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Prevalence of Anaemia and Low Ferritin Among Female Health Sciences Students at a Palestinian University

Fekri Samarah

fekri.samarah@aaup.edu

Arab American University

Omar Samarah

An-Najah National University

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Abstract

Background. Haemoglobin and ferritin identify overlapping but non-equivalent dimensions of iron status. We estimated the frequency of anaemia, low ferritin and their concurrence, and examined selected associations within a defined cohort of Palestinian female health sciences students.

Methods. This cross-sectional analysis included 300 students aged 18–25 years. Anaemia was defined as haemoglobin < 12 g/dL, low ferritin as < 15 µg/L, and concurrence of both as an operational indicator consistent with iron-deficiency anaemia. Four exclusive categories and Wilson 95% confidence intervals were calculated. Recorded questionnaire characteristics were examined with an exploratory modified Poisson model using robust variance; algebraically derived blood indices were distinguished from recorded measurements.

Results. Anaemia was observed in 135 participants (45.0%) and low ferritin in 175 (58.3%). Both occurred in 108 (36.0%, 95% CI 30.8–41.6%), while 67 (22.3%) had low ferritin without anaemia, 27 (9.0%) had anaemia without low ferritin and 98 (32.7%) had neither. Concurrent-low participants had lower median MCV (76.7 vs 85.2 fL) and calculated transferrin saturation (8.3% vs 24.8%) than those with neither threshold low. In an exploratory adjusted model, the lowest versus highest household-income band was associated with greater prevalence (aPR 2.14, 95% CI 1.11–4.15).

Conclusions. Combined assessment of haemoglobin and ferritin demonstrates that neither anaemia nor low ferritin alone adequately describes iron-related status in this university cohort. Associations with household income and selected questionnaire variables are context-bound and should not be interpreted as causal effects.

Background

Haemoglobin concentration and ferritin answer related but distinct questions. Haemoglobin below a population-specific threshold identifies anaemia without establishing its aetiology; ferritin helps characterise stored iron but is also influenced by inflammation [1, 2]. Iron depletion can precede a decline in haemoglobin, while the severity and morphology of anaemia depend on additional physiological and pathological conditions [3, 4]. This distinction matters before statistical comparison: a haemoglobin-only outcome overlooks participants with low iron stores but no anaemia, whereas an undifferentiated anaemia outcome includes cases for which low iron stores have not been demonstrated. The resulting denominators and interpretations need not coincide.

Anaemia is not a single aetiological entity. Global analyses have documented large differences in its burden across population groups and countries [5]; a synthesis of nationally representative surveys further showed that the proportion of anaemia associated with iron deficiency varies substantially across settings [6]. These population-level findings do not provide a direct benchmark for students enrolled at one university. They instead reinforce the need to specify the case definition and the population to which an estimate applies. Iron deficiency without anaemia also has a clinical literature of

its own [7]; however, classification based on ferritin alone warrants qualification where inflammatory information is unavailable [8].

Published estimates cannot be interpreted independently of outcome definition or recruitment context. Weyand et al. estimated iron deficiency and iron-deficiency anaemia separately among US females aged 12–21 years [9]. Owaidah et al. examined young Saudi university students from several regions, drawing a distinction between questionnaire respondents and those assessed in the laboratory [10]. Al Hassan reported anaemia among female students attending a university medical centre; that recruitment and outcome assessment differ from a population survey [11]. These accounts support attention to age, case ascertainment and sampling without implying that their reported percentages measure an identical condition.

The Palestinian literature provides several complementary perspectives. Sirdah et al. examined haemoglobin, ferritin, vitamin B12 and homocysteine among 240 university women in Gaza [12]. Jalambo et al. differentiated anaemia, iron deficiency and iron-deficiency anaemia in adolescent girls and included inflammatory assessment [13]. Qasrawi et al. investigated nutrient-intake patterns and anaemia in university women using a dietary assessment and computational models; their initial dataset contained 145 observations before synthetic minority oversampling increased the analytical dataset to 755 [14]. These studies address related but differently measured phenomena. They also show why a study's analytical contribution is defined by the question, measurement strategy and inferential limits, rather than an assertion of chronological novelty.

