

Prevalence of Metabolic Syndrome and Its Association with Lifestyle and Dietary Factors Among Adolescents in Sulaymaniyah, Iraq

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ABSTRACT

Background and Objectives: Metabolic syndrome (MetS) has grown into a significant global health concern in the world, with an increasing prevalence observed in the Middle East. Despite growing recognition of early metabolic risk in youth, epidemiological data from the Kurdistan region remain limited. This study aimed to determine the prevalence of metabolic syndrome and its individual components among secondary school students in Sulaymaniyah city, using IDF ethnicity-specific diagnostic criteria.

Methods: A cross-sectional study was carried out within a school setting, on 352 students aged (14–19) years during the 2025–2026 academic year. Blood pressure was measured, anthropometric parameters were recorded, and fasting blood samples were tested for glucose and lipid profiles. MetS was diagnosed according to IDF criteria. Analysis used SPSS v27.0.

Results: Overall MetS prevalence was 19.32%. HDL-cholesterol was the most common abnormality, impacting 70.17% of students, followed by central obesity (28.13%), elevated triglycerides (23.6%), increased blood pressure (19.03%), and impaired fasting glucose (16.19%). BMI was positively associated with MetS: 84.09% of obese students, 33.33% of overweight students, and only 2.34% of normal-weight students had MetS ($p < 0.0001$). In binary logistic regression analysis, screen time exceeding five hours/day showed a high level of association ($p < 0.001$), followed by frequent fast food consumption; regular vegetable consumption exhibited protective effects ($p < 0.001$).

Conclusion: The study presents a high prevalence of metabolic syndrome among this age group. The findings underscore the urgent need for comprehensive school-based prevention programs.

Keywords: metabolic syndrome, obesity, screen time, high-density lipoprotein, adolescents

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1. Introduction

Adolescents represent a critical development period during which physiological, behavioral and metabolic patterns take shape that can carry lasting consequences for health into adulthood. Metabolic syndrome, as a

comorbidity that represents a cluster of health abnormalities, has become a public health concern in today's world in all age groups. The syndrome can be defined as a cluster of complicated metabolic abnormalities in the metabolism of lipids, proteins,

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and carbohydrates (1). Due to changes in lifestyle and eating habits, as well as a decrease in overall physical activity, this syndrome, which was previously thought to be an adult condition, now poses a risk factor in teenagers (2). Childhood obesity and overweight are indicative of type 2 diabetes mellitus, hypertension, and dyslipidaemia in adulthood(3,4). Accordingly, early detection of metabolic syndrome represents a major public health concern and a focal point in prevention medicine. Factors contributing to the increase include urbanization, dietary and lifestyle changes leading to a rise in the intake of processed food and low physical activity (5). Similarly, frequent consumption of energy-dense foods, sugar-sweetened beverages, and diets poor in fruits and vegetables promotes the development of obesity and metabolic disturbance (6).

The prevalence of MetS is rising among different populations and societies. A recent review notes that the prevalence of MetS varies widely by population, due to case definition and underlying obesity prevalence(7). Looking at North America and Europe, studies on adolescents have demonstrated an increase in the prevalence of MetS; for example, data from the National Health and Nutrition Examination Survey (NHANES) imply that approximately 5.1% of adolescents in the United States match the criteria for MetS(8). Conversely, in low- and middle income country a systematic review noted that 3.98% of the general adolescent population and 24.09% of overweight and obese adolescents were diagnosed with MetS according to IDF thresholds (9). Shifting the focus to the adolescent population in the Middle East area varies widely by country, age range, gender, and diagnostic criteria. Still, available studies consistently show that it is already present in a meaningful minority of adolescents, especially those who are overweight or obese, and that the region carries some of the highest adolescent obesity rates globally, which drives MetS risk(10). Also, there is a global focus on determining the burden of metabolic syndrome from a young age; however, local data remains limited from the Kurdistan region of Iraq. Therefore, this study aimed to investigate the prevalence of metabolic syndrome and the distribution of its individual components among adolescents, and to examine its association with lifestyle factors. Using the International Diabetes Federation (IDF) International Diabetes Federation ethnicity-specific

criteria for the Middle East. Choosing the IDF criteria for diagnosis due to waist circumference as a mandatory component is key, as it acts as a surrogate of visceral adiposity, which is closely associated with insulin resistance, the underlying pathophysiological mechanism of metabolic syndrome(11).

2. Methodology

2.1 Study design and population

A cross-sectional study in a school setting was deemed suitable for estimating prevalence and analyzing the concept of metabolic syndrome (MetS) prevalence and examining its association with lifestyle and dietary factors. The study was carried out using a standardized protocol starting from 4th of November 2025 till 10th of February 2026. The study participants included adolescents aged 14 to 19 enrolled in public secondary schools in Sulaymaniyah city. Students were excluded if they had a history of chronic disease, were current smokers, were taking lipid-lowering drugs, had used dietary supplements within the previous 3 months, had an infection, or had a history of major surgery. MetS was diagnosed according to IDF criteria as it is a reliable and appropriate method for examining the distribution of cardiometabolic risk along with dyslipidemia and diabetic prediction within a defined population at a specific time interval. All participants have given their written consent after being informed of the nature of the study. The study protocol has been accepted and approved by a board of postgraduate committees of the College of health science/ University of Duhok. Ethical approval was obtained from the Research Ethics Committee of the Sulaymaniyah Directorate General of Health on November 3 2025, with a reference number of 30.

