

Although anorexia nervosa is known as a mental disorder, it usually leaves detrimental effects on physical health such as gastrointestinal disorders, cerebral atrophy, dermatopathologies, fertility challenges, muscle degeneration, and growth suppression [9]. All previously mentioned complications were developed by the lack of proper nutritional intake and higher risks of sudden death [2, 9].

Also, the anorexia nervosa can affect other body organs such as the cardiovascular system (causes cardiac atrophy and low blood pressure) and Hematopoiesis irregularities (causes anemia) [9]. Anemia can be diagnosed based on hemoglobin and hematocrit levels in laboratory diagnostics, which vary by gender [10]. Based on Hemoglobin is the protein contained in red blood cells that is responsible for the delivery of oxygen to the tissues. To ensure adequate tissue oxygenation, a sufficient hemoglobin level must be maintained. The amount of hemoglobin in whole blood is expressed in grams per deciliter (g/dl). The normal Hb level for males is 14 to 18 g/dl; that for females is 12 to 16 g/dl. When the hemoglobin level is low, the patient has anemia. An erythrocytosis is the consequence of too many red cells; this results in hemoglobin levels above normal [10]. The hematocrit measures the volume of red blood cells compared to the total blood volume (red blood cells and plasma). The normal hematocrit for men is 40 to 54%; for women it is 36 to 48% [10].

Anemia is also associated with unpleasant physical and mental complications [11–14] with adverse effects on the immune system (higher risks of diseases) [12], functional impairment of the brain, fatigue [10], and depression [11]. Totally, the severely reduced quality of life is probable in anemic people. Anemia may be underdiagnosed or overlooked in AN patients. This could be because due to the main focus on diagnosing and examining anorexia nervosa, other disorders in these patients are overshadowed and not diagnosed. Therefore, this study, in addition to emphasizing the importance of paying attention

to anemia in these patients, emphasizes that in diagnosing a disease, other disorders in patients may also be overlooked. Thus, according to the adverse effects of anemia among individuals with anorexia nervosa, as well as different published reports in this regard, the present study aimed to determine the global prevalence of anemia in anorexia nervosa patient. The reports of the present study can be considered as a reliable and effective basis for the evaluation of anemia in anorexia nervosa sufferer.

## Methods

### Inclusion and exclusion criteria

Included studies were all investigations reporting the prevalence of anemia in anorexia nervosa patient with extractable available full texts. All included observational studies (including cross-sectional, retrospective observational (cohort), and case-control) were published in English-language studies and non-English-language studies with English abstracts. Besides, case reports, case series, reviews, duplicates, and non-English papers were totally excluded.

### Paper selection

All process of paper selection was carried out based on the guidelines of PRISMA by August 10, 2024. Systematic searching was conducted in valid databases of PubMed, Scopus, WoS, Embase, ScienceDirect, and Google Scholar search engine using keywords of “Prevalence”, “Anemia”, “Iron deficiency”, and “Anorexia”. Relevant keywords were considered based on the PICO criteria. Population (P) patients with anorexia nervosa, Intervention (I): no intervention, Comparison (C): comparison with patients with anorexia nervosa who did not report anemia. Outcome (O) was: prevalence of anemia in patients with anorexia nervosa. The references of gathered investigations were also checked manually to cover the maximum number of eligible studies. Selected papers were transferred to the EndNote Citation Management Software with no restrictions on the year of publication. Duplicate papers were detected and merged and the remaining articles were assessed by Title and Abstract. Then, full texts were assessed and eligible articles were selected. Whole screening processes of paper selection were applied by two researchers, independently and the corresponding author was responsible for the management of any probable contradiction of data.

In this study, an attempt was made to examine gray literature, which refers to evidence and documentation that has not been printed or published for any reason, as well as theses conducted in the country from which articles have not been extracted. For this purpose, the authors conducted a general search on the Google and Google Scholar search engines and reviewed sites related to the

topic, as well as communicating with the authors of these articles via email. These texts were identified by examining them in EndNote software and checking the source of these texts to see if they had a reliable and trustworthy source or if they were only reported on one site.

PubMed search: (((((Anemia [Title/Abstract]) AND (Iron deficiency [Title/Abstract])) OR (Hypoferritinemia [Title/Abstract])) OR ( Latent Iron Deficiency [Title/Abstract])) AND (Anorexia [Title/Abstract])) OR (Anorexia Nervosa [Title/Abstract] AND (Prevalence [Title/Abstract])))). Web of science search: ALL= (“Anemia " AND " Anemia " OR " Hypoferritinemia " OR " Latent Iron Deficiency " AND " Anorexia " AND " Anorexia Nervosa" " AND " Prevalence “). Scopus search: TITLE-ABS-KEY (“Anemia " AND " Anemia " OR " Hypoferritinemia " OR " Latent Iron Deficiency " AND " Anorexia " AND " Anorexia Nervosa" " AND " Prevalence “). ScienceDirect and Embase search: Title, abstract or author-specified keywords (“Anemia " AND " Anemia " OR " Hypoferritinemia " OR " Latent Iron Deficiency " AND " Anorexia " AND " Anorexia Nervosa" " AND " Prevalence “).

#### Paper quality assessment

The Newcastle-Ottawa Scale (NOS) was used to assess quality in this study. The NOS assigns up to a maximum of nine points for the least risk of bias in three domains: 4 points for the selection of study groups; 2 points for comparability of groups and 3 points for ascertainment of exposure and outcomes for case-control and cohort studies, respectively, and 11 scores possible. Eventually, articles were classified as high quality (scoring  $\geq 5$  points) or low quality (scoring  $< 5$  points) [15].

