Original Article

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Frequency of Obesity, Elevated Blood Pressure, Anemia, and Micronutrient Deficiencies in a School-linked Adolescent Screening Cohort

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Abstract

Aim: School-linked adolescent screening may identify nutritional, hematologic, micronutrient, and blood pressure (BP) abnormalities in students outside regular preventive follow-up. This study evaluated the frequency of predefined, screening-detected abnormalities among adolescents who completed a school-linked clinical and laboratory screening pathway.

Methods: This retrospective cross-sectional study included 287 adolescents who attended pediatric outpatient screening after school-based outreach conducted between November 21 and December 6, 2023. Frequencies were reported with Wilson 95% confidence intervals (CIs). Multivariable logistic regression was used to assess factors associated with elevated or hypertensive-range BP.

Results: The sample included 204 girls and 83 boys; the median age was 14.0 years. Overweight/obesity was identified in 32.1% (95% CI, 26.9-37.7); elevated/hypertensive-range BP in 19.5% (95% CI, 15.3-24.5); anemia in 17.1% (95% CI, 13.1-21.9); ferritin <15 ng/mL in 24.7% (95% CI, 20.0-30.2); vitamin B12 <200 pg/mL in 18.8% (95% CI, 14.6-23.8); and folate <4 ng/mL in 15.1% (95% CI, 11.3-19.8). Boys [adjusted odds ratio (OR), 2.38; 95% CI, 1.17-4.83] and body mass index standard deviation score (aOR, 3.03; 95% CI, 2.17-4.25) were independently associated with elevated/hypertensive-range BP.

Conclusion: School-linked screening identified excess weight, abnormal BP screening findings, anemia, and micronutrient deficiencies. Such programs should integrate cardiometabolic assessment with sex-sensitive hematologic and micronutrient evaluation.

Keywords: Adolescent, school health services, mass screening, pediatric obesity, blood pressure, anemia, micronutrients

Introduction

Adolescence is a critical developmental period during which nutritional status, adiposity, blood pressure (BP) patterns, and micronutrient reserves may influence future cardiometabolic and hematologic health (1). Excess weight in childhood and adolescence remains a major public health concern, with recent global estimates showing a sustained and increasing burden of overweight and obesity among children and adolescents (2). Elevated BP during childhood and adolescence is also clinically important because pediatric hypertension predicts later cardiovascular risk, and recent systematic and scoping reviews have highlighted the global and European burden of pediatric hypertension, the higher risk among children and adolescents with overweight or obesity, and the relevance of school-based BP screening (3-5). At the same time, anemia, iron deficiency, and vitamin B12 insufficiency may occur during school age and adolescence and may remain clinically silent unless actively screened (6). Therefore, school-linked health screening may provide an opportunity to identify adolescents who do not routinely attend preventive healthcare visits (4).

In Türkiye, national surveillance data and previous primary care-based screening data indicate that excess weight, BP abnormalities, and anemia remain relevant health issues among school-aged children and adolescents

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(7,8). School-linked screening activities may be organized through collaboration between education authorities and healthcare institutions, with students being informed at school and referred for clinical evaluation when appropriate. However, Turkish data evaluating anthropometric status, BP measurements, anemia, iron status, vitamin B12, and folate together in adolescent school-linked screening settings are limited. In addition, because laboratory testing is not always completed for all students reached during outreach activities, studies based on completed clinical and laboratory screening pathways should clearly distinguish analytic cohort frequencies from population-level prevalence estimates.

We hypothesized that a school-linked adolescent screening pathway would identify a substantial burden of excess weight, elevated/hypertensive-range BP, anemia, and micronutrient deficiencies, with sex- and body mass index (BMI)-related differences in selected abnormalities. Therefore, this study aimed to determine the frequency of predefined screening-detected abnormalities among adolescents who completed a school-linked clinical and laboratory screening pathway and to explore their associations with sex and BMI categories. By defining these patterns, the study may contribute to the development of more targeted adolescent screening and follow-up strategies that integrate cardiometabolic, hematologic, and micronutrient assessments.