2.2 Sample size estimation

The minimum required sample size was calculated using Cochran's formula for a large target population, a widely accepted method for prevalence studies in the medical field(12)

$$n_0 = \{Z^2 p(1 - p)\} / \{e^2\}$$
 where Z corresponds to the 1.96 standard normal deviate associated with a 95% confidence level, p represents the projected prevalence of metabolic syndrome (MetS), and e is the acceptable margin of error (0.05). Due to a lack of a specific study focused solely on the prevalence of metabolic syndrome (MetS) in high school students in Iraq and the Kurdistan Region, the proxy baseline prevalence was derived from a study in Erbil that was conducted using IDF criteria among apparently

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healthy adult individuals that reported a prevalence of 30.6%, with lower prevalence in younger age groups (e.g., 39.9% in >40 years vs 22.4% in <20 years)(13). Based on this type of sample calculation, which is usually used for large populations, a previously reported prevalence of metabolic syndrome of 30.6%, and a 5% margin of error, Cochran's formula yields a raw sample size of 326 subjects.

2.3 Sample strategy

A full list of all the secondary schools from Sulaymaniyah city was obtained from the Sulaymaniyah Directorate of Education, of which 64 were eligible for the study's criteria. These schools were numbered consecutively from 1 to 64 and grouped by their location within one of the four geographic zones: east, west, north, and south, so the sample would reflect the district's spatial distribution. An initial random draw of twelve schools was generated in RStudio: numbers 20, 21, 63, 9, 46, 2, 52, 4, 28, 31, 61, and 1. Within each of the twelve selected schools, classes were numbered from 1 to 10, and five were randomly drawn: 2, 6, 7, 8 and 10. Students in each of these classes were assigned consecutive numbers from 1 to 30, from which six were randomly selected for participants: 7, 13, 14, 20, 25 and 27, this all together resulted 360 samples in the last step of sampling, of which 8 were excluded due to hemolysis, leaving 352 samples that successfully met the predefined statistical threshold of $n = 326$.

2.4. Data Collection and Blood Sampling

The Data were collected over consecutive days using a standardized protocol. On the first visit, the participants were interviewed to answer a structured questionnaire designed to meet the study's specific objectives. The questionnaire collected general information (age, gender, parental education), data on past medical history, and lifestyle habits. Lifestyle included sleep duration and screen watching time that were self-reported (hours/day). Physical activities were assessed using the International Physical Activity Questionnaire (IPAQ) (14), and eating habits according to the Food Frequency Questionnaire (FFQ) (15). Anthropometric measurements were collected from participants using different devices: body weight was measured in kilograms using a digital scale, while height (with no shoes) and waist circumference (WC) were measured using a non-stretchable measuring tape. BMI was calculated from each participant's height and weight using the standard

formula: weight in kilograms divided by height in meters squared (kg/m^2)(16). Systolic and diastolic blood pressure (SBP and DBP) were recorded after five minutes of rest using a Berure Meby Medical Classic sphygmomanometer. All the selected subjects who fulfilled the inclusion criteria were instructed to fast for a minimum of 12 hours before blood collection to ensure accurate assessment of biochemical parameters. On the second day, 5 mL of venous blood was drawn under aseptic conditions following a standard phlebotomy procedure, placed in a gel separating tube, and kept in a medical cold box for mandating until delivery to the laboratory for separation of serum by centrifugation at 1500g for 10 minutes.

2.5 Diagnosis of metabolic syndrome

MetS according to (IDF) was defined, requiring central obesity as mandatory component, measured by waist circumference (WC) (males $\geq 94\text{cm}$ females $\geq 80\text{cm}$), plus any of two of the following four criteria; triglyceride $\geq 150\text{mg/dl}$, HDL-C $< 40\text{mg/dl}$ for males and 50mg/dl for females, blood pressure $\geq 130/85$ mmHg, or impaired fasting glucose $\geq 100\text{mg/dl}$.

2.6 Assessment of the studies variable

Then Sleep duration was categorized into two subgroups: cutoff short sleeper < 8 hours/night, normal sleeper ≥ 8 hours/night (17) Physical activities were assessed using the International Physical Activity Questionnaire (IPAQ) (14) categorized to three subgroups: walking activity: ≥ 5 days/week ≥ 30 min/day moderate physical activity ≥ 3 days/week at ≥ 20 minutes/day vigorous activity ≥ 3 days/week at ≥ 20 minutes/day. Eating habits were assessed according to the Food Frequency Questionnaire (FFQ) (15), in which the frequency of consumption of five main food types, including fruits, vegetables, fast foods, sugary drinks, and fried snacks, was asked. BMI was calculated from each participant's height and weight using the standard formula: weight in kilograms divided by height in meters squared (kg/m^2)(16), classified to the WHO reference-for-age and gender specific z-scores categorized as severe thinness, thinness, normal weight, overweight, and obesity, for the final assessment severe thinness and thinness were combined as underweight. The other variables were assessed using binary (yes/no) questions