The present analysis focuses on the joint distribution of haemoglobin and ferritin thresholds and the associated questionnaire characteristics of students enrolled in four health-related faculties at one Palestinian university. Unlike a dietary-intake investigation, its questionnaire records food-group frequency and meal habits rather than validated quantitative iron intake; the distinction is methodologically consequential because dietary questionnaires require evaluation against their intended measurement task [15]. Iron absorption is also influenced by both meal composition and host iron status, making exposure labels such as breakfast frequency inadequate surrogates for bioavailable iron [16]. The laboratory data nevertheless permit separate reporting of low ferritin, anaemia and their overlap. These measurement boundaries guide the analysis and limit the claims that follow.

We aimed to estimate the frequency of anaemia, low ferritin and their concurrence; characterise the corresponding red-cell and biochemical profiles; and describe associations between the concurrent-low endpoint and selected self-reported socioeconomic and health characteristics.

Methods

Study design, recruitment and eligibility

This cross-sectional study was conducted at Arab American University, Jenin, Palestine, between February and June 2025. Female students aged 18–25 years enrolled in allied medical sciences, nursing,

pharmacy and dentistry were invited and informed about participation. The planned target sample size was 330, based on an assumed 30% prevalence and a five-percentage-point margin of error. Of 500 students invited, 190 did not participate, 310 initially enrolled and 10 identified as carriers of β-thalassaemia trait were excluded. The final analysis included 300 participants (62.0% initial response, 310/500; 60.0% included among those invited, 300/500).

Eligibility screening addressed pregnancy, specified haematological and medical conditions, and haemoglobinopathy status. Exclusion of the ten β-thalassaemia trait carriers followed haemoglobin fraction analysis. The self-reported menstrual-flow category “heavy” was not interpreted as a clinical diagnosis of quantified heavy menstrual bleeding.

Questionnaire and anthropometric variables

The questionnaire recorded age, residence, marital status, faculty, academic year, household income, family structure, selected food and beverage practices, smoking, exercise, menstrual-flow category, medical and medication history, and symptoms. Recorded answers are self-reported categories; they do not quantify dietary iron intake, tobacco exposure or menstrual blood-loss volume. BMI was available as a derived value in kg/m², without separate participant-level height and weight columns in the analytical file. All 300 included records contained values for the variables used in the analyses; no imputation was undertaken. Complete descriptive distributions are provided in Supplementary Table S2.

Haematological and biochemical measures

Venous blood was collected for complete blood counts and iron-profile assessments, using blood and serum specimens as appropriate. Study identifies the Medonic M Series for haematology, Abbott ARCHITECT c4000 for clinical chemistry and the Sebia Minicap Flex Piercing system for haemoglobin fraction analysis. The analytical dataset contains recorded RBC, haemoglobin, MCV, RDW, ferritin, serum iron and TIBC. For the standardised analytical file, haematocrit was derived as RBC × MCV/10, MCH as 10 × haemoglobin/RBC and MCHC as 100 × haemoglobin/haematocrit, with the stated units. Transferrin saturation (TSAT) was derived as 100 × serum iron/TIBC. These derived indices are algebraic functions of their recorded inputs, not additional independent assays.

Operational outcome definitions

Anaemia was defined as haemoglobin < 12.0 g/dL for non-pregnant adult women [1]; low ferritin was defined as < 15 µg/L, consistent with the WHO threshold for apparently healthy individuals [2]. Ferritin in ng/mL and µg/L has the same numerical value. Participants were assigned to four mutually exclusive groups: neither marker low; ferritin low only; haemoglobin low only; and both low. The latter group provides an operational proxy consistent with iron-deficiency anaemia under these thresholds. Because no inflammatory biomarker is available in this analytical file, a ferritin value at or above 15 µg/L cannot

exclude iron deficiency in every clinical circumstance. Serum iron, TIBC, TSAT, MCV and RDW were used for description rather than as mandatory additional diagnostic criteria. This < 15 µg/L definition is an explicitly chosen population threshold, not an assertion that all clinical guidance uses the same ferritin cut-off. Contemporary recommendations discuss other thresholds, complementary biomarkers and adjustments according to clinical and inflammatory context [17, 18]. The threshold-sensitivity analyses below therefore quantify classification dependence without retrospectively redefining the primary outcome. Haemoglobin severity grades followed WHO non-pregnant adult thresholds (mild, 11.0–<12.0 g/dL; moderate, 8.0–<11.0 g/dL; severe, < 8.0 g/dL) [1].

