Metabolic syndrome and obesity among marginalised school-going adolescents in Karachi, Pakistan: a cross-sectional study

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Summary

Background Metabolic syndrome (MetS) is a cluster of cardiometabolic risk factors which increase the likelihood of developing type 2 diabetes and cardiovascular disease. This study aimed to determine the prevalence of MetS among adolescents living in slums aged 11–18 years in Karachi, Pakistan.

Methods Data were collected from 689 adolescents attending five schools in two slum areas of Karachi, Korangi and Baldia, from February 2023 to March 2023. Measurements of weight, height, waist circumference, and blood pressure were obtained from the study participants. Blood samples were collected to assess fasting plasma glucose, High density lipoprotein HDL-cholesterol, and triglyceride levels as per National Cholesterol Education Program Adult Treatment Panel III (NCEP-ATP III). The prevalence of MetS was estimated using five diagnostic criteria, i.e., International Diabetes Federation (IDF-2007), World Health Organization, NCEP-ATP III, de Ferranti et al., and Cruz and Goran.

Findings The study revealed an overall prevalence of MetS among the adolescents in the two slum areas as 16.7%. A higher prevalence of MetS was observed among females (9.1%) and those with lower body mass index BMI (13.6%). The diagnostic criteria proposed by Cruz and Goran were found to be the most sensitive, with a MetS diagnosis rate of 22.93%. The study also identified several significant risk factors associated with MetS, including sedentary lifestyle (7.7%), lack of physical activity (7.5%), increased screen time (1.5%), lower fruit consumption (6.1%), and underweight (7.7%). Among slum-dwelling adolescents, low levels of HDL-cholesterol (33.96 ± 5.21), high triglyceride levels (161.45 ± 63.09), and elevated fasting plasma glucose levels (112.59 ± 28.92) were prevalent components of MetS.

Interpretation This study provides compelling evidence of a high prevalence of MetS among marginalised school-going adolescents in Karachi, Pakistan. The findings underscore the importance of early identification of adolescents at risk of developing MetS (especially those living in slum areas) and the implementation of effective preventive strategies to mitigate the risk of type 2 diabetes and cardiovascular disease in later life.

Funding None.

Keywords: Metabolic syndrome; Adolescents; Slums; Prevalence; Risk factors; Diagnostic criteria; Lifestyle habits; Preventive strategies

Introduction

The global prevalence of obesity has led to a rise in chronic diseases which pose significant treatment challenges. According to the WHO's Global Disease Burden (GDB) report in 2017, over 4 million people are affected by obesity each year. In most countries, being overweight or obese cause more deaths than being underweight, which is of major concern.[1]

In Pakistan, the prevalence of obesity is increasing, leading to a growing economic burden. According to a Forbes survey, Pakistan ranks 165th out of 194 countries in terms of obesity and overweight issues. More than 22.2% of individuals in Pakistan aged ≥15 years exceed the obesity threshold. This rate is higher than neighbouring countries like India (ranked 176th with a rate of 16.2%) and Afghanistan (ranked 179th with a rate of 15.1%).[2]

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Research in context

Evidence before this study

We searched PubMed for studies published in English between January 1, 1999 to May 2, 2023, using the following search keywords: "MetS", "lean MetS", "Obesity", "overweight", "slum populations", and "Metabolic Syndrome". Metabolic syndrome is a cluster of conditions that occur together, increasing the risk of heart disease, stroke, and type 2 diabetes. These conditions include high blood pressure, high blood sugar, excess body fat around the waist, and abnormal cholesterol or triglyceride levels. Research on metabolic syndrome in children and adolescents is constantly evolving. Since then, new discoveries, diagnostic procedures, and therapeutic options may have arisen. Keep up with current literature, scientific publications, and academic conferences to learn about this field's research. Slum teenagers' metabolic syndrome research is scarce. Few studies have examined how socioeconomic factors in slums, such as poverty, limited healthcare, poor nutrition, and sanitation, affect metabolic syndrome in adolescents.

Added value of this study

Our work contributes to the current knowledge by providing one of the limited numbers of Pakistani studies on the prevalence of metabolic syndrome among school-going adolescents residing in urban slum regions of Pakistan. We emphasise the notable disparities in incidence based on gender, ethnic background, frequency, choice, and quality of food, as well as differing diagnostic criteria. We also highlight the significantly elevated occurrence of undetected comorbidities in disadvantaged urban slums in Pakistan.

Implications of all the available evidence

Using population-specific criteria would enhance diagnostic sensitivity in the Pakistani population. Research on lean metabolic syndrome in children and adolescents can significantly contribute to advancing our understanding of metabolic health, guiding clinical practice, shaping public health policies, and developing targeted interventions to improve the health outcomes of the population. Also, further research on interventions related to life-style modification and longitudinal behaviour change in the adolescents at marginalised population is required. The outcomes of such research would help to proactively mitigate the long-term adverse effects caused by MetS.

However, the diagnostic criteria for metabolic syndrome (MetS) in the adolescent population are not well-defined, resulting in ambiguous interpretations of MetS in children and adolescents.[3] Several clinical guidelines include the International Diabetes Federation (IDF),[4] the WHO,[5] the National Cholesterol Education Program Adult Treatment Panel III (NCEP-ATP III)[6] modified for age, the de Ferranti et al. criteria,[7] and the Cruz and Goran criteria.[8] A summary of these criteria is presented in Table 1.

