Available at www.sciencedirect.com

Metabolism

www.metabolismjournal.com

Brief Reports

Metabolic syndrome in a Mediterranean pediatric cohort: prevalence using International Diabetes Federation–derived criteria and associations with adiponectin and leptin

*Constantina Papoutsakis**, *Mary Yannakoulia*, *Ioanna Ntalla*, *George V. Dedoussis*

Department of Nutrition and Dietetics, Harokopio University, Athens, Greece

ARTICLE INFO

Article history:
Received 10 January 2011
Accepted 8 June 2011

ABSTRACT

The aims of the study were to determine the prevalence of metabolic syndrome (MS) components and examine associations with adipokine concentrations in a healthy pediatric cohort. A cross-sectional study of 1138 children (53% girls; mean age of all participants, 11.2 ± 0.7 years) was performed. Anthropometric and medical information was obtained; and a fasting blood sample was used to measure glucose, insulin, high-density lipoprotein cholesterol, low-density lipoprotein cholesterol, triglycerides, leptin, and adiponectin serum concentrations. Insulin resistance was assessed by the insulin resistance homeostasis model assessment. Body weight status (normal, overweight, and obese) was determined according to the International Obesity Task Force. Estimation of the MS was based on the International Diabetes Federation definition. The prevalence of the MS was 0.7% of children, all of whom were obese. Frequency of abdominal obesity, high fasting glucose, elevated triglycerides, low high-density-lipoprotein cholesterol, and elevated blood pressure was 4.8%, 4.7%, 0, 12.3%, and 33%, respectively. Body mass index (BMI) and z-BMI score increased significantly as the number of cardiometabolic risk factors increased. Regression analysis revealed that adiponectin ($\beta = -0.501$, $P = .003$) and leptin ($\beta = 0.184$, $P < .0001$) independently predicted the number of MS features. This finding was no longer significant after adjustment for BMI. In the present study, we provide the first estimate of the prevalence of the MS among healthy periadolescents in Greece using the International Diabetes Federation criteria. The MS prevalence was low, with elevated blood pressure being the most dominant feature. Finally, associations with adipokines are mediated by BMI.

1. Introduction

In recent years, obesity in children has increased [1]; and it is an important risk factor for the development of the metabolic syndrome (MS) [2]. The MS is a cluster of aberrations, including insulin resistance (IR)—hyperinsulinemia, dyslipidemia—high triglycerides (TG) and low high-density lipoprotein cholesterol (HDL-C) serum concentrations; impaired glucose tolerance and/or type 2 diabetes mellitus (DM); and hypertension (HTN).

Despite the wide use of the MS, there have been criticisms against it [3]. It is argued that no actual underlying mechanism

Author contributions: The authors were solely responsible for researching, writing of the manuscript, and decision to submit for publication. CP designed the study, analyzed the data, wrote the first draft, and edited subsequent versions; MY edited the manuscript; IN conducted the laboratory analyses and analyzed the data; GVD designed the study, supervised, and edited the manuscript.

* *Corresponding author*. Tel.: +30 210 9549304; fax: +30 210 9577050.
E-mail address: tina.papoutsakis@hua.gr (C. Papoutsakis).

0026-0495/$ – see front matter © 2012 Elsevier Inc. All rights reserved.
doi:10.1016/j.metabol.2011.06.006

has been agreed, risk factors are dichotomized to a threshold level, and risk factors have a different predictive value depending on the definition used [3]. Nevertheless, the MS provides a conceptual framework for the clustering of cardiometabolic risk factors and facilitates consistent international comparisons among populations when using a unified definition [3]. Importantly, the MS has been associated with a higher rate of future cardiovascular disease (CVD) and all-cause mortality [4,5].

A variety of molecules acts as mediators in obesity-driven IR, such as the adipokines leptin and adiponectin, which exert actions beyond adipose tissue itself. Leptin is involved in the regulation of food intake and basal metabolism and may be associated with IR and DM [6]. Adiponectin is also involved in the regulation of energy homeostasis, glucose, and lipid metabolism but, unlike most other adipokines, exerts beneficial actions against the development of obesity, IR, type 2 DM, and CVD [7]. Lower blood adiponectin has been linked to the development of the MS [8]. Because adipokine changes may precede lipid changes in children [9], the possibility that adipokines play a leading role in the clustering of cardiometabolic risk factors warrants further investigation. The present study describes the prevalence of MS components and examines associations with adipokine concentrations in a pediatric cohort.

