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Research Article

Anaemia among in-school adolescents from Harare, Zimbabwe: Prevalence and key drivers

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Highlights/Key Messages

- Anaemia burden & pattern: Mild–moderate in girls and more mild anaemia in boys
- Key determinants of anaemia: Low parental education, poor nutrition knowledge, and skipping meals more often
- Action needed: Unified school-based nutrition education to improve awareness of anaemia and promote iron- and vitamin C-rich food choices

Background
Anaemia is a public health concern in Zimbabwe. However, evidence to inform policies targeting anaemia among adolescents remains limited.

Objective
This study assessed the prevalence and factors associated with anaemia among in-school adolescents in Harare, Zimbabwe.

Methods
A cross-sectional survey was conducted among 386 adolescents aged 14–19 years. Capillary blood samples were collected, haemoglobin concentration was measured and values were adjusted for Harare's altitude. Anaemia was classified as mild, moderate, or severe according to World Health Organization cut-offs. A structured questionnaire assessed socio-demographic characteristics, dietary habits, nutrition knowledge, and physical activity, while anthropometric measurements were obtained. Pearson's Chi-square and Mantel-Haenszel Chi-square tests assessed associations and linear trends, respectively. Ordinal logistic regression identified factors associated with higher anaemia severity.

Results
Overall anaemia prevalence was 41.4%, and was higher among girls (50.9%) than boys (33.8%). Mild anaemia was most common among boys (18.3%), whereas moderate anaemia was most common among girls (32.9%); severe anaemia affected 6.1% of girls and 6.9% of girls ($p < 0.001$). No significant associations were observed between anaemia severity and anthropometric measurements. In ordinal logistic regression, boys had lower odds of being in a higher anaemia severity category than girls (aOR = 0.61; 95% CI: 0.39–0.96). Primary household head education (aOR = 4.50; 95% CI: 1.55–13.08), low nutrition knowledge (aOR = 1.95; 95% CI: 1.05–3.61) were associated with higher anaemia severity. Compared with adolescents who frequently skipped meals, those who skipped meals infrequently had higher odds of being in a higher anaemia severity category (aOR = 2.21; 95% CI: 1.25–3.92).

Conclusions
Anaemia was highly prevalent among in-school girls. Household education, nutrition knowledge, and meal-skipping behaviours were associated with anaemia severity, highlighting the need for targeted school-, community-, and family-based nutrition interventions.

Keywords: Anaemia; adolescents; nutritional status; nutrition knowledge; meal skipping; Zimbabwe

Introduction

Anaemia is a condition in which the number of red blood cells or the haemoglobin (Hb) concentration is lower than normal (Soundarya & Suganthi, 2016). Iron deficiency is a major cause, generally resulting from dietary iron absorption not meeting the required needs. Iron reserves become depleted and are unable to support the body's physiological demands (WHO, 2011).

Adolescence is a critical period characterised by rapid growth and developmental transitions with a significantly increased need for macro and micronutrients, making adolescents vulnerable to nutritional deficiencies (Fuhrman, 2015). Iron requirements nearly double during adolescence compared to earlier childhood, from about 0.7–0.9 mg per day in preadolescents to approximately 1.37–1.88 mg per day in adolescent boys, and 1.40–3.27 mg per day in adolescent girls (Kumar *et al.*, 2018).

Anaemia is closely related to daily food habits and nutrition knowledge, especially low intake of iron-rich foods, vitamin B_{12}, folate, and vitamin C (Paramastri *et al.*, 2021). Risk is increased by practices such as skipping meals (Channar *et al.*, 2023), eating ultra-processed food (Soans *et al.*, 2025), and drinking tea or coffee with meals (Jawad *et al.*, 2025). Poor awareness about iron sources and how vitamin C improves absorption of iron also increases the risk of anaemia (Fitripancari *et al.*, 2023). Good nutrition knowledge helps people choose balanced meals, select iron-rich foods, and the adopt healthy eating habits to prevent anaemia (Abu-Baker *et al.*, 2021).

Adolescents are at risk of iron deficiency and nutritional anaemia due to factors such as poor dietary intake of iron, for example, not consuming vegetables, meat, poultry, and seafood (Cohen & Powers, 2024), high requirements of iron, heavy menstruation, and teenage pregnancy in girls (Munro *et al.*, 2023). Girls are at higher risk of anaemia than boys (Sparrow *et al.*, 2021). Although the risk of anaemia is low in boys, it should be explored and understood because physical activities like sports require good iron status (Roy *et al.*, 2022). Additionally, in many developing countries, anaemia research presents insufficient data on the risk factors and their interactions (Adokorach *et al.*, 2024). Furthermore, qualitative evidence on what adolescents know and understand about anaemia remains limited. In Zimbabwe, anaemia studies have focused on children from 6 to 59 months (Mutonhodza *et al.*, 2023), children aged 6-10 years (Kuona *et al.*, 2015) and women of reproductive age 15-49 years (Chemhaka *et al.*, 2025a). Limited information exists on adolescents, and tailored nutrition services to meet their needs are lacking (ZNSS, 2018).

