METABOLIC SYNDROME AND RELATED DISORDERS
Volume 8, Number 5, 2010

Pp. 443–449
DOI: 10.1089/met.2010.0022

Metabolic Syndrome and Physical Fitness in a Sample of Azorean Adolescents

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Abstract

Background: Metabolic syndrome, a predecessor of cardiovascular disease and type 2 diabetes, has become prevalent in adolescents. This study aimed to estimate the prevalence of metabolic syndrome and its components and to analyze the relationship between metabolic syndrome and overall physical fitness levels in a sample of Azorean adolescents.

Methods: A cross-sectional school-based study, the Azorean Physical Activity and Health Study II, was conducted on 517 adolescents (297 girls, 220 boys) aged 15–18 years old from the Azorean Islands. Body height, weight, waist circumference, and arterial blood pressure were measured according to standards. Fasting intravenous blood samples were analyzed (high-density lipoprotein cholesterol, triglycerides, and glucose). Physical fitness was assessed using five tests from Fitnessgram Test Battery 8.0: Curl-up, push-up, trunk lift, pacer, and sit-and-reach. Adolescents were then classified as being in the healthy zone or above or under the healthy zone. Metabolic syndrome was defined according to the 2007 International Diabetes Federation's guidelines for adolescents.

Results: The prevalence of metabolic syndrome was 5% (4.7% in girls and 5.5% in boys, $P > 0.05$). Waist circumference was the most prevalent component (32.9%), and hypertriglyceridemia the least (4.4%). Logistic regression analysis showed that after adjusting for pubertal stage and socioeconomic status, unfit adolescents (healthy zone criteria in $\leq$2 tests) were more likely [odds ratio (OR) = 3.414; 95% confidence interval (CI), 1.150–10.129] to be classified as having metabolic syndrome.

Conclusions: The prevalence of metabolic syndrome is high in Azorean adolescents. Unfit adolescents were more likely to have metabolic syndrome than fit adolescents. Improving overall physical fitness levels and abdominal obesity reduction may be important strategies in overcoming this public health problem and its consequences.

Introduction

Metabolic syndrome, defined as a series of risk factors that include atherogenic dyslipidemia, abdominal obesity, hypertension, insulin resistance, and prothrombotic and proinflammatory states, leads to increased risk of cardiovascular disease (CVD) and type 2 diabetes[1,2] and, therefore, represents a major health risk.[3,4] However, despite the abundant research on the subject, no universally accepted definition exists of the metabolic syndrome in children and adolescents; the criteria used have been adapted from adult standards in different ways. In 2007 the International Diabetes Federation (IDF) published a consensus statement on a definition of metabolic syndrome in children and adolescents. This definition was intended to provide a useful and unified tool for the early diagnosis of metabolic syndrome and to take preventive measures before the child or adolescent develops diabetes or CVD.[5]

Body fatness and a sedentary lifestyle, in the setting of a genetic predisposition, are considered the prime etiologic factors of metabolic syndrome.[3,6–8] Indeed obesity[9] and the lack of exercise[10,11] are two modifiable lifestyle factors that have been associated with the metabolic syndrome in adolescents.

The lack of physical fitness has also been associated with the development of CVD risk factors in youth, such as lipid

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disorders, high blood pressure, and insulin resistance, among others.[12] Likewise, some studies have shown that the level of physical fitness in adults is conditioned by the level of physical fitness in childhood or adolescence.[13,14] However, the majority of the studies reported the relationship between physical fitness and metabolic syndrome is confined to cardiorespiratory fitness,[15–17] and, to our knowledge, no studies have been conducted among Portuguese adolescents assessing other health-related fitness outcomes associated with metabolic syndrome. Until now, there have been no data available on Azorean adolescents and the prevalence of metabolic syndrome.

In this context, the aims of this study were to estimate the prevalence of metabolic syndrome using the 2007 IDF criteria and its components, and to analyze the relationship between metabolic syndrome and overall physical fitness levels in a sample of Azorean adolescents.

Subjects and Methods

Study design and sampling

Data for the present study derived from a longitudinal school-based study, the Azorean Physical Activity and Health Study II, aimed to evaluate physical activity, physical fitness, overweight/obesity prevalence, health-related quality of life, and related factors. The study was carried out in six of the nine Azorean Islands, where 95% of the population live[18]—S. Miguel, Terceira, Faial, Pico, S. Jorge, and Graciosa.