Statistical analysis

Categorical variables were summarised as counts and percentages, and quantitative variables as mean (SD) or median (IQR), as appropriate for the reporting purpose. Wilson score 95% confidence intervals described estimated proportions. Pearson chi-squared tests were used for the five selected questionnaire comparisons; these tests describe unadjusted associations, and expected cell sizes were assessed. Because the concurrent-low endpoint was common, a modified Poisson model with HC3 robust standard errors estimated adjusted prevalence ratios (aPRs) instead of relying on odds ratios as approximations to prevalence ratios [19, 20]. Age, household-income category, breakfast regularity, post-meal tea consumption, reported menstrual flow and previous IDA history were included for substantive interpretability; they were not selected through a univariable P-value cut-off. Household income > 10,000 NIS/month, medium menstrual flow, regular breakfast, no post-meal tea and no previous IDA were reference categories. The model was exploratory, not a validated prediction model.

Alternative ferritin thresholds (< 12, < 20 and < 30 µg/L), with haemoglobin held at < 12 g/dL, were examined in post hoc sensitivity analyses; these cut-offs should not be construed as interchangeable clinical diagnostic rules. Additional exploratory models omitted tea, menstrual-flow categories or previous IDA in turn. All confidence intervals and P values are nominal; no multiplicity adjustment was used. No values were missing from the 300 included analytical records, and no imputation was undertaken. Analyses were conducted in Python using SciPy and statsmodels.

Ethics and informed consent

Ethical approval

was granted by the Institutional Review Board of Arab American University, Palestine (R-2024/A/175/N; 29 December 2024). Before the questionnaire and blood collection, all participants received information about the purpose and procedures of the study, confidentiality, voluntary participation and the right to withdraw. Written informed consent was obtained from all participants before any research procedure.

Results

Study population and laboratory-defined categories

The 300 participants had a mean age of 20.4 years (SD 1.9; range 18–25). Table 1 presents selected baseline characteristics; Supplementary Table S2 provides complete distributions of the available categorical variables. Anaemia was observed in 135/300 (45.0%; Wilson 95% CI 39.5–50.7%) and low ferritin in 175/300 (58.3%; 95% CI 52.7–63.8%). Both were low in 108 (36.0%; 95% CI 30.8–41.6%). The other exclusive categories comprised 67 (22.3%) with low ferritin alone, 27 (9.0%) with low haemoglobin alone and 98 (32.7%) with neither (Table 2). Of the 175 participants with low ferritin, 67 (38.3%) did not have anaemia; of the 135 with anaemia, 108 (80.0%) had ferritin below 15 µg/L. Haemoglobin grades comprised 77 mild cases, 58 moderate cases and no severe cases.

Table 1
Participant characteristics (n = 300).

Characteristic	**n (%)**
Age, years: 18–19	103 (34.3)
Age, years: 20–22	151 (50.3)
Age, years: 23–25	46 (15.3)
College: allied medical sciences	109 (36.3)
College: nursing	88 (29.3)
College: pharmacy	61 (20.3)
College: dentistry	42 (14.0)
Residence: city	60 (20.0)
Residence: village	136 (45.3)
Residence: camp	78 (26.0)
Residence: university campus	26 (8.7)
Family income: <5,000 NIS/month	159 (53.0)
Family income: 5,000–10,000 NIS/month	96 (32.0)
Family income: >10,000 NIS/month	45 (15.0)
Regular breakfast	186 (62.0)
Post-meal tea coded “Yes”	187 (62.3)
Previous IDA coded “Yes”	71 (23.7)
Menstrual flow: heavy (self-report)	15 (5.0)
Smoking coded “Yes”	49 (16.3)

Table 2
Haemoglobin–ferritin status categories (n = 300).

Iron-status category	n	Prevalence, %	Wilson 95% CI, %
Neither low Hb nor low ferritin	98	32.7	27.6–38.2
Low ferritin without anaemia	67	22.3	18.0–27.4
Both low: operational IDA	108	36.0	30.8–41.6
Anaemia without low ferritin	27	9.0	6.3–12.8
Total	300	100.0	—

Table 3
Haematological and iron-profile measures by haemoglobin–ferritin category; medians (IQRs).