In Zimbabwe, 23% of adolescent girls become pregnant by age 19 years, and 45% of them experience anaemia during their first pregnancy (ZNSS, 2018). Anaemia prevention in Zimbabwe focuses on iron and folic acid (IFA) supplementation but does not cover those who are not pregnant (Tinago *et al.*, 2017; Mahundi *et al.*, 2021). Thus, this study assessed the severity of anaemia among adolescents living in Harare, Zimbabwe, and identified modifiable risk factors.

Methods

Study setting and participants

The study was carried out in Harare between May and July 2026, which is the winter and dry season in Zimbabwe. Participants were adolescents aged 14 to 19 with signed informed parental consent forms, attending secondary schools in randomly selected areas around Harare. We included public schools with secondary students (Form 1 (youngest); Form 6 (oldest)) for which we had permission from the Ministry of Primary and Secondary Education at the provincial, district, and school levels.

Sample size

The sample size was calculated using the Cochran formula as suggested by (Charan & Biswas, 2013).

$$n = \frac{Z^2\, p(1-p)}{e^2}$$

Where Z-value = 1.96 for 95% confidence level, p is the estimated proportion of an attribute that is present in the population expressed as a decimal = 0.5 when the proportion is unknown (Sathyanarayana *et al.*, 2024), and the confidence interval = 0.95 with a 5% margin of error e = 0.05. A sample size of 437, with a 25% attrition adjustment, was considered sufficient, bringing the total sample size to 546.

Sampling procedure

A simple random sampling technique was used to select 10 schools using a list of all schools in Harare registered with the Ministry of Primary and Secondary Education. Each school was then assigned a unique number from 1 up to the total number of schools (n=3 400). Using a random method of drawing numbers from a container, 10 different numbers were selected. Subsequently, individuals from each school were selected from class registers using systematic random sampling based on a sampling interval calculated from the target sample size.

Participant recruitment and ethics

Recruited participants were asked to remain in the classrooms, received an in-depth orientation about the study's objectives, finger-prick sampling procedure, weight and height measurements for BMI calculations, waist and hip circumference measurements, and were informed how long it would take to fill in the self-administered questionnaire. Participants were also informed that no incentive would be offered for participation, that there would be no penalties for dropping out of the survey, and that participation was limited to those with signed parental consent forms and who consented themselves. Osaka Metropolitan University (OMU/21-52) and the Medical Research Council of Zimbabwe (MRCZ/A/2857) reviewed and approved the study protocol.

Research instruments and data collection methods

Blood sampling for anaemia

Haemoglobin status was assessed using a portable battery-operated HemoCue® Hb 301 Analyzer (HemoCue AB, Sweden). All procedures were carried out as per the manufacturer's instructions. A registered nurse used single-use disposable sterile gloves, and a single-use disposable lancet was used for each participant. Capillary blood samples were taken by pricking the tip of participants' middle finger after rubbing it with a cotton swab immersed in alcohol

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(Nwankwo et al, 2021). The first two drops were wiped away, and the third and fourth drops were used for the Hb reading (Namaste *et al.*, 2024). Two readings were measured and averaged (Kuche *et al.,* 2025).

Anthropometric measurements were taken twice, according to the WHO protocol (De Onis *et al.*, 2007). Waist and hip circumferences were measured using a non-elastic measuring tape following standardised procedures. Waist circumference was measured midway between the lowest rib and the iliac crest after normal expiration, while hip circumference was measured at the widest part of the buttocks. Measurements were recorded to the nearest 0.1 cm and repeated twice; the average value was used for analysis. Waist-to-hip ratio was calculated as waist circumference divided by hip circumference. Height was measured using a Seca 213 Stadiometer (Seca GmbH, Hamburg, Germany) and recorded to the nearest 0.1 cm. During the measurement, participants stood in the Frankfurt position. Shoes were taken off, and occipital, shoulder, buttocks, and heel touched the stadiometer. Weight was measured with a Seca 875 weighing scale (Seca GmbH, Hamburg, Germany), calibrated daily, and recorded to the nearest 0.1 kg. Participants removed heavy clothes and shoes.

Structured questionnaire

Dietary data were collected using questionnaires with four sections: socio-demographic and anthropometric information (10 questions), nutrition knowledge (20 questions), food habits (23 questions), and physical activity (7 questions). Scoring for the latter three was adapted as follows.

