



Association of Metabolic Syndrome with Body Fat Percent, Anthropometric Indices in 10 To 18 Year Old Adolescents

Parvin MIRMIRAN¹, Mansoureh REZAEI², Golaleh ASGHARI¹, Yadollah MEHRABI³, *Fereidoun AZIZI⁴

1. Obesity Research Center, Nutrition and Endocrine Research Center, Research Institute for Endocrine Sciences, Shahid Beheshti University of Medical Sciences, Tehran, Iran
2. Dept. of Clinical Nutrition and Dietetics, Faculty of Nutrition Sciences and Food Technology, National Nutrition and Food Technology Research Institute, Shahid Beheshti University of Medical Sciences, Tehran, Iran
3. Dept. of Epidemiology, Faculty of Public Health, Shahid Beheshti University of Medical Sciences, Tehran, Iran
4. Endocrine Research Center, Research Institute for Endocrine Sciences, Shahid Beheshti University of Medical Sciences, Tehran, Iran

***Corresponding Author:** Tel: +98 21 22432503 Email: azizi@endocrine.ac.ir

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Abstract

Background: Our aim was to evaluate the association of metabolic syndrome (MetS) and its components with body fat percentage (BFP) and anthropometric indices in 10 to 18 year old adolescents.

Methods: This was a cross-sectional study conducted on 134 Tehranian adolescents, aged 10 to 18 years (66 boys and 68 girls) in 2007. The MetS definition proposed by Cook et al. was used. Logistic regression was used to determine the relationship of MetS and its components with body mass index (BMI), waist circumference (WC), waist to height ratio (WHtR), and BFP. Using the areas under the receiver operating characteristic (ROC) curve, the discriminatory ability of anthropometric measurements and BFP was evaluated.

Results: The mean \pm SD for age of boys and girls was 14.5 ± 2.3 and 13.0 ± 2.9 years, respectively ($P=0.001$); the prevalence of MetS in these groups was 32.3 and 6.5%, respectively ($P=0.001$). After adjusting for sex and physical activity, the highest odds ratios (95% CI) for MetS and hypertriglyceridemia were found for WC, 6.27 (2.63-14.94; $P<0.05$) and 3.14 (1.87-5.27; $P<0.05$), respectively, and those for low HDL-C and hypertension were found for BMI, 2.91 (1.73-4.90; $P<0.05$) and 2.26 (1.27-4.02; $P=0.05$), respectively. After adjusting for sex and physical activity, the highest area under ROC curve for MetS and hypertriglyceridemia was seen for WC ($P=0.001$), for hypertension it was seen for BMI ($P=0.001$), and for low HDL-C it was observed for both WC and BMI ($P=0.001$).

Conclusions: In adolescents, WC was the best predictor of MetS and hypertriglyceridemia, BMI was the best predictor of hypertension, and WC and BMI were the best predictors for low HDL-C.

Keywords: Body fat percentage, Body mass index, Waist-to-height ratio, Waist circumference, Metabolic syndrome, Adolescents. Iran

Introduction

The metabolic syndrome (MetS) is defined as clustering of metabolic risk factors including central obesity, hyperglycemia, dyslipidemia, and hypertension (1). In recent decades, increasing obesity and MetS among children and adolescents is associated with a number of adverse consequences in

adulthood including type 2 diabetes mellitus and coronary heart disease (2-4). The process of atherosclerosis starts at an early age and is already linked to obesity and other components of MetS in childhood (5). While current estimates indicate prevalence of 2-9% for MetS in US adolescents

(6), a high prevalence of MetS up to 30% has been reported by Esmailzadeh in Iranian adolescents (7). There is substantial evidence evaluating the association between childhood obesity and cardio-metabolic risk factors, i.e. abdominal obesity, disorders in glucose regulation, dyslipidaemia and hypertension in pediatrics (8, 9). Considering obese European adolescents, 20.3–35.7% had clustering of ≥ 3 risk factors, while only 6.3–8.8% was free from any risk factors (4). Additionally, elevated body mass index (BMI) in adolescents has a distinct relationship with type 2 diabetes mellitus and cardiovascular disease (CVD) incidence in adulthood (2, 10–12). However, documented studies on the association of body fat percent as an indicator of obesity with cardiovascular risk factors are limited (13, 14).