Materials and Methods

Compliance with Ethical Standards

The study was approved by an University of Health Sciences Türkiye, Istanbul Haseki Training and Research Hospital Institutional Non-Interventional Scientific Research Ethics Committee (approval no: 222-2026, date: 30.04.2026). Institutional administrative permission had also been obtained before the retrospective analysis. The study was conducted in accordance with the principles of the Declaration of Helsinki. The requirement for informed consent was waived because the study was retrospective and utilized anonymized data collected from routine screening.

Study Design and Setting

This retrospective cross-sectional study used records from a school-linked adolescent health screening pathway coordinated by a training and research hospital in collaboration with a district directorate of national education. The school-based outreach process and subsequent pediatric outpatient screening were conducted between November 21, 2023, and December 6, 2023. The participant flow is shown in Figure 1.

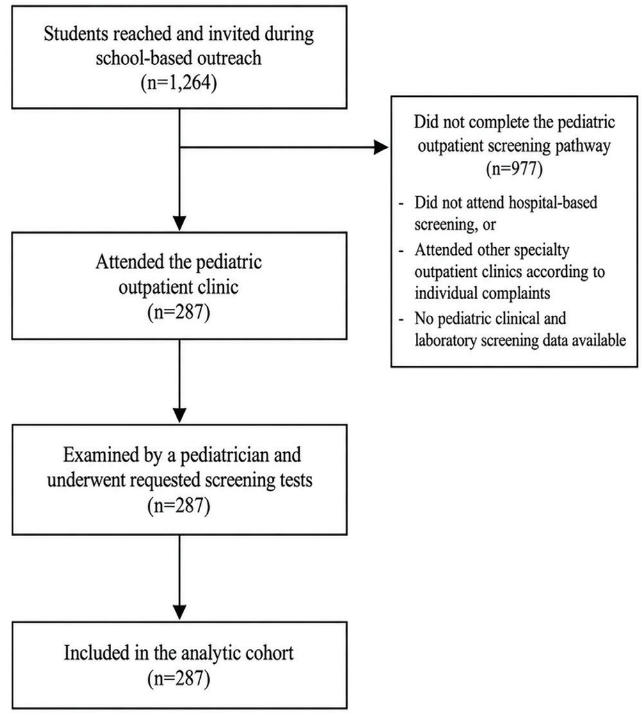

Figure 1. Participant flow of the school-linked adolescent screening cohort
A total of 1,264 students were reached and invited during school-based outreach. Of these, 287 attended the pediatric outpatient clinic, were examined by a pediatrician, underwent requested screening tests, and were included in the analytic cohort. Students who did not attend pediatric outpatient screening or who attended other specialty outpatient clinics were not included because pediatric clinical and laboratory screening data were not available

Participants, Inclusion Criteria, and Exclusion Criteria

During the school-based outreach phase, 1,264 adolescents were reached and informed. Students who had neither a known chronic disease nor regular follow-up at a healthcare center were invited to attend pediatric outpatient screening. Students with a known chronic disease or who were receiving regular healthcare follow-up were not targeted for this screening pathway.

The analytic cohort included adolescents who attended the pediatric outpatient clinic after school-based outreach and for whom anthropometric and BP measurements and relevant laboratory data were available. Adolescents with a known chronic disease were excluded. Data on medication use, vitamin or iron supplementation, and menstrual history were not systematically available. No pediatric clinical or laboratory screening data were available for students who did not attend the pediatric outpatient clinic or who attended other specialty outpatient clinics for individual complaints. Therefore, the present analysis was restricted to 287 adolescents who completed the clinical and laboratory screening pathway.

Sample Size

Assuming a finite population of 23,400 high school students in the district, an expected prevalence of 50%, a 5% absolute precision, a 95% confidence level, and a design effect of 1, the minimum sample size required to estimate prevalence in the target population was calculated to be 378 using OpenEpi version 3. The final analytic sample was smaller than this target; therefore, frequency estimates were interpreted as findings from the analytic cohort rather than precise population-level prevalence estimates. Accordingly, this study should be considered an exploratory descriptive analysis of adolescents who completed the clinical and laboratory screening pathway. The reported estimates represent analytic cohort frequencies and should not be interpreted as population prevalence estimates.

