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Anaemia, Dietary Diversity and School WASH Conditions among Adolescent Girls in Selected Public Secondary Schools in Ogun State, Nigeria: A Cross-Sectional Study

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Abstract

Background: Anaemia remains an important adolescent-health concern, but evidence combining current age-specific haemoglobin classification with dietary and school water, sanitation and hygiene (WASH) conditions is limited in southwestern Nigeria. This study estimated anaemia prevalence and examined selected correlates among adolescent girls attending public secondary schools in Ogun State.

Methods: A school-based cross-sectional study included 277 girls aged 10-19 years from six selected public secondary schools during April-June 2025. A structured, pretested questionnaire captured sociodemographic, menstrual-health, dietary, recent-malaria and participant-reported school WASH indicators; a separate checklist documented school-level WASH conditions. Capillary haemoglobin was measured using a HemoCue Hb 301 analyser, and anaemia was classified using World Health Organization (WHO) 2024 age-specific cut-offs. Logistic regression estimated crude and adjusted odds ratios (ORs) with 95% confidence intervals (CIs).

Results: Anaemia affected 82/277 participants (29.6%; 95% CI 24.5-35.2): 62 (22.4%) had mild and 20 (7.2%) moderate anaemia; no severe cases were identified. School-specific prevalence ranged from 19.6% to 44.7%. Each additional year of age was associated with lower odds of anaemia (adjusted OR [AOR] 0.81, 95% CI 0.68-0.97), as was each one-point increase in the recorded dietary-diversity score (AOR 0.85, 95% CI 0.73-0.99). Participant-reported school water availability had an inverse but imprecisely estimated association in the primary model (AOR 0.57, 95% CI 0.31-1.04); the post-menarcheal sensitivity estimate was 0.53 (95% CI 0.28-0.99). Soap availability, the study-record menstrual-hygiene adequacy indicator and recent malaria were not independently associated.

Conclusion: Anaemia affected nearly one-third of girls in the selected schools. Younger age and a lower recorded dietary-diversity score were the most consistent correlates. The school audit documented WASH service gaps, but WASH-anaemia associations should be regarded as exploratory. The cross-sectional design and purposive school selection preclude causal or population-wide inference.

Keywords: Adolescent Girls, Anaemia, Dietary Diversity, Haemoglobin, School Health, Wash, Nigeria

1. INTRODUCTION

Anaemia is a condition in which haemoglobin concentration is insufficient to meet physiological requirements and adequately support tissue oxygenation. It is an endpoint shared by multiple nutritional, infectious, inflammatory, genetic and gynaecological pathways rather than a single disease entity. Iron deficiency is an important cause, but deficiencies of folate, vitamin B12 and vitamin A, malaria and other infections, chronic inflammation, inherited haemoglobin disorders and blood loss may also contribute. Consequently, low haemoglobin alone cannot establish iron-deficiency anaemia or identify the underlying cause. Current WHO guidance therefore emphasizes age-, sex- and physiological-status-specific thresholds, appropriate adjustment for relevant measurement conditions and clear reporting of the method used when estimating prevalence (World Health Organization, 2024; Pasricha et al., 2024).

Adolescence, defined as 10-19 years of age, is a nutritionally sensitive period that combines rapid somatic growth with changing diets, increasing autonomy and, for girls after menarche, recurrent menstrual blood loss. Expansion of lean body mass and blood volume increases requirements for iron and other micronutrients. At the same time, food insecurity, monotonous diets, meal skipping, malaria, helminth infection and limited access to preventive services may operate concurrently. These overlapping demands can make adolescent girls particularly vulnerable even when overt clinical symptoms are absent. Anaemia may manifest as fatigue, reduced exercise tolerance and diminished physical capacity, while iron deficiency can affect cognitive and neurological function before severe anaemia develops (Das et al., 2017; Yeboah et al., 2024). Such effects may influence concentration, participation and educational attainment, making schools an important platform for early identification, referral, nutrition education and preventive services.

Recent evidence confirms considerable geographical and socioeconomic heterogeneity in adolescent anaemia. A multi-country analysis across sub-Saharan Africa and India and a regional meta-analysis both identified substantial variation by age, sex, setting, diet, infection and household circumstances (Manu et al., 2026; Martins et al., 2026). School-based studies have reported prevalence of 16.0% in rural Uganda, substantial burdens in Burkina Faso and Zanzibar, and heterogeneous results within Nigeria (Adokorach et al., 2024; Millogo et al., 2025; Yusufu et al., 2023; Ejike et al., 2024). Differences in malaria transmission, food access, menstrual characteristics and socioeconomic conditions may partly explain these patterns. Cross-study comparisons are also affected by sampling frames, capillary or venous measurement methods, altitude and other haemoglobin adjustments, and the diagnostic cut-offs applied. Locally generated evidence using current definitions is therefore necessary for proportionate school-health planning.

Diet is a particularly actionable pathway because adolescence is also a period in which lifelong food preferences and eating practices become established. Dietary-diversity scores provide a pragmatic indicator of access to multiple food groups and the likelihood of obtaining a wider range of micronutrients, although they do not directly quantify iron intake, portion size or bioavailability. Iron status depends not only on the quantity consumed but also on the balance between haem and non-haem iron sources and dietary enhancers or inhibitors of absorption. A 2025 meta-analysis reported higher odds of anaemia among children and adolescents with inadequate dietary diversity, while noting high heterogeneity and generally low certainty (Li et al., 2025). In Ogun State, earlier work among adolescents identified inadequate iron intake and a 24.4% prevalence of anaemia, with biochemical evidence that not all anaemia was attributable to iron deficiency (Onabanjo & Balogun, 2014). More recent local evidence also points to persistent dietary and anthropometric vulnerability among public-school adolescents (Tanimonure et al., 2026).