2.7 Performing biochemical analysis

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Serum samples were analyzed for blood glucose, total cholesterol, triglycerides, low-density lipoprotein (LDL-C), and high-density lipoprotein (HDL-C) immediately after separation. Biochemical analyses were performed using an automated clinical chemistry analyzer (BIOLIS series, Tokyo Boeki Medisys, Japan). The analyzer measured the absorbance changes corresponding to enzymatic reactions specific to each chemical analyte; a colorimetric method was used for quantitative measurement of biochemical analytes. The biochemical parameters assessed included fasting blood glucose, total cholesterol, high-density lipoprotein (HDL-C), and triglycerides. Low-density lipoprotein (LDL-C). Instrument calibration was performed based on the manufacturer's instructions. An internal quality control procedure was conducted daily using control sera at normal and pathological concentration ranges to ensure analytical accuracy, precision, and reproducibility throughout the investigation period.

2.8 Statistical analysis

The statistical calculations were performed by IBM Corp. (2020), IBM SPSS Statistics for Windows (Version 27.0). Descriptive statistics were summarized as means $\pm$ standard deviations (SD) for continuous variables, and frequencies and percentages ($n\%$), for categorical variables including the prevalence of metabolic syndrome, eating habits, and physical activity levels. Initial univariate associations between participant characteristics and MetS status were evaluated using independent t-tests or Pearson Chi-squared (χ^2) tests for categorical data. To identify the independent predictors and potential confounding factors associated with MetS, variables demonstrating clinical relevance or univariate significance were entered into a binary logistic regression model. Statistical significance across all analyses was defined a priori at $p < 0.05$.

3. Results

Participants were gender matched (50% male, 50% female) with mean ages (16.58 ± 1.28) years. The mean value of BMI was 23.46 ± 4.49 kg/m². 42% of the subjects in the study reported a family history of chronic diseases. The majority of parents' fathers (33.24%) and mothers (36.93%) had completed only primary education. parents exhibited no education included (15.91%) for fathers and (20.17%) for mothers, as shown in Table 1.

Table 1: General characteristic of participants		
Characteristics (n=352)	Mean (SD)	Min-Max
Age (years)	16.58 (1.28)	14-19
BMI (kg/m ²)	23.46 (4.49)	14.69-35.08
	Number (Percent)	
Gender		
Male	176 (50.0)	
Female	176 (50.0)	
BMI category		
Underweight	16(4.0)	
Normal Weight	214(60.8)	
Overweight	78(21.9)	
Obese	44(12.8)	
FH obesity	115 (32.7)	
FH Diabetes	146 (41.5)	
FH Hypertension	144 (40.9)	
FH Heart disease	76 (21.6)	
Father education		
No education	56 (15.91)	
Primary education	117 (33.24)	
Secondary education	89 (25.28)	
Diploma/bachelor	86 (24.43)	
Higher education	4 (1.14)	
Mother education		
No education	71 (20.17)	
Primary education	130 (36.93)	
Secondary education	77 (21.88)	
Diploma/bachelor	74 (21.02)	
Higher education		

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	0 (0.0)	
Continuous data are reported as mean (standard deviation) and minimum and maximum values, whereas categorical variables are presented as frequencies and percentages. Abbreviations: Body mass Index(BMI)		

3.1 Prevalence of metabolic syndrome and its components

Table 2 shows that metabolic syndrome was diagnosed in 19.3% of participants. 70.17% had reduced HDL cholesterol. Central obesity was present in 28.13% (99 of 352); abnormal triglyceride levels in 23.30%; raised blood pressure in 19.03%; and raised fasting glucose in 16.19% of the subjects. The clustering pattern of metabolic abnormalities demonstrated progressive risk accumulation: 72 students (20.46%) were metabolically normal, (36.93%) had one component, (18.75%) had two components, (14.77%) had three components, (7.39%) had four components, and (1.71%) exhibited all five components simultaneously.

Table 2 Distribution of the metabolic syndrome components according to the diagnostic cut off among the studied subjects (n=352)

Normal	284
Metabolic syndrome	68
Male	31
Female	37
Metabolic syndrome component	Number (percent)
WC cutoffs	
Normal	253(71.9)
Central obesity Males: ≥ 94 cm, Females: ≥ 80 cm	99(28.1)
Triglycerides	
Normal <150 mg/dl	269 (76.4)
Raised ≥ 150 mg/dl	83 (23.6)
HDL-C	
Normal	105 (29.8)
Low (male < 40 mg/dl female < 50 mg/dl)	247 (70.2)
Blood pressure	
Normal	285 (80.9)

Raised $\geq 130/85$ mmHg	67 (19.1)
Fasting blood glucose	
Normal < 100	295 (83.81)
Raised (≥ 100 mg/dl)	57(16.19)
Abnormal metabolic syndrome component present	
Metabolic syndrome component	
0	72 (20.46)
1	130 (36.93)
2	66 (18.75)
3	52 (14.77)
4	26 (7.39)
5	6 (1.71)
Abbreviations: waist circumference (WC), High-density lipoprotein (HDL), triglycerides (TG), Fasting Blood Glucose (FBG).	