Outcomes

The primary outcome was the frequency of predefined screening-detected abnormalities in the analytic cohort, including underweight, overweight, obesity, waist circumference ≥90th percentile, elevated/hypertensive-range BP, anemia, low ferritin concentration, transferrin saturation <16%, iron deficiency anemia, vitamin B12 deficiency, borderline/insufficient vitamin B12 status, and folate deficiency. Secondary outcomes were differences in these abnormalities by sex and BMI category and the independent associations of age, sex, and BMI standard deviation score (SDS) with elevated or hypertensive-range BP.

Measurements and Definitions

Age, sex, body weight, height, BMI, BMI percentile, BMI SDS, waist circumference, waist circumference percentile, mid-upper arm circumference (MUAC), systolic BP, diastolic BP, hemoglobin, serum iron, total iron-binding capacity, ferritin, vitamin B12, and folate were obtained from the hospital information system. Transferrin saturation was calculated as serum iron divided by total iron-binding capacity and then multiplied by 100.

Body mass index-based nutritional status was classified according to age- and sex-specific BMI percentile categories as underweight (<5th percentile), normal weight (5th to <85th percentile), overweight (85th to <95th percentile), and obesity (≥95th percentile) (9).

Mid-upper arm circumference was evaluated as a complementary anthropometric screening indicator and classified according to age- and sex-specific MUAC-for-age categories (10). Waist circumference at or above the 90th percentile was considered high.

Systolic and diastolic BP were measured by the same clinician using an oscillometric device with an appropriately sized cuff after 10 minutes of seated rest. A single blood pressure measurement was obtained during the screening encounter; repeated measurements were not averaged. Blood pressure categories were defined according to the 2017 American Academy of Pediatrics thresholds for adolescents aged 13 years or older (11). For this age group, normal BP was defined as systolic BP <120 mmHg and diastolic BP <80 mmHg; elevated BP as systolic BP 120-129 mmHg and diastolic BP <80 mmHg; stage 1-range BP as systolic BP 130-139 mmHg or diastolic BP 80-89 mmHg; and stage 2-range BP as systolic BP ≥140 mmHg or diastolic BP ≥90 mmHg. Because BP was measured during a single screening encounter, elevated values were interpreted as screening-detected elevated BP or as hypertensive-range BP, rather than confirmed hypertension.

Anemia was defined according to age- and sex-specific World Health Organization hemoglobin thresholds: hemoglobin <12 g/dL for adolescents aged 12-14 years and girls aged 15 years or older, and hemoglobin <13 g/dL for boys aged 15 years or older (12). Low ferritin concentration was defined as serum ferritin <15 ng/mL (13). Transferrin saturation <16% was also reported as a marker of low iron availability. Iron deficiency anemia was defined as the coexistence of anemia and a serum ferritin level <15 ng/mL. Vitamin B12 deficiency was defined as <200 pg/mL, and Vitamin B12 levels of 200-299 pg/mL were reported as borderline low. Vitamin B12 levels <300 pg/mL have also been reported to capture both deficient and borderline low values. Folate deficiency was primarily defined as <4 ng/mL, with <3 ng/mL also reported as a stricter threshold (14).

Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics version 25.0 (IBM Corp., Armonk, NY, USA). Distributions of continuous variables were assessed using the Shapiro-Wilk test and visual inspection of normal probability plots. Normally distributed continuous variables were presented as mean ± standard deviation, whereas non-normally distributed variables were presented as median interquartile range (IQR). Categorical variables were summarized as numbers and percentages.

The frequencies of predefined screening-detected abnormalities were reported with 95% confidence intervals (CIs) calculated using the Wilson method. Comparisons between categorical variables were performed using Pearson's chi-square test or Fisher's exact test, as appropriate, based on expected cell counts. Statistically significant p-values were shown in bold in the tables.

Multivariable logistic regression analysis was performed to identify factors independently associated with elevated/hypertensive-range BP. Age, sex, and BMI SDS were selected a priori based on clinical relevance and to avoid overfitting, considering the number of adolescents with elevated/hypertensive-range BP. Results were reported as adjusted odds ratios with 95% CIs. Model fit and performance were evaluated using the Hosmer-Lemeshow goodness-of-fit test, Nagelkerke R^2, classification accuracy, and the c-statistic/area under the receiver operating characteristic curve. A two-sided p-value <0.05 was considered statistically significant.