All participants in this study were informed about the objectives of the work, and the parent or guardian of each participant provided written informed consent. The study was approved by the faculty and the Portuguese Foundation for Science and Technology ethics committee and was conducted in accordance to the declaration of Helsinki for Human Studies of the World Medical Association.

The population was selected by means of a proportionate stratified random sampling, taking into account the location (island) and the number of students by age and sex in each school. The established number of subjects was 1,422, but the sample was oversized to prevent loss of information and because technically it was necessary to do the fieldwork in complete classrooms. Therefore, data were collected for 1,525 adolescents. Twenty-five subjects aged <14.5 or >18.4 and/or having a health condition that did not allow participating in physical education classes, or had missing information on the variables of interest, were excluded, resulting in a total of 1,500 participants (892 girls and 698 boys).

Baseline data were collected in the fall of 2008, and 850 subjects were reevaluated 1 year later (mean follow-up length 11.5 ± 2.0 months). Of the 850 adolescents that participated in the 2009 data collection, 36 were excluded due to lack of information on several variables, and 297 refused to undergo blood sampling measurement. Therefore, the final sample included in this study was comprised of 517 adolescents (297 girls and 220 boys) aged 15–18 years (mean age 16.5 ± 1.0) who were evaluated in the fall of 2009 and had complete data on the variables of interest. There were no differences in the variables of interest between subjects who underwent blood collection measurement and those who refused to do so (data not shown).

Subjects were evaluated during school physical education classes by physical education teachers specially trained for this data collection (anthropometric measures, physical fitness, and questionnaires). Blood sampling and blood pressure were measured by nurses in a local hospital.

Anthropometric measures

Body height was measured to the nearest millimeter in bare or stocking feet with the adolescent standing upright against a stadiometer (Holtain Ltd., Crymmych, Pembrokeshire, UK). Weight was measured to the nearest 0.10 kg, lightly dressed using a portable electronic weight scale (Tanita Inner Scan BC 532). Body mass index (BMI) was calculated from the ratio of body weight (kg) to body height (m^2). Adolescents were categorized as non-overweight, overweight, and obese, applying the cut-off points suggested by the International Obesity Task Force.[19]

Waist circumference measurement was taken in a standing position, to the nearest 0.1 cm, with a tape measure midway between the lower rib margin and the anterior superior iliac spine at the end of normal expiration.[20]

Blood pressure

Blood pressure (BP) was measured using the Dinamap adult/pediatric vital signs monitors, model BP 8800 (Critikon, Inc., Tampa, Florida). Measurements were taken by nurses, and all adolescents were required to sit and rest for at least 5 min prior to the BP test. Two measurements were taken, after 5 and 10 min of rest. The mean of these two measurements was considered. If the two measurements differed by 2 mmHg or more, a third measure was taken.

Blood sampling

The blood samples were collected from the antecubital vein between 8:00 and 10:00 a.m., in a sitting position after 10 h of fasting. The blood samples were drawn in vacuum tubes gel (Sarstedt) to obtain values of plasmatic high-density lipoprotein cholesterol (HDL-C), triglycerides (TG), and glucose. After resting at room temperature for about 30 min, the samples were centrifuged for 10 min at 3,000 rpm to obtain serum. Samples were divided into aliquots, separated within 30 min, and stored at $-80°C$ until analyzed. The following analyses were measured on a Cobas Integra 400 Plus, (Roche): HDL-C using the precipitation of the apolipoprotein B containing lipoproteins with dextran-magnesium chloride; TG using the glycerokinase-glycerolphosphateoxidase-peroxidase (GK-GPO-POD) method, and glucose using the hexokinase method. The biochemical evaluation of all participants from the different islands was conducted in the same laboratory.

