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ORIGINAL CONTRIBUTION

Decreased high-density lipoprotein cholesterol and insulin resistance were the most common criteria in 12- to 19-year-old adolescents

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Abstract
Background Metabolic syndrome (MetS) is characterized by a group of metabolic risk factors leading to an increase in diabetes mellitus and cardiovascular diseases. It is known that the pathologic processes such as hyperinsulinemia and atherogenic risk profile associated with the development of MetS begin during childhood and adolescence.
Aim of the study To determine the prevalence of MetS and assess the association between MetS and certain demographic and lifestyle factors in a representative adolescent population.
Methods The study was carried out in central and ten districts located around Kayseri Province, Central Anatolia. A total of 790 adolescents aged from 12 to 19 years were selected systematically from the schools. Criteria of MetS were modified from Adult Treatment Panel III: (1) waist circumference $>$ 90th percentile (aged between 12 and 17 years) and $>$102 cm in male, $>$88 cm in female (for aged 18 and 19 years), (2) serum triglycerides [$\geq$136 mg/dl (aged between 12 and 16 years) and $\geq$150 mg/dl (for 17 and 19 years)], (3) high-density lipoprotein cholesterol [$\leq$40 mg/dl (males) and $\leq$50 mg/dl (females)], (4) systolic blood pressure $\geq$ 95th percentile for gender, age and height, (5) insulin resistance HOMA index $<$ 3.16. Multivariate regression model was performed to search for the association between MetS and demographic and lifestyle factors including gender, age, body mass index, settlement, socioeconomic class, smoking habit, physical activity and family history for diseases (cardiovascular diseases and diabetes mellitus).
Results The overall prevalence of MetS was found as 10.8%. The prevalence was significantly higher in males than in females (13.5 and 8.6%, respectively). Low high-density lipoprotein cholesterol and insulin resistance were the most common criteria of the syndrome. According to the analysis, only gender and high socioeconomic class were weak-positive related factors with MetS.
Conclusions High prevalence of MetS especially among overweight and obese adolescents is a serious health problem. Early identification of the syndrome would contribute greatly to the prevention of diabetes and cardiovascular diseases in youth.

Keywords Metabolic syndrome · Insulin resistance · High-density lipoprotein cholesterol · Adolescents

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Introduction

A cluster of diabetes mellitus (DM) and cardiovascular diseases (CVD) risk factors including central adiposity, insulin resistance (IR), alterations in lipid metabolism and hypertension have been referred to metabolic syndrome (MetS) [21]. The prevalence of MetS among adults has increased markedly in different countries, including Turkey. However, in the years 2007, the prevalence of MetS was reported as almost 35.0% in Turkish adults [2, 4, 16, 24, 29, 34]. Although the pathologic processes such as hyperinsulinemia and atherogenic risk profile associated with development of MetS begin during childhood, the frequency of MetS among children and adolescence was demonstrated with a few studies [1, 9, 14].

The pathogenesis of MetS is still unclear; nevertheless, there is an increasing amount of data to show that being overweight and obese in childhood and adolescence are significantly associated with MetS [1, 3, 9, 14]. Thus, excess body weight and body fat were found to be associated with increasing plasma insulin, lipids, lipoproteins levels and also elevated blood pressure in children [6, 30, 37, 40, 43, 45, 46]. Furthermore, data are available about relationships of some lifestyle and environmental factors such as low family income, social class, education level, physical activity and smoking habit with MetS in adults [35, 39, 41]. In this concept, also determining the environmental and lifestyle factors associated with MetS in adolescence may contribute to development of prevention and treatment strategies at an early age.

The aims of this study were: (1) to determine the prevalence of MetS; (2) to assess the association between MetS and certain demographic and lifestyle variables among adolescents living in Kayseri where the prevalence of MetS has previously been reported as high among adults [4].

Materials and methods

Study design and subjects

This study was carried out in two of the central and ten surrounding districts of Kayseri Province located in Central Anatolia. Kayseri constitutes 2.2% of the land of Turkey and almost 34.0% of adult population have MetS [4].