The current study investigated the association of body fat percentage (BFP), BMI, waist circumference (WC) and waist to height ratio (WHtR) with MetS and its components in 10 to 18 year old adolescents.

Materials and Methods

Study population

In this cross-sectional study (conducted in 2007), a multi-stage stratified cluster random sampling technique was used to select 134 adolescents (66 boys and 68 girls), aged 10–18 years from among Tehran's urban population of District No. 13. Participants underwent a physical examination by trained physicians to reasonably exclude any health problems. Subjects were excluded if they had a medical history of chronic disorders including cardiovascular, renal, rheumatologic and congenital diseases. This study was approved by the institutional Ethics Committee of the Research Institute for Endocrine Sciences, affiliated to Shahid Beheshti University of Medical Sciences, and informed written consent was obtained from participants' parents.

Measurements

Weight was measured using digital scale (Seca 707) to the nearest 0.1 kg, while the subjects were minimally clothed. Height was measured using a tape

meter stadiometer in a standing position, without shoes, with the shoulders in a normal position to the nearest 0.1 cm, and WC was measured with an unstretched tape measure, at the narrowest level over light clothing, without any pressure to body surface and was recorded to the nearest 1 cm. BMI was calculated as $\text{weight}/\text{height}^2$ (kg/m^2), and WHtR was calculated by dividing WC (cm) by height (cm). Body fat percent was determined using the bioelectrical impedance analysis (BIA) method. Whole body impedance at 50 kHz was measured using a Quadscan 4000 analyzer from Bodystat 1500 in UK. Measurements were taken after at least 5h (overnight) fasting and with an empty bladder. Any jewelry and metal accessories were removed and children were asked to lie supine for 5min before starting the measurements. One electrode was attached at the level of the ulnar head at the wrist and the other just behind the knuckles. On the foot, the two electrodes were attached at the level of the medial and lateral malleoli and just behind the toes, respectively. Impedance (Ω) at 50 kHz and BF% measurements was recorded.

To measure blood pressure, subjects were first asked to rest for 15min. Then, a qualified physician measured blood pressure twice using a standard mercury sphygmomanometer with the subject in a seated position, during physical examinations after one initial measurement for determining peak inflation level. There was at least a 30s interval between these two separate measurements, and thereafter the mean of two measurements was considered to be the subject's blood pressure. The systolic blood pressure (SBP) was defined as the appearance of the first sound (Korotkoff phase 1), and diastolic blood pressure (DBP) was defined as the disappearance of the sound (Korotkoff phase 5) during deflation of the cuff at a 2- to 3-mm/s decrement rate of the mercury column.

Fasting blood samples for the measurement of glucose and lipid concentrations were drawn after the subjects had fasted overnight. Fasting plasma glucose (FPG) was measured on the day of blood collection by the enzymatic colorimetric method using glucose oxidase. Triglycerides (TGs) concentration was measured by commercially available

enzymatic reagents (Pars Azmoon, Tehran, Iran) adapted to a Selectra autoanalyzer (Vital Scientific, Spankeren, The Netherlands). High-density lipoprotein- cholesterol (HDL-C) was measured after precipitation of the apolipoprotein B-containing lipoproteins with phosphotungstic acid.

Endocrinologists determined the stage of puberty using Tanner criteria as the stage 1 indicates pre-adolescent characteristics, and stage 5 indicates adult characteristics (15).

Definition of the components of the metabolic syndrome

We used the definition based on Cook et al work (16), which defines MetS as three or more of the following: fasting TGs ≥ 110 mg/dL; HDL-C ≤ 40 mg/dL; WC ≥ 90 th percentile for age and sex, according to national reference curves(17); SBP and /or DBP ≥ 90 th percentile for sex, age and height, from national reference cut-off points(18); and FBS ≥ 100 mg/dL, according to the recent recommendation of American Diabetes Association(19). Based on the standardized percentile curves of BMI suggested for Iranian children and adolescents, obesity was defined as ≥ 95 th percentile of BMI for age and sex, overweight as between ≥ 85 - < 95 th percentile of BMI for age and sex, and nor-

mal weight as < 85 th percentile of BMI for age and sex (20).