#### Data extraction and meta-analysis

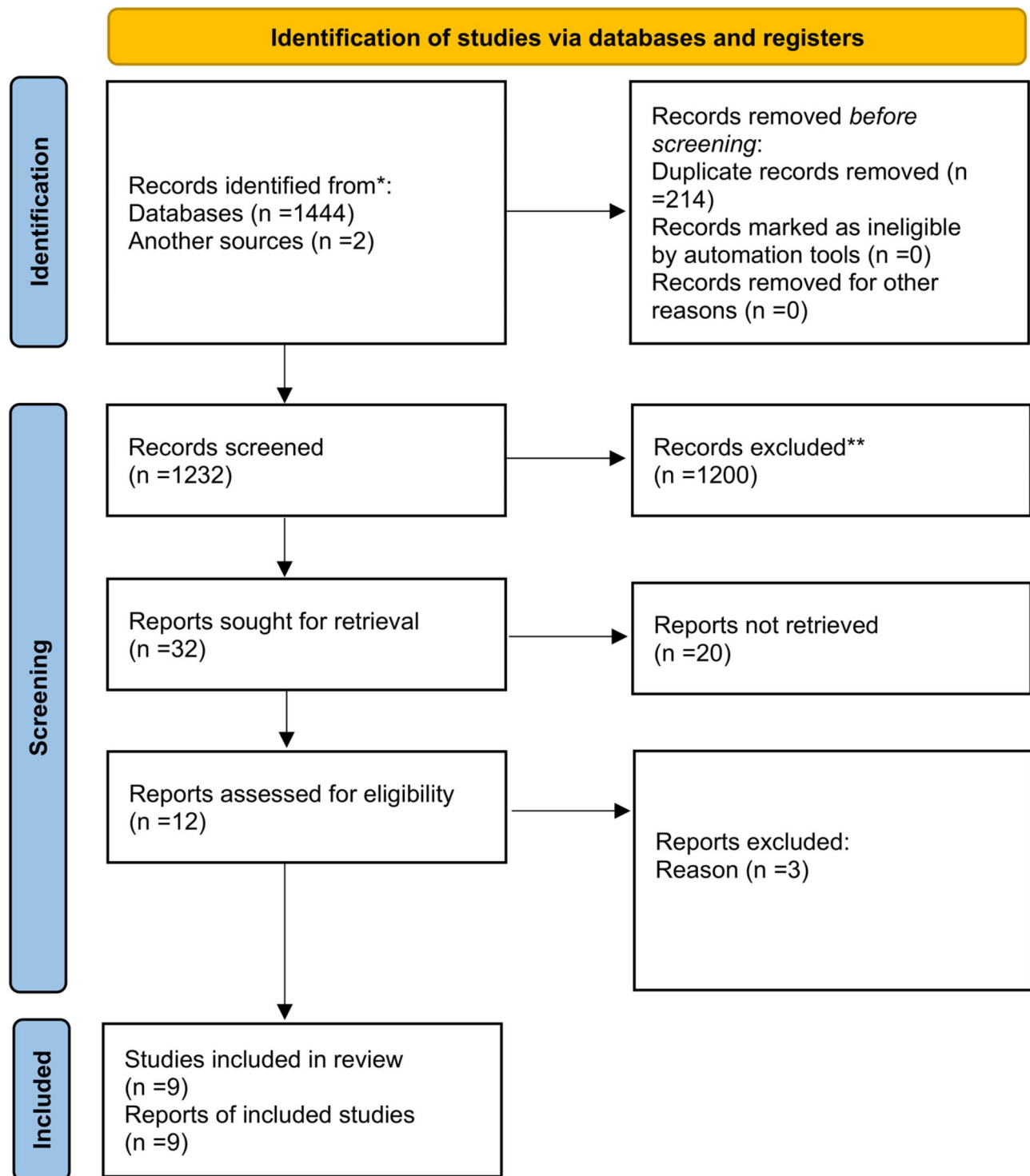
In order to extract data, a checklist was designed including the “Name of the first author”, “Year of paper publication”, “Location of study”, “Type of study”, “Sample size”, “Prevalence of anemia in anorexia nervosa patients”, “Mean age”, and “Study tools for anemia reports”. The results extracted from different studies were imported into the Comprehensive Meta-Analysis software v.2. The heterogeneity of the studies was examined using the  $I^2$  index, and based on this, the fixed effects model was used in low heterogeneity and the random effects model in high heterogeneity. The publication bias in the reviewed studies was examined using the Funnel Plot and the Egger test, and in order to examine the factors affecting the heterogeneity of the studies, meta-regression was used to examine the two factors of sample size and year of study, as well as subgroup analysis was used to examine the two factors of diagnosis type and type of studies. The significance level was considered as  $p$ -value  $< 0.05$ .

#### Results

In primary searching, 1444 studies were obtained (2 investigations were selected by manual searching in Google Scholar). Following the exclusion of duplicate papers, 1232 studies underwent primary and secondary screening. In this regard, 1200 irrelevant papers were also excluded. Then, full texts were evaluated and 20 studies were removed according to the inclusion/exclusion criteria. Among the 12 remaining investigations, 3 low-quality studies were also ignored. Finally, 9 high-quality extractable studies were selected for data extraction. Eligible papers were published from 1993 to 2024 (Fig. 1; Table 1) [16–23]. The maximum prevalence of anemia in anorexia nervosa patients was associated with the study of Sabel et al. in the German population as 83% (calculated based on the hematocrit level) [16] and the lowest value was detected among Italian female patients reported by Filippo et al., as 16.7% (calculated based on the hemoglobin level) [17].