School WASH may influence adolescent wellbeing through several direct and indirect mechanisms. Reliable water, usable sanitation, soap, privacy and menstrual-disposal facilities support hand hygiene, infection prevention, toilet use and dignified menstrual management. Inadequate services may increase exposure to enteric or parasitic infection, discourage toilet use and make it difficult for menstruating girls to wash or change materials safely at school. Recurrent infection and inflammation can, in turn, interact with nutrient intake, absorption and iron metabolism, although the relationship between WASH and anaemia is neither universal nor necessarily direct (Kothari et al., 2019; Baldi et al., 2020). School WASH conditions may also reflect broader differences in school resources and community disadvantage, making careful interpretation of observed associations essential. A recent review found that school WASH interventions can affect health, education and gender-equity outcomes, but effects vary by context and intervention design (Bick et al., 2025). Globally, major service gaps persist: the 2024 WHO/UNICEF update estimated that hundreds of millions of children lacked basic water, sanitation or hygiene services at school (WHO & UNICEF, 2024).

Despite the potential interaction of nutritional, infectious and school-environmental conditions, these domains are often examined separately. Evidence integrating objectively measured haemoglobin with dietary diversity, participant-reported WASH conditions and a school-facility audit among adolescent girls in Ogun State remains limited. This study therefore aimed to: (1) estimate the prevalence and severity of anaemia using WHO 2024 age-specific cut-offs; (2) describe participant-reported and school-audit WASH conditions; (3) examine associations of age, residence, selected participant-reported WASH indicators, the recorded dietary-diversity score and recent malaria with anaemia; and (4) assess robustness in post-menarcheal and school-adjusted sensitivity analyses.

2. MATERIALS AND METHODS

2.1 Study Design, Setting And Period

The study population comprised girls aged 10–19 years who were enrolled in the selected public secondary schools. Girls within the specified age range and enrolled in the selected schools were eligible for selection. Participation following selection required willingness to participate and completion of the appropriate consent and assent procedures. Written parental or guardian consent and adolescent assent were obtained for minors, while participants legally able to provide consent did so in accordance with the approved study procedures.

A multistage sampling procedure was used. First, one local government area was selected from each of the three senatorial districts of Ogun State by simple random ballot. Second, two public secondary schools were purposely selected within each selected local government area on the basis of accessibility, enrolment and willingness to participate, yielding six schools. Third, within each selected school, eligible girls were enumerated from class registers and stratified by class (JSS1–JSS3 and SS1–SS3). The required number of participants was allocated proportionately to each class according to the number of eligible girls in that class. Within each class, eligible girls were assigned unique sequential identification numbers, and the required number of participants was selected by simple random sampling using a computer-generated random-number sequence.

Selected girls were subsequently approached for enrolment and the required consent or assent obtained before data collection. The final analytical sample comprised 277 participants with complete questionnaire and haemoglobin records. Because the schools were purposely selected, inference is restricted to the participating schools and broadly comparable settings rather than to all adolescent girls in Ogun State.

2.2 Questionnaire And Participant Variables

Trained research assistants administered a structured questionnaire that had been pretested among adolescents outside the six selected schools. Pretesting assessed clarity, comprehension, sequencing and field feasibility. The retained participant dataset included age in completed years, class, residence, menarcheal status, usual menstrual material, menstruation-related school absence, a study-record menstrual-hygiene adequacy indicator, dietary-diversity score, iron-rich-food frequency, recent malaria, recent deworming and iron supplementation. Recent malaria, deworming and supplementation were analysed as questionnaire indicators because diagnostic confirmation, exact timing, dose and adherence details were not retained. Dietary diversity was represented by a recorded score ranging from 1 to 8, with higher values indicating a greater number of represented food groups in the study record. Component food-group responses, portion sizes, the recall specification and a validated adequacy threshold were not retained; the score was therefore analysed continuously per one-point increase, and no participant was classified as having adequate or inadequate dietary diversity.

2.3 WASHAassessment

The participant questionnaire contained binary indicators of school water availability, drinking-water availability, water for handwashing, a functional girls toilet, toilet privacy, a usable lock, toilet cleanliness, soap availability, a menstrual-material disposal facility, a private changing space and water for menstrual washing. These indicators represented participant-reported or participant-recorded availability/access and did not measure water quantity, continuity, distance, microbial quality or safely managed service level. A separate one-time school-level facility checklist documented a functional water source, drinking-water facility, handwashing facility, soap, total and functional girls toilets, menstrual changing space and menstrual-waste disposal. Because the audit yielded only six school-level observations, it was summarized descriptively rather than entered as a school-level exposure model. Participant-level WASH indicators were used in individual-level regression and interpreted as exploratory reports of school access; school fixed-effects and small-cluster sensitivity analyses were used to examine robustness to school membership.