Statistical Methods

Distribution of variables was checked using the Kolmogorov–Smirnov analysis. Student *t*-test was used to compare MetS components between the two genders. Fisher's exact and Chi-square analyses were used for qualitative variables. To evaluate the association of MetS and its components with BFP, BMI, WHtR and WC, multiple logistic regression analysis was applied, and ORs with 95% confidence intervals (CIs) were reported. Sex and physical activity were adjusted in the models. Area under the receiving operating curve (ROC) was estimated to compare the prediction power of anthropometric indices and BFP for the MetS and its components. All data were analyzed by SPSS software package (version 20; SPSS Inc., Chicago, IL, USA), and significance was set at $P < 0.05$.

Results

The mean \pm SD ages of boys and girls were 14.5 ± 2.3 and 13.0 ± 2.9 years, respectively ($P = 0.001$). Characteristics of study participants are summarized in Table 1.

Table 1: Cardio-metabolic, anthropometric, body composition and physical activity variables of the study population

Characteristic	Girls (n=68)	Boys (n=66)	P-value
Metabolic syndrome (%)	6.5	32.3	0.001
Hypertriglyceridemia (%)	32.8	54.5	0.013
Systolic blood pressure (mmHg)	92.6 \pm 9.8	106.9 \pm 12.9	0.001
Diastolic blood pressure (mmHg)	57.8 \pm 10.2	64.4 \pm 8.5	0.001
Hypertension (%)	9.2	21.5	0.048
Fasting plasma glucose (mg/dl)	86.6 \pm 7.9	90.2 \pm 8.0	0.010
High fasting plasma glucose (%)	7.8	12.1	0.413
HDL-C(mg/dl)	49.7 \pm 11.5	43.1 \pm 9.3	0.001
Low HDL-C (%)	20.0	39.4	0.015
Body mass index (kg/m ²)	21.3 \pm 4.5	24.3 \pm 5.2	0.001
Normalweight (%)	52.9	43.9	0.006
Overweight(%)	32.4	18.2	0.006
Obesity(%)	14.7	37.9	0.006
Body fat percent	30.7 \pm 6.1	26.6 \pm 9.0	0.003
High body fat percent (%)	55.9	60.0	0.631
Waist to height ratio	0.46 \pm 0.05	0.49 \pm 0.06	0.007
High waist to height ratio (%)	30.9	47.0	0.056
Physical activity (MET-hr/week)	17.40 \pm 17.32	40.35 \pm 38.24	0.001

Data are mean \pm standard deviation unless otherwise noted/ Normal weight, overweight, and obesity were defined as BMI < 85 th, 85 th \leq BMI < 95 th, and BMI ≥ 95 th percentile of BMI for age and sex, respectively

Overall, boys had higher mean levels of SBP, DBP, FBS, WHtR and physical activity, and lower mean levels of BFP and HDL-C than girls ($P < 0.05$). The prevalence of MetS was higher in boys than girls (32.3 versus 6.5%). On the basis of BMI values, boys tended to be more obese (37.9 versus 14.7%), but girls were more commonly overweight (32.4% versus 18.2%).

Odds ratios and 95% confidence interval of anthropometric measurements and BFP with MetS and its components are shown in Table 2. After adjusting sex and physical activity, the risk of developing MetS and hypertriglyceridemia among subjects who had abdominal obesity was increased significantly, compared with subjects who had normal WC [6.27(95% CI:2.63-14.94), 3.14(95%

CI:1.87-5.27), respectively]. After adjusting for sex and physical activity, the risk of developing low HDL-C and hypertension among obese subjects was increased significantly compared with subjects with normal BMI [2.91(95% CI:1.73-4.90), 2.26(95% CI:1.27-4.02), respectively].