In the review of 9 studies with a sample size of 1512 individuals with anorexia nervosa, the  $I^2$  heterogeneity test was found at a high value ( $I^2:97.7$ ); thus, the Random Effect Model was used to analyze the results. According to the meta-analysis, the global prevalence of anemia in anorexia nervosa patients was 44.8% (95%CI:25.7–65.7) (Fig. 2). In the forest plot figure, the black square represents the prevalence rate and the length of the line segment on which the square is located is the 95% confidence interval in each study, while the diamond symbol represents the prevalence rate in all studies (Fig. 2). A funnel plot is a scatterplot that plots the logit event rate on the horizontal axis and the standard error of each study on the vertical axis. In meta-analyses without publication bias, a funnel plot resembles a funnel with the effect size of studies with small sample sizes and high variance at the large end. The effect size of studies with large sample sizes and smaller variance at the small end of the funnel (Fig. 3) the Egger test showed no publication bias among the reports ( $p:0.738$ ) (Fig. 3). Sensitivity analysis was performed to ensure stable results, and based on Fig. 4, it is reported that after removing the results of each study, the overall study result will not change very significantly (Fig. 4).

Meta-regression analysis showed that following the increase in sample size (Fig. 5) and year of paper publication (Fig. 6), the global prevalence of anemia in anorexia nervosa patients decreased and increased, respectively ( $p < 0.05$ ). According to the results of Table 2 representing the global prevalence of anemia in anorexia nervosa patients categorized based on hemoglobin and hematocrit groups, the highest prevalence of anorexia nervosa in patients based on hematocrit test was reported 48% (95%CI:19.9–77.4). In order to investigate the factors affecting the heterogeneity of studies, subgroup analysis



**Figs. 1** PRISMA flow diagram for identification of relevant studies

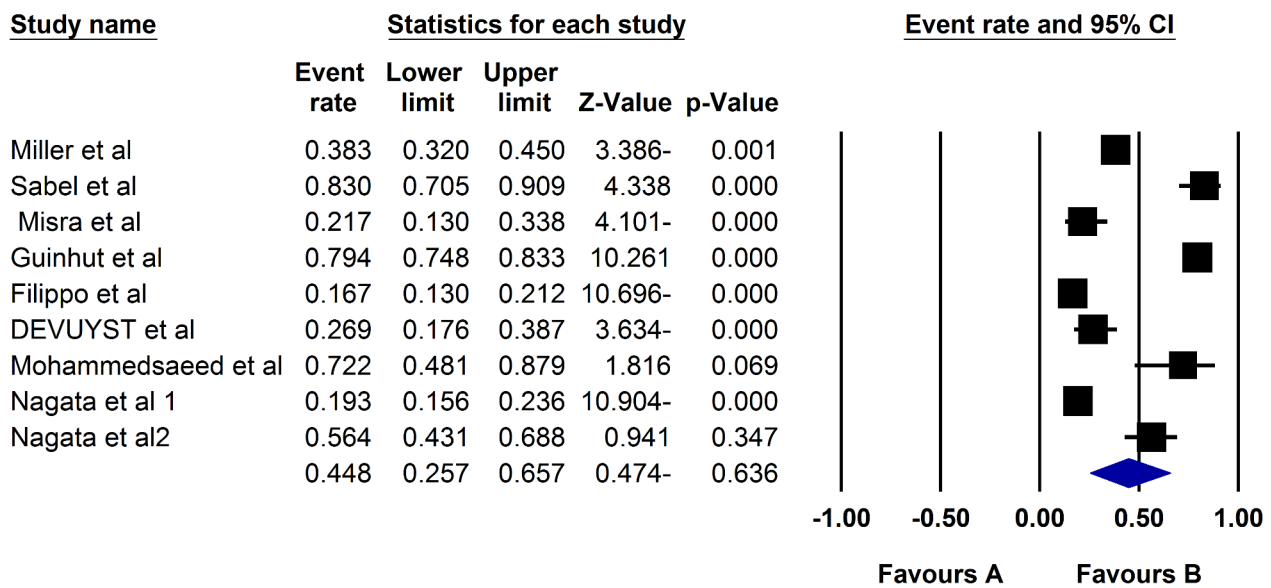
was performed to examine the effect of the type of diagnosis as well as the type of studies examined in the meta-analysis. Due to the limited number of studies on this topic, we used all methods of cross-sectional, case-control, and retrospective cohort studies, so analysis was also

performed based on the type of study, but since there was only one case-control study in the study, no analysis was performed for case-control studies. Accordingly, the global prevalence of anemia in patients with anorexia nervosa was reported based on cross-sectional studies

**Table 1** Extracted data from eligible included papers

First author	Type-study	Year	Country	Age Range (years)	Sample size (n)	Prevalence (%)	Analysis of laboratory test	HCT or HB levels	NOS scores
Miller et al. [18]	Cross-sectional	2005	USA	17–45 (25.0±6.4)	214	38.60	Hematocrit (HCT)	-	7
Sabel et al. [16]	Cross-sectional	2013	Germany	17–65	53	83	Hematocrit (HCT)	HCT < 37%	9
Misra et al. [19]	Cross-sectional	2015	USA	15.86±1.6	60	22	Hematocrit (HCT)	HCT < 37%	7
Guinhut et al. [20]	retrospective observational	2021	France	15–65 (28.7±10.7)	354	79	Hemoglobin (HB)	HB < 13 g/dl for male HB < 12 g/dl for female	10
Filippo et al. [17]	Cross-sectional	2016	Italy	14–47 (20.4±5.6)	318	16.70	Hemoglobin (HB)	HB < 12 g/dl	10
DEVUYST et al. [21]	case-control	1993	Belgium	10–30 (18.7±3.8)	67	27	Hemoglobin (HB)	HB < 120gr/l	6
Mohammedsaeed et al. [22]	Cross-sectional	2024	Saudi Arabia	18–50	18	72.20	Hemoglobin (HB)	HB < 12gr/dl	10
Nagata et al. [23]	retrospective observational	2024	USA	9–25	373	19.30	Hemoglobin (HB)	HB < 11.8gr/dl	10
Nagata et al. [23]	retrospective observational	2024	USA	9–25	55	56.36	Hemoglobin (HB)	HB < 13.6gr/dl	11