Food habits

The food habits questionnaire was adapted from (Johnson *et al.,* 2002). The food habits score (FHS) is a metric that quantifies dietary patterns by assigning points for healthy eating behaviours (like eating fruits/veg, limiting fats/sugars) and unhealthy ones, resulting in a total score indicating overall diet quality, with higher scores meaning healthier habits, helping assess nutritional intake beyond just calories.

FHS = (Number of healthy responses × 23) ÷ 23 items completed X 100

Scores were categorised as *inadequate* if FHS was below 50%, and *adequate* if FHS was 50% or higher.

Nutrition knowledge

The questionnaire was adapted from Oz *et al.* (2016) for high school students. The nutrition knowledge scores (NKS) were categorised as inadequate = 0 (NKS < 50%) or adequate = 1 (NKS ⩾ 50%). It measured general nutrition knowledge and did not focus on anaemia-related issues. The questionnaire consisted of three subscales: adequate and balanced nutrition, essential nutrients, and malnutrition-related diseases. Questions were presented as complete sentences, requiring respondents to identify statements as true, false, or indicate if they were unsure. The Cronbach's alpha coefficient for it was 0.85, indicating adequate reliability.

Physical activity

The physical activity questionnaire was adapted from (Silva *et al.*, 2018). The Physical Activity Score (PAS) was calculated based on responses, which were structured differently depending on the specific questions. Overall, scores were classified as *inadequate* (PAS < 50%) or *adequate* (PAS ⩾ 50%). The questionnaire demonstrated acceptable internal reliability, with a Cronbach's alpha of 0.71.

Variables categorization

Anaemia status was considered the outcome variable and was defined according to WHO age- and sex-specific cutoffs as <12.0 g/dL (both sexes) for 12–14 years; <12.0 g/dL for 15–19 years (girls); and <13.0 g/dL for 15–19 years (boys). Anaemia severity was defined as mild, 11-11.9 g/dL; moderate, 8–10.9 g/dL; and severe, <8 g/dL (WHO, 2011). Independent variables were identified by reviewing previous literature (Chauhan *et al.*, 2022; Habtegiorgis *et al.*, 2022; Kebede *et al.*, 2025; Yusufu *et al.*, 2023). Hemoglobin concentrations were adjusted for Harare altitude, 1483 meters above sea level (UN, 2022) according to WHO (2024b) methods. The following formula was used

Hb adjustment = −0.032 x (altitude in metres x 0.0032808) + 0.022 x (altitude in metres x 0.0032808). The adjustment factor was subtracted from the individual Hb concentrations (WHO, 2024b).

Nutritional status was evaluated following the WHO standard procedures for children aged 5–19 years (WHO, 2016). Body Mass Index (BMI, kg/m^2) was converted to z-scores using WHO data. BMI-for-age z-scores were classified as underweight (<−2 SD), normal (⩾ −2 to ⩽ +1 SD), overweight (⩾ +1 to +2 SD), and obese (> +2 SD). Waist–hip ratio (WHR) was classified as abnormal in males if the ratio was ⩾0.9 and ⩾0.85 in females (Bacopoulou *et al.*, 2015). Waist-to-height (WHtR) was classified as an indicator of a high risk of central obesity if the ratio was ⩾0.5 (Bacopoulou *et al.*, 2015).

Data Analysis

Data were analysed using IBM SPSS version 23. After data cleaning and excluding dropouts (62) and participants' data with missing variables (98), data from 386 participants remained and were analysed further. We assessed the normality of continuous variables using the Shapiro-Wilk test. Normally distributed variables were summarised as mean ± standard deviation (SD), while non-normally distributed data were presented as median ± interquartile range (IQR). The Mantel-Haenszel chi-square test (linear-by-linear association) was used to evaluate whether a linear (ordinal) trend exists between two ordered categorical variables while controlling for confounding factors. Associations between categorical variables were evaluated using Pearson's chi-square (χ^2) test. This study used an ordinal logistic regression model to identify factors

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associated with anaemia. Statistical inference was based on a significance threshold of $p < 0.05$. Regression estimates are presented alongside 95% confidence intervals (CIs).

Results

Table 1 summarises the socio-demographic characteristics of the participants (n = 386) stratified by anaemia status. The median age and IQR were 16 ± 1.292 (15-17) years. There were more boys (55.2%) than girls (44.8%). Mild anaemia was higher among boys (18.3%), and girls exhibited a higher prevalence of moderate severity (32.9%) compared with boys (9.4%).