MetS encompasses a cluster of cardiometabolic risk factors such as central obesity, low levels of HDL-cholesterol (HDL-C), hypertriglyceridemia, hypertension, and hyperglycaemia.[9,10] Identifying children and adolescents at risk of developing MetS early on is crucial, as they are highly susceptible to developing type 2 diabetes (T2D) and cardiovascular disease (CVD) later in life.[11] Consanguinity (marriages between first or second cousins) can contribute to multiple factors associated with the disease.[12] Obesity and insulin resistance are contributing factors to MetS in children and adolescents,[13] with obesity being the primary factor that worsens with increased body weight.[14]

In Pakistan, several studies have addressed MetS and its associated complications, including the issue of screening affordability in children.[15] Initiatives focusing on balanced dietary advice and interventions to identify alarming biomarkers of MetS have been implemented.[16] Furthermore, a study conducted at a tertiary care hospital in Rawalpindi, Pakistan, found that non-ketotic hyperglycinemia was the most diagnosed disorder associated with MetS.[17] The high prevalence of type 2 diabetes (T2DM) in Pakistan may contribute to lean MetS, where lean offspring of T2DM parents exhibit a higher degree of insulin resistance, a strong predisposing predictor of MetS.[18]

Currently, there is no universally accepted gold standard for defining MetS criteria. One of the most used criteria is the National Cholesterol Education Program Adult Treatment Panel III (NCEP ATP III) definition.[6] This criterion includes key elements such as visceral obesity, atherogenic dyslipidaemia, hypertension, and hyperglycaemia or insulin resistance. It employs readily accessible measurements and test results, facilitating its clinical and epidemiological application. The NCEP ATP III criteria[6] are straightforward and easy to remember, requiring the satisfaction of at least three out of the five criteria, without any specific criterion being mandatory. Thus, the concept does not presume a predetermined etiology of MetS, whether it be insulin resistance or obesity.[19]

In Pakistan, there is a growing concern regarding the increasing prevalence of obesity, particularly considering the country's high rates of type 2 diabetes.[20] Moreover, the incidence and severity of obesity among children have been on the rise, leading to a significant burden of metabolic syndrome (MetS) in the younger population.[21] However, despite the alarming rates of obesity and MetS in Pakistan, there is a lack of research focusing on marginalised and vulnerable populations

	IDF-2007[4]	WHO[5]	NCEP-ATP III[6]	de Ferranti et al.[7]	Cruz and Goran[8]
1	[a]Waist circumference (WC) ≥ 90th percentile	BMI > 95th percentile	WC ≥ 90th percentile	WC > 75th percentile	WC > 90th percentile
2	Triglyceride (TG) ≥ 150 mg/dl	TG = 105/136 mg/dl	TG ≥ 110 mg/dl	TG ≥ 100 mg/dl	TG > 90th percentile
3	High-density lipoprotein cholesterol (HDL-C) < 40 mg/dl	HDL-C < 35 mg/dl	HDL-C ≤ 40 mg/dl	HDL-C ≤ 50 mg/dl (except in male aged 15–19 years in whom the cut-off point is 45 mg/dl)	HDL-C > 10th percentile
4	Systolic blood pressure (BP) ≥ 130 mmHg/ diastolic BP ≥ 85 mmHg	Systolic BP > 95th percentile	Systolic BP or diastolic BP ≥ 90th percentile	Systolic BP > 90th percentile	Systolic or diastolic BP > 90th percentile
5	Fasting plasma glucose (FPG) ≥ 100 mg/dl	FPG ≥ 100 mg/dl	FPG ≥ 110 mg/dl	FPG ≥ 110 mg/dl	FPG > 100 mg/dl
6	–	Hyperinsulinemia	–	–	–

IDF: International Diabetes Federation. WHO: World Health Organization: any of the 3 out of 6 criteria. NCEP-ATP III: National Cholesterol Education Program Adult Treatment Panel III, any of the 3 out of 5 criteria. de Ferranti et al.: any of the 3 out of 5 criteria. Cruz and Goran: any of the 3 out of 5 criteria. [a]WC is mandatory along with any of the 2 other criteria.

Table 1: **The diagnostic criteria for metabolic syndrome (MetS) near to the several clinical guidelines.**

living in slums, specifically in Karachi.[22] In the current study, we aimed to assess the prevalence of metabolic syndrome (MetS) among adolescents living in slums aged 11–18 years residing in a marginalised population in Karachi, Pakistan.

Methods

This was a cross-sectional study conducted from February 2023 to March 2023 and individuals within the age range of 11–18 years representing the target population were included in the study. This study was conducted in five schools situated in two densely populated slum areas of Karachi, namely Korangi and Baldia. It is worth noting that in Karachi, approximately 60.0% of the population resides in rural areas, while the remaining 40.0% live in urban areas.[23] The city is home to a significant number of slums, with nearly 70% of them concentrated in 18 towns of Karachi.[24]

Inclusion criteria

School-aged adolescents living in slums between the ages of 11–18 years and enrolled in public schools located in Baldia Town and Korangi District of Karachi. Participants who assented, provided informed consent of their parents and without significant physical, cognitive, or emotional impairments that would impede their ability or well-being in following the study protocol were included in this study. However, those who were undergoing treatment with medications that affect body weight or already enrolled in other obesity treatment programs or whose families planned to relocate beyond a commutable distance during the study period were excluded from the study. Those who refused or were unable to provide informed consent or suffered with chronic illnesses such as diabetes or human immunodeficiency virus (HIV) were also excluded from the study. The study obtained approval from the SINA Medical Board and subsequently from the SINA Ethical Review Board (SINA-ERB) with the approval number ERB0000012/01-23.