## Meta Analysis



### Meta Analysis

**Fig. 2** Forest plot representing the global prevalence of anemia in patients with anorexia nervosa based on the Random Effect Model

### Funnel Plot of Standard Error by Logit event rate

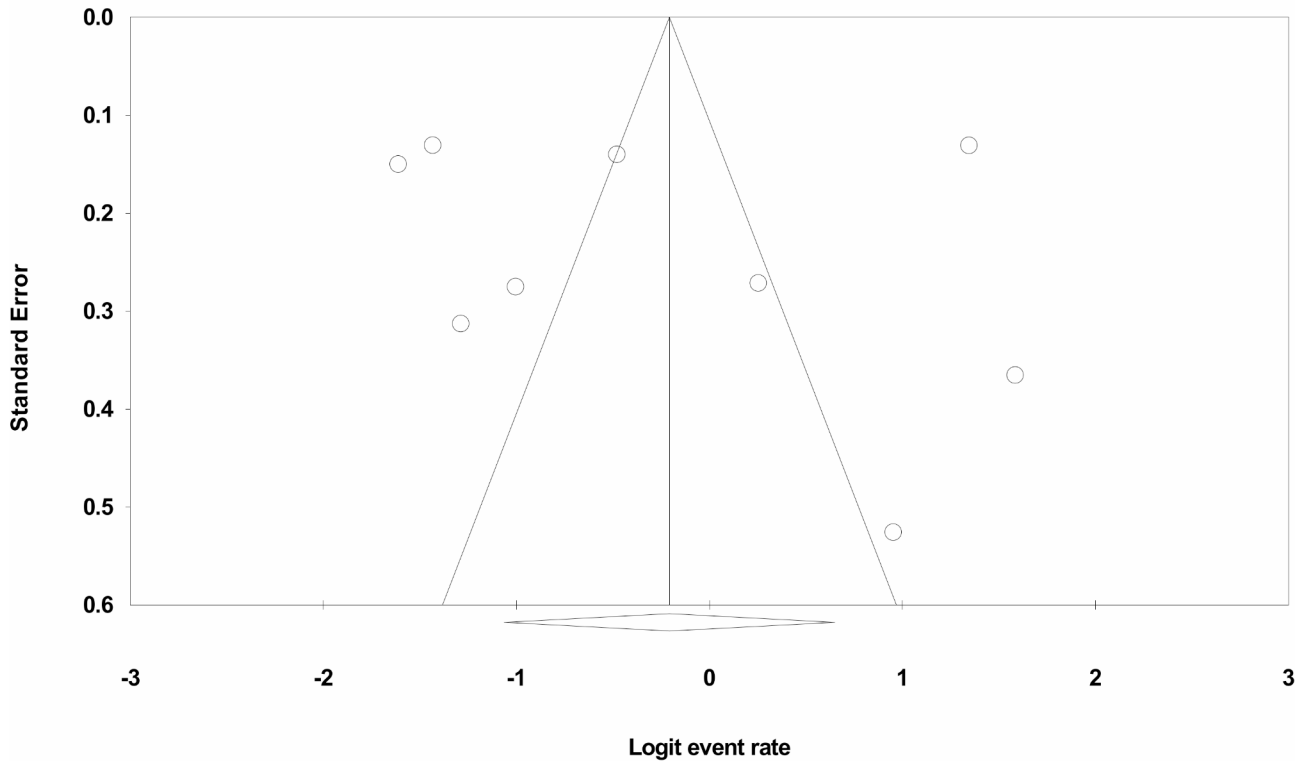
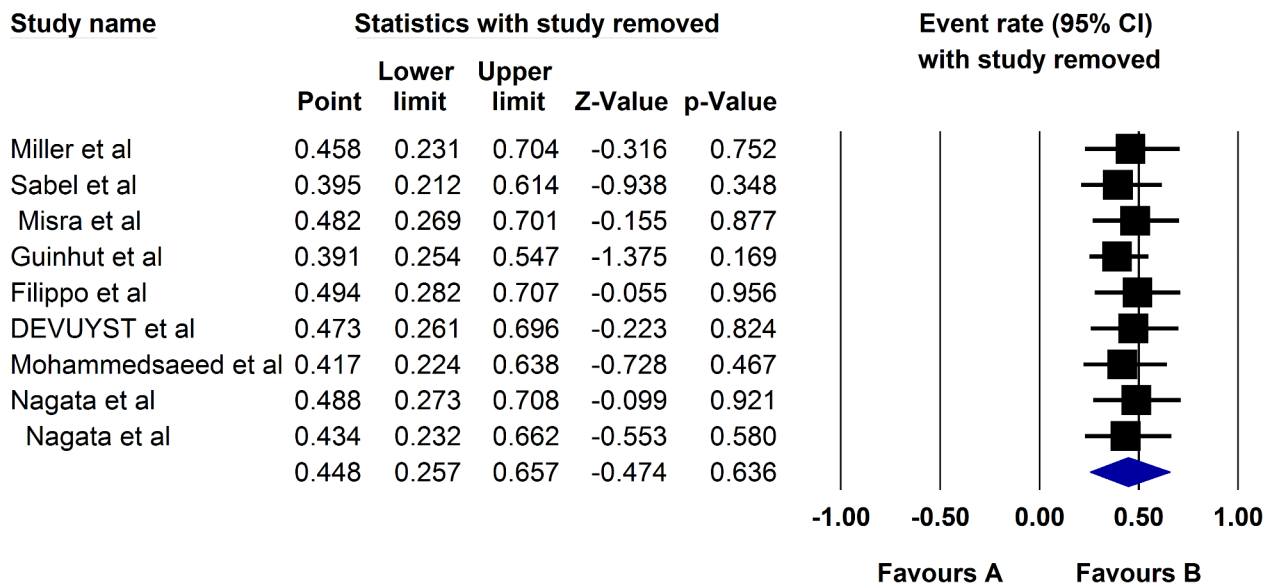