Anaemia severity was significantly associated with sex ($\chi^2 = 34.821$, p = 0.001) and the household head's education level ($\chi^2 = 41.110$, $p = 0.001$). Participants whose household heads had tertiary education had the highest proportion of normal outcomes (78.7%) and the lowest proportion of severe cases (2.7%). No significant associations were found between severity and age group, place of residence, employment status of the household head, family structure, or household size (all $p > 0.05$). Anaemia severity differed significantly by sex (Pearson $\chi^2 = 34.821$, $p < 0.001$). Moderate anaemia was higher among girls (39.2%) than boys (9.4%), while severe anaemia was distributed between boys (6.1%) and girls (6.9%). Place of residence was not significantly associated with anaemia severity (Pearson $\chi^2 = 3.330$, $p = 0.766$). Employment status of the household head was also not significantly associated with anaemia severity (Pearson $\chi^2 = 3.209$, $p = 0.782$). Family structure was not significantly associated with anaemia severity (Pearson $\chi^2 = 8.390$, $p = 0.754$). Household size showed no statistically significant ordered association with anaemia severity using the Linear-by-Linear Association test ($\chi^2 = 2.713$, $p = 0.100$).

Table 1. Sociodemographic characteristics of participants stratified by the anaemia status of 386 participants

Variable	Category	Total n (%)	No anaemia n (%)	Mild anaemia n (%)	Moderate anaemia n (%)	Severe anaemia n (%)	Test used	Test statistic	p-value
Sex	Male	213 (55.2)	141 (66.2)	39 (18.3)	20 (9.4)	13 (6.1)	Pearson χ^2	34.821	<0.001*
	Female	173 (44.8)	85 (49.1)	19 (11.0)	57 (32.9)	12 (6.9)			
Place of residence	HES	56 (14.5)	28 (50.0)	10 (17.9)	15 (26.8)	3 (5.4)	Pearson χ^2	3.330	0.766
	Intermediate	91 (23.6)	56 (61.5)	12 (13.2)	16 (17.6)	7 (7.7)			
	LES	239 (61.9)	142 (59.4)	36 (15.1)	46 (19.2)	15 (6.3)			
Employment status of HH	Formally employed	202 (52.3)	112 (55.4)	36 (17.8)	41 (20.3)	13 (6.4)	Pearson χ^2	3.209	0.782
	Unemployed	23 (6.0)	1 (60.8)	3 (13.0)	5 (21.7)	1 (4.3)			
	Entrepreneur	161 (41.7)	100 (42.6)	19 (11.8)	31 (19.3)	11 (6.8)			
Family structure	Both parents	259 (67.1)	155 (59.8)	38 (14.7)	49 (18.9)	17 (6.6)	Pearson χ^2	8.390	0.754
	Single parent	68 (17.6)	40 (58.8)	11 (16.2)	12 (17.6)	5 (7.4)			
	Relatives/guardians	51 (13.2)	28 (54.9)	7 (13.7)	14 (27.5)	2 (3.9)			
	Child-headed	5 (1.3)	1 (20.0)	2 (40.0)	1 (20.0)	1 (20.0)			
	Other	3 (0.8)	2 (66.7)	0 (0.0)	1 (33.3)	0 (0.0)			
Household size	Average	326 (84.5)	186 (57.2)	48 (14.7)	70 (21.5)	22 (6.7)	Linear-by-Linear χ^2	2.713	0.100
	Above average	60 (15.5)	40 (66.7)	10 (16.7)	7 (11.7)	3 (5.0)			

Notes: Notes: HH is household head, HES is high economic status, LES is low economic status. For household size; average is 5 members, above average is above 5. For nominal variables, Pearson Chi-square was reported. For ordered variables, the Linear-by-Linear Association statistic was reported. *p < 0.05.

Table 2 shows the association between nutrition status and anaemia. Although moderate anaemia was more common among underweight participants (24.3%), those with a high waist-to-height ratio (28.9%), and those with a high waist-to-hip ratio (28.3%), these differences were not statistically significant. Overall, the findings suggest that the anthropometric indicators assessed were not significantly related to anaemia severity in the study population.

Table 2. Nutrition status and anaemia status

Variable	Category	Total n (%)	No anaemia n (%)	Mild anaemia n (%)	Moderate anaemia n (%)	Severe anaemia n (%)	Test used	Test statistic	p-value
BMI group	Underweight	37 (9.6)	23 (62.6)	5 (13.5)	9 (24.3)	0 (0.0)	Linear-by-Linear χ^2	0.610	0.435
	Normal	286 (74.1)	168 (58.7)	41 (14.3)	58 (20.3)	19 (6.6)			
	Overweight and obesity	63 (16.3)	35 (55.6)	12 (19.0)	10 (15.9)	6 (9.5)			
Waist-height ratio	Normal	341 (88.3)	203 (59.5)	50 (14.7)	64 (18.8)	24 (7.0)	Linear-by-Linear χ^2	0.322	0.571
	High	45 (11.7)	23 (51.1)	8 (17.8)	13 (28.9)	1 (2.2)			
Waist-hip ratio	Normal	340 (88.1)	200 (58.8)	54 (15.9)	64 (18.8)	22 (6.5)	Linear-by-Linear χ^2	0.579	0.447
	High	46 (11.9)	26 (56.5)	4 (8.7)	13 (28.3)	3 (6.5)			

Notes: BMI = body mass index. For nutrition-status variables with ordered categories, the Linear-by-Linear Association statistic was reported.

