Components of the metabolic syndrome among a sample of overweight and obese Costa Rican schoolchildren

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Abstract

Background. *The term "pediatric metabolic syndrome" includes a cluster of cardiovascular risk factors such as insulin resistance, dyslipidemia (including increased triglycerides and decreased HDL cholesterol), hypertension, and obesity in children. No studies have been performed on this syndrome in a pediatric population in Costa Rica.*

Objective. *To establish the prevalence of metabolic syndrome and its components in 8- to 10-year old prepuberal overweight and obese schoolchildren.*

Methods. *This cross-sectional survey was conducted in 214 overweight and obese boys and girls, aged 8 to 10 years, who were selected from six urban schools from San José, Costa Rica. Anthropometric measurements and determinations of blood glucose, insulin, triglycerides, total cholesterol, HDL cholesterol, and high-sensitivity C-reactive protein (hs-CRP) were performed. The homeostasis model assessment of insulin resistance (HOMA-IR) index and the Castelli index were calculated to assess insulin resistance and cardiovascular risk, respectively. Social and lifestyle variables were obtained through validated questionnaires.*

Results. *A total of 110 boys and 104 girls participated in this study; 37.9% of them were overweight and 62.1% were obese. Compared with boys, girls were more sedentary and had higher insulin levels (16.05 ± 10.45 μIU/mL vs. 12.72 ± 7.63 μIU/mL,* p = *.008), body fat (36.5% vs. 30.9%,* p < *.001), and HOMA-IR indexes (3.5 ± 2.4 vs. 2.8 ± 1.7,* p = *.014) but lower HDL cholesterol (0.99 ± 0.23 mmol/L vs. 1.08 ± 0.27 mmol/L,* p = *.009). Obese children had significantly higher mean serum concentrations of insulin, hs-CRP, and triglycerides and higher insulin resistance (estimated by HOMA-IR) than overweight children, but lower mean serum levels of HDL cholesterol. The prevalence of metabolic syndrome in the study population was 5.6%. Other risk factors for developing cardiovascular disease and type 2 diabetes had high prevalence rates among the children: sedentarism (40.6%), family history of type 2 diabetes (73.3%), high LDL cholesterol levels (≥ 2.84 mmol/L) (57.0%), hyperinsulinemia (> 10.5 μIU/mL) (59.8%), insulin resistance (estimated by HOMA-IR ≥ 2.4) (55.1%), and total cholesterol (> 4.39 mmol/L) (60.7%). Children with metabolic syndrome had significantly higher body mass indexes, glucose levels, and triglyceride levels and lower HDL cholesterol levels than children without metabolic syndrome. Insulin had a very strong positive correlation with HOMA-IR values (*r = *0.982), and hs-CRP had a mild positive correlation with body mass index (*r = *0.296) and body fat (*r = *0.320).*

Conclusions. *This study reported a prevalence of 5.6% of metabolic syndrome among a sample of Costa Rican overweight and obese prepuberal children. Lifestyle interventions focusing on weight reduction and increasing physical activities should be promoted by education and health authorities in order to avoid the early development and onset of type 2 diabetes and atherosclerosis in childhood.*

Key words: Cardiovascular risk, children, dyslipidemia, insulin resistance, metabolic syndrome, overweight/obesity, syndrome X

Introduction

The "metabolic syndrome" is a term that is used to cluster a number of cardiovascular risk factors such as insulin resistance, dyslipidemia (including increased

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triglycerides and decreased high-density lipoprotein [HDL] cholesterol), hypertension, and obesity [1–4]. Originally, this condition was defined in adults, but in the last decade the term has also been applied to children and adolescents [5, 6]. There is no standard pediatric definition of metabolic syndrome that is accepted by the scientific community at this time, since it has not been well characterized in children in terms of diagnostic criteria [7]. Therefore, there is little information on the epidemiology of metabolic syndrome in the pediatric age group [7].

However, it is well known that obesity plays a key role in metabolic syndrome, since this condition leads to insulin resistance and cardiovascular disease [8, 9]. The World Health Organization (WHO) has described obesity as the world epidemic of the twentieth century in all age groups [10–14], and it is considered the sixth most important risk factor contributing to the overall burden of disease worldwide [15]. In the United States in the past 25 years, the frequency of obesity has increased by 3.8 times in children aged 6 to 11 years (from 4% to 15.3%) and by 2.6 times in the population aged 12 to 19 years (from 6.0% to 15.5%) [13]. In Costa Rica, according to the Institute for Research and Education on Nutrition and Health (INCIENSA), overweight and obesity are highly prevalent among schoolchildren (34.5% and 26.2% respectively)[16]. Likewise, in the past 2 or 3 years the Children's National Hospital has reported an increasing number of cases of insulin resistance in preadolescent boys and girls [17]. However, no studies have been performed yet in Costa Rica to study the metabolic syndrome in the pediatric population.