Measure (unit)	Neither low (n = 98)	Ferritin low only (n = 67)	Hb low only (n = 27)	Both low (n = 108)
Haemoglobin (g/dL)	12.85 (12.41–13.30)	12.67 (12.39–13.14)	11.63 (11.35–11.81)	10.96 (10.40–11.49)
Ferritin (µg/L)	32.51 (22.94–48.09)	7.29 (4.47–10.72)	24.87 (20.30–35.72)	5.62 (4.09–7.96)
MCV (fL)	85.23 (80.97–91.16)	86.80 (80.78–91.60)	87.94 (80.75–91.14)	76.71 (71.80–81.99)
RDW (%)	11.76 (11.09–12.33)	12.05 (11.23–13.00)	12.39 (11.66–12.97)	14.86 (13.15–16.54)
Serum iron (µmol/L)	17.13 (12.68–21.55)	16.33 (10.13–21.10)	15.58 (13.50–20.98)	8.48 (5.43–12.78)
TIBC (µmol/L)	70.85 (65.03–76.94)	72.50 (66.41–79.04)	72.70 (68.52–78.71)	102.71 (93.95–109.49)
Calculated TSAT (%)	24.82 (17.73–30.91)	22.75 (13.97–30.56)	21.24 (18.08–31.51)	8.31 (5.20–12.97)

Hb and ferritin define the groups; comparisons of their values across groups are therefore partly definitional. TSAT = 100 × serum iron/TIBC. No between-group P values are presented for these descriptive biomarker profiles.

The biomarker distributions are described in Table 3. The joint-low group had a median MCV of 76.7 fL, RDW of 14.9% and calculated TSAT of 8.3%, compared with 85.2 fL, 11.8% and 24.8% in the group with neither threshold low. These patterns are descriptive: differences in haemoglobin and ferritin across groups are partly predetermined by the classification rules, and calculated indices cannot be used as independent confirmation of the same measurements.

Associations with recorded characteristics

The selected unadjusted comparisons are shown in Table 4; the full set of questionnaire categories is disclosed descriptively in Supplementary Table S2. Concurrent-low status occurred in 47/114 (41.2%) participants reporting irregular breakfast, compared with 61/186 (32.8%) reporting regular breakfast (P = 0.140). Among those reporting post-meal tea, 56/187 (29.9%) met the combined endpoint, compared with 52/113 (46.0%) among those answering no (P = 0.005). These P values refer to Pearson chi-squared associations, not intervention effects. The tea result is inverse in direction but does not establish any protective biological action. Household income, menstrual-flow categories and previous IDA history also differed in the selected unadjusted comparisons.

Table 4
Selected questionnaire associations with concurrent low haemoglobin and ferritin; Pearson chi-squared tests.

Variable	Category	Both low / total	Both low, %	Omnibus P
Breakfast	Irregular	47/114	41.2	0.140
	Regular	61/186	32.8	
Tea consumption after meals	No	52/113	46.0	0.005
	Yes	56/187	29.9	
Menstrual flow (self-reported)	Heavy	10/15	66.7	0.010
	Little	18/39	46.2	
	Medium	80/246	32.5	
Previous IDA (self-reported)	No	72/229	31.4	0.003
	Yes	36/71	50.7	
Family income (NIS/month)	5,000–10,000	34/96	35.4	0.014
	> 10,000	8/45	17.8	
	< 5,000	66/159	41.5	

Adjusted exploratory estimates

In the adjusted exploratory model (Table 5), the lowest compared with the highest income band was associated with higher prevalence of the concurrent-low endpoint (aPR 2.14, 95% CI 1.11–4.15). The high-income reference band comprised 45 participants, of whom eight met the outcome. Previous self-reported IDA (aPR 1.52, 95% CI 1.14–2.03) and reported heavy menstrual flow (aPR 1.70, 95% CI 1.13–2.55; 15 participants in the heavy-flow category) were also associated with the endpoint. The coefficient for post-meal tea was inverse (aPR 0.65, 95% CI 0.49–0.86) while irregular breakfast was compatible with both modestly lower and higher prevalence (aPR 1.15, 95% CI 0.86–1.55). These are conditional associations and not causal effects or externally validated prediction coefficients.