The study team consisted of two endocrinologists from Divisions of Internal Medicine and Paediatrics, specialists for nutrition and dietetics, family physician, biostatistics and clinical biochemistry. The study protocol was approved by Medical Faculty Ethics Committee, Erciyes University.

The group of this cross-sectional study was made up of adolescents aged between 12 and 19 years. The optimal sample size of the study was calculated as 812 adolescents.

The study was designed in two stages: in the first stage, the schools representing the city centre and districts were selected randomly by the stratified sampling method according to low, medium and high socioeconomic levels. In the second stage, adolescents have been sampled randomly from the schools' enrolments. The study team visited the selected schools to explain the study in detail to the adolescents and their parents. As a priority of the study written consent was obtained from the parents of adolescents and all other procedures applied were in accordance with those outlined by the Declaration of Helsinki.

Anthropometric and SBP measurements

Of the 812 adolescents, 790 (97.3%) accepted to participate in the study and gave consent to measure the body weight, height, waist circumference (WC) and systolic blood pressure (SBP) and also get blood sample for lipids, glucose and insulin analysis.

The weight of adolescents in minimal clothes was measured by a portable scale to an accuracy of 0.1 kg. The height of adolescents without shoes standing straight with back, buttock, heals and head against the wall was measured by using a portable measuring device to an accuracy of ± 0.5 cm. WC was measured at the site of the shortest circumference between the umbilicus and the superior border of the iliac crest by a flexible tape measure when the adolescents were in standing position. SBP was measured on the right arm with a standard mercury sphygmomanometer after resting period.

Biochemical analysis

The blood samples of adolescents were drawn after a 12-h overnight fast at school between 08.00 and 09.00 hours. Serum was centrifuged directly at the school (for 10 min, at room temperature). Serum samples were transported at optimal conditions from the schools to the Biochemistry Laboratory of Erciyes University where the samples were examined. Samples were stored at -20 °C until analysis. Total high-density lipoprotein cholesterol (HDL-C), triglyceride and glucose were analysed with routine enzymatic procedures (Beckman Coulter LX-20 Analyzer, Ireland). Intra-assay/inter-assay coefficients of variations (CV) were 3/4.5%; 3/4.5% and 2/3% for HDL-C, triglyceride and glucose, respectively. Insulin was determined with Biosource IRMA immunoassay (Biosource Europe S.A.-Rue de I'Industrie, 8-B1400 Nivelles, Belgium). The intra-assay and inter-assay CVs for insulin were 2.2 and 6.5%, respectively.

Definition of metabolic syndrome

Criteria of MetS were adopted from Adult Treatment Panel (ATP III) not having been applied to adolescents, but those based on large research trials and the most widely using in diagnosis of MetS [19]. MetS was diagnosed when at least three of the five criteria were fulfilled:

1. *Abdominal obesity* WC > 90th percentile (aged 12–17 years) and >102 cm in male and >88 cm in female (aged 18 and 19 years) [20, 27].
2. *Hypertriglyceridemia* Serum triglycerides ≥ 136 mg/dl (aged 12–16 years) and ≥150 mg/dl (aged 17–19 years) [2, 19].
3. *Low HDL-C* Serum HDL-C > 40 mg/dl for male and >50 mg/dl for female [19].
4. *Elevated SBP* SBP ≥ 95th percentile for gender, age, height (aged 12-to-18 years) and >130 mmHg (aged 19 years) [32, 44].
5. *IR* HOMA index < 3.16 [homeostasis model assessment; fasting plasma insulin (μU/ml) × fasting plasma glucose (mg/dl)/22.5] [22].