Table 3 shows nutrition factors associated with anaemia. The Linear-by-Linear Association test showed a statistically significant ordered association between skipping meals and anaemia severity ($\chi^2 = 88.996$, $p < 0.001$) with participants reporting lower meal-skipping frequency showing progressively higher proportions of mild and moderate anaemia. A significant ordered association was also observed between adequate and balanced nutrition knowledge and anaemia severity ($\chi^2 = 32.097$, $p < 0.001$) with adequate nutrition knowledge associated with a higher proportion of

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participants without anaemia and lower proportions of mild and moderate anaemia for example, inadequate nutrition knowledge was more common among adolescents with moderate anaemia (30.7%) than for those with adequate knowledge (11.8%). Healthy food choices, adequate consumption of fruits and vegetables, knowledge of sugar, fats, and essential nutrients, knowledge of malnutrition-related diseases, and physical activity were not significantly associated with anaemia severity.

Table 3. Dietary factors and anaemia status

Variable	Category	Total n (%)	No anaemia n (%)	Mild anaemia n (%)	Moderate anaemia n (%)	Severe anaemia n (%)	Test used	Test statistic	p-value
Food habits									
Healthy food choices	Inadequate	259 (67.1)	155 (59.8)	38 (14.7)	48 (18.5)	18 (6.9)	Linear-by-Linear χ^2	0.250	0.617
	Adequate	127 (32.9)	71 (55.9)	20 (15.7)	29 (22.8)	7 (5.5)			
Fruits and vegetables	Inadequate	186 (48.2)	116 (62.4)	29 (15.6)	29 (15.6)	12 (6.5)	Linear-by-Linear χ^2	2.475	0.116
	Adequate	200 (51.8)	110 (55.0)	29 (15.6)	48 (24.0)	13 (6.5)			
Sugar consumption	High	369 (95.6)	216 (58.5)	54 (14.6)	76 (20.6)	23 (6.2)	Linear-by-Linear χ^2	0.026	0.873
	Normal	17 (4.4)	10 (58.8)	4 (23.5)	1 (5.9)	2 (11.8)			
Fat consumption	High	282 (73.1)	169 (59.9)	41 (14.5)	51 (18.1)	21 (7.4)	Linear-by-Linear χ^2	0.181	0.670
	Normal	104 (26.9)	57 (54.8)	17 (16.3)	26 (25.0)	4 (3.8)			
Skipping meals	High frequency	192 236 (61.1)	14 (5.9)	18 (7.6)	12 (85.0) (5.1)	Linear-by-Linear χ^2 88.996	<0.001*		
	Low frequency	150 (38.9)	34 (22.7)	44 (29.3)	59 (39.3)	13 (8.7)			
Adequate and balanced nutrition knowledge	Inadequate	166 (43.0)	65 (39.2)	37 (22.3)	51 (30.7)	13 (7.8)	Linear-by-Linear χ^2	32.097	<0.001*
	Adequate	220 (57.0)	161 (73.2)	21 (9.5)	26 (11.8)	12 (5.5)			
Essential nutrients knowledge	Inadequate	115 (29.8)	75 (65.2)	14 (12.2)	19 (16.5)	7 (6.1)	Linear-by-Linear χ^2	1.975	0.160
	Adequate	271 (70.2)	151 (55.7)	44 (16.2)	58 (21.4)	18 (6.6)			
Malnutrition-related diseases knowledge	Inadequate	122 (31.6)	79 (64.8)	18 (14.8)	18 (14.8)	7 (5.7)	Linear-by-Linear χ^2	3.016	0.082
	Adequate	264 (68.4)	147 (55.7)	40 (15.2)	59 (22.3)	18 (6.8)			
Physical activity	Inadequate	196 (50.8)	117 (59.7)	32 (16.3)	34 (17.3)	13 (6.6)	Linear-by-Linear χ^2	0.479	0.489
	Adequate	190 (49.2)	109 (57.4)	26 (13.7)	43 (22.6)	12 (6.3)			

Notes: Food habits subscales were defined as: Inadequate: (FH < 50%) and adequate: as (FH ⩾ 50%). Fruit and vegetable consumption <50% is inadequate and ⩾50%. Sugar and fat consumption: <50% is normal and ⩾50% high; skipping meals: <50% low frequency and ⩾50% high frequency. For nutrition knowledge (NK) sub scales, a score NK<50% was defined as inadequate and NK ⩾50% was defined adequate. For physical activity score: <50% was defined as inadequate and PAS ⩾50% was defined adequate. The p-value is for Linear-by-Linear Association statistics was reported as *p < 0.05.