Table 5
Exploratory modified Poisson regression with HC3 robust variance; outcome = concurrent Hb < 12 g/dL and ferritin < 15 µg/L (108 events among 300 participants).

Covariate	aPR	95% CI	P
Age (per year)	1.03	0.96–1.11	0.443
Income < 5000 vs > 10000	2.14	1.11–4.15	0.023
Income 5000–10000 vs > 10000	1.81	0.92–3.57	0.088
Irregular breakfast	1.15	0.86–1.55	0.341
Tea after meals yes	0.65	0.49–0.86	0.003
Menstrual flow little vs medium	1.40	0.97–2.02	0.069
Menstrual flow heavy vs medium	1.70	1.13–2.55	0.010
Previous IDA yes	1.52	1.14–2.03	0.005

Sensitivity to the ferritin threshold

Table 6
Ferritin-threshold sensitivity with Hb held at < 12 g/dL.

Ferritin cut-off, µg/L	IDA / 300	IDA prevalence, %	Interpretation
< 12	100	33.3	Sensitivity check
< 15 (primary)	108	36.0	Primary analytical threshold
< 20	114	38.0	Sensitivity check
< 30	124	41.3	Sensitivity check; not inflammation adjustment

With haemoglobin held at < 12 g/dL, concurrent-low prevalence ranged from 100/300 (33.3%) at ferritin < 12 µg/L to 124/300 (41.3%) at < 30 µg/L (Table 6). The lowest-income association was numerically similar when tea, menstrual-flow categories or previous IDA were excluded from the regression in turn (aPR 2.14–2.20; Supplementary Table S1). These analyses assess descriptive and model sensitivity, not the validity of any unmeasured causal mechanism.

Internal consistency of haematology variables

The calculated haematocrit, MCH, MCHC and TSAT values satisfied their stated arithmetic definitions across the 300 analytical records. A range check identified 17 calculated MCHC values above 40 g/dL; the recorded inputs were not changed. Calculated indices were not treated as independent assays or diagnostic confirmation.

Discussion

The central finding is a patterned coexistence, rather than equivalence, of anaemia and low ferritin in this cohort. More than one-third of participants with low ferritin were not anaemic; conversely, one-fifth of those meeting the haemoglobin criterion for anaemia did not have ferritin below 15 µg/L. These proportions arise from a specified pair of cut-offs, but their interpretation matters: haemoglobin alone overlooks participants whose ferritin suggests depleted stores, while treating every case of anaemia as iron-deficiency anaemia would exceed the measurement evidence [6, 7]. A ferritin concentration above the operational threshold does not establish iron sufficiency where inflammation might have elevated ferritin [2]; the BRINDA work demonstrates the importance of considering inflammatory biomarkers when estimating depleted stores in populations [8].

Studies within Palestine demonstrate why a simple ordering of prevalence percentages would be misleading. Sirdah et al. identified 49/240 (20.4%) participants with low haemoglobin and ferritin in a Gaza university sample, but the study also targeted vitamin B12 and homocysteine and involved a different setting and participant pool [12]. Jalambo et al. evaluated younger adolescents and incorporated measures of inflammation [13], which are absent here. Qasrawi et al. addressed nutrient intakes with an initially collected sample of 145 and an artificially expanded dataset used for machine learning [14]; their outcome and analytical denominator cannot be treated as interchangeable with this study's 300 laboratory-linked records. These differences define what can reasonably be compared; they do not imply a geographical or temporal trend between the studies.

The secondary iron-profile measures help describe the concurrent-low subgroup but do not independently validate the outcome that defined it. This subgroup had lower median MCV, serum iron and TSAT, and higher RDW and TIBC, than the category meeting neither threshold. Current diagnostic recommendations describe these biomarkers as complementary indicators whose interpretation depends on the clinical context, rather than a set of uniform mandatory abnormalities [17, 18]. Because TSAT is calculated from serum iron and TIBC, these are related observations rather than separate assays. Similarly, corrected haematocrit, MCH and MCHC are algebraically determined from recorded haemoglobin, RBC and MCV and cannot be used as independent confirmatory tests. A Bangladesh university survey labelled anaemia outcomes without ferritin assessment [21], while a clinical study of women attending an iron-deficiency outpatient service evaluated symptoms against multiple iron biomarkers [22]. Their differing recruitment and ascertainment strategies limit direct comparison of prevalence and associations.