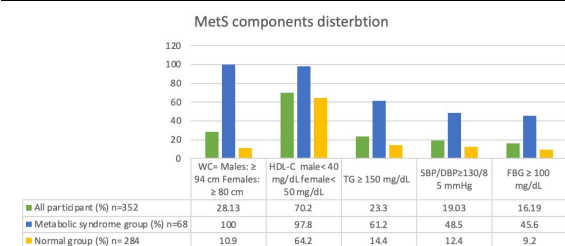


Fig 1. Prevalence of abnormal MetS components among the studied subjects

Abbreviations: Waist circumference (WC), High-density lipoprotein (HDL), Systolic blood pressure (SBP), Diastolic blood pressure (DBP), Triglyceride (TG), Fasting Blood Glucose (FBG).

3.2 Dietary behavior among the participants

Dietary intake patterns are presented in Table 3; Sugary drink consumption was not significantly associated with MetS overall ($p = 0.120$). However, compared with the never/rarely group, daily consumption ($OR = 4.765$, 95% CI: 1.053-21.565, $p = 0.043$) and consumption more than once daily ($OR = 5.500$, 95% CI: 1.112-27.195, $p = 0.037$) were associated with significantly higher odds of MetS. Fast food consumption was significantly associated with MetS overall ($p = 0.006$). Participants consuming fast food 3-6 times weekly had significantly higher odds of MetS ($OR = 2.904$, 95% CI: 1.175-7.178, $p = 0.021$), whereas daily consumption was not statistically significant ($OR = 2.750$, 95% CI: 0.986-7.666, $p = 0.053$). Vegetable consumption showed a significant overall association with MetS ($p = 0.001$). Although participants consuming vegetables 3-6 times weekly

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(OR = 0.442, 95% CI: 0.171-1.145, $p = 0.093$) and daily (OR = 0.350, 95% CI: 0.117-1.051, $p = 0.061$) had lower odds of MetS, neither category was statistically significant. Fruit consumption was not significantly associated with MetS overall ($p = 0.424$), and no consumption category differed significantly from the never/rarely group. Fried snack consumption was significantly associated with MetS overall ($p = 0.003$). Daily consumption (OR = 4.333, 95% CI: 1.082-17.355, $p = 0.038$) and consumption more than once daily (OR = 9.778, 95% CI: 1.430-66.860, $p = 0.020$) were associated with significantly higher odds of MetS compared with the never/rarely group.

Table 3. To assess the link between dietary habit (fast food, surgery drink, vegetables, fruit, fried snacks) and metabolic syndrome					
category	(n)	Food type	OR (95% CI)	P-value	Over all P-value
Never/Rarely	29	Sugary Drinks			0.120
1-3/ month	45		OR = 2.919 (95% CI: 0.574–14.853)	0.197	
1-2/ week	80		OR = 2.619 (95% CI: 0.554–12.394)	0.225	
3-6/ week	68		OR = 2.328 (95% CI: 0.477–11.361)	0.296	
Daily	92		OR = 4.765 (95% CI:)	0.043	

			1.053–21.565)		
>1/ Day	38		OR = 5.500 (95% CI: 1.112–27.195)	0.037	
Never / rarely	60	Fast Foods			0.006
1-3/ month	76		OR = 1.598 (95% CI: 0.628–4.069)	0.325	
1-2/ week	103		OR = 0.699 (95% CI: 0.260–1.880)	0.478	
3-6/ week	68		OR = 2.904 (95% CI: 1.175–7.178)	0.021	
Daily	37		OR = 2.750 (95% CI: 0.986–7.666)	0.053	
>1/ Day	8		OR = 3.900 (95% CI: 0.777–19.576)	0.098	
Never / rarely	64	Vegetables			0.001
1-3/ month	70		OR = 2.047 (95% CI:)	0.073	

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			CI:0.9 35- 4.482)		
1-2/ week	66		OR = 1.361 (95% CI:0.5 98- 3.096)	0.4 62	
3-6/ week	79		OR = 0.442 (95% CI:0.1 71- 1.145)	0.0 93	
Daily	61		OR = 0.350 (95% CI:0.1 17- 1.051)	0.0 61	
>1/ Day	12		OR = 0.357 (95% CI:0.0 42- 3.018)	0.3 44	
Never rarely	27				
1-3/ month	37		OR = 2.130 (95% CI: 0.589– 7.706)	0.2 49	
1-2/ week	67	Fruits	OR = 1.519 (95% CI: 0.451– 5.115)	0.5 00	0.42 4
3-6/ week	98		OR = 0.879 (95% CI: 0.262– 2.954)	0.8 35	

Daily	11 2		OR = 1.652 (95% CI: 0.523– 5.224)	0.3 93	
>1/ Day	11		OR = 1.278 (95% CI: 0.198– 8.242)	0.7 97	
Never rarely	25				
1-3/ month	77		OR = 0.733 (95% CI: 0.175– 3.079)	0.6 72	
1-2/ week	13 4		OR = 1.600 (95% CI: 0.443– 5.781)	0.4 73	
3-6/ week	74	Fried Snacks	OR = 2.187 (95% CI: 0.583– 8.206)	0.2 64	0.00 3
Daily	35		OR = 4.333 (95% CI: 1.082– 17.355)	0.0 38	
>1/ Day	7		OR = 9.778 (95% CI: 1.430– 66.860)	0.0 20	
A logistic regression test was performed for statistical analyses.					