2.4 Haemoglobin Measurement And Outcome Definition

Capillary blood was obtained by finger prick using a sterile disposable lancet. The first drop was wiped away and the second drop was collected into a microcuvette for measurement with a HemoCue Hb 301 analyser by trained personnel following the manufacturer's operating procedure. Haemoglobin was recorded in g/dL. A single haemoglobin result was available for each participant; duplicate readings and device quality-control logs were not available for analysis. The primary outcome used WHO 2024 sea-level age-specific cut-offs: Hb <11.5 g/dL for girls aged 10-11 years and Hb <12.0 g/dL for girls aged 12-19 years. Mild anaemia was Hb 11.0-11.4 g/dL at ages 10-11 and 11.0-11.9 g/dL at ages 12-19; moderate anaemia was Hb 8.0-10.9 g/dL and severe anaemia Hb <8.0 g/dL. Exact elevation, smoking and pregnancy information was unavailable, so no corresponding haemoglobin adjustments were made.

2.5 Statistical Analysis

Data integrity checks assessed row counts, participant-code duplication, missingness, valid ranges and consistency between haemoglobin values and recorded anaemia status. The WHO 2024 age-specific anaemia outcome was derived from exact age and haemoglobin concentration. All 277 analytical records were complete for variables used in the reported models; no imputation was performed.

Continuous variables were summarized using means and standard deviations or medians and interquartile ranges, as appropriate; categorical variables were summarized using frequencies and percentages. Overall and school-specific anaemia prevalence CIs were calculated using the Wilson method. Univariable logistic regression estimated crude ORs and 95% CIs for prespecified candidate correlates. Effect estimates and CIs were emphasized rather than interpretation based solely on a p-value threshold.

The primary multivariable logistic model was specified a priori to balance substantive relevance and the number of anaemia events. It included age (per year), residence (urban reference), participant-reported school water availability (no/unavailable reference), participant-reported soap availability (no reference), recorded dietary-diversity score (per point) and recent malaria (no reference). Adjusted ORs are presented with 95% CIs. No stepwise variable selection was used. ORs quantify associations with the odds of anaemia and should not be interpreted as prevalence ratios.

Four sensitivity analyses were performed. First, the primary model was repeated using the original uniform Hb <12.0 g/dL definition. Second, analysis was restricted to 262 post-menarcheal girls and added the study-record menstrual-hygiene adequacy indicator. Third, school fixed effects were included to assess between-school confounding. Fourth, cluster-robust covariance estimates were calculated by school with small-sample correction; these were interpreted cautiously because only six clusters were available. Model discrimination (AUC), calibration (Hosmer-Lemeshow test) and Brier score were reported as secondary descriptive diagnostics and were not used for predictor selection or individual clinical prediction. All tests were two-sided, with $p < 0.05$ used as a conventional reference while effect magnitude and uncertainty were prioritized. Analyses were performed using IBM SPSS Statistics version 28.

2.6. Ethical Considerations

Permission was obtained from the participating school authorities. Study procedures were explained to participants, participation was voluntary, and confidentiality was maintained. Written parental or guardian consent and adolescent assent were obtained for minors; participants legally able to consent did so according to applicable requirements. Reporting followed the STROBE recommendations for cross-sectional studies (von Elm et al., 2007).

3. RESULTS

3.1 Participant Characteristics

The analytical dataset contained 277 girls with complete data for the variables used in the reported analyses. Mean age was 14.78 ± 1.53 years (range 11-19); 169 (61.0%) were aged 13-15 years. Senior-secondary students constituted 193 (69.7%) participants. Most lived in urban or peri-urban settings (218/277, 78.7%), and 262 (94.6%) had reached menarche. Recent malaria was recorded for 50 (18.1%), recent deworming for 154 (55.6%) and iron supplementation for 31 (11.2%) participants (Table 1).

Table 1. Participant Characteristics (N = 277)

Characteristic	Category	n (%) or mean ± SD
Age, years	Mean ± SD	14.78 ± 1.53

Characteristic	Category	n (%) or mean ± SD
Age group, years	10-12	18 (6.5)
Age group, years	13-15	169 (61.0)
Age group, years	16-19	90 (32.5)
Class	JSS1	9 (3.2)
Class	JSS2	32 (11.6)
Class	JSS3	43 (15.5)
Class	SS1	79 (28.5)
Class	SS2	58 (20.9)
Class	SS3	56 (20.2)
Residence	Urban	100 (36.1)
Residence	Peri-urban	118 (42.6)
Residence	Rural	59 (21.3)
Menstruation started	Yes	262 (94.6)
Recent malaria	Yes	50 (18.1)
Dewormed recently	Yes	154 (55.6)
Iron supplementation	Yes	31 (11.2)
Recorded dietary-diversity score	Mean ± SD	3.83 ± 1.87
Iron-rich-food days/week	Mean ± SD	2.65 ± 1.65

JSS = junior secondary school; SS = senior secondary school; SD = standard deviation.

3.2 School and Participant WASH Conditions

The school audit found a functional water source in four of six schools, a drinking-water facility in four, a handwashing facility in three and soap in three on the audit day. Across schools, 45 girls toilets were recorded, of which 28 (62.2%) were functional. None had a designated menstrual changing space, although all had a recorded menstrual-waste disposal option (Table 2). At participant-report level, 204/277 (73.6%) reported school water availability, 187 (67.5%) drinking-water availability, 156 (56.3%) water for handwashing, 216 (78.0%) a functional girls toilet and 132 (47.7%) soap availability. Participant reports and the one-time audit represent different measurement levels and were not assumed to be interchangeable.