Sampling procedure

A systematic and rigorous sampling procedure was employed to ensure the scientific validity and professionalism of the study. The process involved the following steps:

School selection

A complete list of public schools located in the slums of Korangi and Baldia was obtained from the School of Education & Literacy Department, Sindh, Pakistan. From this list, five schools were selected using the Probability Proportional to Size (PPS) method. This ensured that the chosen schools were representative of the population.

Prior to conducting any assessments, consent was obtained from the Headmaster/Mistress and teachers of the selected schools. Students were then enrolled using the attendance register of their respective classes. Written informed consent was obtained from parents, and assent was obtained from the children themselves (were also informed that their participation was voluntary). To maintain anonymity and confidentiality, personal identification numbers were assigned to each student.

Trained research associates administered questionnaires and conducted physical measurements on the enrolled students. This included weight, height, waist circumference, and blood pressure measurements etc. Clear roles and responsibilities were defined for each person involved in the study. Paramedics, including a Pakistan Nursing council (PNC) registered nurse and two phlebotomists, were responsible for drawing blood samples and recording data. One junior Research Associate maintained participant files and assigned unique identification numbers. Another research associate coordinated with the clinic for registration, lab findings, and consent forms.

Blood sampling and biomarker analysis

Participants were instructed to fast for at least 8 h before a venous blood sample was obtained by a Pakistan Nursing council (PNC) trained nurse. The blood

samples were sent to SINA Diagnostic Laboratory for standardised and quality-controlled analysis of fasting plasma glucose (FPG), high-density lipoprotein-cholesterol (HDL-C), and triglycerides (TG). The study adhered to a comprehensive and standardised protocol for participant enrolment, data collection, and biomarker analysis. This ensured the accuracy and reliability of the results obtained from the study.

Trained phlebotomists obtained venous blood samples from the children using a Serum Separator Tube for lipid profile analysis and a fluorinated tube specifically for measuring fasting plasma glucose (FPG). The collected samples were then sent to the SINA Diagnostic Laboratory for systematic and quality-controlled analysis. The laboratory analysis was conducted using the fully automated chemistry analyzer (Selectra Pro-M from ELITEC Group, USA). Routine laboratory reagents as well as standardised procedures and techniques (enzymatic and spectrometric techniques), were used for the analysis.

MetS has been reported to occur in Pakistan at a prevalence ranging from 18% to 46%, a rate that is comparable to other South Asian countries.[25] To calculate the sample size for our study, we assumed a prevalence of 50% based on this range. Using the formula for determining prevalence, 4 pq/d^2 (where p is the anticipated prevalence, q = 1–p, and d is the margin of error), we calculated a sample size of 689.[26] We chose a margin of error of 4% at a 95% CI, assuming a majority prevalence of 50%. The calculation was as follows: Prevalence = 1.96^2 (50)*(1–50)/4 × 4 = 3.84 × 0.50 × 0.5/16 = 9408/16 = 600. Accounting for a 13% non-response rate, we arrived at a final sample size of 689 (600 + 89 = 689).

Data collection tool or questionnaire

The first part of the data collection tool consisted of questions related to demographic factors. These included age, ethnicity, food preferences, parental education, salt consumption, duration of physical activity, type of food consumed (according to the WHO definition[27]–healthy homemade or junk/unhealthy food), fruit consumption, smoking status, sleep duration, and number of meals per day. These demographic-related questions were designed to gather information about the participants' characteristics and lifestyle factors.

Anthropometric measurement

The height of the participants was measured using a portable stadiometer (Seca GmbH, Germany). Weight measurements were taken in an upright position, with light clothing and no shoes, using a scale accurate to the nearest 0.1 kg. These measurements were used to calculate the participants' BMI, which is obtained by dividing weight (in kg) by the square of height (in meters). Waist and hip circumferences were also measured using an inelastic fiberglass tape, accurate to the nearest 0.1 cm. The waist circumference was measured at the iliac crest, while the hip circumference was measured at the widest part of the buttocks. Standardised protocols were followed to calibrate the scales and stadiometers on a weekly basis, and to inspect the anthropometry tapes for any signs of wear.[28] These measures were taken to ensure accuracy and consistency in the anthropometric data collected during the study. The blood pressure of the children was measured while they were seated, using a normal mercury sphygmomanometer and the appropriate cuff size for their arm. Prior to the measurement, the children were given at least 5 min to relax. Three consecutive readings were taken at 1-min intervals. The average of the last two readings was used for assessment purposes. The diagnosis of high blood pressure was determined based on sex and height percentile-based tables.[29]

Regarding the BMI criteria, the Asian Pacific BMI classification[30] was used to define BMI categories. The BMI values were compared against this classification to determine whether a participant fell into the underweight, normal weight, overweight, or obese category. These criteria allowed for accurate classification of participants based on their BMI status. Underweight <18.5 kg/m^2, Normal range is 18.5–22.9 kg/m^2, Overweight range is 23–24.9 kg/m^2, Obese ≥25 kg/m^2.

To diagnose MetS, we referred to the NCEP-ATP III criteria, which included: Waist circumference (WC) greater than or equal to the 90th percentile; Triglycerides (TG) levels greater than or equal to 110 mg/dl; High-density lipoprotein cholesterol (HDL-C) levels lower than or equal to 40 mg/dl; Systolic or diastolic blood pressure (BP) greater than or equal to the 90th percentile; and Fasting plasma glucose (FPG) levels greater than or equal to 110 mg/dl.