Table 4 shows the overall factors associated with anaemia using ordinal logistic regression analysis. Males had lower odds of being in a higher anaemia severity category (OR = 0.61; 95% CI: 0.39–0.96; p = 0.033). Household head education level was also significantly associated with anaemia severity. Adolescents whose household heads had no formal education had higher odds of being in a more severe anaemia category compared with those whose household heads had tertiary education (OR = 2.83; 95% CI: 1.29–6.21; p = 0.010). Similarly, primary education of the household head was associated with higher odds of greater anaemia severity compared with tertiary education (OR = 4.50; 95% CI: 2.00–10.15; p < 0.001). Inadequate nutrition knowledge was independently associated with more severe anaemia (OR = 2.68; 95% CI: 1.69–4.22; p < 0.001). Skipping meals was also significantly associated with less anaemia (OR = 0.13; 95% CI: 0.08–0.21; p < 0.001).

Table 4. Factors associated with anaemia among adolescents

Predictor	Category/ comparison	B	SE	Wald	p-value	OR = Exp(B)	95% CI for OR
Demographic factors							
Sex	Boys	-0.498	0.233	4.557	0.033*	0.61	0.39–0.96
Age group	14–16 years	-0.139	0.234	0.351	0.554	0.87	0.55–1.38
Place of residence	HES	0.544	0.352	2.398	0.122	1.72	0.87–3.43
	Intermediate	0.200	0.292	0.467	0.494	1.22	0.69–2.17

Predictor	Category/ comparison	B	SE	Wald	*p*-value	OR = Exp(B)	95% CI for OR
Education level of HH	No formal education	1.039	0.401	6.708	0.010*	2.83	1.29–6.21
	Primary education	1.505	0.414	13.204	<0.001*	4.50	2.00–10.15
	Ordinary education	0.485	0.645	0.565	0.452	1.62	0.46–5.75
Employment status of HH	Formally employed	0.192	0.244	0.620	0.431	1.21	0.75–1.95
	Unemployed	0.330	0.493	0.449	0.503	1.39	0.53–3.65
Nutrition status							
BMI group	Underweight	-0.533	0.494	1.164	0.281	0.59	0.22–1.54
	Overweight/obese	-0.173	0.324	0.285	0.593	0.84	0.45–1.59
Nutrition Knowledge							
Adequate and balanced nutrition knowledge	Inadequate	0.984	0.233	17.843	<0.001	2.68	1.69–4.22
Essential nutrients knowledge	Inadequate	0.224	0.283	0.631	0.427	1.25	0.72–2.18
Malnutrition-related diseases knowledge	Inadequate	-0.249	0.279	0.802	0.371	0.78	0.45–1.34
Food habits							
Healthy choices	Inadequate	-0.027	0.264	0.010	0.920	0.97	0.58–1.63
Fruits and vegetables	Inadequate	-0.189	0.246	0.591	0.442	0.83	0.51–1.34
Sugar consumption	High	0.480	0.596	0.648	0.421	1.62	0.50–5.20
Fats consumption	High	-0.120	0.274	0.191	0.662	0.89	0.52–1.52
Skipping meals	High frequency	-2.024	0.241	70.754	<0.001	0.13	0.08–0.21
Physical activity	Inadequate	0.127	0.245	0.270	0.603	1.14	0.70–1.83

Notes: Model goodness of fit: Cox and Snell $R^2 = 0.342$; Nagelkerke $R^2 = 0.386$; McFadden $R^2 = 0.191$. Valid cases = 385. Reference categories, respectively, were Girls, 17–19 years, LES (Low economic status), Tertiary education, Entrepreneur, Normal sugar consumption, fats consumption and skipping meals, Adequate knowledge/behaviour categories, and Adequate physical activity. HH is household head, BMI is body mass index, HES is high economic status. For variable definitions, see Table 3 footnotes.