The purpose of this study was to determine the frequency of metabolic syndrome and its components among a sample of overweight and obese prepuberal boys and girls 8 to 10 years old.

Materials and methods

Study population

A total of 214 Hispanic male and female children aged 8 to 10 years attending public and private schools in the city of San José were recruited for this study in 2003. The sample size was determined with a confidence level of 95% and a sampling error of 5%. Selected overweight and obese prepuberal boys and girls from six urban schools were invited to participate in this investigation after being given a motivational speech and a written circular to be taken home. The schools were selected with probability proportional to size from a list of urban schools in the study area. The inclusion criteria included nationality, age, and a body mass index (BMI) equal to or greater than the 85th percentile for age and sex according to WHO guidelines. Prepuberal state (Tanner stage 1) generally refers to boys and girls 10 years old and under. The mean age of appearance of Tanner stage 2, as described in the literature [18] and according to the experience of the Children's National Hospital of Costa Rica, is 12 years in girls and 13.5 years in boys. A total of 420 children agreed to participate in the study, but only 214 of them fulfilled all the inclusion criteria.

Ethical procedures

Written informed consent was obtained from the parents of the participants, and oral consent was required from each child. All procedures followed were approved in accordance with the guidelines of the bioethics committees of the University of Costa Rica and the Costa Rican Institute for Research and Education on Nutrition and Health (INCIENSA).

Sociodemographic and anthropometric variables

Information about the child's age, sex, and family history of type 2 diabetes was collected by a validated instrument offered to the parents. Another questionnaire designed for the children and administered by four trained interviewers assessed the children's physical activities at school, at home, and during leisure time. Scores ranged from 0 to 48, and those children who scored 30 or less were considered sedentary.

Weight was measured without the subjects wearing shoes or heavy outer clothing. Height was measured with the children not wearing shoes and facing away from the stadiometer. Standing height was measured to the nearest 0.1 cm and weight to the nearest 0.1 kg. To assess nutritional status, BMI was calculated as the weight in kilograms divided by the square of the height in meters. Children with BMI at or above the 85th percentile for age and sex were considered overweight, and those with BMI at or above the 95th percentile for age and sex were considered obese. BMI data for US children according to age and sex were used as cutoff values for the Costa Rican children, as recommended by the WHO Expert Committee [19]. A leg-to-leg bioimpedance portable device (model TBF-401, Tanita Corporation) was used to determine percentage of body fat. The children were asked to wear light clothing, empty their bladders, remove all metallic objects (rings, necklaces, earrings, and coins), and stand barefoot on the machine. Data on sex and height were entered manually into the system via a keyboard. Body fat was estimated by using the standard built-in prediction equations for children and printed out.

Biochemical variables

Blood was drawn after a 12- to 14-hour fast by

antecubital venipuncture according to Clinical and Laboratory Standards Institute (CLSI) procedures [20] and collected into plain Vacutainer tubes (Becton-Dickinson). Serum was obtained by centrifugation at 6,000 rpm for 5 minutes at 25°C, and removal from the red cell pack was performed within 30 minutes after venipuncture. The samples were stored at –20°C until biochemical tests were performed. Insulin was determined by immunoassay methods in a fully automated IM_X System (Abbott Laboratories, Diagnostics Division Dainabot) with an intra-assay variation of 8%. High-sensitivity C-reactive protein (hs-CRP) was quantified by an enzyme immunoassay test (Diagnostic Automation, Immunodiagnostics Division). Total serum cholesterol, HDL cholesterol, triglycerides, and glucose were determined by enzymatic colorimetric reactions using an Hitachi automated analyzer, model 911 (Roche). The intra-assay coefficients of variation of the assays were 1.8% for total cholesterol, 3.7% for HDL cholesterol, 2.1% for triglycerides, and 1.7% for glucose. Low-density lipoprotein (LDL) cholesterol was calculated by the equation of Friedewald et al. [21]. The Castelli index was determined by dividing the total cholesterol level by the HDL cholesterol level and was defined as indicating a risk of cardiovascular disease when it was over 4.5 [22]. Serum levels of total cholesterol greater than 4.39 mmol/L and of LDL cholesterol greater than or equal to 2.84 mmol/L were considered as risk factors according to the National Cholesterol Education Program Guidelines [23]. A level of hs-CRP above 8.2 mg/L was considered high [22], and fasting hyperinsulinemia in prepuberal children was defined as a serum insulin level greater than 10.5 μIU/mL [7].