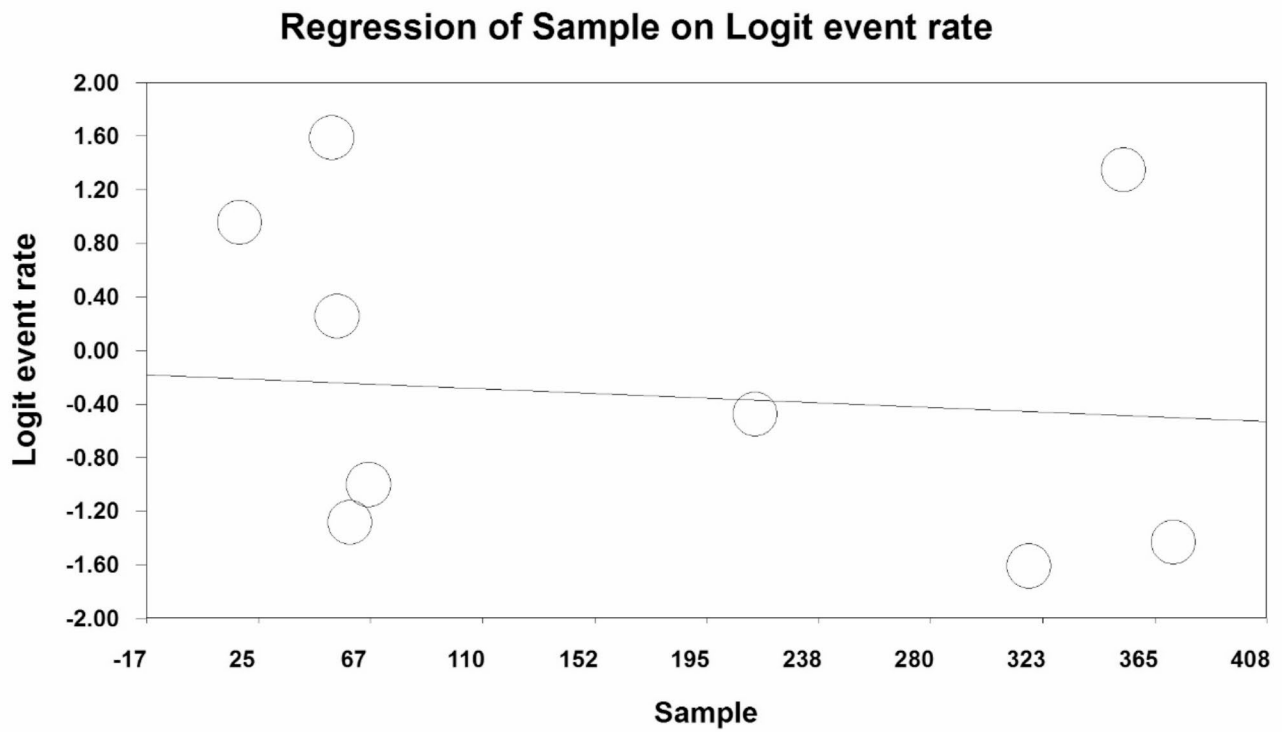
Fig. 3 Funnel plot representing distribution bias in the reviewed studies