Results

A total of 1,264 students were reached and invited during the school-based outreach phase. Among them, 287 adolescents attended the pediatric outpatient clinic, were examined by a pediatrician, underwent the requested screening tests, and constituted the analytic cohort (Figure 1). Students who did not attend pediatric outpatient screening or attended other specialty outpatient clinics were excluded because pediatric clinical and laboratory screening data were unavailable.

The median age of the analytic cohort was 14.0 years (IQR, 14.0-14.0), and 204 participants (71.1%) were girls. Continuous clinical and laboratory characteristics are shown in Table 1, and categorical characteristics in Table 2. Overall, 21 adolescents (7.3%) were underweight, 42 (14.6%) were overweight, and 50 (17.4%) were obese. Thus, 92 adolescents (32.1%) were overweight or obese.

Table 1. Continuous clinical and laboratory characteristics of the analytic cohort

Variable	N	Summary statistic
Age, years	287	14.0 (14.0-14.0)
Height, cm	287	158.0 (155.0-164.0)
Weight, kg	287	55.0 (46.9-65.0)
BMI, kg/m^2	287	21.45 (19.18-25.00)
BMI percentile	287	64.43 (29.46-90.82)
BMI SDS	287	0.35±1.33
Waist circumference, cm	287	70.0 (64.0-78.5)
Waist circumference percentile	287	48.0 (18.0-80.0)
MUAC, cm	285	24.0 (22.0-27.0)
Systolic BP, mmHg	287	110.0 (100.0-116.0)
Diastolic BP, mmHg	287	60.0 (60.0-72.0)
Hemoglobin, g/dL	281	13.1 (12.3-14.1)
Ferritin, ng/mL	275	25.4 (15.0-40.3)
Vitamin B12, pg/mL	272	268.5 (218.0-329.5)
Folate, ng/mL	272	5.9 (4.5-7.1)
Transferrin saturation, %	280	19.0 (12.9-26.7)

Values are presented as median (interquartile range) for non-normally distributed variables and mean ± standard deviation for normally distributed variables
BMI: Body mass index, BP: Blood pressure, MUAC: Mid-upper arm circumference, SDS: Standard deviation score

Waist circumference ≥90th percentile was identified in 49 adolescents (17.1%). Normal BP was recorded in 231 adolescents (80.5%), elevated BP in 15 (5.2%), stage-1 range BP in 38 (13.2%), and stage-2 range BP in 3 (1.0%).

The frequencies of predefined screening-detected abnormalities are presented with 95% confidence intervals in Table 3. Elevated or hypertensive-range BP was detected in 56 adolescents (19.5%; 95% CI, 15.3-24.5), including 41 adolescents (14.3%; 95% CI, 10.7-18.8) who had hypertensive-range BP. Anemia was detected in 48 of 281 adolescents (17.1%; 95% CI, 13.1-21.9); low ferritin concentration was detected in 68 of 275 adolescents (24.7%; 95% CI, 20.0-30.2); transferrin saturation <16% was detected in 104 of 280 adolescents (37.1%; 95% CI, 31.7-42.9); and iron deficiency anemia was detected in 30 of 274 adolescents (10.9%; 95% CI, 7.8-15.2). Vitamin B12 deficiency, defined as vitamin B12 <200 pg/mL, was present in 51 of 272 adolescents (18.8%; 95% CI, 14.6-23.8). Vitamin B12 <300 pg/mL, representing a broader category including both deficient and borderline low values, was present in 174 of 272 adolescents (64.0%; 95% CI, 58.1-69.4). Folate <4 ng/mL was detected in 41 of 272 adolescents (15.1%; 95% CI, 11.3-19.8).