Statistical analysis

All collected data were meticulously reviewed for accuracy and consistency before being entered into Microsoft Excel. Subsequently, the data were exported to SPSS version 24 for further analysis. To assess the association between metabolic syndrome (MetS) and the selected predictors, we utilized sample *t*-tests for continuous variables and chi-square tests for categorical variables, comparing them based on the MetS status of the participants. Categorical variables were presented as frequencies and proportions, while continuous variables were expressed as means and standard deviations. Bivariate analysis was conducted to screen the variables and identify those that showed significance under the unadjusted analysis threshold (p-value <0.20). These significant variables were then included in the subsequent multivariate analysis model. Furthermore, multivariate logistic regression was employed to determine the significant associations with MetS by incorporating the variables that demonstrated statistical significance in the bivariate analysis. Additionally, a

chi-square test was used to assess the variability of BMI and gender among the different MetS groups. These statistical procedures and tests were employed to examine the relationships and identify significant factors associated with MetS in a scientifically rigorous manner.

Role of the funding source
There was no funding source for this study.

Results
Out of the 689 participants, 388 (56.30%) were females, and among them, 63 (54.78%) had MetS. Most of the study participants belonged to the Urdu-speaking ethnicity (56.80%). The most represented age groups were 15 (25.0%) and 16 (24.50%) years, with 31 (26.90%) and 22 (19.10%) of them, respectively, having MetS. The most prevalent BMI categories were underweighted (58.30%) and normal weight (35.20%), in which 46.01% and 38.20%, respectively were having MetS condition.

Table 2 provides the prevalence of metabolic syndrome (MetS) based on different diagnostic criteria in this study. The criteria proposed by Cruz and Goran8 demonstrated the highest sensitivity for diagnosing MetS in the sample, with 22.93% (95% CI: 19.30–26.10) of the participants identified as positive for MetS. The NCEP-ATP III criteria identified 16.69% (95% CI: 13.30–17.20%) of the sample as positive. The prevalence of MetS was 11.46% based on the WHO criteria and 12.90% using the de Ferranti et al.[7] criteria. The IDF criteria identified only 2.17% of the sample as positive. Table 2 summarises the prevalence values reported for these different criteria when estimating the prevalence of MetS.

A sedentary lifestyle was observed among most of the participants, with 47.90% reporting no physical activity per week and 35.10% reporting more than 2 h of television or computer screen time. More than half of the study subjects had two meals per day (53.30%), used the canteen as a source of food for lunch (67.40%), and consumed mostly junk food (67.60%). Normal salt intake was reported by 487 (70.60%) participants, while tea consumption was reported by 445 (64.50%) participants. Fruit intake once a week was reported by 293 (42.50%) participants. A subset of the study participants were smokers (52.30%), and 52.8% reported sleeping less than 7.5 h per day. In terms of parental education, 52.10% had a secondary level of education, and 44.80% did not report a consistent family history of illnesses.

Definition	Prevalence (%)	95% CI
IDF-2007[4]	1.74	0.30–2.80
WHO[5]	11.46	9.60–13.38
NCEP-ATP III[6]	16.69	13.30–17.20
de Ferranti et al.[7]	12.19	10.80–14.45
Cruz and Goran[8]	22.93	9.30–26.10

Table 2: **Prevalence of metabolic syndrome according to various diagnostic criteria.**

Table 3 presents the descriptive and bivariate analysis results for all study variables in relation to MetS and non-MetS groups. In the adjusted bivariate analysis, all independent variables were significantly associated (p-value <0.20) with the dependent variable (MetS/No MetS), except for age, sex, ethnicity, screen time, number of meals per day, nature of food intake, beverage intake, salt consumption, smoking, presence of a smoker family member at home, and family history of diabetes. Consequently, these variables were not included in the multivariate adjusted analysis model.

The results of the multivariate logistic regression analysis are presented in Table 4. The analysis included predictors and MetS components that were significant in the bivariate analysis (p-value <0.20). Physical activity, sleep duration, BMI, fasting plasma glucose (FPG), triglycerides, and HDL were found to be significantly associated with MetS (p-value <0.0001) after adjusting for other variables in the model.

Participants with a sedentary physical activity level had 4.98 times the odds of developing MetS compared to those with vigorous physical activity (95% CI: 2.05–12.09). Participants with a sleep duration of less than 7.5 h had 0.945 times higher odds of developing MetS compared to those with a sleep duration of more than 7.5 h (95% CI: 0.90–0.99).

The odds of developing MetS were 4.45 times higher among participants with overweight BMI compared to those with obesity (95% CI: 1.51–13.13). For every 1 mg/dl increase in fasting plasma glucose (FPG) and triglycerides, the odds of developing MetS increased by 1.08 and 1.01 times, respectively. Conversely, for every 1 mg/dl increase in HDL, the odds of developing MetS decreased by 0.85 times.

Table 5 presents the association between the dependent variable (MetS vs. No MetS) with gender and BMI. BMI was significantly associated with the dependent variable, indicating mean differences in MetS and non-MetS groups across different BMI categories. However, gender did not show a significant difference in means between male and female study participants.

These results provide valuable insights into the prevalence of MetS and its associated factors in the study population, highlighting the significance of physical activity, sleep duration, BMI, FPG, triglycerides, and HDL as important predictors of MetS.