## Meta Analysis

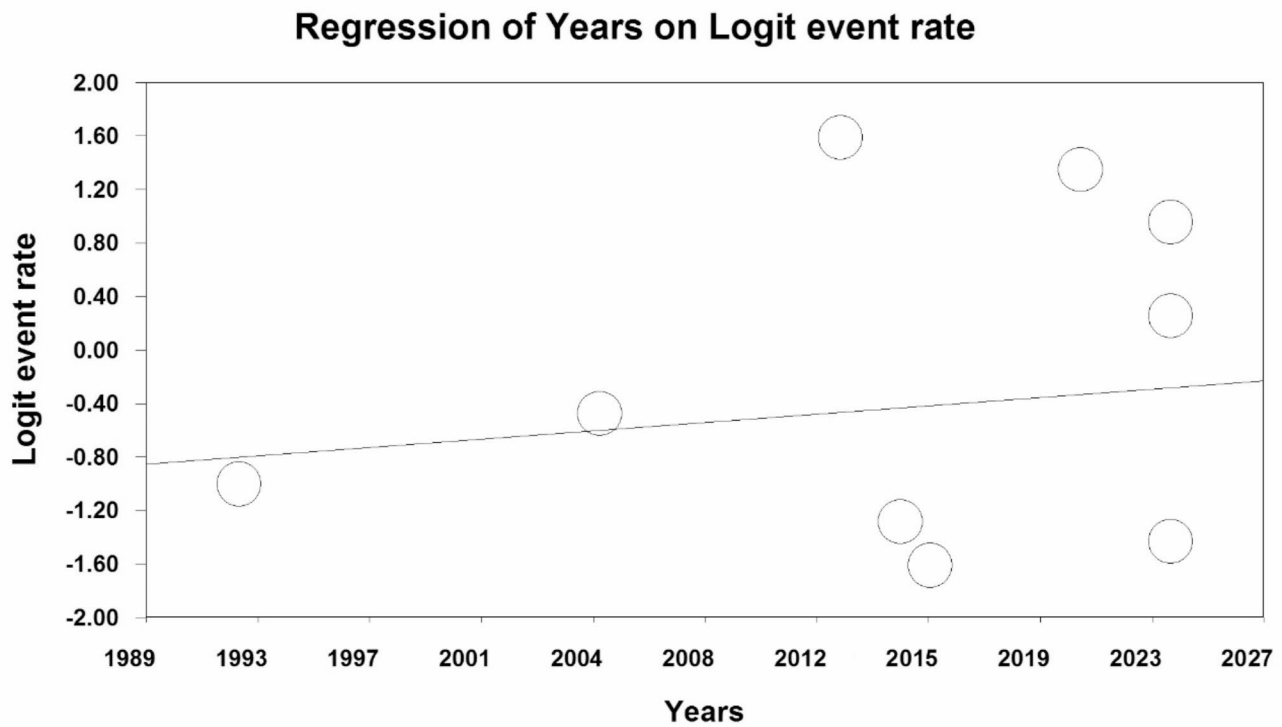


### Meta Analysis

Fig. 4 Results of sensitivity analysis



**Fig. 5** Meta-regression analysis regarding the role of sample size on the global prevalence of anemia in patients with anorexia nervosa



**Fig. 6** Meta-regression analysis regarding the role of the year of paper publication on the global prevalence of anemia in patients with anorexia nervosa

**Table 2** The global prevalence of anemia in patients with anorexia nervosa based on diagnosis by hemoglobin and hematocrit levels

Sub-group		N	Sample size (n)	I <sup>2</sup>	Egger test	Prevalence (95% CI)
Diagnosis type	Hemoglobin	6	1185	98.4	0.893	43.4 (95%CI: 18.6–72)
	Hematocrit	3	327	94.6	0.748	48 (95%CI: 19.9–77.4)
Study type	cross-sectional	5	663	95.5	0.328	44.4 (95%CI: 23.1–67.9)
	retrospective observational	3	782	99.1	0.954	51.4 (95%CI: 13.1–88.1)

44.4 (95%CI: 23.1–67.9) and retrospective observational studies 51.4 (95%CI: 13.1–88.1) (Table 2).

## Discussion

In the current systematic review and meta-analysis, the global prevalence of anemia in anorexia nervosa patients was found 44.8%. As mentioned previously, anorexia nervosa as a psychiatric disorder occurs following dysmorphia and fear of obesity. anorexia nervosa lead to low food intake [2, 24] and psychosomatic changes [24]. In this pathology, bone marrow fat turns into a type of mucopolysaccharide affecting progenitor cells and hematopoiesis-associated factors [9]. Accordingly, the prevalence of some hematological manifestations such as anemia in people with anorexia nervosa was examined in various studies [20, 22, 23].

Meta-regression analysis showed that as the year of publication of the article increases, the global prevalence of anemia in anorexia nervosa patients increases, which may indicate the importance of this disease in anorexia nervosa patients and the increased use of diagnostic tests, as well as physicians' awareness of the importance of anemia in these patients.

In line with the results of the present study, Miller et al. reported the prevalence of anemia in American anorexia nervosa woman (17–45 years) as 38.6% [18]. Also, in another related study conducted in the USA, the prevalence of anemia in men was 56.36% [23]. However, in the study of Gwin Hutt et al., 79% of adult French participants were diagnosed with anemia [20]. Another cross-sectional study conducted in Germany showed an abnormal level of hemoglobin among 83% of affected anorexia nervosa women and men [16], which is relatively higher compared to the results of the present study. As mentioned in studies, the severity of disease is one of the factors affecting the levels of symptoms and complications [9]. Changes and differences in reported prevalence in different regions of the world can be affected by dietary habits and lifestyle-related dietary patterns, diverse diagnostic methods, and health systems in these countries, which ultimately lead to differences in prevalence reports in these countries.

Thus, the high severity of anorexia nervosa among the participants causes a high prevalence of anemia. In the study by Filippo et al., 16.7% of Italian women with anorexia nervosa were identified as anemic individuals [17].

Also, another study reported the prevalence of anemia at 19.3% among female sufferers [23], less value than other reports. According to the studies, in addition to nutrition and type of diet, some underlying diseases (including infection, inflammation, and congenital disorders) can increase the rate of anemia [25, 26]. Although some underlying diseases and infectious agents were recognized as the second most common cause of anemia, some gastrointestinal diseases or autoimmune pathologies were introduced as a cause of anemia [27, 28].

The Mediterranean diet may have a protective role in reducing the incidence of hematological changes, although calorie intake in these patients has been reported to be low. However, it has been observed that hematological abnormalities in this selected sample of patients with anorexia nervosa are strictly related to the duration of the disease [29]. It has also been reported that increased levels of Preadipocyte Factor Pref-1, a member of the epidermal growth factor protein family and a regulator of adipocyte and osteoblast differentiation, have been reported in patients with anorexia nervosa, and it has been suggested that since osteoblasts are closely associated with hematopoiesis, it can be speculated that their reduction in production, following increased secretion of Pref-1, could interfere with hematopoiesis in individuals with anorexia nervosa [29, 30]. It has also been suggested that leptin plays a role in the development of hematopoietic bone marrow through hematopoietic stimulating factors. An imbalance in the leptin/Pref-1 ratio could lead to another disruption of the microenvironment with subsequent interference with hematopoiesis in patients with anorexia nervosa [30, 31]. Thus, such diseases can affect the prevalence of anemia along with different social, cultural, or lifestyle conditions [28] and different evaluation criteria justify the heterogeneity among the studies. The results of this study emphasize the importance of diagnosing anemia in patients with anorexia nervosa and suggest that screening protocols or treatment guidelines for patients with anorexia nervosa should include diagnostic tests for anemia and other related disorders.