The income association warrants attention because its direction persisted in alternative model specifications, but its interpretation is restricted. Household-income bands are broad proxies for material circumstances, not direct measures of iron intake, food security, access to care or prior treatment. The comparison group with the highest income contained only eight endpoint events, leaving the effect size comparatively imprecise. Similarly, previous IDA may reflect recurrence, recognition of symptoms or differential contact with health services. Menstrual blood loss is an established route of iron loss [23],

but a questionnaire category labelled “heavy” is not an objectively measured volume or a clinical diagnosis. The 15 participants selecting that category allow an exploratory comparison; they do not demonstrate a dose–response mechanism.

Tea illustrates the danger of conflating a self-reported exposure label with its biological meaning. Controlled experiments indicate that polyphenol-containing beverages can reduce non-haem iron absorption when consumed with a meal [24], and that delaying tea intake attenuates this inhibitory effect [25]. Evidence on dietary bioavailability further indicates that effects observed for individual meal components do not necessarily translate directly to diverse mixed diets [16]. Our inverse association cannot overturn these experimental findings: the questionnaire contains no quantitative information about tea strength, serving volume, meal composition, exact timing interval or changes in consumption after an earlier diagnosis. Selection, reverse temporal ordering and residual confounding remain plausible explanations. Because these alternatives cannot be separated in this cross-sectional design, the coefficient cannot support advice to consume tea for iron status.

A similar distinction applies to breakfast, exercise, smoking and grouped food-intake questions. Meal frequency is not synonymous with absorbed iron, and broad food-group questions cannot reproduce interventions with specified nutrient intake and duration [26]. The interpretation of food-frequency measurements depends on the development and validation of the instrument for its intended use [15]. The cigarette-smoking quantity required for recommended haemoglobin adjustment is absent from the general smoking variable [1]. These variables retain descriptive value, but numerical precision in a regression output is not equivalent to precision in exposure measurement. The present data cannot distinguish whether the reported patterns reflect dietary intake, prior disease awareness, contextual constraints or unmeasured behaviours.

The main analytical contribution lies in distinguishing operationally defined states that would be collapsed by a single haemoglobin or binary IDA label, then examining their laboratory profiles and the interpretation of associated questionnaire variables. This does not establish unique diagnostic categories, representativeness beyond one university, a biological mechanism for the tea result or a basis for population-wide screening advice. It provides a precise estimate for the enrolled cohort and identifies questions about iron status, socioeconomic conditions and exposure measurement that could be tested in broader studies.

Strengths and limitations

Strengths include participant-level linkage of haemoglobin, ferritin and additional iron-profile variables with a broad questionnaire, complete fields in the 300 included records, clearly defined operational endpoints and a reproducible analytical workflow. Important limitations are recruitment from one university, non-participation among those invited, the small high-income reference and heavy-flow categories, broad self-reported exposure measures, the absence of inflammatory markers needed to contextualise ferritin [8], and multiple exploratory comparisons without multiplicity adjustment. The

findings do not establish causal relationships, and neither the study population nor its selection process supports extrapolation to all Palestinian university women.

Conclusions

Among 300 female health sciences students at one Palestinian university, 36.0% had concurrent haemoglobin < 12 g/dL and ferritin < 15 µg/L, while an additional 22.3% had low ferritin without anaemia. Reported household income and some health-history and menstrual-flow categories were associated with the combined endpoint in exploratory analyses, whereas questionnaire exposures did not support causal inference. Separate reporting of anaemia, low ferritin and their overlap clarifies the cohort's measured iron-status patterns without implying population representativeness.

Declarations

Ethical Approval and accordance. The study protocol was approved by the Institutional Review Board of Arab American University, Palestine (Approval No. R-2024/A/175/N; 29 December 2024). The study was conducted in accordance with the ethical guidelines and regulations applicable to the approval granted by the Institutional Review Board. Written informed consent was obtained from all participants before questionnaire administration and blood collection.