Demographic and lifestyle factors

Age, gender, settlement, socioeconomic class, physical activity status, smoking habit and family history of chronic diseases were selected as certain factors that may be associated with MetS. Data were collected by a structured questionnaire. Information of socioeconomic class was obtained from the Province National Education Directorate. BMI [weight (kg)/height^2 (m)] for age and gender between ≥85th and <95th percentile and BMI ≥ 95th percentile for adolescents aged below 18 years were defined as overweight and obesity, respectively. And also BMI score of 25 and 30 kg/m^2 for aged 18 and 19 years were defined as overweight and obese, respectively [8]. Physical activity status was evaluated for both duration of daily physical activity in minutes and frequency of weekly physical activity performed by adolescents. The intensity of physical activity accepted as moderate was described as the activity raising the heart beat and leaving the person feeling warm and slightly out of breath equivalent to 3–6 times the resting level. Smoking habit was categorized as current smoker and never smoked. Family history of chronic diseases including DM, hypertension and other CVD were assessed by self-report of adolescents.

Statistical analysis

Statistical analyses were performed using Statistical Package for Social Sciences version 13.0 (SPSS Inc., Chicago, Illinois, USA). Numerical results were expressed as mean ± standard deviation (SD), and also median (minimum–maximum). Categorical results were expressed as *n* (%). Prevalence of MetS was given in 95% confidence interval (CI). Normality distribution of the data was tested using Kolmogorov–Smirnov test. Differences between groups were assessed using Student's *t* test for normal and Mann–Whitney *U* test for non-normal distributed data. The difference between each gender for criteria of MetS was tested by Chi-square test. The association between MetS and demographic and lifestyle factors were examined by multivariate regression model. A *P* value was less than 0.05 considered statistically significant.

Results

The prevalence of MetS was studied in 441 female (55.8%) and 349 male (44.2%) a total of 790 adolescents aged 12–19 years. The overall prevalence was found as 10.8% (95% CI, 8.7–13.1) and higher in males than in females (13.5 and 8.6%, respectively) ($P < 0.001$).

The mean age of adolescents with MetS and without MetS were 15.4 ± 1.7 years and 15.9 ± 1.9 years, respectively ($P < 0.001$). Although there was no significant difference between the heights of adolescents with MetS and without MetS, weight, WC and BMI of adolescents with MetS were significantly higher than those of adolescents without MetS ($P < 0.001$). While 38.8 and 24.7% of adolescents with MetS were overweight and obese, respectively, 11.2 and 1.4% of adolescents without MetS were overweight and obese, respectively ($P < 0.001$) (Table 1).

Metabolic characteristics and SBP of adolescents are presented in Table 2. Whereas SBP, HDL-C, triglyceride, insulin levels and HOMA index of adolescents with and without MetS were significantly different ($P < 0.001$), total cholesterol and glucose levels of adolescents with and without MetS were not different.

More than half of the adolescents with MetS had low HDL-C (49.4%), one of third of them had IR (34.7%) and one fifth had elevated SBP (18.1%). The least common criterion of MetS was hypertriglyceridemia (7.5%). On the other hand, low HDL-C and IR were more common in females than in males. In contrast, high WC, elevated SBP and hypertriglyceridemia were more prevalent in males than in females ($P < 0.001$) (Table 3).

The multiple logistic regression analysis of the correlations between MetS and certain demographic and lifestyle variables are given in Table 4. According to the analysis, only gender and high socioeconomic class were weak-positive related factors with Mets.