## Limitations

The small number of related studies, especially investigations reporting the prevalence of anemia among anorexia nervosa men was the main limitation of this research. In addition, non-English published papers (of course, an attempt was made to review the English abstracts of

these studies if they existed, but if there were no English abstracts for non-English language articles, these studies were not considered.), non-random selection of participants in some studies, and different criteria for anemia status assessment were other limitations of the present study. The lack of provision and disaggregation of additional information on gender distribution in all studies also made it impossible to conduct subgroup analysis based on gender. Another limitation of this study was the high heterogeneity in the meta-analysis, which is natural given the different age groups, different years of study, different races, and different methods in the studies reviewed. An attempt was made to respond to this high heterogeneity using meta-regression and subgroup analyses. However, this heterogeneity is one of the limitations of the study and can reduce the reliability of the meta-analysis.

## Conclusion

The results of this research showed that anemia is seen in 44.8% of patients with anorexia nervosa; thus, hematological evaluation of affected patients and frequent check-ups of blood factors seem necessary in this regard. Health measures adopted can reduce the complications and burden caused by anemia in individuals with anorexia nervosa. Therefore, in terms of health policy, to increase awareness measures among families and patients with anorexia nervosa regarding anemia, increasing screening and diagnostic measures for patients with anorexia nervosa, as well as increasing awareness among doctors and nurses to pay attention to anemia in these patients, can be considered. Also, based on the results of this study, physicians should consider diagnosing and examining anemia in anorexia nervosa patients and, when dealing with these patients, consider performing diagnostic tests for these patients.

## Abbreviations

CS	Cross-sectional
HCT	Hematocrit
HB	Hemoglobin

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## Author contributions

NS and SR and MM contributed to the design, MM statistical analysis, and participated in most of the study steps. MM and AA and PH prepared the manuscript. MM and AR and SR and SHSH assisted in designing the study, and helped in the interpretation of the study. All authors have read and approved the content of the manuscript.

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## Data availability

Datasets are available through the corresponding author upon reasonable request.

## Declarations

### Ethics approval and consent to participate

Ethical approval was received from the ethical committee of deputy of research and technology, Kermanshah University of Medical Sciences (IR.KUMS. REC.1403.559).

### Consent for publication

Not applicable.

### Competing interests

The authors declare no competing interests.

### Clinical trial number

not applicable.

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## References

1. Adams DM, Reay WR, Cairns MJ. Multiomic prioritisation of risk genes for anorexia nervosa. *Psychol Med.* 2023;53(14):1–9. <https://doi.org/10.1017/S0033291723000235>.
2. Neale J, Hudson LD. Anorexia nervosa in adolescents. *British journal of hospital medicine (London, England: 2005).* 2020;81(6):1–8. <https://doi.org/10.12968/hmed.2020.0099>
3. Edakubo S, Fushimi K. Mortality and risk assessment for anorexia nervosa in acute-care hospitals: a nationwide administrative database analysis. *BMC Psychiatry.* 2020;20(1):19. <https://doi.org/10.1186/s12888-020-2433-8>.
4. Søebye M, Gribsholt SB, Clausen L, Richelsen B. Fracture risk in patients with anorexia nervosa over a 40-Year period. *J Bone Mineral Research: Official J Am Soc Bone Mineral Res.* 2023;38(11):1586–93. <https://doi.org/10.1002/jbmr.4901>.
5. Qian J, Wu Y, Liu F, Zhu Y, Jin H, Zhang H, et al. An update on the prevalence of eating disorders in the general population: a systematic review and meta-analysis. *Eat Weight Disorders: EWD.* 2022;27(2):415–28. <https://doi.org/10.1007/s40519-021-01162-z>.
6. Hashemi SH, Hosseini SH, Moosazadeh M, Shamspour M, Hajizadeh-Zaker R, Hashemi SB. Prevalence of eating disorders in Iran from preschool to old age: A systematic review and Meta-analysis. *J Pediatr Rev.* 2022;10(3):175–90. <https://doi.org/10.32598/jpr.10.3.1026.1>.
7. Sandri E, Cantin Larumbe E, Cerdá Olmedo G, Luciani G, Mancin S, Sguanci M, et al. Anorexia and bulimia nervosa in Spanish Middle-Aged adults: links to sociodemographic factors, diet, and lifestyle. *Nutrients.* 2024;16(16):2671. <https://doi.org/10.3390/nu16162671>.
8. Chua SN, Fitzsimmons-Craft EE, Austin SB, Wilfley DE, Taylor CB. Estimated prevalence of eating disorders in Malaysia based on a diagnostic screen. *Int J Eat Disord.* 2022;55(6):763–75. <https://doi.org/10.1002/eat.23711>.
9. Cost J, Krantz MJ, Mehler PS. Medical complications of anorexia nervosa. *Cleve Clin J Med.* 2020;87(6):361–6. <https://doi.org/10.3949/ccjm.87a.19084>.
10. Himmerich H, Treasure J. Anorexia nervosa: diagnostic, therapeutic, and risk biomarkers in clinical practice. *Trends Mol Med.* 2024;30(4):350–60. <https://doi.org/10.1016/j.molmed.2024.01.002>.
11. Nam HK, Park J, Cho SI. Association between depression, anemia and physical activity using isotemporal substitution analysis. *BMC Public Health.* 2023;23(1):2236. <https://doi.org/10.1186/s12889-023-17117-1>.
12. Aynalem M, Shiferaw E, Adane T, Gelaw Y, Enawgaw B. Anemia in African malnourished pre-school children: A systematic review and meta-analysis. *SAGE Open Med.* 2022;10:20503121221088433. <https://doi.org/10.1177/20503121221088433>.
13. Karndumri K, Tantiworawit A, Hantrakool S, Fanhchaksai K, Rattarittamrong E, Limsukon A, Pruksakorn D, Karndumri S, Rattanathammethee T, Chai-Adisaksotha C, Norasetthada L. Comparison of hemoglobin and hematocrit levels at 1, 4 and 24 h after red blood cell transfusion. *Transfus Apher Sci.* 2020;59(1):102586.
14. Myers GJ, Browne J. Point of care hematocrit and hemoglobin in cardiac surgery: a review. *Perfusion.* 2007;22(3):179–83.
15. Alpoim PN, de Barros Pinheiro M, Junqueira DR, Freitas LG, das Gracas Carvalho M, Fernández AP et al. Preeclampsia and ABO blood groups: a systematic review and metaanalysis. *Mol Biol Rep.* 2012;40:2253–2261.