Table 2. Categorical characteristics of the analytic cohort

Category	n (%)
Sex	
Girls	204 (71.1)
Boys	83 (28.9)
BMI category	
Underweight	21 (7.3)
Normal weight	174 (60.6)
Overweight	42 (14.6)
Obese	50 (17.4)
MUAC category	
Severe malnutrition	5 (1.7)
Moderate malnutrition	21 (7.3)
At risk of underweight	87 (30.3)
Normal nutritional status	165 (57.5)
At risk of overweight	7 (2.4)
Overweight	2 (0.7)
Obese	0 (0.0)
Blood pressure category	
Normal blood pressure	231 (80.5)
Elevated blood pressure	15 (5.2)
Stage 1-range blood pressure	38 (13.2)
Stage 2-range blood pressure	3 (1.0)

Values are presented as n (%). Percentages were calculated using the analytic cohort denominator (n=287). Blood pressure categories were based on a single screening measurement and do not indicate confirmed hypertension.
BMI: Body mass index, MUAC: Mid-upper arm circumference

Sex-based comparisons are shown in Table 4. Girls had higher frequencies of anemia, low ferritin concentrations, and iron deficiency anemia than boys. In contrast, boys had higher frequencies of waist circumference ≥90th percentile, elevated/hypertensive-range BP, and hypertensive-range BP. Vitamin B12 and folate abnormalities did not differ significantly by sex.

Table 3. Frequency of predefined screening-detected abnormalities

Finding	n/N (%)	95% CI
Adiposity and anthropometry		
Underweight	21/287 (7.3)	4.8-10.9
Overweight	42/287 (14.6)	11.0-19.2
Obesity	50/287 (17.4)	13.5-22.2
Overweight or obesity	92/287 (32.1)	26.9-37.7
Waist circumference ≥90th percentile	49/287 (17.1)	13.2-21.9
Blood pressure		
Elevated/hypertensive-range BP	56/287 (19.5)	15.3-24.5
Hypertensive-range BP, stage 1 or 2	41/287 (14.3)	10.7-18.8
Hematologic and micronutrient findings		
Anemia	48/281 (17.1)	13.1-21.9
Ferritin <15 ng/mL	68/275 (24.7)	20.0-30.2
Transferrin saturation <16%	104/280 (37.1)	31.7-42.9
Iron deficiency anemia	30/274 (10.9)	7.8-15.2
Vitamin B12 <200 pg/mL	51/272 (18.8)	14.6-23.8
Vitamin B12 200-299 pg/mL	123/272 (45.2)	39.4-51.2
Vitamin B12 <300 pg/mL	174/272 (64.0)	58.1-69.4
Folate <4 ng/mL	41/272 (15.1)	11.3-19.8
Folate <3 ng/mL	14/272 (5.1)	3.1-8.5

Values are presented as n/N (%). Confidence intervals were calculated using the Wilson method
BP: Blood pressure, CI: Confidence interval

Body mass index category-based comparisons are shown in Table 5. Waist circumference ≥90th percentile, elevated/hypertensive-range BP, and hypertensive-range BP differed significantly across BMI categories, with the highest frequencies observed among adolescents with obesity. Hematologic and micronutrient abnormalities did not differ significantly across BMI categories.

In multivariable logistic regression analysis, boys had higher odds of elevated/hypertensive-range BP than girls (aOR, 2.38; 95% CI, 1.17-4.83; p=0.016). BMI SDS was independently associated with elevated or hypertensive-range BP (aOR, 3.03 per 1-SD increase; 95% CI, 2.17-4.25; p<0.001), whereas age was not significantly associated with this outcome (aOR, 1.06; 95% CI, 0.61-1.86; p=0.835) (Table 6). The overall model was statistically significant (χ^2=66.562, df=3, p<0.001), with Nagelkerke R^2=0.330. The Hosmer-Lemeshow goodness-of-fit test did not indicate poor fit (χ^2=15.185, df=8, p=0.056). Overall classification accuracy was 85.7%, and the c-statistic/AUC was 0.817 (95% CI, 0.749-0.885; p<0.001).