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3.3 Lifestyle Factors

Lifestyle factors and their association with metabolic syndrome in the participants are presented in Table 4. MetS prevalence increased with BMI category: 0% among the severely thin and thin groups, 2.3% among normal-weight participants, 33.3% among overweight participants, and 84.1% among obese students. Regarding physical activity, insufficient walking (n=182), 24.18% had metabolic syndrome, compared with 14.12% of those who walked sufficiently (n=170; P=0.017). A similar pattern was observed for moderate physical activity: metabolic syndrome was present in 21.43% of the 308 adolescents reporting none, 6.25% of the 16 reporting insufficient activity, and 3.57% of the 28 reporting sufficient activity (P=0.029). Vigorous physical activity was reported by only two adolescents in the entire sample, neither of whom had metabolic syndrome; among the remaining 350 who reported none, 19.43% had the syndrome (Fisher's exact test, P=1.000). Sleep duration was not significantly associated with metabolic syndrome, which was present in 22.60% of short sleepers (n=177) and 16.00% of normal sleepers (n=175; P=0.152). Screen time showed the strongest gradient among the behavioral variables: metabolic syndrome prevalence increased from 7.87% among adolescents with 0-3 hours of daily screen time (n=127), to 17.76% among those with 4-5 hours (n=107), to 33.05% among those exceeding 5 hours (n=118; P<0.0001).

Table 4: Association of lifestyle behaviors: Physical activity, sleep duration, screen time with the component of metabolic syndrome

Factors	Study groups no. (%)		P
	Metabolic syndrome (n=68)	Normal (n=284)	
BMI(18)			
underweight	0(0.00)	16(100.0)	<0.0001 ^a
normal	5(2.34)	209(97.66)	
Weight	26(33.33)	52(66.67)	
Overweight	37(84.09)	7(15.91)	
Obese			
Walking			
Insufficient	44 (24.18)	138 (75.82)	0.0169
Sufficient	24 (14.12)		

		146 (85.88)	
Moderate physical activity			
None	66 (21.43)	242 (78.57)	0.029 ^a
Insufficient	1 (6.25)	15 (93.75)	
Sufficient	1 (3.57)	27 (96.43)	
Vigorous physical activity			
none	68 (19.43)	282 (80.57)	1.000 ^a
Sufficient	0 (0.00)	2 (100)	
Sleep			
Short sleeper	40 (22.6)	137 (77.4)	0.152
Normal sleeper	28 (16.0)	147 (84.0)	
Screen time			
0-3 hrs.	10 (7.87)	117 (92.13)	<0.0001
4-5 hrs.	19 (17.76)	88 (82.24)	
>5 hrs.	39 (33.05)	79 (66.95)	

Data are n (%). Percentages indicate the proportion of participants within each category who met criteria for metabolic syndrome. Chi-squared test was performed for statistical analyses. ^a Fisher's exact test, used because one or more expected cell counts were below 5

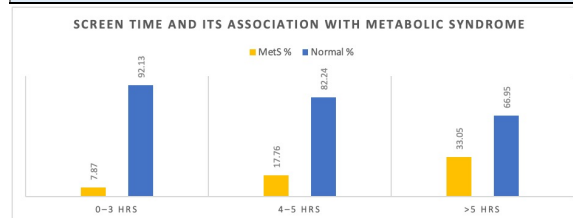


Figure 3 presents the association between screen time and metabolic syndrome. The prevalence of MetS increased progressively with longer daily screen time, from 7.87% (0-3 hours/day) to 17.76% (4-5 hours/day) and 33.05% (>5 hours/day), while the proportion of students without MetS decreased accordingly.

3.4 Lipid components and association with MetS

Besides the investigation of two lipid criteria of metabolic syndrome have shown in Table 5, cholesterol and low-density lipoprotein as dyslipidemia in overall showed significant association

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with metabolic syndrome; 52.9% of participants with MetS had dyslipidemia, while 23.9% of non-metabolic disturbed participants had dyslipidemia. 47.1% of participants with metabolic syndrome didn't have dyslipidemia, and 76.1% of metabolically normal participants were also normal regarding dyslipidemia based on both cholesterol and low-density lipoprotein cholesterol.

Table 5. Association of Dyslipidemia (TC $\geq$ 200 mg/dL and/or LDL $\geq$ 130 mg/dL) with MetS

Variable	MetS (n=68) n (%)	NO. MetS (n=284) n (%)	P-value
Dyslipidemia- yes	36 (52.9%)	68 (23.9%)	<0.001
Dyslipidemia- no	32 (47.1%)	216 (76.1%)	
Pearson chi-square test of independence for statistical analyses Abbreviation: TC (total cholesterol), LDL (low-density lipoprotein)			

3.5 Family history of chronic disease and its association with metabolic syndrome

Family history of chronic disease was not significantly associated with metabolic syndrome among the study participants, as shown in Table 6.