16. Sabel AL, Gaudiani JL, Statland B, Mehler PS. Hematological abnormalities in severe anorexia nervosa. *Ann Hematol.* 2013;92(5):605–13. <https://doi.org/10.1007/s00277-013-1672-x>.
17. De Filippo E, Marra M, Alfinito F, Di Guglielmo ML, Majorano P, Cerciello G, et al. Hematological complications in anorexia nervosa. *Eur J Clin Nutr.* 2016;70(11):1305–8. <https://doi.org/10.1038/ejcn.2016.115>.
18. Miller KK, Grinspoon SK, Ciampa J, Hier J, Herzog D, Klibanski A. Medical findings in outpatients with anorexia nervosa. *Arch Intern Med.* 2005;165(5):561–6. <https://doi.org/10.1001/archinte.165.5.561>.
19. Misra M, Aggarwal A, Miller KK, Almazan C, Worley M, Soyka LA, et al. Effects of anorexia nervosa on clinical, hematologic, biochemical, and bone density parameters in community-dwelling adolescent girls. *Pediatrics.* 2004;114(6):1574–83. <https://doi.org/10.1542/peds.2004-0540>.
20. Guinhut M, Melchior JC, Godart N, Hanachi M. Extremely severe anorexia nervosa: hospital course of 354 adult patients in a clinical nutrition-eating disorders-unit. *Clin Nutr.* 2021;40(4):1954–65. <https://doi.org/10.1016/j.clnu.2020.09.011>.
21. Devuyst O, Lambert M, Rodhain J, Lefebvre C, Coche E. Haematological changes and infectious complications in anorexia nervosa: a case-control study. *Q J Med.* 1993;86(12):791–9.
22. Mohammadsaeed W, El Shikieri AB. Cardiometabolic risk factors among women with eating disorders in Saudi Arabia. *J Nutr Metabolism.* 2024;2024. <https://doi.org/10.1155/2024/5953893>
23. Nagata JM, Vargas R, Sanders AE, Stuart E, Downey AE, Chaphekar AV, et al. Clinical characteristics of hospitalized male adolescents and young adults with atypical anorexia nervosa. *Int J Eat Disord.* 2024;57(4):1008–19. <https://doi.org/10.1002/eat.24132>.
24. Resmark G, Herpertz S, Herpertz-Dahlmann B, Zeeck A. Treatment of anorexia Nervosa-New Evidence-Based guidelines. *J Clin Med.* 2019;8(2). <https://doi.org/10.3390/jcm8020153>.
25. Deivita Y, Syafruddin S, Andi Nilawati U, Aminuddin A, Burhanuddin B, Zahir Z. Overview of anemia; risk factors and solution offering. *Gac Sanit.* 2021;35(Suppl 2):S235–41. <https://doi.org/10.1016/j.gaceta.2021.07.034>.
26. Andersen CT, Tadesse AW, Bromage S, Fekadu H, Hemler EC, Passarelli S, et al. Anemia etiology in Ethiopia: assessment of nutritional, infectious disease, and other risk factors in a Population-Based Cross-Sectional survey of women, men, and children. *J Nutr.* 2022;152(2):501–12. <https://doi.org/10.1093/jn/nxab366>.
27. Kundu S, Alam SS, Mia MA, Hossan T, Hider P, Khalil MI, et al. Prevalence of anemia among children and adolescents of Bangladesh: A systematic review and Meta-Analysis. *Int J Environ Res Public Health.* 2023;20(3). <https://doi.org/10.3390/ijerph20031786>.
28. Abaynew Y, Ali A, Taye G, Shenkut M. Prevalence and types of anemia among people with tuberculosis in Africa: a systematic review and meta-analysis. *Sci Rep.* 2023;13(1):5385. <https://doi.org/10.1038/s41598-023-32609-1>.
29. Marra M, Caldara A, Montagnese C, De Filippo E, Pasanisi F, Contaldo F, et al. Bioelectrical impedance phase angle in constitutionally lean females, Ballet dancers and patients with anorexia nervosa. *Eur J Clin Nutr.* 2009;63:905–8.
30. De Filippo E, Marra M, Alfinito F, Di Guglielmo ML, Majorano P, Cerciello G, De Caprio C, Contaldo F, Pasanisi F. Hematological complications in anorexia nervosa. *Eur J Clin Nutr.* 2016;70(11):1305–8.
31. Zhang J, Wang N. Leptin in chronic kidney disease: a link between hematopoiesis, bone metabolism, and nutrition. *Int Urol Nephrol.* 2013;46:1169–74.

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