2. Subjects and methods

The Gene-Diet in Attica Investigation (GENDAI) included students from Attica, Greece. The methods have been published elsewhere [10]. Parents signed an informed consent form, whereas children provided their verbal assent. A total of 1138 children participated (53% girls; mean age of participants, 11.2 ± 0.7 years; range, 9.8-13.8 years). The first and fourth Korotkoff sounds were recorded as systolic (SBP) and diastolic arterial blood pressure (DBP). Participants were evaluated according to pubertal stages (Tanner stage I = prepuberty, stages II-IV = puberty, and V = postpuberty). Physical measurements of body weight and height were used to calculate body mass index (BMI) (BMI = weight [kilograms] divided by height [square meters]). Body mass index was used for subjects' classification as normal weight, overweight, or obese [11]. Furthermore, BMI was standardized (z-BMI) [12]. Waist circumference (WC) (centimeters) was used to describe central obesity.

From a fasting blood sample, serum glucose, total cholesterol, HDL-C, TG, low-density lipoprotein cholesterol (LDL-C), insulin, leptin, and adiponectin concentrations were determined [10]. The intra- and interassay coefficients of variation for the determination of all biochemical variables did not exceed 5%, with the exception of insulin and leptin, for which they did not exceed 10%. Insulin resistance was estimated using the homeostasis model assessment (HOMA-IR) [13].

Features of the MS were explored according to the International Diabetes Federation (IDF) [14]. The IDF requires the presence of central obesity (WC ≥90th percentile for age and sex, using the 1999-2002 pediatric reference values [15]) plus any 2 other factors present: fasting glucose of at least 100 mg/dL, SBP of at least 130 mm Hg or DBP of at least 85 mm Hg, TG of at least 150 mg/dL, and HDL-C concentrations less than 40 mg/dL.

Continuous variables are shown as mean ± standard deviation, whereas categorical variables are shown as frequencies or proportions (percentage). Associations between categorical variables were tested by χ^2. Comparisons between continuous variables and groups were performed by analysis of covariance, adjusting for age, sex, and Tanner stage. Pearson correlation coefficients identified correlations between continuous variables. Multiple regression analyses examined relationships between increasing number of MS components and adipokines after adjusting for potential confounders, namely, age, sex, and pubertal status. Reported *P* values are based on 2-sided tests, and statistical significance was set at $P < .05$. Statistical analyses were performed using SPSS 17.0 for Windows (SPSS, Chicago, IL).

3. Results

3.1. *Frequency of MS components*

A total of 28.9% of participants were overweight, and 9.1% were obese. Descriptive characteristics by BMI status appear in Table 1. Distribution of each MS component for the total sample and by participant characteristics (Table 2) indicates that 4.8% (n = 54) had abdominal obesity, among which 8 (0.7%) (4 boys and 4 girls) qualified for the MS. All of these children were obese. The prevalence of the MS among obese participants was 7.7%. Elevated BP and low HDL-C were the most frequently encountered (33% and 12.3%, respectively), and no child had elevated TG concentrations. Abdominal obesity was higher in boys compared with girls, whereas the opposite was observed for low HDL-C concentrations. Higher BMI status was associated with higher prevalence of abdominal obesity, lower HDL-C, and elevated BP (Table 2). As the number of cardiometabolic risk factors increased, there were an increase in mean BMI, z-BMI, HOMA-IR, and leptin and a decrease in adiponectin concentrations (Supplemental Table 1). Frequency data on the number of MS criteria indicated that 56.3% were free of risk factors, 34.7% satisfied at least 1 criterion, 8.1% satisfied 2 criteria, and 0.9% satisfied any 3. There was a trend ($P_{trend} < .0001$) for overweight and obese children to have a greater number of MS criteria compared with normal-weight children (28.1% with no criteria were overweight/obese, 40.5% with 1 criterion were overweight/obese, 72.9% with 2 criteria were overweight/obese, and 100% with 3 MS criteria were overweight/obese) (Supplemental Figure 1).