Insulin resistance was established by the homeostasis model assessment of insulin resistance (HOMA-IR): [fasting insulin (mIU/L) × fasting glucose (mmol/L)]/22.5. Prepuberal participants were classified as having insulin resistance when HOMA-IR was equal to or greater than 2.4 [7]. Metabolic syndrome was diagnosed in accordance with the criteria proposed by Tapia-Ceballos [10]: high triglyceride levels (≥ 1.24 mmol/L), low HDL cholesterol (< 1.03 mmol/L), and high fasting glucose (≥ 5.55 mmol/L).

Data analysis

Statistical analysis was performed with SPSS, version 10.0 for Windows. Student's *t*-test was used for the analysis of normally distributed data and the Mann-Whitney *U*-test for skewed data. Continuous variables are expressed as means ± SD and categorical variables as frequencies. A value of $p < .05$ was considered to indicate statistical significance. Nonparametric Spearman's correlation coefficients were calculated for biochemical and anthropometric variables.

Results

The mean age of the 110 boys and 104 girls who participated in the study was 9.14 ± 0.80 years; 37.9% were overweight and 62.1% were obese, with no significant differences in the percentages of overweight and obesity between boys and girls. **Table 1** shows the sociodemographic, anthropometric, and biochemical characteristics of the study population. Overall, boys and girls had a similar prevalence of family history of type 2 diabetes and similar mean values of glucose, hs-CRP, triglycerides, total cholesterol, LDL cholesterol, and Castelli index. More girls than boys were sedentary (50.0% vs. 31.8%, $p = .010$). Girls also had higher insulin levels (16.05 ± 10.45 μIU/mL vs. 12.72 ± 7.63 μIU/mL, $p = .008$), more body fat (36.5% vs. 30.9%, $p < .001$), and higher HOMA-IR indices (3.5 ± 2.4 vs. 2.8 ± 1.7, $p = .014$) than boys but lower HDL cholesterol levels (0.99 ± 0.23 mmol/L vs. 1.08 ± 0.27 mmol/L, $p = .009$). Obese children had significantly higher mean serum concentrations of insulin, hs-CRP, and triglycerides than overweight children. Insulin resistance, as estimated by HOMA-IR, was also higher in obese than in overweight children. Obese children had lower mean serum levels of HDL cholesterol than overweight children (data not shown).

The prevalence of metabolic syndrome in the study population was 5.6% overall (**table 2**), 3.8% in overweight children, and 6.9% in obese children. The prevalence of high triglyceride levels (≥ 1.24 mmol/L) was 48.1%, 54.7% had low HDL cholesterol (< 1.03 mmol/L), and 9.3% had high fasting glucose concentrations (≥ 5.55 mmol/L). More girls than boys had fasting hyperinsulinemia (> 10.5 μIU/mL) (68.3% vs. 51.8%, $p = .020$). Other risk factors for developing cardiovascular disease and type 2 diabetes had overall high prevalence rates among the study population: sedentarism (40.6%), family history of type 2 diabetes (73.3%), high LDL cholesterol levels (≥ 2.84 mmol/L) (57.0%), hyperinsulinemia (> 10.5 μIU/mL) (59.8%), insulin resistance (HOMA-IR ≥ 2.4) (55.1%), and high total cholesterol levels (> 4.39 mmol/L) (60.7%).

In the overall population, 48.1% had one of the risk factors for the metabolic syndrome, 7.5% had two risk factors, and 5.6% had three risk factors (**table 3**).