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Discussion

The prevalence of anaemia among adolescents

The aim of the study was to estimate the prevalence of mild, moderate and severe anaemia among adolescents in Harare, Zimbabwe. The anaemia prevalence of 41.4%; (33.8% for boys and 62.4% for girls) found in this study could be linked to nutrition and socio-economic factors like food habits and is often associated with the education level of the household head (Muhammad *et al.*, 2019). High percentages have also been reported in other African countries like Tanzania, 58.3% (Mildon *et al.*, 2023), Gabon, 63.5% (Dain *et al.*, 2021; Nair & Doibale, 2023), and 30% for girls in Southern Africa (Dagnaw *et al.*, 2025). As a comparison, countries with more advanced economies have reported a prevalence of 18.1% in Canada (Stabell *et al.*, 2021), China, 11.7% (Zhu *et al.*, 2021) and Japan, 5.3% (Kunitsugu *et al.*, 2012).

Anaemia was more prevalent among girls, and the most prevalent form was moderate anaemia, as seen elsewhere (Kumari *et al.*, 2017). Mild to moderate anaemia was more prevalent among participants aged 14–16 years, and severe anaemia was more prevalent among participants aged 17–19 years.

Although BMI was not significantly associated with anaemia, it was observed not only among underweight adolescents but also among those with overweight/obesity. This observation may point to issues beyond energy deficiency, such as poor diet quality and inadequate micronutrient density in the diet (Alshwaiyat *et al.*, 2021; Mehdad *et al.*, 2022). Overweight/obesity is a risk factor for several comorbidities and complications, including iron deficiency anaemia due to increased hepcidin levels (a hormone) that functions as a negative regulator of intestinal iron absorption mediated by chronic inflammation (Alshwaiyat *et al.*, 2021). Nevertheless, a high prevalence of moderate and severe anaemia was observed also among participants in the normal weight category. This could be explained by the low nutrition knowledge about adequate and balanced nutrition observed in this study, which could lead to low dietary diversity. This finding reinforces the suggestion that adolescents can eat enough calories to keep normal body weight but still lack essential micronutrients like iron (Reshma, 2014).

Factors associated with anaemia

In the adjusted model, boys had significantly lower odds of anaemia than girls, as seen in other studies (Anwar *et al.,* 2025; Dagnaw *et al.*, 2025). Additionally, anaemia was significantly associated with the education level of the household head. Low parental education levels have been linked to a higher risk of anaemia in adolescents elsewhere (Nair & Doibale, 2023), likely due to reduced household income, poor dietary knowledge, and inadequate access to nutritious food (Mulianingsih *et al.*, 2025; Harding *et al.*, 2018; Choi *et al.*, 2011). In Zimbabwe, low parental education has been linked to the double burden of malnutrition (Pencil *et al.*, 2024). However, as far as we know, the finding connecting parental education with anaemia status is novel to the Zimbabwe nutrition research landscape.

The finding that inadequate nutrition knowledge was significantly associated with anaemia risk is consistent with pre-existing studies (Mok *et al.*, 2024). In this study, we observed that adolescents generally had inadequate nutrition knowledge and odds of having anaemia were higher in such cases.

Addressing anaemia through food-based approaches would be more effective if adolescents were equipped with the know-how to make the best use of their resources and select the right foods (dark leafy greens, red meat, beans for iron and/or high-vitamin-C foods with main meals to

enhance absorption). To better understand the effectiveness of food-based approaches to prevent anaemia, further investigations into adolescents' attitudes toward nutrition, diet, and foods are needed. Structured educational intervention has effectively improved knowledge, attitude, and practice regarding anaemia among adolescents elsewhere (Abu-Baker *et al.,* 2021).

Skipping meals, particularly breakfast, substantially decreases dietary diversity and is associated with reduced intake of essential nutrients, diminished diet quality, and an elevated risk of nutrient deficiencies and unhealthy eating behaviours (Rosário *et al.*, 2022). We found that anaemia was associated with not skipping meals. This finding is inconsistent with other nutrition problems associated with skipping meals, particularly breakfast (Pencil *et al.*, 2021; Pencil *et al.*, 2023). Among those who skipped meals (adequate), 23.5% had mild anaemia and 5.9% had moderate anaemia, while those in the high category had 5.9% mild anaemia and 7.6% moderate anaemia (Table 3). Existing studies have linked anaemia deficiency to meal skipping associated with food insecurity (Hoteit *et al.,* 2022; Moosavian *et al.*, 2025). This could not be a contributing factor in this context, since meal skipping was protective. Dietary diversity in Harare has already been reported to be lower than other Sub-Saharan capital cities like Gaborone, Maseru and Windhoek; with only 33% of Harare households eating 6 or more food groups compared with 51% of households in the regional sample (Frayne *et al.*, 2010).

Meal-skipping behaviour was significantly negatively associated with anaemia severity (linear-by-linear χ^2 = 88.996, $p < 0.001$). Among adolescents reporting high meal skipping, the majority (85.0%) had no anaemia, compared with only 22.7% among those with a more normal meal pattern. Conversely, mild, moderate and severe anaemia were more frequently observed among adolescents with a normal meal pattern. Although this finding suggests an inverse association between meal skipping and anaemia in the study population, this association may reflect differences in dietary quality, meal composition, nutrient intake, or other unmeasured confounding factors.