Discussion
The current study is the first to investigate the prevalence of metabolic syndrome (MetS) among adolescents aged 11–18 years in resource-poor areas of Karachi,

Variables	Total n (%)	MetS n (%)	No MetS n (%)	Bivariate statistics (p-value ≤0.20)
N (%)	689	115 (16.69)	574 (83.30)	–
Age (in years) mean ± SD		15.64 ± 1.44	15.48 ± 1.41	ns
a. 11	4 (0.50)	0 (0)	4 (0.69)	
b. 12	9 (1.30)	2 (1.73)	7 (1.21)	
c. 13	40 (5.72)	5 (4.34)	35 (6.09)	
d. 14	114 (16.50)	18 (15.65)	96 (16.72)	
e. 15	172 (24.90)	31 (26.95)	141 (24.56)	
f. 16	169 (24.50)	22 (19.13)	147 (25.60)	
g. 17	129 (18.60)	25 (21.73)	104 (18.11)	
h. 18	51 (7.50)	12 (10.43)	40 (6.96)	
Sex				ns
a. Male	301 (43.60)	52 (45.21)	249 (43.37)	
b. Female	388 (56.30)	63 (54.78)	325 (56.62)	
BMI				[a]
a. Underweight	402 (58.30)	53 (46.08)	349 (60.80)	
b. Normal weight	243 (35.20)	44 (38.26)	199 (34.66)	
c. Over weight	29 (4.20)	9 (7.82)	20 (3.48)	
d. Obese	15 (2.17)	9 (7.82)	6 (1.04)	
Ethnicity				ns
a. Baloch	10 (1.4)	1 (0.86)	9 (1.56)	
b. Hindko	1 (0.10)	0 (0)	1 (0.17)	
c. Kashmiri	2 (0.30)	0 (0)	2 (0.34)	
d. Memon	5 (0.70)	3 (2.60)	2 (0.34)	
e. Pathan	196 (28.40)	36 (31.30)	160 (27.87)	
f. Punjabi	77 (11.20)	11 (9.56)	66 (11.49)	
g. Sindhi	6 (0.87)	0 (0)	6 (1.04)	
h. Urdu speaking	392 (56.90)	64 (55.65)	328 (57.14)	
Physical activity				[a]
a. Sedentary	330 (47.90)	53 (46.08)	277 (48.25)	
b. Low	61 (8.90)	10 (8.69)	51 (8.88)	
c. Moderate	285 (41.30)	52 (45.21)	233 (40.59)	
d. Vigorous	13 (1.88)	0 (0)	13 (2.26)	
Physical activity (days/week)				[a]
a. 0 day/week (no physical activity)	329 (47.70)	53 (46.08)	277 (48.25)	
b. 1 day/week	21 (3.06)	13 (11.30)	8 (1.39)	
c. 2 day/week	41 (8.80)	33 (28.69)	28 (4.87)	
d. 3 day/week	23 (3.30)	5 (4.34)	18 (3.13)	
e. 4 day/week	213 (31.30)	9 (7.82)	204 (35.54)	
f. 5 day/week	29 (7.20)	3 (2.60)	26 (4.52)	
g. 6 day/week	2 (0.30)	0 (0)	2 (0.34)	
h. 7 day/week	11 (1.60)	0 (0)	11 (1.91)	
Screen time (hours/day)				ns
a. 0 screen time	70 (10.20)	10 (8.69)	60 (10.45)	
b. Less than 2 h	152 (22.10)	28 (24.34)	124 (21.60)	
c. 2 h	225 (32.10)	35 (30.43)	190 (33.10)	
d. More than 2 h	242 (35.10)	42 (36.52)	200 (34.84)	
How many times you take meal in a day?				ns
a. 1 time	26 (3.70)	4 (3.47)	22 (3.83)	
b. 2 time	368 (53.30)	63 (54.78)	305 (53.13)	
c. 3 time	270 (39.20)	46 (40.00)	224 (39.02)	
d. 4 time	25 (3.60)	2 (1.73)	23 (4.00)	
Lunch brings from?				[a]
a. Canteen food	465 (67.40)	71 (61.73)	394 (68.64)	
b. Homemade food	24 (3.40)	3 (2.60)	21 (3.65)	
c. No lunch	200 (29.00)	41 (35.65)	159 (27.70)	

(Table 3 continues on next page)