Metabolic syndrome

Metabolic syndrome was defined using the adolescent 2007 IDF criteria.[5] According to this definition, a waist circumference above the 90th percentile for age and sex for adolescents aged <16 years old (or adult cutoff if 90th percentile is lower); and adult cutoff for adolescents aged ≥ 16 years old (≥ 80 cm for girls and ≥ 94 cm for boys) is a mandatory criterion. For adolescents aged <16 years old, we used the waist circumference percentiles (sex- and age-specific 90th percentiles) for British children,[21] as previously used in Portuguese adolescents.[22] In addition, the presence of two or more of the following components were also required:

TG $\geq$150 mg/dL; HDL-C <40 mg/dL for both genders, except for HDL-C <50 mg/dL for girls age $\geq$16 years; fasting glucose $\geq$100 mg/dL; and systolic blood pressure (SBP) $\geq$130 mmHg or diastolic blood pressure (DBP) $\geq$85 mmHg.

Pubertal stage

To determine the pubertal stage (ranging from stage 1 to 5), each subject was asked to self-assess his/her stage of secondary sex characteristics. Stages of breast development in girls and genital development in boys were evaluated according to the criteria of Tanner and Whitehouse.[23]

Socioeconomic status

The highest level of parental education (in completed years of education) was considered as a proxy of socioeconomic status. Similar procedures had previously been applied in the Portuguese context.[24]

Physical fitness

Health-related components of physical fitness were evaluated using the Fitnessgram Test Battery, version 8.0. The Fitnessgram is included in the physical education curriculum, and the five tests recommended in the Portuguese National Program (curl-up, push-up, trunk lift, pacer, and the modified back saver sit-and-reach) were used in this study. All tests were conducted according to the Fitnessgram measurement procedures.[25]

The pacer test was used to evaluate cardiorespiratory fitness. This test requires participants to run back and forth between two lines set 20 m apart. Running speed started at 8.5 km/h and increased by 0.5 km/h each minute, reaching 18.0 km/h at minute 20. Each level was announced on the tape. The participants were told to keep up with the pacer until exhausted. The test was finished when the participant failed to reach the end lines concurrent with the audio signals on two consecutive occasions. Otherwise, the test ended when the subject stopped because of fatigue. Participants were encouraged to keep running as long as possible throughout the course of the test. Numbers of shuttles performed were recorded.

The curl-up test was used to evaluate abdominal strength and endurance. Participants lie down with knees bent and feet unanchored. Set to a specified pace, adolescents complete as many repetitions as possible to a maximum of 75.

The push-up test was used to evaluate upper body strength and endurance. Participants lower the body to a 90-degree elbow angle and push up. Set to a specified pace, adolescents complete as many repetitions as possible.

The trunk lift test was used to evaluate trunk extensor strength. Participants lie face down and slowly raise their upper body long enough for the tester to measure the distance between the floor and the adolescent's chin, up to a maximum of 30 cm.

The modified back saver sit-and-reach test was used to evaluate the flexibility. Testing one leg at a time, adolescents sit with one knee bent and one leg straight against a box and reach forward. In this study we considered the better of the two results (right and left leg).

According to the results of each test, adolescents were then classified according to the age and sex-specific cut-off points of Fitnessgram criteria, as belonging to the healthy zone or above or under the healthy zone. Adolescents were then classified in three groups: "Fittest" if they had reached the healthy zone or above healthy zone in four or five tests, "fit" if they had reached the healthy zone or above healthy zone in three tests, and "unfit" if they had reached the healthy zone or above healthy zone in two or fewer tests.

Statistical analysis

Descriptive data are presented as means and standard deviation unless otherwise stated. All variables were checked for normality and appropriately transformed if necessary. The HDL-C, TG, SBP, and waist circumference were transformed logarithmically. Independent sample *t*-tests with Bonferroni corrections were performed to compare sexes in continuous variables, and the chi-squared test was used in categorical variables. Binary logistic regression was used to study the relationship between metabolic syndrome and overall physical fitness levels further, adjusting for pubertal stage and socioeconomic status. Data were analyzed with SPSS for Windows (version 17.0). A P value under 0.05 denoted statistical significance.

Results

Descriptive characteristics of the adolescents are shown in Table 1. Boys had higher levels of height, weight, waist circumference, SBP, and glucose than girls ($P < 0.05$ for all), whereas girls had higher values of HDL-C and TG ($P < 0.05$ for both). No differences in age, BMI, and DBP were observed between sexes.