3.2. *Associations between metabolic markers*

There were significant correlations between BMI, WC, SBP, DBP, HDL-C, TG, glucose, insulin, HOMA-IR, adiponectin, and leptin (Supplemental Table 2). There were highly significant correlations between insulin and all of the MS components and adiponectin and leptin. Higher BMI status was associated with higher WC, SBP, DBP, TG, insulin, HOMA-IR, and leptin, and significantly lower HDL-C and adiponectin

Table 1 – Clinical and metabolic characteristics of GENDAI participants

	All participants (n = 1128)	Normal weight (n = 698)	Overweight (n = 327)	Obese (n = 103)	P
Age, y	11.2 ± 0.66	11.2 ± 0.02	11.1 ± 0.04	11.0 ± 0.06	.080
Sex, n (%)					
Male	528 (46.8)	306 (43.8)	170 (52.0)	52 (50.5)	.220
Female	600 (53.2)	392 (56.2)	157 (48.0)	51 (49.5)	
Birth weight, g	3,269 ± 537	3,240 ± 538	3,317 ± 532	3,316 ± 531	.096
BMI, kg/m^2	20.0 ± 3.4	17.9 ± 1.6	22.6 ± 1.4	27.3 ± 1.5	<.0001 [a,b]
z-BMI		0.62 ± 0.46	0.68 ± 0.39	2.12 ± 0.59	<.0001 [a,b]
WC, cm	68.8 ± 9.6	63.5 ± 5.5	75.1 ± 6.3	86.2 ± 6.7	<.0001 [a,b]
z-WC		0.55 ± 0.56	0.61 ± 0.67	1.85 ± 0.76	<.0001 [a,b]
SBP, mm Hg	120 ± 14	118 ± 14	123 ± 12	129 ± 12	<.0001 [a,b]
z-SBP		-1.65 ± 0.99	0.19 ± 0.91	0.62 ± 0.96	<.0001 [a,b]
DBP, mm Hg	75 ± 11	74 ± 11	77 ± 11	79 ± 10	<.0001 [a,c]
z-DBP		-1.52 ± 0.95	0.20 ± 1.02	0.43 ± 1.1	<.0001 [a,b]
LDL-C, mg/dL	121 ± 23	120 ± 23	122 ± 23	125 ± 23	.212 [a]
z-LDL-C		-0.039 ± 1.00	0.46 ± 0.96	0.19 ± 1.0	.210 [a]
HDL-C, mg/dL	52 ± 10	54 ± 10	50 ± 10	47 ± 10	<.0001 [a,d]
z-HDL-C		0.17 ± 1.00	-0.20 ± 0.94	-0.55 ± 0.87	<.0001 [a,b]
TG, mg/dL	63 ± 22	59 ± 18	69 ± 24	81 ± 27	<.0001 [a,b]
z-TG		-0.23 ± 0.75	0.28 ± 1.18	0.79 ± 1.24	<.0001 [a,b]
Glucose, mg/dL	86 ± 9	86 ± 9	86 ± 8	85 ± 9	.398 [a]
z-Glucose		0.017 ± 1.13	-0.011 ± 0.74	-0.04 ± 0.79	.527
Insulin, μU/mL	7.7 ± 4.1	6.55 ± 3.42	8.89 ± 4.36	11.78 ± 4.86	<.0001 [a,b]
z-Insulin		-0.21 ± 0.80	0.26 ± 1.26	0.66 ± 0.87	<.0001 [a,b]
HOMA-IR	1.67 ± 1.00	1.43 ± 0.843	1.92 ± 1.03	2.53 ± 1.13	<.0001 [a,b]
z-HOMA-IR		-1.72 ± 0.87	0.22 ± 1.22	0.53 ± 0.77	<.0001 [a,b]
Adiponectin, μg/mL	4.5 ± 2.3	4.8 ± 2.4	4.2 ± 1.9	3.7 ± 1.7	.001 [a,e]
z-Adiponectin		0.119 ± 1.11	-0.18 ± 0.69	-0.27 ± 0.87	<.0001 [a,b]
Leptin, ng/mL	6.8 ± 6.2	4.5 ± 4.1	9.7 ± 6.0	15.3 ± 8.9	<.0001 [a,b]
z-Leptin		-0.32 ± 0.71	0.30 ± 0.87	1.31 ± 1.58	<.0001 [a,b]
Pubertal status, n (%) [f]					
Pre	90 (8.1)	60 (8.7)	18 (5.6)	12 (11.9)	.024
Pubertal (Tanner 2)	1,009 (90.5)	622 (90.0)	300 (92.9)	87 (86.2)	
Post	16 (1.4)	9 (1.3)	5 (1.5)	2 (2.0)	