Table 6. Family history of obesity, diabetes, hypertension, and heart disease by metabolic syndrome (MetS) status among study participants

Family history	MetS (n=68) n (%)	NO. MetS (n=284) n (%)	P-Value
FH obesity - Yes	27 (39.7)	88 (31.0)	0.217
FH diabetes - Yes	29 (42.6)	117 (41.2)	0.935
FH hypertension – Yes	30 (44.1)	114 (40.1)	0.644
FH heart disease – Yes	17 (25.0)	59 (20.8)	0.551

Pearson chi-square test of independence for statistical analyses

Abbreviation: FH(family history)

3.6 Paternal and maternal education

Table 7 summarizes paternal and maternal educational attainment stratified by MetS status. In both groups for the fathers, primary and secondary education were the most common levels. Also, comparing the MetS group (20.6%) and the MetS-free group (14.8%), Fathers who had received no formal education were common in the MetS group (20.6%). In Contrast, those fathers who had studied for a diploma, bachelor's degree, or higher education were common in the MetS-free group (26.8%). Yet, these differences were not statistically significant ($p=0.426$).

Similarly, a comparable pattern was also found among mothers. The percentage of mothers with no formal education was almost the same in both groups (20.6% and 20.4%). Secondary education was more common among mothers in the MetS group (29.4% vs. 20.1%). However, mothers who had received higher education were slightly more common in the MetS-free group (21.8% vs. 17.6%). Yet, these differences were not statistically significant ($p=0.381$).

Overall, the results show that parents' education level was not significantly related to MetS status among the adolescents.

Table 7. Distribution of parental education level by metabolic syndrome (MetS) status among study participants (N = 352)

Education level	MetS + (n=68) n (%)	No, MetS (n=284) n (%)	P
Father's education			
No education	14 (20.6)	42 (14.8)	0.426
Primary	20 (29.4)	96 (33.8)	
Secondary	20 (29.4)	70 (24.6)	
Diploma/Bachelor or higher ¹	14 (20.6)	76 (26.8)	
Mother's education			
No education	14 (20.6)	58 (20.4)	0.381

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Table 7. Distribution of parental education level by metabolic syndrome (MetS) status among study participants (N = 352)			
Education level	MetS + (n=68) n (%)	No, MetS (n=284) n (%)	P
Primary	22 (32.4)	107 (37.7)	
Secondary	20 (29.4)	57 (20.1)	
Diploma/Bachelor	12 (17.6)	62 (21.8)	

3.7 Binary logistic regression of controlling factors associated with metabolic syndrome

Table 8 presents the results of binary logistic regression assessing each candidate variable individually against MetS status. Screen time emerged as the strongest predictor in the model (overall $p < 0.001$), with a clear dose–response pattern: compared with 0–3 hours of screen time daily, the odds of MetS were nearly three times higher among students reporting 4–5 hours ($OR = 2.83$, 95% CI: 1.02–7.86, $p = 0.046$) and more than eight times higher among those exceeding five hours ($OR = 8.44$, 95% CI: 2.97–23.97, $p < 0.001$); the odds nearly tripled again when comparing more than five hours directly against 4–5 hours ($OR = 2.98$, 95% CI: 1.29–6.88, $p = 0.010$). Moderate physical activity showed an overall significant association with MetS ($p = 0.005$), although this finding warrants caution: very few students reported insufficient or sufficient moderate activity, and the comparisons of none versus insufficient activity ($OR = 9.13$, 95% CI: 0.45–184.54, $p = 0.150$) and insufficient versus sufficient activity ($OR = 1.99$, 95% CI: 0.04–89.01, $p = 0.723$) carried extremely wide confidence intervals as a result. Only none versus sufficient activity reached significance ($OR = 18.15$, 95% CI: 1.52–217.16, $p = 0.022$), and even this estimate should be read as imprecise rather than a stable effect size. Walking activity was not significantly associated with MetS in this model (insufficient vs. sufficient: $OR = 1.61$, 95% CI: 0.76–3.44, $p = 0.214$). Neither father's education (overall $p = 0.432$) nor mother's education (overall $p = 0.401$) showed a significant relationship with MetS status,

with odds ratios for every category remaining close to 1.

Dyslipidemia carried the second-strongest association with MetS after screen time: students with elevated total cholesterol and/or LDL-cholesterol had more than three times the odds of meeting MetS criteria compared with students with normal lipid values ($OR = 3.57$, 95% CI: 2.06–6.19, $p < 0.001$).

Table 8. binary logistic regression controlling factors for metabolic syndrome vs. healthy students		
Controlling factors (n=352)	OR (95% CI)	P
Age	1.09 (0.83–1.43)	0.547
Gender		0.076
Male vs. Female	0.52 (0.25–1.08)	0.080
Screen time		<0.001
4–5 hrs. vs. 0–3 hrs.	2.83 (1.02–7.86)	0.046
>5 hrs. vs. 0–3 hrs.	8.44 (2.97–23.97)	<0.001
>5 hrs. vs. 4–5 hrs.	2.98 (1.29–6.88)	0.010
FH obesity Yes vs. No	1.47 (0.85–2.53)	0.170
Moderate physical activity		0.005
None vs. Insufficient	9.13 (0.45–184.54)	0.150
Insufficient vs. Sufficient	1.99 (0.04–89.01)	0.723