Consent for publication. Not applicable; no identifiable individual information is reported.

Availability of data and materials. The datasets generated during and/or analysed during the current study are not publicly available due to participant confidentiality considerations but are available from the corresponding author on reasonable request.

Competing interests. The authors declare that they have no competing interests.

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Authors' contributions. F.S. and O.S. made substantive contributions to the study, including its design, data acquisition and analysis, interpretation of findings, and preparation of the manuscript. Both authors reviewed and approved the final manuscript and its submission to Discover Public Health.

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Reporting guideline. Reporting followed the STROBE statement [27] and its accompanying explanation and elaboration guidance [28]. A separate STROBE checklist identifies where the relevant reporting items are addressed, while complete descriptive distributions across questionnaire categories are provided in Supplementary Table S2.

Declaration of AI Use. The authors declare that no artificial intelligence (AI) tools, including generative AI technologies, were used at any stage of the research process or in the preparation, writing, editing, or revision of this manuscript.

References

1. World Health Organization. Guideline on haemoglobin cutoffs to define anaemia in individuals and populations. Geneva: WHO; 2024. https://www.who.int/publications/i/item/9789240088542.
2. World Health Organization. WHO guideline on use of ferritin concentrations to assess iron status in individuals and populations. Geneva: WHO; 2020. https://www.ncbi.nlm.nih.gov/books/NBK569877/.
3. Pasricha S-R, Tye-Din J, Muckenthaler MU, Swinkels DW. Iron deficiency. Lancet. 2021;397(10270):233–48. https://doi.org/10.1016/S0140-6736(20)32594-0.
4. Sholzberg M, Hillis C, Crowther M, Selby R. Diagnosis and management of iron deficiency in females. CMAJ. 2025;197(24):E680–7. https://doi.org/10.1503/cmaj.240570.
5. GBD 2021 Anaemia Collaborators. Prevalence, years lived with disability, and trends in anaemia burden by severity and cause, 1990–2021: findings from the Global Burden of Disease Study 2021. Lancet Haematol. 2023;10(9):e713–34. https://doi.org/10.1016/S2352-3026(23)00160-6.
6. Petry N, Olofin I, Hurrell RF, Boy E, Wirth JP, Moursi M, et al. The proportion of anemia associated with iron deficiency in low, medium, and high Human Development Index countries: a systematic analysis of national surveys. Nutrients. 2016;8(11):693. https://doi.org/10.3390/nu8110693.
7. Al-Naseem A, Sallam A, Choudhury S, Thachil J. Iron deficiency without anaemia: a diagnosis that matters. Clin Med (Lond). 2021;21(2):107–13. https://doi.org/10.7861/clinmed.2020-0582.
8. Namaste SML, Rohner F, Huang J, Bhushan NL, Flores-Ayala R, Kupka R, et al. Adjusting ferritin concentrations for inflammation: Biomarkers Reflecting Inflammation and Nutritional Determinants of Anemia (BRINDA) project. Am J Clin Nutr. 2017;106(Suppl 1):S359–71. https://doi.org/10.3945/ajcn.116.141762.
9. Weyand AC, Chaitoff A, Freed GL, Sholzberg M, Choi SW, McGann PT. Prevalence of iron deficiency and iron-deficiency anemia in US females aged 12–21 years, 2003–2020. JAMA. 2023;329(24):2191–3. https://doi.org/10.1001/jama.2023.8020.
10. Owaidah T, Al-Numair N, Al-Suliman A, et al. Iron deficiency and iron deficiency anemia are common epidemiological conditions in Saudi Arabia: report of the national epidemiological survey. Anemia. 2020;2020:6642568. https://doi.org/10.1155/2020/6642568.
11. Al Hassan NN. The prevalence of iron deficiency anemia in a Saudi University female students. J Microsc Ultrastruct. 2015;3(1):25–8. https://doi.org/10.1016/j.jmau.2014.11.003.
12. Sirdah MM, Yassin MM, El Shekhi S, Lubbad AM. Homocysteine and vitamin B12 status and iron deficiency anemia in female university students from Gaza Strip, Palestine. Rev Bras Hematol Hemoter. 2014;36(3):208–12. https://doi.org/10.1016/j.bjhh.2014.03.005.