Table 1 Age and anthropometric characteristics of adolescents

Characteristics	Overall ($n = 790$)		Adolescents with MetS ($n = 85$)		Adolescents without MetS ($n = 705$)		P value
	$\bar{x} \pm SD$	Median (range)	$\bar{x} \pm SD$	Median (range)	$\bar{x} \pm SD$	Median (range)	
Age (year)	15.8 ± 1.9	16.0 (12–19)	15.4 ± 1.7	15.0 (12–19)	15.9 ± 1.9	16.0 (12–19)	<0.001
Height (cm)	162 ± 9.8	162.0 (127–195)	165.7 ± 9.9	165 (144–195)	161.7 ± 9.8	162 (127–194)	0.002
Weight (kg)	56.2 ± 12.6	54.5 (28–129)	70.9 ± 17.6	68.8 (40–129)	54.5 ± 10.5	53.2 (28–95.5)	<0.001
Waist circumference (cm)	66.0 ± 8.9	65.0 (45–110)	79.1 ± 11.0	78.0 (54–109)	64.4 ± 7.2	64.0 (45–110)	<0.001
BMI (kg/m^2)	21.2 ± 3.6	20.6 (13.8–37.5)	25.6 ± 4.8	25.1 (16.7–37.5)	20.7 ± 3.0	20.4 (13.8–33.2)	<0.001
BMI category [% (n)]							
Overweight	14.2 (112)		38.8 (33)		11.2 (79)		<0.001
Obese	3.9 (31)		24.7 (21)		1.4 (10)		<0.001

Table 2 Metabolic characteristics of adolescents

Characteristics	Overall ($n = 790$)		Adolescents with MetS ($n = 85$)		Adolescents without MetS ($n = 705$)		P value
	$\bar{x} \pm SD$	Median (range)	$\bar{x} \pm SD$	Median (range)	$\bar{x} \pm SD$	Median (range)	
Systolic blood pressure (mmHg)	119.4 ± 14.8	120.0 (70–200)	136.9 ± 17.9	140 (100–200)	117.3 ± 12.9	120.0 (70–170)	<0.001
Total cholesterol	155.7 ± 33.4	151.0 (80–348)	159.7 ± 39.2	156.0 (80–348)	155.3 ± 32.6	151.0 (86–280)	0.294
HDL– cholesterol (mg/dl)	47.3 ± 12.4	46.8 (19–102)	39.7 ± 9.7	39 (20–75)	48.2 ± 12.3	47.0 (19–102)	<0.001
Triglyceride (mg/dl)	78.9 ± 40.9	70.0 (18–350)	122.1 ± 66.7	106 (31–350)	73.7 ± 33.0	67 (18–241)	<0.001
Glucose (mg/dl)	83.0 ± 14.2	83.0 (50–132)	86.4 ± 13.5	86.0 (53–119)	82.6 ± 14.3	82.0 (50–132)	0.018
Insulin (μU/ml)	14.9 ± 9.9	12.1 (0.2–71.9)	26.9 ± 15.1	22.2 (5.8–71.9)	13.5 ± 8.0	11.6 (0.2–67.4)	<0.001
Insulin resistance (HOMA)	3.1 ± 2.1	2.5 (0.03–15.7)	5.7 ± 3.2	4.6 (1.06–15.7)	2.8 ± 1.7	2.4 (0.03–13.6)	<0.001

Table 3 The prevalence of metabolic syndrome criteria based on gender

Criteria	Total ($n = 790$)		Female ($n = 441$)		Male ($n = 349$)	
	n (%)	95% CI (lower–upper)	n (%)	95% CI (lower–upper)	n (%)	95% CI (lower–upper)
Low HDL-C	390 (49.4)	45.8–52.9	255 (57.8)	53.1–62.5	135 (38.7)*	33.5–44.0
IR	274 (34.7)	31.4–38.1	159 (36.1)	31.6–40.7	115 (33.0)*	28.0–38.2
Elevated SBP	143 (18.1)	15.5–20.9	60 (13.6)	10.5–17.2	83 (23.8)*	19.4–28.6
High WC	84 (10.6)	8.5–13.0	38 (8.6)	6.2–11.6	46 (13.2)*	9.8–17.2
Hypertriglyceridemia	59 (7.5)	5.7–9.5	25 (5.7)	3.7–8.2	34 (9.7)*	6.8–13.3

HDL-C High-density lipoprotein cholesterol, *HOMA-IR* homeostasis model assessment, *SBP* systolic blood pressure, *WC* waist circumference
* $P < 0.001$

Discussion

MetS with 10.8% rate is very important health problem among also adolescents living in Kayseri, Turkey. The prevalence was found similar to reported among adolescents living in Iran, United States and Korea (10.1, 9.2 and 9.2%, respectively), but lower than only reported in rural Georgia (15.0%) [12, 14, 15, 23]. The prevalence, which was almost one third of those adults population living in Kayseri, was probably due to lifestyle of the families.