Table 2. School-level WASH Audit

School	Water source	Drinking water	Handwashing	Soap	Functional/total girls toilets	Changing space	Waste disposal
1	Yes	Yes	No	Yes	5/8	No	Yes
2	Yes	Yes	No	No	3/9	No	Yes
3	No	Yes	Yes	Yes	7/8	No	Yes

School	Water source	Drinking water	Handwashing	Soap	Functional/total girls toilets	Changing space	Waste disposal
4	Yes	No	Yes	No	6/10	No	Yes
5	Yes	Yes	No	No	4/6	No	Yes
6	No	No	Yes	Yes	3/4	No	Yes

Binary indicators describe the recorded service/facility at each school. Toilet counts were checked against the corrected school record.

3.3 Prevalence And Severity Of Anaemia

Mean haemoglobin was 12.60 ± 1.21 g/dL; median haemoglobin was 12.7 g/dL (interquartile range 11.8-13.3). Applying WHO 2024 age-specific cut-offs, 82 participants were anaemic, corresponding to 29.6% (95% CI 24.5-35.2). Mild anaemia affected 62 (22.4%) and moderate anaemia 20 (7.2%); no severe cases were identified (Table 3; Figure 1). The original uniform Hb <12.0 g/dL rule classified 83 participants (30.0%) as anaemic. The single discordant participant was aged 11 years with Hb 11.6 g/dL.

Table 3. Haemoglobin Concentration And Who 2024 Age-Specific Anaemia Classification

Measure	Value
Haemoglobin, mean ± SD (g/dL)	12.60 ± 1.21
Haemoglobin, median (IQR) (g/dL)	12.7 (11.8-13.3)
Not anaemic	195 (70.4%)
Any anaemia	82 (29.6%; 95% CI 24.5-35.2)
Mild anaemia	62 (22.4%)
Moderate anaemia	20 (7.2%)
Severe anaemia	0 (0.0%)

Anaemia was classified using WHO 2024 age-specific cut-offs. IQR = interquartile range; SD = standard deviation.

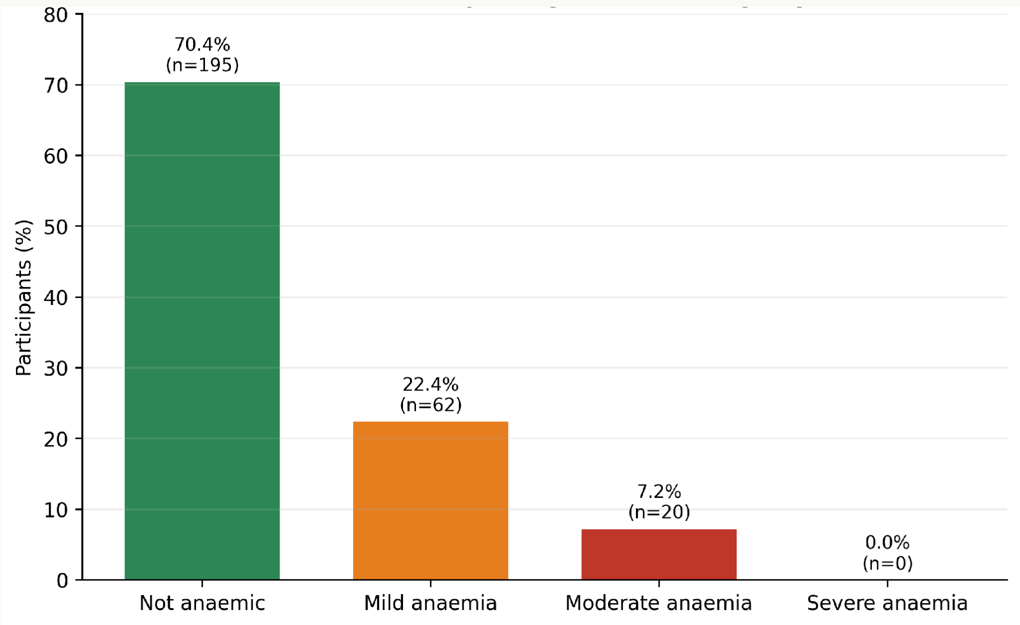

Figure 1. Anaemia status and severity using WHO 2024 age-specific haemoglobin cut-offs.

3.4 Variation Between Schools

School-specific prevalence ranged from 19.6% (95% CI 10.7-33.2) in School 3 to 44.7% (95% CI 31.4-58.8) in School 6 (Figure 2). Confidence intervals overlapped substantially because each school contributed only 46 or 47 participants. The school audit documented service differences, but six school-level observations were insufficient for reliable ecological regression and the schools should not be ranked on these estimates.