Variables	Total n (%)	MetS n (%)	No MetS n (%)	Bivariate statistics (p-value ≤0.20)
(Continued from previous page)				
Nature of food use to eat mostly				ns
a. Junk food	466 (67.60)	71 (61.73)	395 (68.81)	
b. Healthy food	23 (3.30)	3 (2.60)	20 (3.48)	
c. Mix (junk and healthy both)	200 (29.00)	41 (35.65)	159 (27.70)	
Beverages				ns
a. Juice	93 (13.50)	13 (11.30)	80 (13.93)	
b. Soft drink	151 (21.90)	24 (20.86)	127 (22.12)	
c. Tea	445 (64.50)	78 (67.82)	367 (63.93)	
Fruit intake				[a]
a. Daily	139 (20.10)	31 (26.95)	108 (18.81)	
b. Once a week	293 (42.50)	38 (33.04)	255 (44.42)	
c. Twice a week	26 (3.79)	4 (3.47)	22 (3.83)	
d. Once a month	231 (33.50)	42 (36.52)	189 (32.92)	
Salt intake				ns
a. Low	113 (16.50)	17 (14.78)	96 (16.72)	
b. Normal	487 (70.60)	84 (73.04)	403 (70.20)	
c. High	79 (12.80)	14 (12.17)	75 (13.06)	
Sleep duration				[a]
a. Less than 7.5 h	364 (52.80)	69 (60.00)	295 (51.39)	
b. More than 7.5 h	325 (47.10)	46 (40.00)	279 (48.60)	
Do you smoke?				ns
a. Yes	140 (52.30)	25 (21.73)	115 (20.03)	
b. No	285 (41.30)	47 (40.86)	238 (41.46)	
Parent's educational level				[a]
a. No education	172 (24.90)	37 (32.17)	135 (23.51)	
b. Primary	42 (6.10)	8 (6.95)	34 (5.92)	
c. Secondary	359 (51.10)	50 (43.47)	309 (53.83)	
d. Intermediate	84 (12.90)	15 (13.04)	74 (12.89)	
e. Graduate	27 (3.79)	5 (4.34)	22 (3.83)	
Does anyone smoke at home?				ns
a. Yes	404 (58.60)	68 (59.13)	336 (58.53)	
b. No	285 (41.30)	47 (40.86)	238 (41.46)	
Family disease history of diabetes/hypertension				ns
a. No	309 (44.80)	52 (45.21)	257 (44.77)	
b. Diabetes	83 (12.00)	16 (13.91)	67 (11.67)	
c. Diabetes + hypertension	281 (35.80)	46 (40.00)	235 (40.94)	
d. Hypertension	15 (2.10)	1 (0.86)	14 (2.43)	
Waist circumference mean ± SD	689	69.02 ± 14.26	63.45 ± 11.32	[a]
Fasting plasma glucose (mg/dl) mean ± SD	689	112.59 ± 28.92	100.61 ± 12.68	[a]
Total cholesterol (mg/dl) mean ± SD	689	143.67 ± 27.11	137.01 ± 27.85	[a]
Triglycerides (mg/dl) mean ± SD	689	161.45 ± 63.09	96.36 ± 41.50	[a]
High density lipid (mg/dl) mean ± SD	689	33.96 ± 5.21	40.23 ± 8.51	[a]
Low density lipid cholesterol (mg/dl) mean ± SD		85.81 ± 23.86	78.91 ± 22.18	[a]
BP systolic (mmHg) mean + SD	689	103.46 ± 17.57	99.45 ± 12.05	[a]
BP diastolic (mmHg) mean + SD	689	66.81 ± 9.84	64.16 ± 8.65	[a]

ns: non-significant. [a]p-value ≤0.20.

Table 3: **Demographic, anthropometric, and laboratory characteristics of adolescents with and without metabolic syndrome (MetS) in marginalised population.**

Pakistan. Our findings reveal that the prevalence of MetS in the collected sample is approximately 17%, which is considerably higher than the prevalence reported in similar age groups in Jammu and Kashmir, India (2.60%),[31] and Chandigarh, India (4.20%).[32]

Among the 689 adolescents in our sample, 301 (43.60%) were male, and 52 (17.30%) of them had MetS based on clinical investigations. Gender did not have a significant impact on the prevalence of MetS in our data. Specifically, there were 63 (64.70%) females and 52

MetS	Adjusted OR (95% CI)	p value[a]
Physical activity (days/week)		
Sedentary	4.98 (2.05–12.09)	[a]
Low	3.17 (1.85–5.44)	[a]
Moderate	1.01 (1.00–1.02)	[a]
Vigorous	Ref	–
Sleep duration		
Less than 7.5 h	0.94 (0.90–0.99)	[a]
More than 7.5 h	Ref	–
Fruit intake		
Daily	0.95 (0.83–1.09)	ns
Once a month	0.99 (0.87–1.13)	ns
Once a week	1.02 (0.90–1.16)	ns
Twice a week	Ref	–
Type of food in meal		
Mix (both junk and healthy)	1.00 (0.95–1.06)	ns
Mostly healthy food	0.97 (0.85–1.11)	ns
Mostly junk food	Ref	–
Level of parental education		
Graduate	1.03 (0.91–1.17)	ns
Intermediate	1.01 (0.93–1.08)	ns
No education	0.96 (0.90–1.01)	ns
Primary level	0.99 (0.90–1.10)	ns
Secondary level	Ref	–
BMI		
Underweight	0.991 (0.98–0.99)	[a]
Normal weight	0.37 (0.17–0.77)	[a]
Over weight	4.45 (1.51–13.13)	[a]
Obese	Ref	–
Waist circumference	0.999 (0.997–1.002)	ns
FPG (mg/dl)	1.08 (1.06–1.11)	[a]
Triglycerides (mg/dl)	1.019 (1.012–1.025)	[a]
Cholesterols (mg/dl)	0.999 (0.996–1.001)	ns
HDL cholesterol (mg/dl)	0.85 (0.81–0.90)	[a]
LDL cholesterol (mg/dl)	1.001 (0.99–1.004)	ns
BP systolic	0.999 (0.996–1.002)	ns
BP diastolic	1.000 (0.996–1.003)	ns

ns: non-significant; MetS: metabolic syndrome; Adjusted OR: Adjusted Odds Ratio. [a]p-value <0.0001.

Table 4: **Multivariate Logistic Regression between "MetS vs. No MetS" with predictor variables.**

(45.20%) males with MetS. This finding is consistent with a study by Shah and colleagues in the United Arab Emirates.[33] However, our data shows that females had a higher prevalence of MetS than males, which is unlike the findings reported in Jammu Kashmir (3.84% among males and 1.60% among females)[13] and China (2.80% among males and 1.70% among females).[34] There could be several reasons for the higher prevalence of MetS among females in our study. First, hormonal factors may play a role. It is well-established that hormonal changes during puberty can influence body composition, fat distribution, and insulin sensitivity, which are all factors associated with MetS. Females may undergo more significant hormonal changes during adolescence, which could contribute to their increased susceptibility to developing MetS. Second, differences in lifestyle and behaviour patterns between males and females may contribute to the disparity in MetS prevalence. Our study found a higher prevalence of sedentary lifestyle and increased consumption of unhealthy food among females, which are known risk factors for MetS. Additionally, cultural and societal factors may influence dietary habits and physical activity levels differently for males and females, further contributing to the gender disparity in MetS prevalence.