Data are mean ± standard deviation or frequencies and proportions (percentage).
[a] Adjusted for age and sex.
[b] Pairwise comparisons were significantly different ($P < .0001$) as assessed by Bonferroni.
[c] Except in the pairwise comparison between overweight and obese ($P = .565$) children, the remainder of pairwise comparisons were significantly different ($P < .0001$) as assessed by Bonferroni.
[d] Pairwise comparisons were significantly different (overweight vs obese, $P = .016$); the remainder of pairwise comparisons were also significantly different ($P < .0001$) as assessed by Bonferroni.
[e] Except in the pairwise comparison between overweight and obese children ($P = .623$), the remainder of pairwise comparisons were significantly different (normal vs obese, $P = .002$, normal vs overweight $P = .021$) as assessed by Bonferroni.
[f] Pubertal status was available for 1115 participants.

concentrations. The strongest correlations were for BMI and WC ($r = 0.872$, $P < .0001$) and BMI and leptin ($r = 0.593$, $P < .0001$). Multiple linear regression analysis was performed to examine the relationship of number of MS features satisfied (dependent variable) to adiponectin and leptin (independent variables). Adiponectin and leptin were independently associated with increasing number of MS features, even after adjustment for age, sex, and pubertal status ($\beta = -0.501$, $P = .003$ for adiponectin and $\beta = 0.184$, $P < .0001$ for leptin). Further adjustment for BMI rendered the associations nonsignificant.

4. Discussion

We describe a low prevalence of the MS in a healthy pediatric sample from Greece. Furthermore, this is the first report on associations between adipokines and features of the MS in Greek youth.

Childhood obesity rates in Greece are among the highest, with approximately 27% overweight and 11% to 12% obese children [1]. A total of 0.7% of GENDAI participants or 7.7% of obese children fulfilled the MS definition [14]. In Turkey [16], a rather low prevalence of MS as defined by IDF was reported (2.3%). In contrast, Aldaghri [17] estimated that 9.4% of Saudi Arabian children satisfied the National Cholesterol Education Program (NCEP) definition of the MS [17]. International estimates of the MS have ranged from 0% to 59% [2,18-20]. Besides the difference in ethnicity, different sets of criteria have been used. To provide a comparison, we additionally applied age-modified standards of the NCEP-defined MS [21] (data not shown) and found again a low MS percent (1.6%) (all were overweight or obese, except

Table 2 – Prevalence of each component of the MS by demographic characteristics

	Abdominal obesity		High glucose concentration		High TG concentration		Low HDL-C concentration		Elevated BP	
	n	%	n	%	n	%	n	%	n	%
Total	54	4.8	52	4.7	0	0	135	12.3	366	33.0
Sex										
Male	39	7.5*	30	5.8	0	0	50	9.9†	175	33.7
Female	15	2.5	22	3.8	0	0	85	14.5	191	32.3
BMI status										
Normal weight	0	0	32	4.7	0	0	53	7.8	189	27.6
Overweight	5	1.5	15	4.7	0	0	52	16.5	122	38.0*
Obese	42	43.3*	5	5.2	0	0	28	29.2*	55	55.0*
Pubertal status, n (%)[a]										
Prepubertal (Tanner 1)	8	8.7	5	5.6	0	0	7	7.8	27	29.0
Pubertal (Tanner 2-4)	42	4.2	46	4.7	0	0	124	12.7	331	33.3
Postpubertal (Tanner 5)	1	6.3	1	6.7	0	0	2	12.5	5	33.3

Data are frequencies and proportions (percentage).
* Significant difference ($P < .0001$).
† Significant difference ($P = .021$).
[a] Pubertal status was available for 1115 participants.

for one normal-weight child). The value of 1.6% is more than double the prevalence estimated by IDF (0.7%). This is not unexpected because the IDF requires abdominal obesity plus any 2 other criteria, whereas the NCEP definition treats all criteria equally and qualifies a participant as having the MS whenever any 3 of the 5 criteria are met.

Children with an increasing number of cardiometabolic risk factors had a significantly higher BMI and z-BMI. In normal-weight children, 419 (or 63.8%) did not satisfy any criteria, 215 (or 32.7%) satisfied 1 criterion, and 23 (or 3.5%) met 2 criteria. In similar studies [22,23] and in GENDAI, the percentage of normal-weight children with 2 criteria falls sharply compared with the percentage of children meeting 1 criterion. Normal weight seems to be a potent protective attribute against the development of multiple cardiovascular risk factors even in young ages.