The prevalence of metabolic syndrome and its components according to the 2007 IDF definition is presented in Table 2. The overall prevalence of metabolic syndrome was 5%, and there was no sex difference (girls 4.7%, boys 5.5%, $P > 0.05$). The large waist circumference (32.9%) was the most prevalent component of the metabolic syndrome criteria, followed by high blood pressure (20.1%), and hypertriglyceridemia was the least (4.4%). The prevalence of hyperglycemia, and high blood pressure in boys was significantly higher than in girls, whereas the prevalence of abdominal obesity was significantly higher in girls ($P < 0.001$ for all). The prevalence of metabolic syndrome rose with the increase of BMI: 1.4% in not overweight, 7.6% in overweight, and 34.3% in obese adolescents.

Adolescent's overall physical fitness levels showed that 26.3% were considered unfit. The results in Table 3 show that the prevalence of metabolic syndrome is higher among those under the healthy zone in the push-up and pacer tests ($P < 0.001$ for both).

Logistic regression analyses showed that unfit adolescents were more likely [odds ratio (OR) = 3.414; 95% confidence interval (CI), 1.150–10.129) to be classified as having metabolic syndrome when compared to the fittest ones, after adjusting for pubertal stage and socio-economic status (Table 4).

Discussion

To our knowledge, this is the first study to report the prevalence of metabolic syndrome and to analyze the relationship between metabolic syndrome and overall physical fitness levels in a sample of Azorean adolescents. In this

Table 1. Descriptive Characteristics of the Adolescents

Variables	*Total* (n = 517)	*Girls* (n = 297)	*Boys* (n = 220)
Age, years	16.5 ± 1.0	16.5 ± 1.0	16.5 ± 1.0
Height, cm	165 ± 12.8	160 ± 10.1	172 ± 12.6
Weight, kg	63.1 ± 12.5	58.6 ± 10.0	69.1 ± 12.9*
BMI, kg/m^2	22.9 ± 3.7	22.8 ± 3.6	23.1 ± 4.0
Waist circumference, cm	79.3 ± 10.7	78.3 ± 10.3	80.7 ± 11.1*
SBP, mm Hg	115.2 ± 15.0	111.8 ± 13.6	119.7 ± 15.7*
DBP, mm Hg	66.6 ± 9.5	66.7 ± 10.0	66.3 ± 8.8
HDL-C, mg/dL	55.5 ± 13.3	59.4 ± 12.9	50.3 ± 11.9*
Triglycerides, mg/dL	71.6 ± 37.9	74.5 ± 37.3	67.7 ± 38.4*
Glucose, mg/dL	86.8 ± 9.2	84.6 ± 8.7	89.7 ± 9.1*
BMI (%)			
Non-overweight	70.4%	71.0%	69.5%
Overweight	22.8%	23.2%	22.3%
Obesity	6.8%	5.7%	8.2%

Data are means ± SD, Student *t*-test, with Bonferroni corrections for differences between gender: *$p < 0.05$.
Abbreviations: BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; HDL-C, high-density lipoprotein cholesterol; SD, standard deviation.

study, the prevalence of metabolic syndrome was 5%. Within the metabolic syndrome components, abdominal obesity was the most prevalent and hypertriglyceridemia the least observed in our study. Unfit adolescents were more likely to have metabolic syndrome than fit adolescents.

Several studies have established the prevalence of metabolic syndrome during childhood and adolescence,[26–29] however, with different definitions of the syndrome. This fact limits the ability to compare prevalence rates across studies. The first national report of the metabolic syndrome in U.S. adolescents was published in 2003,[30] and it used a definition adapted from the National Cholesterol Education Program Adult Treatment Panel III (NCEP ATP III) adult criteria. The results of Cook's study indicate that the prevalence of the syndrome among adolescents from ages 12 to 19 was 4.2%. However, current estimates indicate that 2% to 9.4% of United States adolescents have metabolic syndrome.[31] In the developed countries, the overall prevalence of metabolic syndrome in healthy children and adolescents based on the same modified NCEP ATP III criteria is estimated to be between 2.0 and 11.5%.[27]

Table 2. Prevalence of Metabolic Syndrome and Its Components According to the International Diabetes Federation 2007 Criteria