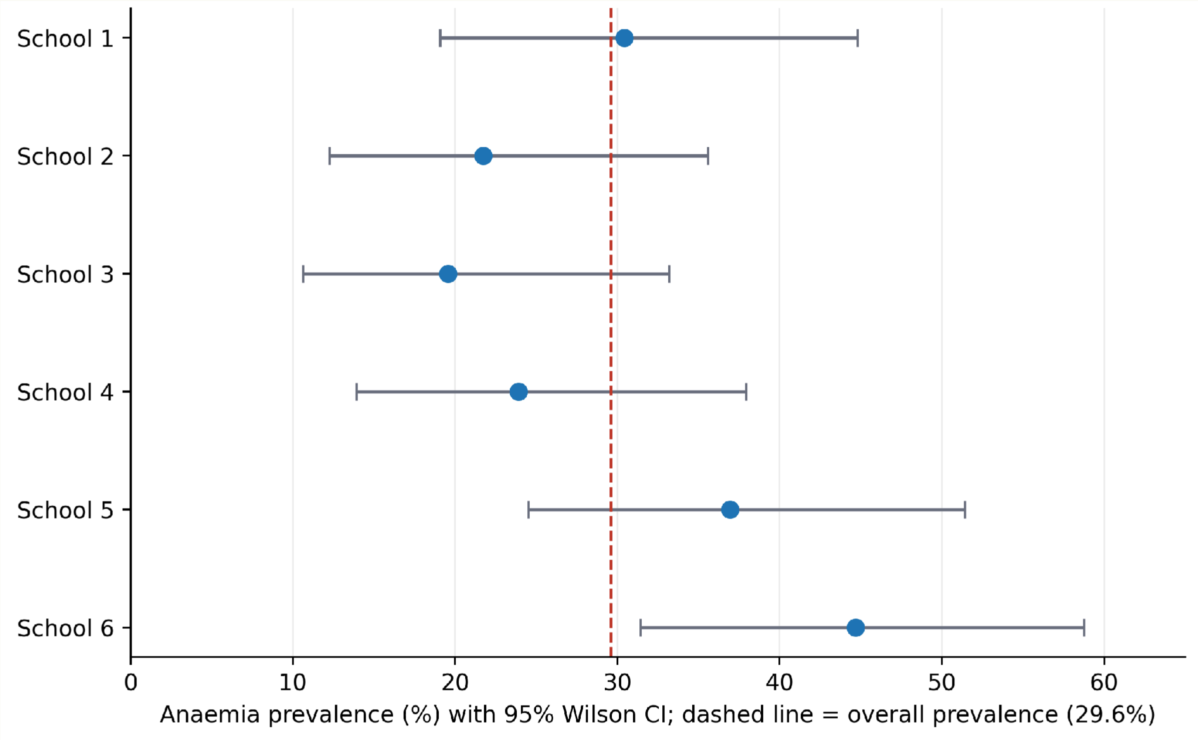

Figure 2. School-specific prevalence of anaemia with 95% Wilson confidence intervals. The dashed vertical line indicates the overall prevalence (29.6%).

3.5 Univariable Associations

In univariable analyses, each additional year of age was associated with lower odds of anaemia (OR 0.81, 95% CI 0.68-0.96), and each one-point increase in the recorded dietary-diversity score was also associated with lower odds (OR 0.86; unrounded 95% CI 0.747-0.998). Participant-reported water, drinking water, handwashing water, toilet privacy and soap had point estimates below unity but confidence intervals included the null; a reported functional girls toilet had a point estimate above unity with a wide CI (Table 4). These simplified WASH indicators should not be interpreted as causal measures of service quality.

Table 4. Univariable logistic regression for WHO 2024 age-specific anaemia

Variable/comparison	Crude OR	95% CI	p-value
Age, per year	0.81	0.68-0.96	0.017
Peri-urban vs urban residence	1.30	0.73-2.32	0.366
Rural vs urban residence	0.63	0.29-1.35	0.230
Participant-reported school water: yes vs no	0.63	0.36-1.11	0.109

Variable/comparison	Crude OR	95% CI	p-value
Participant-reported drinking water: yes vs no	0.83	0.48-1.43	0.508
Participant-reported handwashing water: yes vs no	0.75	0.44-1.25	0.268
Participant-reported functional girls toilet: yes vs no	1.73	0.88-3.41	0.111
Participant-reported toilet privacy: yes vs no	0.68	0.39-1.20	0.185
Participant-reported soap: yes vs no	0.75	0.45-1.27	0.283
Recorded dietary-diversity score, per point	0.863	0.747-0.998	0.046
Recent malaria: yes vs no	1.28	0.67-2.46	0.453

For binary indicators, No/Unavailable (0) is the reference. Urban residence is the reference. WASH variables are participant-report indicators. OR = odds ratio; CI = confidence interval.

3.6 Multivariable And Sensitivity Analyses

In the primary model, age (AOR 0.81 per year, 95% CI 0.68-0.97; p=0.025) and recorded dietary-diversity score (AOR 0.85 per point, 95% CI 0.73-0.99; p=0.035) remained associated with anaemia. Participant-reported school water availability had an inverse but imprecisely estimated association (AOR 0.57, 95% CI 0.31-1.04; p=0.066). Residence, participant-reported soap availability and recent malaria were not independently associated (Table 5; Figure 3).

The primary model included 82 anaemia events and seven predictor degrees of freedom and converged successfully. Secondary diagnostics indicated modest discrimination (AUC 0.647) and a Brier score of 0.193; the Hosmer-Lemeshow statistic did not indicate gross lack of fit (χ^2=4.72, 8 df, p=0.787), although such diagnostics have limited precision in modest samples. The model was used for association estimation, not individual clinical prediction.

Results were broadly stable when the original uniform Hb <12.0 g/dL outcome was used: age (AOR 0.79, 95% CI 0.65-0.94) and recorded dietary diversity (AOR 0.86, 95% CI 0.74-1.00) remained associated. Among 262 post-menarcheal girls, participant-reported school water availability (AOR 0.53, 95% CI 0.28-0.99) and recorded dietary diversity (AOR 0.84, 95% CI 0.72-0.98) were associated, while the study-record menstrual-hygiene adequacy indicator was not (AOR 1.09, 95% CI 0.62-1.92). School fixed-effect models retained inverse associations for age and dietary diversity. Small-cluster robust estimates were directionally consistent, but inference from only six clusters remains unstable; the post-menarcheal water estimate is therefore treated as exploratory rather than confirmatory.