Nutrition education can contribute to behaviour change and improved dietary diversity and micronutrient intake in a cost-effective manner (Wiafe *et al.*, 2023). Nutrition-sensitive agriculture, including home and school gardens and certain varieties of biofortified beans, can also improve iron status (Boy et al., 2017). Community engagement through behaviour change campaigns, integrated with sexual and reproductive health services, and promoting menstrual hygiene are essential (UNICEF, 2025). These efforts should be supported by strong data systems, regular monitoring, and coordinated multi-sectoral collaboration, with a focus on including vulnerable groups such as rural, out-of-school adolescents and those living with HIV (Mildon *et al.*, 2023).

Limitations of the study

This study highlighted some important factors associated with adolescents' anaemia in Harare's urban schools. We relied on self-reported answers for the food habits and nutrition knowledge questionnaire. This could potentially result in memory errors or social desirability bias. Although meal-skipping frequency demonstrated a statistically significant linear trend with anaemia severity (linear-by-linear χ^2 = 88.996, $p < 0.001$), the direction of the association was unexpected. This finding may be attributable to residual confounding, measurement or reporting bias, or reverse causality. Consequently, the result should be interpreted cautiously and requires confirmation in longitudinal studies. Additionally, this study did not include menstruation-related factors. Furthermore, anaemia results were determined from finger-prick blood sampling using HemoCue, which tends to give 0.3 to 0.9 g/dL higher Hb readings than standard venous draws (Patel *et al.,* 2013), thus slightly underestimating anaemia prevalence. Finally, because the stratified analyses in this study were based on relatively small sample sizes, statistical power may have been limited to detect some significant associations. Lastly, dichotomising variables may result in some loss of information, and future studies with larger sample sizes may consider ordinal or multinomial regression approaches to better explore factors associated with anaemia severity. Nonetheless, this study contributes important information regarding the status of anaemia and factors associated with it among in-school adolescents in Harare.

Recommendations

Research is needed to determine the extent to which the high levels of anaemia in Harare adolescents documented here is due to deficiencies of iron or other nutrients, blood loss, particularly girls with heavy menstrual blood loss, infections, and/or parasitism, especially hookworm during the rainy season. Scaling up IFA supplementation, including to boys, could be beneficial (Chiromba *et al.*, 2020a) since WHO recommends intermittent IFA supplementation to all children aged 10–12 years and to menstruating adolescent girls where anaemia prevalence is ⩾20% (WHO, 2018). Intermittent IFA supplementation in schools should be tested, while adolescent-friendly health services should be strengthened with routine Hb screening (WHO, 2014). However, compliance with IFA is low among the studied population groups due to bad taste and negative side effects (Chiromba *et al.*, 2020b; Mahundi et al., 2021). Negative perceptions and attitudes toward iron supplementation may have spilt over to adolescents. Dietary approaches might be the next best option; however, further research is needed to determine whether additional iron and/or vitamin C with major meals would be the best dietary approach. However, without the implementation of school feeding, currently not available for this age group in Harare, food-based interventions face extreme limitations also. Lastly, future longitudinal research should further investigate the unexpected inverse relationship between meal-skipping frequency and anaemia severity, while accounting for potential dietary, socioeconomic, behavioural, and reporting-related factors. Further research is needed to

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determine whether this inverse relationship reflects a true association or is influenced by residual confounding or other unmeasured factors.

Conclusions

This study identified a high prevalence of anaemia (41.4%) overall, with differences by gender; girls (62.4%) and boys (33.8%). Additional key drivers for anaemia included education level of the household head, inadequate nutrition knowledge, and, counterintuitively, not skipping meals. School-based, family-oriented nutrition education and other preventative strategies are needed to reduce the risk of anaemia among this critical age group. Further research is needed to understand why in this population meal skipping was inversely associated anaemia.

Author Contributions

AP, TM, and NH led project conceptualization, methodology development, formal analysis, and original draft writing. AP, TMC and KMM participated in data collection, analysis, and earlier drafts of the manuscript. AP led project administration with guidance from TM, NKH, and NH. KMM, NKH and TMC provided editorial support for manuscript review, editing, and submission. All authors then critically reviewed the following versions. All authors have read and approved the final version of the paper and its submission and have given consent for publication.

Declaration of Generative AI and AI-Assisted Technologies in Scientific Writing

Nothing to disclose.

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Data Availability Statement

A supplementary Information file is included for this study. Data is available upon request.

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Conflict of Interest

The authors declare that they have no conflicts of interest.

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