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Table 8. binary logistic regression controlling factors for metabolic syndrome vs. healthy students		
Controlling factors (n=352)	OR (95% CI)	P
None vs. Sufficient	18.15 (1.52–217.16)	0.022
Walking physical activity		0.211
Insufficient vs. Sufficient	1.61 (0.76–3.44)	0.214
FH diabetes Yes vs. No	1.06 (0.62–1.81)	0.828
FH hypertension Yes vs. No	1.18 (0.69–2.01)	0.549
FH heart disease Yes vs. No	1.27 (0.68–2.36)	0.448
Father's education		0.432
Primary vs. No education	0.63 (0.29–1.35)	0.234
Secondary vs. No education	0.86 (0.39–1.87)	0.700
Diploma/Bachelor+ vs. No education	0.55 (0.24–1.27)	0.162
Mother's education		0.401
Primary vs. No education	0.85 (0.41–1.79)	0.672
Secondary vs. No education	1.45 (0.67–3.15)	0.344
Diploma/Bachelor vs. No education	0.80 (0.34–1.88)	0.611

Table 8. binary logistic regression controlling factors for metabolic syndrome vs. healthy students		
Controlling factors (n=352)	OR (95% CI)	P
Dyslipidemia (TC ≥200 or LDL ≥130)		
Yes vs. No	3.57 (2.06–6.19)	<0.001

4. Discussion

4.1. Metabolic syndrome prevalence in regional and global context

The prevalence observed in our study (19.32%) markedly exceeds the global estimate. This finding is hardly comparable with prevalence estimates from other adolescent populations, which are limited by the range of diagnostic criteria used across studies and by how little MetS has been examined specifically in this demographic in this region. Findings, which are notably higher compared to the estimated data values of the syndrome in 2020; the investigators found that approximately 4.8% of adolescents globally have been diagnosed with MetS(19). A recent meta-analysis of pediatric metabolic syndrome in low- and middle-income countries reported a pooled prevalence of 3.3% using IDF criteria(20). Research from Western populations has documented prevalence ranging from 4.2% to 9.2% in this age group(21). A Saudi Arabian study on children and adolescents aged 10-18 years reported a 9.4% prevalence using the modified ATP-III criteria(22). While Egyptian adolescent data showed a 7.4% prevalence(23). In Iran, this age group demonstrated a prevalence of 10.1% (24). The one comparable Iraqi study, conducted among university students (aged 18-25) in Wasit province, reported 41.3% using IDF/NHLB criteria (25), substantially higher than our findings. Several studies in the region reported findings across elderly age groups with high trends of prevalence; for example, a study on metabolic syndrome in Sulaymaniyah among obese people showed that 63% had the syndrome (26). Among healthy adults in Erbil, the prevalence of metabolic syndrome was reported to be approximately 30.6% using the International Diabetes Federation (IDF) criteria(13). Among patients with type 2

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diabetes mellitus in Duhok, the prevalence reached approximately 77%, demonstrating the close pathological relationship between insulin resistance, dyslipidemia, hypertension, and abdominal obesity(27). Taken together, the increasing prevalence from 19.3% in our adolescent cohort to 41.3% among Iraqi university students and 30.6-77% in adult populations across the region suggests that the risk of metabolic syndrome builds gradually with longer exposure to unhealthy lifestyle and environmental factors, rather than appearing suddenly in adulthood. This pattern indicates that metabolic risk accumulates over time, highlighting adolescence, particularly the secondary-school population, as a critical period for implementing preventive strategies to reduce the development and progression of metabolic abnormalities.

4.2 Reduced HDL-C as the most prevalent component

The most striking finding in our study is that low HDL-cholesterol was the predominant component of metabolic syndrome. It affected 70.17% of students, a prevalence far exceeding all other components. This finding is divergent, mainly arising from the Western population where central obesity typically predominates(28), but aligns with several Middle Eastern studies that HDL-C status is the predominant metabolic abnormality among adolescents (24). A Lebanese study found HDL in 66.7% of children with metabolic syndrome(29). Low HDL-C affected 247 of the 352 participants (70.2%), more than double the 104 participants (29.5%) who met the LDL/TC dyslipidemia criterion ($TC \geq 200$ mg/dL and $LDL \geq 130$ mg/dL). This predominance of low HDL-C is unlikely to represent an incidental finding. Rather, it is consistent with the atherogenic dyslipidemia phenotype described in pediatric lipid research, which is characterized by elevated triglycerides and reduced HDL-C; LDL-C may remain within the normal range, although the circulating LDL population may become enriched in smaller, denser particles. This lipid pattern is commonly associated with insulin resistance and obesity in children and adolescents(30).

Fast food consumption frequency was significantly associated with MetS overall ($p = 0.006$), but the pattern was threshold-like rather than linear however, odds rose sharply and stayed elevated: $OR = 2.904$ (95% CI: 1.175-7.178, $p = 0.021$) at 3–6 times/week,

$OR = 2.750$ (95% CI: 0.986-7.666, $p = 0.053$) daily, and $OR = 3.900$ (95% CI: 0.777-19.576, $p = 0.098$) more than once daily closely parallels the most comparable adolescent evidence available. In the Tehran Lipid and Glucose Study's 3 to 6 year follow-up of 424 children and adolescents, only the highest quartile of fast food intake showed significantly elevated odds of incident MetS (31). Fast food is energy dense and has low fiber and micronutrient content, plausibly explaining why the effect concentrates at higher exposure frequencies rather than appearing gradually (32).