	Girls (n = 297)	*Boys* (n = 220)	*Total* (n = 517)	p[a]
Components of metabolic syndrome				
Large waist circumference	46.8	14.1	32.9	<0.001
Hypertriglyceridemia	5.1	3.6	4.4	0.441
Low HDL-C	20.9	17.3	19.3	0.305
Hyperglycemia	3.7	13.6	7.9	<0.001
High blood pressure	15.2	26.8	20.1	<0.001
Metabolic syndrome	4.7	5.5	5	0.703
Metabolic syndrome within BMI categories				
Non-overweight	2.4	0	1.4	
Overweight	7.2	8.2	7.6	<0.001
Obesity	23.5	44.4	34.3	

Data are %.
[a]Chi-squared test.
Abbreviations: HDL-C, high-density lipoprotein cholesterol; BMI, body mass index.

The new IDF (2007) pediatric definition of the metabolic syndrome provides a standard that facilitates comparisons on the prevalence of metabolic syndrome across studies. The prevalence of metabolic syndrome in this study is slightly higher than the prevalence previously reported,[22,32–34] which used the same definition of the syndrome. In U.S. adolescents from age 12 to 17, the prevalence of metabolic syndrome was ∼4.5% and was relatively stable across the 6-year period: 4.5% for 1999–2000, 4.4%–4.5% for 2001–2002, and 3.7%–3.9% for 2003–2004.[32] The prevalence of metabolic syndrome in Korean adolescents was 2.6%[34] and in 16-year-old adolescents participating in the Northern Finish Birth Cohort examined between 2001 and 2002, the prevalence was 2.4%.[33] Metabolic syndrome was diagnosed in 0.2% of 10-year-old children and in 1.4% of 15-year-old children.[22] Recently Park et al. reported that the prevalence of metabolic syndrome in adolescents from the United States and Korea was 5.5% and 2.5%, respectively.[35] In this last study, the prevalence of metabolic syndrome in U.S. adolescents was slightly higher than our result (5.5% vs. 5%). The prevalence of metabolic syndrome reported in our study is slightly higher than studies mentioned above.

The most prevalent component of the metabolic syndrome in this study was increased waist circumference, followed by high blood pressure; hypertriglyceridemia was the least prevalent. The measure of abdominal obesity and the waist circumference have been consistently identified as better measures of cardiovascular risk than the BMI.[36,37] Data from Bogalusa Heart Study[38] demonstrated significant correlations between waist circumference and cardiovascular disease risk factor levels in children and adolescents. Waist circumference has been shown to be the best predictor of metabolic syndrome in children[39] and in different adult populations.[40] In this study, the prevalence of abdominal obesity in girls was higher than in boys, although the BMI was slightly higher in boys than girls. Similar results were

Table 3. Relationship Between Metabolic Syndrome and Physical Fitness

	No metabolic syndrome n (%)	*Metabolic syndrome* n (%)	P[a]
Best of sit-and-reach			0.63
Under healthy zone	26 (5.3)	0 (0)	
Healthy zone or above	465 (94.7)	26 (100)	
Curl-up			0.47
Under healthy zone	120 (24.4)	8 (30.8)	
Healthy zone or above	371 (75.6)	16 (69.2	
Push-up			0.001
Under healthy zone	195 (39.7)	19 (73.1)	
Healthy zone or above	296 (60.3)	7 (26.9)	
Pacer			<0.001
Under healthy zone	279 (56.8)	26 (100)	
Healthy zone or above	212 (43.2)	0 (0)	
Trunk lift			0.44
Under healthy zone	227 (46.2)	10 (38.5)	
Healthy zone or above	264 (56.8)	16 (61.5)	
Healthy zone or above in ≤2 or tests	125 (22.5)	11 (42.3)	0.58
Healthy zone or above in 3 tests	166 (33.8)	10 (38.5)	
Healthy zone or above in 4 or 5 tests	200 (40.7)	5 (19.2)	

[a]Chi-squared test.

reported by Park.[35] These differences can be explained by a gender-variable genetic predisposition to the accumulation of visceral fat. Indeed, the gonadarche occurs earlier in girls than boys, reflecting the earlier maturation of the hypothalamic–pituitary–gonadal axis, and waist circumference seems to reflect in girls the increasing fat content, whereas in boys it reflects the predominant lean tissue mass.[41] Moreover, BMI is a measure of excess weight rather than excess body fatness[42] and does not have the capacity to differentiate body fat and lean body mass, or even the distribution of fat. Nevertheless, these findings of an increased waist circumference suggest that Azorean adolescents may be at an increased risk of comorbidities associated with abdominal obesity, including type 2 diabetes.