Discussion

In this school-linked adolescent screening cohort, excess weight, elevated or hypertensive-range BP, anemia, low ferritin concentration, abnormal vitamin B12 levels, and folate deficiency were frequently detected. Approximately one-third of the analytic cohort had overweight or obesity, and nearly one-fifth had elevated/hypertensive-range BP. Boys had higher frequencies of abdominal obesity and abnormal BP screening findings, whereas girls had higher frequencies of anemia, low ferritin concentrations, and iron-deficiency anemia. In multivariable analysis, male sex and BMI SDS were independently associated with elevated or hypertensive-range BP. These findings suggest that school-linked screening pathways may identify clinically relevant cardiometabolic and hematologic abnormalities in

Table 4. Comparison of screening-detected abnormalities according to sex

Finding	Girls n/N (%)	Boys n/N (%)	p-value*
Anemia	46/200 (23.0)	2/81 (2.5)	**<0.001**
Ferritin <15 ng/mL	58/196 (29.6)	10/79 (12.7)	**0.003**
Transferrin saturation <16%	78/200 (39.0)	26/80 (32.5)	0.309
Iron deficiency anemia	28/195 (14.4)	2/79 (2.5)	**0.005**
Vitamin B12 <200 pg/mL	36/195 (18.5)	15/77 (19.5)	0.846
Vitamin B12 <300 pg/mL	121/195 (62.1)	53/77 (68.8)	0.294
Folate <4 ng/mL	29/195 (14.9)	12/77 (15.6)	0.882
Waist circumference ≥90th percentile	25/204 (12.3)	24/83 (28.9)	**<0.001**
Elevated/hypertensive-range BP	33/204 (16.2)	23/83 (27.7)	**0.025**
Hypertensive-range BP, stage 1 or 2	19/204 (9.3)	22/83 (26.5)	**<0.001**

Values are presented as n/N (%). *Pearson's chi-square test. Statistically significant p-values are shown in bold
BP: Blood pressure

Table 5. Comparison of screening-detected abnormalities according to BMI category

Finding	Underweight n/N (%)	Normal weight n/N (%)	Overweight n/N (%)	Obese n/N (%)	p-value
Anemia	5/20 (25.0)	31/169 (18.3)	6/42 (14.3)	6/50 (12.0)	0.536†
Ferritin <15 ng/mL	7/21 (33.3)	46/168 (27.4)	7/42 (16.7)	8/44 (18.2)	0.267*
Transferrin saturation <16%	11/21 (52.4)	62/168 (36.9)	14/42 (33.3)	17/49 (34.7)	0.479*
Iron deficiency anemia	4/20 (20.0)	21/168 (12.5)	2/42 (4.8)	3/44 (6.8)	0.209†
Vitamin B12 <200 pg/mL	2/19 (10.5)	29/161 (18.0)	9/42 (21.4)	11/50 (22.0)	0.718†
Vitamin B12 <300 pg/mL	10/19 (52.6)	101/161 (62.7)	26/42 (61.9)	37/50 (74.0)	0.330*
Folate <4 ng/mL	4/19 (21.1)	22/161 (13.7)	8/42 (19.0)	7/50 (14.0)	0.656†
Waist circumference ≥90th percentile	0/21 (0.0)	6/174 (3.4)	7/42 (16.7)	36/50 (72.0)	**<0.001†**
Elevated/hypertensive-range BP	0/21 (0.0)	14/174 (8.0)	12/42 (28.6)	30/50 (60.0)	**<0.001†**
Hypertensive-range BP, stage 1 or 2	0/21 (0.0)	9/174 (5.2)	9/42 (21.4)	23/50 (46.0)	**<0.001†**

Values are presented as n/N (%).*Pearson's chi-square test; †Fisher's exact test. Statistically significant p-values are shown in bold
BMI: Body mass index, BP: Blood pressure

Table 6. Multivariable logistic regression analysis for elevated/hypertensive-range blood pressure

Variable	aOR	95% CI	p-value
Age, per 1-year increase	1.06	0.61-1.86	0.835
Boys vs. girls	2.38	1.17-4.83	**0.016**
BMI SDS, per 1-SD increase	3.03	2.17-4.25	**<0.001**

The dependent variable was elevated/hypertensive-range blood pressure. The model included age, sex, and BMI SDS. Statistically significant p-values are shown in bold
aOR: Adjusted odds ratio, BMI: Body mass index, CI: Confidence interval, SDS: Standard deviation score

adolescents who would otherwise remain outside routine preventive follow-up.