Elevated BP (33%) and low HDL-C (12.3%) were the 2 most frequent MS criteria (Table 2). Low HDL-C, as observed in the present sample, is often cited among the most frequent cardiometabolic risk factors [17,18,20]. The common etiological basis leading to lower HDL-C in youth should be explored. The high prevalence of elevated BP, around one third of the study population, was similar to young Europeans (33%-38%) [18], but noticeably higher than in the United States (3.5%) [20]. Obesity is one of the main causes of pediatric HTN [24]. The increased obesity in GENDAI [10] could be responsible for the high prevalence of elevated BP. Ninety-three percent of subjects with elevated BP were overweight or obese. In contrast, no hypertriglyceridemia was identified, compared with 10% to 33% in other cohorts [17,20]. Variation in hypertriglyceridemia is wide. There are specific ethnicities, such as non-Hispanic blacks who are at higher risk for CVD and type 2 DM but satisfy less frequently the MS definition specifically because of a low frequency of hypertriglyceridemia [25]. About 5% of GENDAI participants had a high fasting glucose in comparison to 10% to 19% reported by others [18,20]. These differences in each cardiometabolic risk factor may be due to ethnicity. Ethnic-specific tools are needed to better predict risk for type 2 DM and CVD.

Fasting glucose concentrations were not associated with WC. Hyperglycemia may occur later, when the function of the pancreas is challenged because of its ongoing efforts to maintain normal glucose levels via increased insulin production. Here, IR was assessed via HOMA-IR; and we show that IR significantly correlated with increasing BMI, WC, TG, LDL-C, and SBP as others have [2]. It is likely that early IR adversely influences cardiometabolic variables and is a link to future disease.

The number of MS features was independently related, negatively to adiponectin and positively to leptin, even when we accounted for possible confounding factors such as age, sex, and puberty status. Adjustment for BMI resulted in nonsignificant associations. Our findings agree with a study on Korean prepubertal children [26] that exhibited the mediating role of adiponectin on the effect of obesity on MS development, while taking into account pubertal status. This similarity in 2 ethnically diverse cohorts is reassuring because it has been suggested that associations between MS and adipokines during periadolescence may be confounded by

pubertal changes. The association with adiponectin has clinical implications because lifestyle modification increases circulating adiponectin [27]. It is not unexpected that associations with adipokines are mediated by BMI [26]. A question remains about the role of central obesity. Adiponectin was inversely related with central obesity and HOMA-IR, and the opposite was true for leptin. This supports that adipokines are implicated early in the IR process driven by central obesity.

In this study, unaccounted confounding factors may exist and no causal inference can be assumed because of the cross-sectional design. As there are no international standards for pediatric central obesity and there are no Greek validated standards, the use of reference data from the 1999-2002 National Health and Nutrition Examination Survey cannot exclude the possibility of bias.

In summary, we report a low percentage of the MS in Greek youth. Leptin and adiponectin predict an increasing number of MS features, yet this relationship is dependent upon BMI. Given some of our surprising results, including an increased percentage with higher BP but no hypertriglyceridemia, it is important to follow pediatric cohorts prospectively to monitor HTN and DM. Finally, there is a need for ethnic-specific reference ranges for cardiometabolic risk factors.

Supplementary materials related to this article can be found online at doi:10.1016/j.metabol.2011.06.006.

Funding

The study was supported financially by Coca-Cola Hellas.

Acknowledgment

We thank our participants and field investigators for their contributions, and Camela Rising, MS, RD, for editing.

Conflict of Interest

The authors have no financial or other conflict of interest related to this manuscript.