Area under the ROC curves (AUC) of BFP, anthropometric indices with MetS and its components are shown in Figure 1 and Table 3. After adjusting for sex and physical activity, WC had the highest AUC for MetS (AUC = 0.89) and hypertriglyceridemia (AUC = 0.88); BMI had the highest AUC for hypertension (AUC = 0.78). WC and BMI were both had the highest AUC for low HDL-C (AUC = 0.78).

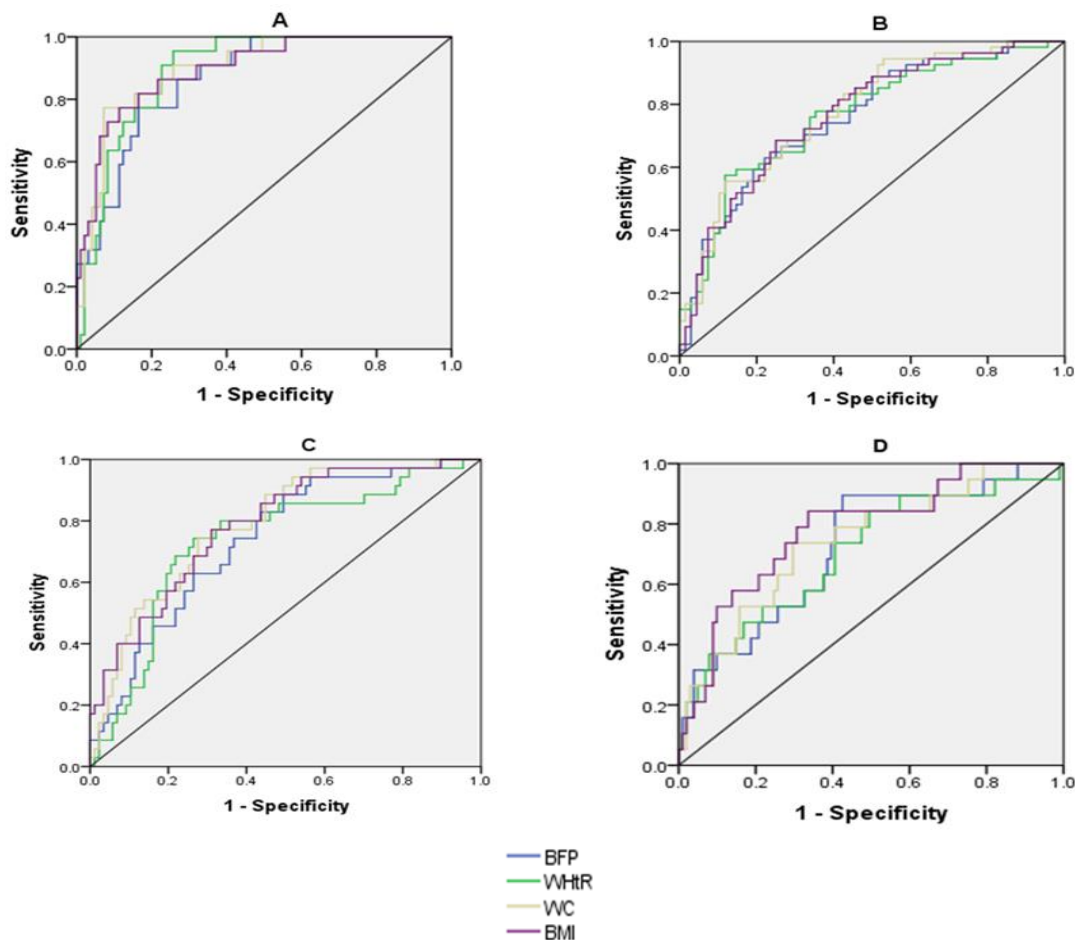


Fig. 1: Receiver operating characteristic (ROC) curves with area under curve (AUC) and 95% confidence intervals of body fat percent (BFP), waist-to-height ratio (WHtR), waist circumference (WC) and body mass index (BMI) for predicting MetS and components among 10 to 18 year adolescents

Table 2: Odds Ratio (95% CI) of metabolic syndrome and components with anthropometric measurements and body fat percent in adolescents 10 to 18 years old