13. Jalambo MO, Karim NA, Naser IA, Sharif R. Prevalence and risk factor analysis of iron deficiency and iron-deficiency anaemia among female adolescents in the Gaza Strip, Palestine. Public Health Nutr. 2018;21(15):2793–802. https://doi.org/10.1017/S1368980018001568.
14. Qasrawi R, Badrasawi M, Abu Al-Halawa DA, et al. 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. Eur J Nutr. 2024;63:1635–49. https://doi.org/10.1007/s00394-024-03360-8.
15. Cade J, Thompson R, Burley V, Warm D. Development, validation and utilisation of food-frequency questionnaires – a review. Public Health Nutr. 2002;5(4):567–87. https://doi.org/10.1079/PHN2001318.
16. Hurrell R, Egli I. Iron bioavailability and dietary reference values. Am J Clin Nutr. 2010;91(5):S1461–7. https://doi.org/10.3945/ajcn.2010.28674F.
17. Iolascon A, Andolfo I, Russo R, Sanchez M, Busti F, Swinkels D, et al. Recommendations for diagnosis, treatment, and prevention of iron deficiency and iron deficiency anemia. HemaSphere. 2024;8(7):e108. https://doi.org/10.1002/hem3.108.
18. Cappellini MD, Musallam KM, Taher AT. Iron deficiency anaemia revisited. J Intern Med. 2020;287(2):153–70. https://doi.org/10.1111/joim.13004.
19. Barros AJD, Hirakata VN. Alternatives for logistic regression in cross-sectional studies: an empirical comparison of models that directly estimate the prevalence ratio. BMC Med Res Methodol. 2003;3:21. https://doi.org/10.1186/1471-2288-3-21.
20. Zou G. A modified Poisson regression approach to prospective studies with binary data. Am J Epidemiol. 2004;159(7):702–6. https://doi.org/10.1093/aje/kwh090.
21. Shill KB, Karmakar P, Kibria MG, et al. Prevalence of iron-deficiency anaemia among university students in Noakhali Region, Bangladesh. J Health Popul Nutr. 2014;32(1):103–10.
22. Özbilen M, Kaya Y. Beyond anemia: a comprehensive analysis of iron deficiency symptoms in women and their correlation with biomarkers. BMC Womens Health. 2025;25:376. https://doi.org/10.1186/s12905-025-03906-w.
23. Munro MG, Mast AE, Powers JM, Kouides PA, O'Brien SH, Richards T, et al. The relationship between heavy menstrual bleeding, iron deficiency, and iron deficiency anemia. Am J Obstet Gynecol. 2023;229(1):1–9. https://doi.org/10.1016/j.ajog.2023.01.017.
24. Hurrell RF, Reddy M, Cook JD. Inhibition of non-haem iron absorption in man by polyphenolic-containing beverages. Br J Nutr. 1999;81(4):289–95. https://doi.org/10.1017/S0007114599000537.
25. Ahmad Fuzi SF, Koller D, Bruggraber S, Pereira DIA, Dainty JR, Mushtaq S. A 1-h time interval between a meal containing iron and consumption of tea attenuates the inhibitory effects on iron absorption: a controlled trial in a cohort of healthy UK women using a stable iron isotope. Am J Clin Nutr. 2017;106(6):1413–21. https://doi.org/10.3945/ajcn.117.161364.
26. McManus L, Veras K, Faria VS, Manninen M, Egan B. Effect of increasing red meat intake on iron status in adults with normal and suboptimal iron status: a systematic literature review and meta-

analysis of intervention studies. Nutr Rev. 2025;83(8):1389–401. https://doi.org/10.1093/nutrit/nuaf016.

27. von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP, STROBE Initiative. The strengthening the reporting of observational studies in epidemiology (STROBE) statement: guidelines for reporting observational studies. Bull World Health Organ. 2007;85(11):867–72. https://doi.org/10.2471/BLT.07.045120.
28. Vandenbroucke JP, von Elm E, Altman DG, Gøtzsche PC, Mulrow CD, Pocock SJ, et al. Strengthening the Reporting of Observational Studies in Epidemiology (STROBE): explanation and elaboration. PLoS Med. 2007;4(10):e297. https://doi.org/10.1371/journal.pmed.0040297.

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