REFERENCES

[1] Tambalis KD, Panagiotakos DB, Kavouras SA, et al. Eleven-year prevalence trends of obesity in Greek children: first evidence that prevalence of obesity is leveling off. Obesity (Silver Spring) 2010;18:161-6.
[2] Weiss R, Dziura J, Burgert TS, et al. Obesity and the metabolic syndrome in children and adolescents. N Engl J Med 2004;350:2362-74.
[3] Simmons RK, Alberti KG, Gale EA, et al. The metabolic syndrome: useful concept or clinical tool? Report of a WHO Expert Consultation. Diabetologia 2010;53:600-5.
[4] Ford ES. Risks for all-cause mortality, cardiovascular disease, and diabetes associated with the metabolic syndrome. Diabetes Care 2005;28:1769-78.
[5] Morrison JA, Friedman LA, Gray-McGuire C. Metabolic syndrome in childhood predicts adult cardiovascular disease 25 years later: the Princeton Lipid Research Clinics Follow-up Study. Pediatrics 2007;120:340-5.
[6] Girard J. Is leptin the link between obesity and insulin resistance? Diabetes Metab 1997;23(Suppl 3):16-24.
[7] Hara K, Yamauchi T, Kadowaki T. Adiponectin: an adipokine linking adipocytes and type 2 diabetes in humans. Curr Diab Rep 2005;5:136-40.
[8] Winer JC, Zern TL, Taksali SE, et al. Adiponectin in childhood and adolescent obesity and its association with inflammatory markers and components of the metabolic syndrome. J Clin Endocrinol Metab 2006;91:4415-23.
[9] Cianflone K, Lu H, Smith J, et al. Adiponectin, acylation stimulating protein and complement C3 are altered in obesity in very young children. Clin Endocrinol (Oxf) 2005;62:567-72.
[10] Papoutsakis C, Vidra NV, Hatzopoulou I, et al. The Gene-Diet Attica Investigation on childhood obesity (GENDAI): overview of the study design. Clin Chem Lab Med 2007;45:309-15.
[11] Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: international survey. BMJ 2000;320:1240-3.
[12] Kuczmarski RJ, Ogden CL, Grummer-Strawn LM. CDC growth charts: United States. Advance data from vital and health statistics no. 314. Hyattsville, Maryland: National Center for Health Statistics; 2000.
[13] Matthews DR, Hosker JP, Rudenski AS, et al. Homeostasis model assessment: insulin resistance and beta-cell function from fasting plasma glucose and insulin concentrations in man. Diabetologia 1985;28:412-9.
[14] Zimmet P, Alberti KG, Kaufman F, et al. The metabolic syndrome in children and adolescents—an IDF consensus report. Pediatr Diabetes 2007;8:299-306.
[15] McDowell MA, Fryar CD, Hirsch R, Ogden CL. Anthropometric reference data for children and adults: US population, 1999-2002. Advance Data No 361. http://www.cdc.gov/nchs/data/ad/ad361.pdf. 2005; accessed December 10, 2010.
[16] Cizmecioglu FM, Etiler N, Ergen A, et al. Association of adiponectin, resistin and high sensitive CRP level with the metabolic syndrome in childhood and adolescence. Exp Clin Endocrinol Diabetes 2009;117:622-7.
[17] Al-Daghri NM. Extremely high prevalence of metabolic syndrome manifestations among Arab youth: a call for early intervention. Eur J Clin Invest 2010;40:1063-6.
[18] Linardakis M, Bertsias G, Sarri K, et al. Metabolic syndrome in children and adolescents in Crete, Greece, and association with diet quality and physical fitness. J Public Health 2008;16:421-8.
[19] Johnson WD, Kroon JJ, Greenway FL, et al. Prevalence of risk factors for metabolic syndrome in adolescents: National Health and Nutrition Examination Survey (NHANES), 2001-2006. Arch Pediatr Adolesc Med 2009;163:371-7.
[20] Ford ES, Li C, Zhao G, et al. Prevalence of the metabolic syndrome among U.S. adolescents using the definition from the International Diabetes Federation. Diabetes Care 2008;31:587-9.
[21] Pan Y, Pratt CA. Metabolic syndrome and its association with diet and physical activity in US adolescents. J Am Diet Assoc 2008;108:276-86.
[22] Hirschler V, Oestreicher K, Maccallini G, et al. Relationship between obesity and metabolic syndrome among Argentinean elementary school children. Clin Biochem 2010;43:435-41.

[23] Kranz S, Mahood L, Wagstaff D. Diagnostic criteria patterns of U.S. children with metabolic syndrome: NHANES 1999-2002. Nutr J 2007;6:38.
[24] Paradis G, Lambert M, O'Loughlin J, et al. Blood pressure and adiposity in children and adolescents. Circulation 2004;110: 1832-8.
[25] Deboer MD. Underdiagnosis of metabolic syndrome in non-Hispanic black adolescents: a call for ethnic-specific criteria. Curr Cardiovasc Risk Rep 2010;4:302-10.
[26] Choi KM, Yannakoulia M, Park MS, et al. Serum adipocyte fatty acid-binding protein, retinol-binding protein 4, and adiponectin concentrations in relation to the development of the metabolic syndrome in Korean boys: a 3-y prospective cohort study. Am J Clin Nutr 2011;93:19-26.
[27] Kim SM, Cho GJ, Yannakoulia M, et al. Lifestyle modification increases circulating adiponectin concentrations but does not change vaspin concentrations. Metabolism 2011;60: 1294-9.