Characteristic	Body fat percent	Waist to height ratio	Waist circumference	Body mass index
Metabolic syndrome				
Model 1	2.42(1.33-4.38)	4.16(2.20-7.86)	7.28(3.17-16.68)	6.27(2.84-13.82)
P-value	0.004	0.001	0.001	0.001
Model 2	3.69(1.81-7.51)	3.81(1.95-7.46)	6.27(2.63-14.94)	5.63(2.98-12.75)
P-value	0.001	0.001	0.001	0.001
Hypertriglyceridemia				
Model 1	2.07(1.35-3.15)	2.86(1.82-4.49)	3.10(1.92-4.99)	2.66(1.71-4.12)
P-value	0.001	0.001	0.001	0.001
Model 2	2.57(1.60-4.14)	2.70(1.70-4.29)	3.14(1.87-5.27)	2.57(1.63-4.07)
P-value	0.001	0.001	0.001	0.001
Low HDL-C				
Model 1	1.70(1.09-2.66)	1.99(1.31-3.03)	2.97(1.81-4.87)	3.04(1.84-5.00)
P-value	0.018	0.001	0.001	0.001
Model 2	1.95(1.21-3.13)	1.78(1.16-2.73)	2.89(1.68-4.97)	2.91(1.73-4.90)
P-value	0.005	0.008	0.001	0.001
High fasting plasma glucose				
Model 1	0.77(0.43-1.38)	0.62(0.32-1.20)	0.87(0.48-1.59)	0.79(0.43-1.45)
P-value	0.394	0.158	0.669	0.455
Model 2	0.78(0.42-1.44)	0.59(0.30-1.13)	0.78(0.40-1.51)	0.73(0.39-1.39)
P-value	0.433	0.117	0.468	0.350
Hypertension				
Model 1	1.34(0.80-2.26)	1.51(0.94-2.43)	1.90(1.15-3.11)	2.15(1.28-3.60)
P-value	0.263	0.082	0.011	0.004
Model 2	1.77(1.00-3.13)	1.58(0.93-2.68)	1.97(1.09-3.54)	2.26(1.27-4.02)
P-value	0.047	0.086	0.024	0.005

Model 1 was unadjusted and Model 2 was adjusted for sex and physical activity.

Table3: Area under the curve (AUC) of metabolic syndrome and its components with anthropometric measurements and body fat percent in adolescents 10 to 18 years old

Characteristic	Body fat percent	Waist to height ratio	Waist circumference	Body mass index
Metabolic syndrome				
Model 1	0.667 (0.54-0.79)	0.832(0.75-0.91)	0.884(0.82-0.94)	0.845(0.77-0.92)
P-value	0.010	0.001	0.001	0.001
Model 2	0.868(0.79-0.93)	0.894(0.83-0.95)	0.899(0.83-0.96)	0/897(0.82-0.96)
P-value	0.001	0.001	0.001	0.001
Hypertriglyceridemia				
Model 1	0.666(0.57-0.76)	0.751(0.66-0.83)	0.770(0.69-0.85)	0.747(0.66-0.83)
P-value	0.001	0.001	0.001	0.001
Model 2	0.759(0.67-0.84)	0.766(0.68-0.85)	0.881(0.70-0.86)	0.770(0.68-0.85)
P-value	0.001	0.001	0.001	0.001
Low HDL-C				
Model 1	0.619(0.51-0.72)	0.693(0.59-0.78)	0.759(0.67-0.84)	0.749(0.66-0.83)
P-value	0.031	0.001	0.001	0.001
Model 2	0.738(0.51-0.83)	0.737(0.63-0.83)	0.789(0.70-0.87)	0.788(0.70-0.87)
P-value	0.001	0.001	0.001	0.001
High fasting plasma glucose				
Model 1	0.605(0.44-0.76)	0/603(0.42-0.77)	0/535(0.34-0.72)	0.551(0.37-0.72)
P-value	0.215	0.225	0.681	0.545
Model 2	0.585(0.42-0.74)	0/619(0.44-0.79)	0.577(0.40-0.75)	0.591(0.42-0.75)
P-value	0.336	0.175	0.380	0.302
Hypertension				
Model 1	0.576(0.43-0.72)	0.634(0.51-0.75)	0.718(0.62-0.81)	0.724(0.61-0.82)
P-value	0.283	0.057	0.002	0.001
Model 2	0.722(0.59-0.84)	0.701(0.56-0.83)	0.739(0.61-0.86)	0.780(0.66-0.89)
P-value	0.002	0.006	0.001	0.001