Table 5. Multivariable logistic-regression models for WHO 2024 age-specific anaemia

Predictor	Primary model AOR (95% CI)	p	Post-menarcheal model AOR (95% CI)	p
Age, per year	0.81 (0.68-0.97)	0.025	0.85 (0.70-1.02)	0.082
Peri-urban vs urban	1.46 (0.80-2.67)	0.215	1.70 (0.92-3.15)	0.091
Rural vs urban	0.63 (0.29-1.40)	0.262	0.68 (0.30-1.52)	0.345
Participant-reported school water: yes vs no	0.57 (0.31-1.04)	0.066	0.53 (0.28-0.99)	0.045

Predictor	Primary model AOR (95% CI)	p	Post-menarcheal model AOR (95% CI)	p
Participant-reported soap: yes vs no	0.66 (0.38-1.14)	0.138	0.70 (0.40-1.23)	0.215
Recorded dietary-diversity score, per point	0.85 (0.73-0.99)	0.035	0.84 (0.72-0.98)	0.029
Recent malaria: yes vs no	1.48 (0.75-2.94)	0.263	1.57 (0.78-3.18)	0.206
Study-record menstrual-hygiene adequate: yes vs no	Not included	-	1.09 (0.62-1.92)	0.772

Primary model N=277 (82 events); post-menarcheal model N=262 (79 events). Urban residence and No/Unavailable (0) are reference categories. School water and soap are participant-report indicators. Dietary diversity is the recorded 1-8 score analysed per point. AOR = adjusted odds ratio; CI = confidence interval.

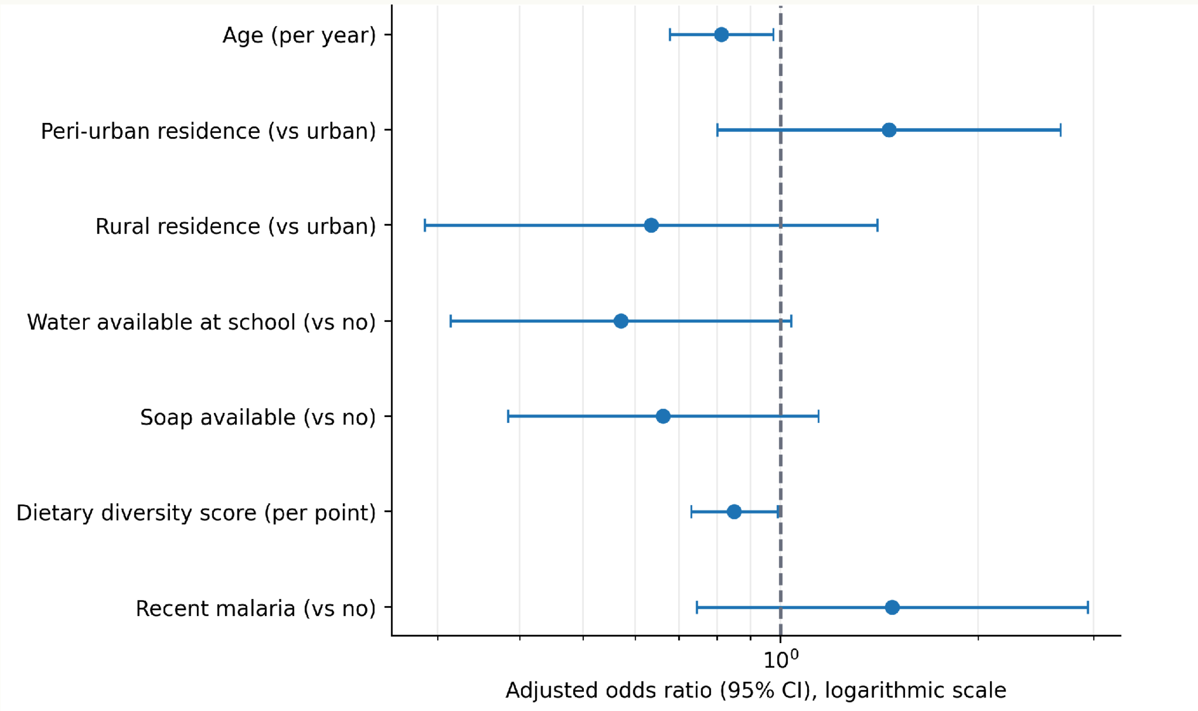

Figure 3. Adjusted odds ratios and 95% confidence intervals from the primary multivariable model. Estimates are plotted on a logarithmic scale; WASH terms are participant-report indicators.

4. DISCUSSION

4.1 Principal Findings

Using WHO 2024 age-specific cut-offs, 29.6% of girls in the six selected public secondary schools were anaemic. Most cases were mild, 7.2% were moderate and none were severe. Younger age and a lower recorded dietary-diversity score were the most consistent correlates across the primary and sensitivity models. Participant-reported school water availability was inversely associated in the post-menarcheal sensitivity model but was imprecisely estimated in the primary model, so this finding is exploratory. Prevalence varied more than twofold between schools, while the facility audit documented important

WASH service gaps.