Our study included 689 adolescents aged 11–18 years from low-resource areas of Karachi, Pakistan. Among the sample, 402 (58.00%) were underweight, 29 (4.20%) were overweight, and 15 (2.17%) were obese. Of these, 53 (46.00%) belonged to the underweight category, and 44 (38.20%) belonged to the normal weight category. In contrast to a study conducted in the USA, where most obese adolescents had a higher prevalence of MetS,[35] our study found that lean individuals with non-alcoholic fatty liver disease (lean-NAFLD), particularly those in the underweight and normal weight categories, are at a higher risk of developing MetS, especially in the Asian population.[36] This observation is supported by another study that found females in the lean-NAFLD category are more prone to developing MetS.[37] Therefore, even individuals with a normal weight are at risk of developing cardiovascular disease, particularly in the Asian population.[38] The higher prevalence of MetS among lean individuals could be attributed to various factors. First, ethnicity and genetics might play a role in the development of MetS. Certain populations, such as Asians, have abdominal obesity, which is associated with insulin resistance, dyslipidaemia, and other components of MetS.[38] Second, the nutritional status and dietary patterns of individuals in resource-poor areas may contribute to the development of MetS. Limited access to nutritious food, coupled with a high

Variables	Statistical analysis Chi-Square test[a]
Sex	$\chi^2 = 0$
Male	df = 1
Female	p value = ns > 0.05
	Critical value = 3.84
BMI	$\chi^2 = 28$
Underweight	df = 3
Normal weight	p value = 2.95E-06 < 0.05
Overweight	Critical value = 7.81
Obese	

[a]χ^2; df: degree of freedom; CV: critical value; ns: non-significant; MetS: metabolic syndrome.

Table 5: **Association between the dependent variable (MetS vs. No MetS) with gender and BMI.**

consumption of energy-dense, processed, and unhealthy foods, can lead to metabolic imbalances and increased risk of MetS. In our study, we found a higher prevalence of MetS among individuals who consumed canteen food over homemade food, indicating the influence of poor dietary choices on metabolic health. Furthermore, it is important to consider the impact of socioeconomic factors on the development of MetS in lean individuals. Poverty, limited educational opportunities, and lack of healthcare resources can contribute to unfavourable living conditions, including inadequate access to healthcare services and preventive measures. These factors may further exacerbate the risk of metabolic disorders among individuals with a lean body mass.

The consumption of processed and oily foods, such as junk food, can contribute to the development of MetS, even without significantly impacting BMI. In our study, those who preferred canteen food over homemade food had a higher percentage of MetS, and this finding is similar to a study in India by Gupta and colleagues.[39] Additionally, higher screen time, a sedentary lifestyle, and increased consumption of fast food, especially from the canteen, significantly contributed to the rising prevalence of MetS among healthy individuals, as supported by various studies.[40–42] The link between sedentary behaviour and MetS can be explained by the adverse effects of reduced physical activity on energy metabolism, insulin sensitivity, lipid profile, and cardiovascular health. Furthermore, increased screen time is often accompanied by unhealthy snacking habits and a higher intake of energy-dense, nutrient-poor foods, which further contribute to the development of MetS.

Our study found a higher prevalence of MetS among tea consumers compared to sugary drinks and carbonated drinks. This finding is in contrast to a study conducted in China by Chan and colleagues, where smoking, tea consumption, and alcohol were inversely related to MetS among the Chinese population.[41] However, our findings are consistent with other studies that have found an increased risk of MetS associated with the consumption of carbonated and sweetened beverages.[42] Tea, particularly green tea, has been recognised for its potential health benefits due to its rich content of polyphenols and antioxidants. Some studies have suggested that tea consumption may have a protective effect against MetS and its individual components, such as obesity, dyslipidaemia, and insulin resistance. The proposed mechanisms include improved lipid metabolism, enhanced insulin sensitivity, and reduced inflammation.

However, the higher prevalence of MetS among tea consumers in our study suggests that there may be other factors at play in the context of our population. It is important to consider the cultural and regional differences in tea consumption patterns and tea preparation methods. For example, in our study population, tea consumption may be associated with the addition of excessive sugar or other sweeteners, which can contribute to the development of MetS. Additionally, tea consumption habits may be linked to other unhealthy lifestyle behaviours, such as a preference for high-calorie snacks or a sedentary lifestyle, which could further contribute to metabolic abnormalities. On the other hand, our findings align with other studies that have reported an increased risk of MetS associated with the consumption of carbonated and sweetened beverages.[42] These types of beverages are known to be high in added sugars and contribute to excessive calorie intake. Regular consumption of sugary drinks has been linked to weight gain, insulin resistance, dyslipidaemia, and an increased risk of MetS. The high sugar content in these beverages can lead to elevated blood glucose levels, dysregulated lipid metabolism, and increased visceral fat deposition. It is important to note that our study did not specifically analyse the types or amounts of tea consumed by the participants, nor did it differentiate between different tea varieties. Therefore, further research is needed to better understand the relationship between tea consumption and MetS in our specific population, considering the nuances of tea preparation, additives, and accompanying lifestyle factors.