The emergence of metabolic syndrome parallels the rising rates of overweight and obesity observed in youth worldwide.[43] Indeed, various studies have shown that the prevalence of the syndrome was higher when the subjects were obese.[44–47] Cruz et al. demonstrated that metabolic syndrome was present in 30% of the overweight and obese children.[29] These findings are in agreement with our study showing that metabolic syndrome in adolescents is largely confined to the overweight population and may represent a subgroup of youth who carry a larger risk for CVD and type 2 diabetes later in life.

Table 4. Logistic Regression Analyses Predicting the Metabolic Syndrome

	OR (95% CI)	P *value*
Fittest		
Healthy zone or above in ≥4 tests	1	
Fit[a]		
Healthy zone or above in 3 tests	2.293 (0.764–6.887)	0.139
Unfit[a]		
Healthy zone or above in ≤2 tests	3.414 (1.150–10.129)	0.027

[a]Adjusted for pubertal stage and socioeconomic status.

Abbreviations: OR, odds ratios; CI, confidence intervals; 1, reference category.

Fitness has been proposed as a major marker of health status at any age.[48] Our results showed a positive influence of overall physical fitness levels on metabolic syndrome. Fit adolescents had less prevalence of the syndrome than unfit adolescents, and low levels of overall fitness were a positive predictor of metabolic syndrome. Ruiz et al. have shown an inverse association between cardiorespiratory fitness and clustered metabolic risk factors in 9- to 10-year-old Swedish and Estonian children.[49] Reinforcing this idea, Ortega et al.[50] reported that children and adolescents with higher levels of cardiorespiratory fitness also have a more favorable cardiovascular profile compared with their unfit counterparts. Conversely, other studies have shown that high levels of cardiorespiratory fitness and physical activity are associated with a favorable metabolic risk profile.[51,52] On the other hand, evidence suggests that sedentary behavior and low levels of physical activity and cardiorespiratory fitness in youth track into adulthood,[53,54] and may predispose young people to disease later in life.[13] Nevertheless, future cardiovascular risk seems to be more conditioned by the physical fitness attained (especially strength and aerobic capacity) than by the level of physical activity undertaken.[55] Our study is in line with these investigations and extends previous findings by showing that overall fitness capacity and only cardiorespiratory fitness are negatively associated with the presence of the metabolic syndrome.

This study is limited because it consisted of a cross-sectional design, which limits inferences about causality and its direction, as well as the convenient sample. Balancing these limitations are the strengths of this study. This is the first study to estimate the prevalence of the metabolic syndrome in a sample of Azorean adolescents applying the new 2007 IDF pediatric definition. The use of field tests for fitness assessment, which can be administered in school settings while a large number of subjects can be tested simultaneously, enhances participant motivation, making it a valuable tool for studying physical fitness in youth.

Conclusions

The results of this study indicate that prevalence of metabolic syndrome in this sample of Azorean adolescents is slightly higher than other studies that used the same definition according to the newly released 2007 IDF definition. Unfit adolescents were more likely to have metabolic syndrome than fit adolescents. These data also showed that a low waist circumference would be potentially important in reducing the prevalence of metabolic syndrome. Therefore, improving overall physical fitness levels and waist circumference reduction may be important strategies to overcome this public health problem and its consequences.

Our results have important public health implications. Identification of the percentage of adolescents who had abdominal obesity and those who were unfit can help identify youths at increased risk of metabolic diseases and can emphasize the importance of promoting healthy lifestyle habits at these ages and maintaining these practices into and throughout adulthood.

Acknowledgments

This study was supported by FCT-MCTES Grant (BD/44422/2008) and by Azorean Government, Department of Sports.

Author Disclosure Statement

No competing financial interests exist.

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