These findings describe a heterogeneous school-health burden rather than a uniform condition across the study population. Mild anaemia may be clinically subtle, whereas the 20 moderate cases warrant clinical and nutritional assessment because haemoglobin concentration alone cannot identify iron deficiency, infection, blood loss or another cause. The absence of severe anaemia is reassuring but does not remove the need for appropriate follow-up of affected participants.

The analysis also resolves an important classification issue. Applying a uniform Hb <12.0 g/dL threshold produced 83 cases, while WHO 2024 age-specific classification produced 82. Although the numerical difference was small in this dataset because only three participants were aged 11 years, using exact age prevents systematic overclassification of younger adolescents and improves comparability with current guidance.

The consistency of the age and dietary-diversity associations across several model specifications is more informative than any single p-value. By contrast, the water estimate changed with the analytic population and its confidence intervals were wide. The most defensible interpretation is therefore that age and recorded dietary diversity are the more reproducible individual-level correlates, whereas WASH results identify service deficits and hypotheses requiring confirmation with more schools and stronger exposure measurement.

4.2 Prevalence In Relation To Nigerian And Regional Evidence

The 29.6% prevalence is somewhat higher than the 24.4% reported by Onabanjo and Balogun (2014) among 127 adolescents in selected Ogun State schools and is close to the pooled estimate of 33% reported in a recent sub-Saharan African adolescent meta-analysis (Martins et al., 2026). Direct comparison remains limited by differences in sampling, sex composition, season, biomarkers, measurement procedures and haemoglobin definitions. The earlier Ogun study included biochemical iron-status markers and found that not all anaemia could be equated with iron deficiency, reinforcing the present study's aetiological caution.

The difference from the earlier Ogun estimate should not be interpreted as a temporal trend. The present study included only girls, sampled different schools and used current age-specific thresholds, whereas the earlier investigation used a smaller sample and additional biomarkers. The more defensible conclusion is that anaemia remains an important concern in school-going adolescents in Ogun State, with magnitude and aetiology likely to vary across settings.

African school-based estimates are likewise heterogeneous: Adokorach et al. (2024) reported 16.0% among rural school-going adolescents in Uganda, while studies in Burkina Faso and Zanzibar found different burdens and determinant structures (Millogo et al., 2025; Yusufu et al., 2023). Nigerian evidence also varies by setting (Ejike et al., 2024). This heterogeneity argues for locally grounded surveillance rather than transfer of a single regional prevalence estimate.

4.3 Age And Adolescent-Stage Differences

The inverse association with age was consistent across the primary, uniform-threshold and school fixed-effect models, and a younger-age pattern has been reported in recent multicountry adolescent analyses (Manu et al., 2026). In the primary model, each additional year of age corresponded to approximately 19% lower odds of anaemia, assuming the specified linear association on the log-odds scale. Age should not be interpreted as intrinsically protective: it may represent pubertal growth, dietary autonomy, school retention, infection history or other unmeasured processes.

The small number of participants at the youngest ages limits age-specific inference. Future prospective work should measure pubertal stage, age at menarche, menstrual characteristics, school attendance and repeated haemoglobin rather than relying on chronological age alone.

Programmatically, the result supports attention to younger adolescents as well as older menstruating girls. Screening and nutrition education can begin in junior secondary school, with referral based on haemoglobin concentration, symptoms and clinical assessment rather than age alone.

4.4 Dietary Diversity

Each additional point in the recorded dietary-diversity score was associated with approximately 15% lower adjusted odds of anaemia. The direction is consistent with the meta-analysis by Li et al. (2025) and with school-based Ugandan evidence (Adokorach et al., 2024), but the present score is a proxy rather than a measure of iron intake or bioavailability.

Interpretation is limited because component food groups, portion sizes, the recall specification and absorption modifiers were not retained. The association therefore cannot identify which foods or nutrients account for the pattern, establish iron deficiency, or justify a diagnostic threshold. Future Ogun State studies should retain a validated adolescent dietary instrument and pair dietary data with ferritin and inflammatory markers. In practice, schools can promote feasible dietary variety while avoiding claims that the recorded score itself diagnoses nutritional deficiency.

4.5 School WASH and Water Availability

Participant-reported school water availability had an inverse but imprecisely estimated association in the primary model and a borderline inverse association in the post-menarcheal sensitivity analysis. Reliable water could support drinking, handwashing, toilet operation and menstrual washing, but it may also mark broader school resources. Because the exposure was participant-reported, the design was cross-sectional and only six schools were included, these estimates should not be interpreted as a causal effect of water on haemoglobin.

The difference between the primary and post-menarcheal estimates may reflect chance, restriction of the analytic sample, residual confounding or greater relevance of water for menstruating girls; the study was not designed to distinguish these explanations. Confirmation would require more schools and direct measures of water continuity, quantity, accessibility and quality, with any effect-modification hypothesis specified in advance.

The broader WASH-anaemia literature is mixed and context dependent (Kothari et al., 2019; Baldi et al., 2020). Potential mechanisms involving enteric infection, helminths and inflammation require direct measurement. The present study did not test water quality, enteric pathogens, helminths or inflammatory markers; its WASH variables should therefore be understood as service indicators rather than demonstrated biological pathways.