The prevalence of MetS varies by gender. However, males tended to have higher prevalence of MetS compared with females consistent with the data reported by Cook et al. [9] and Cruz et al. [10]. In contrast, Davis et al. [12], Esmaillzadeh et al. [14] and Lambert et al. [25] showed no differences in the prevalence of MetS between genders. Although the reason for the rapid increase in MetS in males seems unclear, it may depend on the pubertal differences at these ages. Also males have higher WC than females may explain higher prevalence of MetS in males.

Table 4 Univariate and multiple logistic regression analysis (backward Wald) of MetS and certain variables

Variable	Univariate logistic regression analysis		Multiple logistic regression analysis (backward Wald)	
	Odds ratio	95% CI (lower–upper)	Odds ratio (lower–upper)	95% CI (lower–upper)
Gender				
Female	1		–	–
Male	1.650	1.049–2.569		
Age	0.884	0.787–0.993	–	–
Settlement				
Province	1		–	–
District	1.063	0.606–1.864		
Socioeconomic class				
Low	1		–	–
Medium	1.514	0.844–2.717		
High	3.033	1.622–5.673		
Smoking habit				
No	1		–	–
Yes	1.515	0.764–3.003		
Physical activity status	1.218	0.776–1.910		
Presence of diseases in family[a]	1.552	0.928–2.594	–	–

CI confidence interval

[a] Hypertension, diabetes and CVD

While Salazar et al. [38] reported the main components of MetS as elevated SBP and impaired fasting glucose among adolescents, the main features of MetS in Turkish adolescents were IR and low HDL-C consistent with the data reported by Agirbasli et al. [1] and Esmaillzadeh et al. [14]. Turkish adolescents face significant further risks of both DM and CVD because both have positive relationships between IR and low HDL-C level among youth [10] and having low HDL-C which is main characteristic of lipid metabolism also of Turkish adults [26]. This result may reflect the change in nutritional habits towards consumption of foods, especially containing saturated fat and high-refined carbohydrate and low fibre from vegetables, fruits, whole grains and also processed foods such as soft drinks and fast foods together with sedentary life style depending on social and economic development of Turkish population. Just as Ekelund et al. [13] and McMurrry et al. [28] showed that low levels of childhood physical activity and aerobic fitness were associated with the presence of MetS in adolescence and physical inactivity was a metabolic risk indicator in adolescents. However, being overweight and obese were the most related factors to MetS [2, 7, 10, 11, 36, 46–48]. Central obesity is also the most prevalent criterion of MetS. Also the family history of obesity is a strong determinant of childhood obesity in addition to a considerable risk factor in the tracking of childhood obesity to adulthood [4, 5, 18, 33]. In this concept, especially family-based lifestyle intervention has beneficial effects on associated factors related to MetS, confirmed by Monzavi et al. [31]. There was an association between MetS and socioeconomic class in our study in accordance with other studies [17, 42]. It seems that MetS is more prevalent among adolescents representing high socioeconomic class (OR = 3.033; 95% CI = 1.622–5.673). Despite the report by Cruz [10] that overweight Hispanic youth with a family history of DM were at increased risk for MetS, we detected no association between MetS and family history for both DM and CVD. Individual risk factors except being overweight and obese may differ in other communities depending on different lifestyles.

In conclusion, the results of our study support the previous studies indicating that overweight and obesity have an important impact on the development of MetS among adolescents and the identification of additional clinic syndromes. Unless a proper lifestyle is adopted to prevent overweight and obesity, CVD and DM will increase more. In this concept, identification of adolescents at risk of MetS and focusing on health promotion will be a great contribution to community health and decrease health service costs.

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