Fried snack frequency showed the clearest dose–response gradient of the dietary variables examined (overall $p = 0.003$). This finding is well supported by adolescent-specific cohort data. In the same Tehran cohort, children and adolescents in the highest quartile of energy-dense, nutrient-poor snack intake had roughly triple the odds of incident MetS(31). Causation maybe due to fried snacks being energy-dense and rich in trans fats, refined carbohydrates, and sodium. Regular intake can promote visceral adiposity, insulin resistance, inflammation, and adverse lipid metabolism, contributing to hypertriglyceridemia, reduced HDL cholesterol, and impaired glucose regulation(33). Sugary drinks reaching significance only at daily-or-greater intake fits a similar threshold logic and is consistent with adolescent SSB literature where risk concentrates at the highest consumption levels rather than appearing gradually(34). The inverse gradient observed for vegetable intake reinforces this literature: habitual consumption is thought to be protective largely through dietary fiber, potassium, and antioxidant micronutrients that offset the oxidative stress and insulin resistance central to MetS pathophysiology(35). Fruit's null result here is more surprising given meta-analytic evidence of a modest protective effect elsewhere(35); this may reflect limited variability in fruit-eating frequency within this population, or that fruit intake in this setting does not track as closely with an otherwise healthy diet as it does in populations where the association is stronger.

4.3 Lifestyle factor and metabolic syndrome

A critical finding of this study is that metabolic syndrome in secondary school students arises mainly from modifiable behavioral factors rather than genetic predisposition. Family history of (diabetes, hypertension, heart disease, and obesity) showed no

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significant association with MetS in bivariate analyses (all $p > 0.05$); this suggests that environmental factors are predominant correlates of cardiometabolic dysfunction in this setting. Screen time emerged as the strongest independent association with metabolic syndrome; students who spend more than five hours daily on screen time had over eight times the odds of having MetS compared to those with zero to three hours. The magnitude of this association, combined with the finding in a systematic review, reported that children and adolescents with the highest screen time had about 64% higher odds of developing metabolic syndrome (36). The mechanism linking excessive screen time to metabolic dysfunction in this population is probably due to hormonal disruption through stress hormone activation, which in prolonged cases, leads to insulin resistance, the main mechanism in metabolic syndrome occurrence (37). The correlation between BMI and MetS is highly significant ($p < 0.0001$), compared to people with lower BMI; Visceral fat secretes pro-inflammatory cytokines (e.g., TNF- α , IL-6) and reduces adiponectin, resulting in worsening insulin sensitivity, contributing to the outcome between high BMI and MetS status in this population (38).

Physical activity told an inconsistent story in this cohort. Walking and moderate activity both distinguished the two groups in bivariate analysis ($p = 0.017$ and $p = 0.029$), but only moderate activity held up once logistic regression was applied ($p = 0.005$); walking did not ($p = 0.211$). The clearest signal came from comparing no moderate activity against sufficient moderate activity, where the odds of MetS rose sharply; this significant finding with moderate physical activity mirrors what adolescent physical activity research has found elsewhere: moderate activity supports insulin sensitivity, lipid profile balance, and blood pressure maintenance(39), which together may be protective against metabolic abnormalities.

4.4 Limitations and future direction.

While this study provides valuable insights, there are a few limitations to keep in mind. First, we focused exclusively on students from public secondary schools in Sulaymaniyah. Because of this, our findings might not fully translate to adolescents in private schools and to adolescents who have dropped out of school, who often have different socioeconomic backgrounds, diets, and daily habits. Second, we encountered a

specific methodological hurdle: the lack of validated, ethnicity-specific waist circumference cut-offs for Kurdish adolescents, especially those aged 14 to 15. To define central obesity, we had to rely on the best available international guidelines. This was the approach available. Third, the cross-sectional design precludes causal inference between lifestyle factors and MetS, and longitudinal studies are needed to establish temporal relationships. Despite these constraints, this research establishes crucial baseline data on how lifestyle and diet intersect with metabolic syndrome among adolescents in the Kurdistan Region of Iraq. Moving forward, future studies should cast a wider net by including both public and private schools and drawing from larger, more diverse populations.

5. Conclusion

This study reveals that among the 352 of the involved secondary school students in Sulaymaniyah city, 19.32% (68/352) were identified with metabolic syndrome, indicating that nearly one in five students in this population exhibited clustering of cardiometabolic risk factors. Strikingly, low HDL cholesterol affected 70.17% of participants, establishing dyslipidemia as the predominant metabolic abnormality in this population. Importantly, metabolic syndrome is driven by modifiable behaviors rather than genetics. Excessive screen time emerged as the strongest risk factor. Physical inactivity and frequent fast food consumption further amplified risk, while regular vegetable intake provided substantial protection. The strong association with excess adiposity and modifiable life style factors-particular excessive screen time, unhealthy dietary patterns, and insufficient physical activity underscore the preventable nature of much of this metabolic burden.

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