The school audit nevertheless identified actionable service gaps independent of the regression results: two schools lacked a functional water source, three lacked a handwashing facility, three lacked soap, none had a designated menstrual changing space and only 28 of 45 girls toilets were functional. These deficits matter for infection prevention, dignity and participation even if a direct effect on haemoglobin is not established (WHO & UNICEF, 2024; Bick et al., 2025).

4.6 Menstrual Hygiene, Malaria and other Health Indicators

The study-record menstrual-hygiene adequacy indicator was not associated with anaemia in the post-menarcheal model. This simplified indicator is more directly relevant to privacy, comfort and participation than to quantification of blood loss, and the dataset did not measure cycle length, bleeding intensity or gynaecological symptoms. The null estimate therefore does not address menstrual blood loss as a haematological exposure.

Recent malaria had a positive but imprecise adjusted association. The recorded variable did not specify diagnostic method, timing, severity or treatment, so exposure misclassification is possible. The same caution applies to deworming and iron supplementation, which may also be affected by programme access and confounding by indication. Future studies should incorporate confirmed malaria and parasite testing, menstrual-bleeding measures and verified supplement dose and adherence.

4.7 School Heterogeneity and Analytical Robustness

Anaemia prevalence ranged from 19.6% to 44.7% across schools, but school-specific CIs overlapped and each school contributed only 46 or 47 participants. The variation may reflect participant composition, diet, infection, services or chance and should not be interpreted as a performance ranking. A larger probability-based sample would permit multilevel modelling of participant- and school-level variation.

With only six schools, ecological regression would be unstable and conventional cluster-robust inference is fragile. Ordinary individual-level logistic regression was therefore retained as the primary association model, with school fixed effects and small-cluster covariance used only as sensitivity analyses. Age and recorded dietary diversity remained directionally consistent in the school fixed-effect model, whereas the WASH findings remained secondary and exploratory.

The primary model's AUC of approximately 0.65 indicates modest discrimination and confirms that the included variables are not suitable for an individual clinical risk score. Important determinants were unmeasured, including ferritin, inflammation, confirmed infection, menstrual blood loss, household food security and haemoglobin disorders. The model's value is therefore association estimation and hypothesis generation rather than prediction.

4.8 Strengths and Limitations

Strengths include individual haemoglobin measurement, exact-age reclassification under current WHO guidance, complete analytical records for 277 participants, representation of six schools across the three senatorial districts, parallel participant-report and school-audit WASH measures, explicit reference categories, avoidance of stepwise modelling and several sensitivity analyses. The reproducible analysis package separates raw variables from derived outcomes and documents model terms.

Several limitations are important. Cross-sectional data cannot establish temporality or causality. Purposive school selection limits generalisability, and only six clusters preclude precise school-level inference. Capillary haemoglobin was measured once; duplicate readings and device quality-control logs were unavailable. Exact altitude, smoking and pregnancy status were unavailable for haemoglobin adjustment. The dietary-diversity components, recall specification and formal validation metrics were not retained. Participant-reported WASH indicators did not capture service reliability, quantity, microbial quality or safely managed service level. Malaria and deworming lacked diagnostic and timing detail, and ferritin, inflammatory markers, helminth testing, haemoglobin disorders and menstrual blood loss were not measured. Finally, ORs describe odds rather than prevalence ratios, and zero severe cases prevented modelling severity as an ordinal outcome.

4.9 Implications for Policy and Research

The findings support a proportionate school-health response. Nutrition programmes can promote varied, locally available foods while clinical screening and referral should investigate the cause of low haemoglobin rather than assume iron deficiency. WASH improvements are justified by the documented service gaps and their broader health, dignity and educational importance, not by a claim that the present study proved a causal effect on anaemia. Malaria prevention and deworming should follow local epidemiology and national guidance.

Where feasible, haemoglobin screening should be linked to confidential result communication, symptom assessment and referral, particularly for moderate anaemia or persistent symptoms. School-level action should include routine checks of water continuity, soap, toilet functionality, privacy and menstrual-changing facilities, with attention to girls' experience of access as well as infrastructure counts.

Nutrition activities can be embedded in school meals, food-vendor guidance and health education, emphasizing dietary variety and combinations of iron-containing foods with absorption enhancers while accounting for affordability and local food availability. Such programmes should be evaluated using dietary measures and biochemical iron-status indicators rather than the present recorded score alone.

Future research should use probability-based school sampling, prospective or repeated-measures multilevel designs, validated dietary and menstrual-health instruments, direct measures of WASH service reliability and water quality, confirmed malaria and helminth testing, ferritin with inflammation adjustment, and menstrual-blood-loss assessment. These additions would help separate nutritional, infectious, gynaecological and environmental pathways and support evaluation of combined school-health interventions.

5. CONCLUSION

Anaemia affected 29.6% of girls in the six selected public secondary schools, with mild cases predominating and no severe cases identified. Younger age and a lower recorded dietary-diversity score were the most consistent individual-level correlates across the primary and sensitivity analyses. Participant-reported school water availability showed an inverse but imprecisely estimated association in the primary model and an exploratory inverse association in the post-menarcheal sensitivity analysis. The school audit independently documented gaps in water, handwashing, soap, toilet functionality and menstrual-changing space. These findings support nutrition assessment, appropriate haemoglobin follow-up and school WASH improvement, but the cross-sectional design, purposive school selection and small number of schools preclude causal or population-wide inference. Future probability-based, prospective studies should combine haemoglobin with iron-status, infection, menstrual and higher-quality WASH measurements.

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