Regarding smoking, the relationship between smoking and MetS is unclear in our study. Among the 689 adolescents in our sample, only 25 (3.60%) developed MetS, which is lower compared to the 47 (6.80%) among non-smokers, like previous studies.[43–45] The unclear relationship between smoking and MetS in our study is an interesting finding that warrants further discussion. Several factors could contribute to this unexpected finding. First, it is important to consider the age group of our study participants, as they were adolescents aged 11–18 years. At this stage, the duration and intensity of smoking may be relatively low compared to adults who have been smoking for a longer period. Therefore, the cumulative harmful effects of smoking on metabolic health may not yet be fully manifested in this young age group. Second, it is possible that the lower prevalence of MetS among smokers in our study is influenced by other confounding factors, such as lifestyle behaviours and socioeconomic status. Smokers may exhibit different patterns of physical activity, dietary choices, and overall health behaviours compared to non-smokers. These factors can have a significant impact on metabolic health and may explain the observed association. Additionally, it is important to note that our study focused on a specific population of adolescents from resource-poor areas of Karachi, Pakistan. The smoking patterns and tobacco-related behaviours in this population may differ from other populations, which could contribute to the unique findings regarding the association between smoking and MetS. Furthermore, the small number of adolescents in slums who developed MetS in our sample, both among smokers and non-smokers, should be taken into consideration when interpreting these results. The limited number of cases of MetS in our study may limit

the statistical power to detect significant associations and may contribute to the observed variability in the relationship between smoking and MetS.

We also found that the prevalence of MetS was higher among adolescents in slums whose parents had a secondary level of education or no education, and there was no significant impact of parents' education on their children's risk of developing MetS, similar to a study conducted in China by Li and colleagues about the no impact of parents' education on their children metabolic status.[45] There could be several reasons for this lack of association. First, it is possible that other socioeconomic factors, such as income level, occupation, or the overall environment in which the adolescents live, may have a stronger influence on their risk of developing MetS. These factors could affect access to healthy food options, opportunities for physical activity, and exposure to other health-promoting resources.

Low HDL is one of the significant contributors to the development of MetS among adolescents.[46] In our collected data, we found that most school-going adolescents in slums, have a high prevalence of low HDL, consistent with findings from other studies.[47] HDL cholesterol is often referred to as "good cholesterol" because it plays a crucial role in the reverse cholesterol transport process, removing excess cholesterol from peripheral tissues and transporting it back to the liver for metabolism and excretion. Adequate levels of HDL cholesterol are associated with a lower risk of cardiovascular disease. Several factors may contribute to the high prevalence of low HDL among adolescents. First, lifestyle behaviors such as sedentary lifestyle, poor dietary habits, and high consumption of unhealthy foods can have a negative impact on HDL cholesterol levels. Lack of physical activity and a diet rich in processed foods, saturated fats, and sugars can lead to dyslipidemia, including low HDL levels. Second, genetic factors may also play a role in determining HDL cholesterol levels. Genetic variations can influence the metabolism and transport of cholesterol, including HDL particles. These genetic factors, combined with environmental influences, may contribute to the observed high prevalence of low HDL levels among adolescents in our study. Furthermore, the high prevalence of low HDL cholesterol in adolescents may also be associated with other components of metabolic syndrome, such as obesity, insulin resistance, and dyslipidaemia. These components often coexist and interact with each other, contributing to the overall metabolic health of individuals. These findings shed light on the high prevalence of MetS and its associated factors among adolescents in resource-poor areas of Karachi, Pakistan. The study highlights the importance of addressing lifestyle factors such as physical activity, dietary habits, and sedentary behaviours to prevent and manage MetS in this vulnerable population.

In conclusion, by conducting this research, we aim to shed light on the extent of MetS within this specific population and contribute to a better understanding of the health challenges they face. It is important to recognize that both childhood obesity and being underweight can increase the risk of developing metabolic syndrome (MetS) later in life. Early intervention and management strategies are crucial in slowing down the progression of the disease and improving long-term health outcomes. Healthcare professionals play a vital role in identifying at-risk patients and providing guidance on illness prevention and management.

To further our understanding of MetS, more research is needed to explore its underlying mechanisms and risk factors, particularly in different populations. This will contribute to the development of targeted interventions and strategies for prevention and management. Food interventions and the promotion of a healthy lifestyle are key components in preventing and managing MetS. Educating both children and parents about the benefits of healthy eating habits and regular physical activity is crucial. Encouraging the consumption of nutritious foods, reducing the intake of processed and unhealthy foods, and promoting regular exercise can have a significant positive impact on metabolic health. Health education programs should focus on raising awareness about MetS, its risk factors, and the importance of early intervention. By providing education and support, healthcare professionals can empower individuals and families to make informed choices and adopt healthier lifestyles. By implementing these changes, we can work towards reducing the prevalence of MetS in the younger population and improving their overall health outcomes. It is essential to prioritise the early identification and management of MetS to mitigate its long-term consequences and improve the well-being of individuals at risk. Together, healthcare professionals, policymakers, and communities can make a significant impact in preventing and managing MetS, ultimately leading to healthier futures for future generations.

Contributors

HS proposed the concept and the study design and prepared the early version of the manuscript; HS and SSJ did a literature search and finalized the manuscript; TS and HN collected and sorted out the data; SSS was involved in biostatistics analysis, SSS involved in result interpretation, and UK shared the valuable feedback. SSJ supervised the overall Research project. All authors reviewed and approved the final version of the study.

Data sharing statement

De-identified datasets used and analysed during the current study would be provided by the corresponding author upon request.

Declaration of interests

The authors state that the study was conducted without commercial or financial ties, which may be seen as a potential conflict of interest.

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