The proportion of adolescents with overweight or obesity in the present analytic cohort was notable but should be interpreted cautiously because the cohort consisted of students who completed the pediatric outpatient screening pathway, rather than all students who were reached during school outreach. Nevertheless, the finding is consistent with the increasing burden of adolescent overweight and obesity reported in recent global estimates and with national data from Türkiye indicating that excess weight remains an important public health issue in school-aged children (2,7). Previous primary care-based data from Türkiye also support the relevance of obesity and related risk factors in children and adolescents (8). In the present study, waist circumference ≥90th percentile was particularly frequent among adolescents with obesity, indicating that excess adiposity was not limited to BMI-defined obesity but also included central adiposity, which is clinically relevant for cardiometabolic risk assessment.

Blood pressure findings are among the most clinically actionable outcomes of this study. Elevated or hypertensive-range BP was detected in 19.5% of adolescents; hypertensive-range BP was present in 14.3%. These values should not be interpreted as the prevalence of confirmed hypertension because BP was measured during a single screening encounter. However, they indicate a substantial need for repeated BP measurements and clinical follow-up. Recent systematic reviews have emphasized the global and European burden of high BP and hypertension in children and adolescents, as well as the association between excess weight and abnormal BP (3,5). In addition, a recent scoping review of school-based BP screening highlighted the heterogeneity of screening methods and the importance of clear referral and diagnostic pathways after elevated BP is detected (4). Our finding that BMI SDS was independently associated with elevated or hypertensive-range BP supports the need to integrate BP assessment into adolescent obesity screening pathways rather than relying on anthropometric measures alone.

The sex differences in BP findings also deserve attention. Boys had higher frequencies of elevated/hypertensive-range BP than girls, and male sex remained independently associated with elevated/hypertensive-range BP after adjustment for age and BMI SDS. This suggests that sex-related differences in adolescent BP screening findings may not be fully explained by adiposity alone. Because pubertal stage, physical activity, dietary sodium intake, family history, and repeated BP measurements were not available, the mechanisms underlying this difference could not be evaluated. Therefore, the observed association should be interpreted as a screening signal requiring follow-up rather than evidence of established sex-specific hypertension risk in this cohort.

Hematologic and iron-related abnormalities were also common. Anemia, low ferritin concentration, transferrin saturation <16%, and iron deficiency anemia were detected in 17.1%, 24.7%, 37.1%, and 10.9% of adolescents, respectively. These findings are compatible with previous reports showing that iron-related abnormalities remain relevant among school-age children and adolescents and may be identified through screening-based approaches (6,15,16). Girls had markedly higher frequencies of anemia, low ferritin concentrations, and iron-deficiency anemia than boys. Menstrual blood loss, dietary iron intake, and sex-specific nutritional patterns may contribute to this difference; however, menstrual history and detailed dietary data were not systematically available in the present study. Therefore, the sex difference should be discussed as a clinically plausible finding rather than attributed to a single mechanism.

Findings for vitamin B12 and folate indicate that micronutrient assessment may provide additional information beyond anthropometry and BP measurements. Vitamin B12 concentrations <200 pg/mL and <300 pg/mL were detected in 18.8% and 64.0% of adolescents, respectively. The latter threshold includes both deficient and borderline low values and should therefore be interpreted as a broader screening indicator rather than a definitive indicator of biochemical deficiency. Previous pediatric and adolescent studies have also shown that vitamin B12 insufficiency may be frequent, although reported frequencies vary according to population characteristics and biochemical thresholds (6,17,18). Folate concentrations were detected in 15.1% of adolescents, whereas concentrations <3 ng/mL were less frequent. Because serum folate interpretation in otherwise healthy children and adolescents may be influenced by testing context and threshold selection, folate findings should be interpreted as screening signals requiring clinical correlation rather than as standalone diagnostic conclusions (14,19,20).

An important finding was that the frequency of hematologic and micronutrient abnormalities did not differ significantly across BMI categories, whereas the frequency of waist circumference and BP abnormalities increased markedly with higher BMI categories. This pattern suggests that BMI-based targeting alone may be insufficient for detecting anemia, low ferritin concentration, vitamin B12 abnormality, or folate deficiency. In practical terms, adolescents with normal BMI may still require hematologic and micronutrient assessment depending on the clinical context, dietary risk, symptoms, and local screening priorities. Conversely, adolescents with overweight or obesity may require structured cardiometabolic follow-up, especially repeat BP measurement, in addition to nutritional counseling.