Model 1 was unadjusted and Model 2 was adjusted for sex and physical activity

Discussion

Our findings suggest that in Tehranian adolescents, WC was the best predictor of MetS and Hypertriglyceridemia, BMI was the best predictor of hypertension and both BMI and WC were associated with low HDL-C. It seems that WC and BMI together may be good predictors of MetS and its components in adolescents, aged 10 to 18 years.

Several studies have shown the association between morbidity and abdominal fat in children/adolescents (21-25). In the current study, WC was the best predictor of MetS. Similar to our findings, central adiposity measures including WHtR and / or WC were strong predictors of an increased risk of MetS or clustering of dyslipidemia, hypertension and hyperglycemia both adolescents girls and boys (21, 24). Besides, in our previous study, WHtR and WC predicted early adulthood MetS better than BMI in male Tehranian adolescents, 11–18 years old (22). Additionally, the Bogalusa Heart Study found that WC was a better predictor of CVD risk factors than WHtR and BMI in Greek-Cypriot children (23). A study in obese adolescents has shown that the amount of intra-abdominal fat is directly related to cardiovascular risk factors, including HDL-C and SBP(25). However, Jung et al. reported BMI as the most accurate predictor of MetS(26). Insulin sensitivity and related metabolic CVD risk factors worsened as a result of increased obesity, regardless of whether BMI or WC was used as an index of excess adiposity (27). In terms of hypertriglyceridemia, among anthropometric indices, WC found to be the best predictor. Similar to our results, WC was a better predictor for hypertriglyceridemia in comparison to BMI (28, 29). Moreover, another index of abdominal obesity, WHtR, found to be the strong predictor of TGs among anthropometric indices in Japanese school children(30). Regarding general obesity, BMI was directly related to TGs (31, 32). Increased TGs and WC were most highly associated with MetS (24), results similar to ours i.e. elevated TGs and increased WC also predicted MetS well. This could be explained by the fact that plasma TG

levels correlate very closely with the amount of intra-abdominal fat in adolescents (33).

All anthropometric indices showed excellent power in relation to low HDL-C (26). WC predicted low HDL-C better than BMI (28, 29). Decreased HDL-C and WC were most highly associated with MetS (24). However, BMI had an inverse relationship with HDL-C(31), both the above mentioned results about WC are similar to our study. In terms of hypertension, BMI was the best predictor. Comparing different anthropometric parameters, Kaur et al. reported that classical values like BMI and WC were suitable for predicting elevated SBP, whereas WHtR was not as practical(34). However, a meta-analysis showed that WHtR was associated most strongly with hypertension in both girls and boys (35). Zeelie et al. reported a significant positive association between BFP and SBP (36). In Chinese children, WC was strongly associated most with blood pressure (29). However, BMI was a better predictor for hypertension (28). Our results clearly support this finding to predict elevated blood pressure, parameters incorporating the BMI were more appropriate. This could be explained by the fact that relationship between fasting insulin and blood pressure is partially confounded by differences in body size expressed as BMI (37). Insulin resistance and hyperinsulinemia appear to develop in obese children at an early age (38). Insulin resistance plays a role in the development of hypertension (39).

Our survey had both limitations and strengths. As limitations, the cross-sectional design does not allow investigating the causal relationship of anthropometric variables, BFP with MetS and its components. Additionally, BIA devices are not checked for validity. As strengths, to the best of our knowledge, this was the first cross sectional study that investigated the association of both anthropometric indices and BFP as predictors of MetS in adolescents in Iran.

Conclusion

The main implication of the current study is that WC and BMI may be used together as screening tools for the diagnosis of MetS in clinics and to

predict the risk of MetS and its components in adolescents, aged 10 to 18 years.

Ethical considerations

Ethical issues (Including plagiarism, Informed Consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors.

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