Taken together, these findings support a school-linked screening model that combines anthropometric, BP, hematologic, and micronutrient assessments. However, the results indicate that screening programs should be designed with clear post-screening pathways. Adolescents with elevated/hypertensive-range BP require repeat office BP measurements and, when indicated, further diagnostic evaluation rather than immediate labeling as having hypertension (11). Similarly, adolescents with anemia, low ferritin concentration, vitamin B12 abnormality, or folate deficiency require clinical assessment to confirm the abnormality, evaluate the etiology, and guide treatment. In this context, school-linked screening should be viewed not as a standalone diagnostic intervention but as an entry point into structured adolescent preventive care.

Study Limitations

This study has several limitations. First, the study employed a retrospective cross-sectional design and was conducted within a single school-linked screening pathway, limiting causal inference and generalizability. Second, although 1,264 adolescents were reached and informed during school-based outreach, individual-level clinical and laboratory data were available for only 287 adolescents who completed the pediatric outpatient screening pathway. Therefore, the analytic cohort may not represent all students reached during outreach, and selection bias cannot be excluded. The analytic sample was also smaller than the sample size calculated for precise population-level prevalence estimation. For this reason, the reported values should be interpreted as frequencies within the analytic cohort of attendees rather than as population prevalence estimates.

Third, BP was measured during a single screening encounter using an oscillometric device. Although measurements were performed by the same clinician using an appropriately sized cuff after a period of seated rest, repeat measurements on separate visits and ambulatory BP monitoring were not available. Therefore, elevated or hypertensive-range BP values should be interpreted as screening findings rather than confirmed hypertension. Fourth, although adolescents with known chronic diseases were excluded, data on medication use, vitamin or iron supplementation, menstrual history, dietary intake, socioeconomic indicators, inflammatory markers, and follow-up outcomes were not systematically collected. These unmeasured factors may have influenced hematologic, micronutrient, and BP findings. Finally, ferritin was interpreted as an iron-store marker, but inflammatory status was not assessed; therefore, ferritin results should be interpreted in the context of screening rather than for definitive etiologic classification.

Despite these limitations, the study provides clinically relevant school-linked screening data from an adolescent cohort, evaluated using standardized anthropometric and BP definitions, along with hematologic and micronutrient measurements. The inclusion of confidence intervals, sex-and BMI category-based comparisons, and multivariable analysis for elevated/hypertensive-range BP improves the transparency and interpretability of the findings. The results may inform more structured screening and referral pathways for adolescents that combine cardiometabolic and nutritional assessments.

Conclusion

Among adolescents who completed a school-linked clinical and laboratory screening pathway, excess weight, elevated or hypertensive-range BP, anemia, low ferritin concentration, vitamin B12 abnormalities, and folate deficiency were frequently detected. Girls had a higher burden of anemia and iron-related abnormalities, whereas boys had higher frequencies of abdominal obesity and abnormal BP screening findings. Higher BMI SDS and male sex were independently associated with elevated or hypertensive-range BP. These findings support integrating repeat BP assessment and targeted hematologic and micronutrient evaluation into school-linked adolescent health screening pathways, with particular attention to cardiometabolic follow-up in adolescents with higher BMI and to iron status evaluation in girls.

Ethics

Ethics Committee Approval: The study was approved by an University of Health Sciences Türkiye, Istanbul Haseki Training and Research Hospital Institutional Non-Interventional Scientific Research Ethics Committee (approval no: 222-2026, date: 30.04.2026).

Informed Consent: The requirement for informed consent was waived because the study was retrospective and utilized anonymized data collected from routine screening.

Authorship Contributions

Concept: H.U.H., D.B., Design: H.U.H., D.B., Data Collection or Processing: H.U.H., E.O., O.H., M.B., Analysis or Interpretation: H.U.H., Literature Search: H.U.H., E.O., O.H., M.B., Writing: H.U.H., E.O., O.H., M.B., D.B.

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