The sociodemographic, anthropometric, and biochemical characteristics of the children with and without metabolic syndrome are summarized in **table 4**. Children with metabolic syndrome had significantly higher BMIs (24.45 ± 4.86 vs. 22.54 ± 3.11, $p = .047$), glucose levels (5.84 ± 0.46 mmol/L vs. 4.89 ± 0.43 mmol/L, $p < .001$), and triglyceride concentrations (2.97 ± 1.34 mmol/L vs. 1.37 ± 0.81 mmol/L, $p < .001$) and lower HDL cholesterol levels (0.81 ± 0.12 mmol/L vs. 1.05 ± 0.25 mmol/L, $p = .001$) than children without metabolic syndrome. Among the children with insulin

TABLE 1. Sociodemographic, anthropometric, and biochemical characteristics of the study population[a]

Characteristic	Boys (n = 110)	Girls (n = 104)	p value[b]	Total (n = 214)
Age—yr	9.21 ± 0.78 (8.00–10.00)	9.08 ± 0.82 (8.00–10.00)	.236	9.14 ± 0.80 (8.00–10.00)
Nutritional status—%				
Overweight	37.3	38.5	.968	37.9
Obese	62.7	61.5	.968	62.1
School—%				
Public	80.0	77.9	.834	79.0
Private	20.0	22.1	.834	21.0
Sedentarism—%	31.8	50.0	.010	40.7
Family history of type 2 diabetes—%	75.2	72.1	.719	73.7
BMI—kg/m^2	22.50 ± 3.28	22.80 ± 3.20	.499	22.65 ± 3.24
Body fat—%	30.9 ± 6.8	36.5 ± 6.4	< .001	33.6 ± 7.2
Glucose—mmol/L[c]	4.99 ± 0.43 (3.22–6.22)	4.90 ± 0.54 (3.00–7.16)	.178	4.94 ± 0.49 (3.00–7.16)
Insulin—μIU/mL	12.72 ± 7.63 (1.40–57.00)	16.05 ± 10.45 (2.30–77.00)	.008	14.35 ± 9.25 (1.40–77.00)
hs-CRP—mg/L	3.10 ± 2.69 (0.50–10.00)	3.06 ± 2.31 (0.30–10.10)	.907	3.08 ± 2.51 (0.30–10.10)
Total cholesterol—mmol/L[d]	4.72 ± 0.88 (2.72–7.12)	4.63 ± 0.93 (2.46–8.44)	.468	4.68 ± 0.91 (2.46–8.44)
HDL cholesterol—mmol/L[d]	1.08 ± 0.27 (0.34–1.84)	0.99 ± 0.23 (0.36–1.68)	.009	1.04 ± 0.25 (0.34–1.84)
LDL cholesterol—mmol/L[d]	2.98 ± 0.79 (0.85–4.97)	2.96 ± 0.82 (0.98–6.99)	.856	2.97 ± 0.80 (0.85–6.99)
Triglycerides—mmol/L[e]	1.44 ± 1.05 (0.04–6.27)	1.48 ± 0.78 (0.46–4.25)	.753	1.46 ± 0.92 (0.04–6.27)
Castelli index	4.7 ± 1.5 (2.4–11.0)	4.8 ± 1.3 (2.5–9.4)	.604	4.7 ± 1.4 (2.4–11.0)
HOMA-IR	2.8 ± 1.7 (0.3–11.7)	3.5 ± 2.4 (0.6–18.6)	.014	3.2 ± 2.1 (0.3–18.6)

BMI, body mass index; HOMA-IR, homeostasis model assessment of insulin resistance; HDL, high-density lipoprotein; hs-CRP, high-sensitivity C-reactive protein; LDL, low-density lipoprotein

a. Plus–minus values are means ± SD. Numbers in parentheses are ranges.

b. Differences are considered significant if $p < .05$ (Mann-Whitney test)

c. To convert mmol/L glucose to mg/dL, divide by 0.0555.

d. To convert mmol/L cholesterol to mg/dL, multiply by 38.7.

e. To convert mmol/L triglycerides to mg/dL, multiply by 88.6.

resistance (HOMA-IR ≥ 2.4), the prevalence of metabolic syndrome increased to 8.5% (data not shown).

Nonparametric Spearman correlations among biochemical and anthropometric values showed very strong positive correlations between insulin and HOMA-IR (r = 0.982) and between total cholesterol and LDL cholesterol (r = 0.909). Body fat correlated positively with triglycerides (r = 0.376). HDL cholesterol had a mild negative correlation with body fat (r = –0.400), triglycerides (r = –0.542), and Castelli index (r = –0.684). hs-CRP showed a mild positive correlation with BMI (r = 0.296) and body fat (r = 0.320) (data not shown).

Discussion

To our knowledge, this is the first study that reports the prevalence of metabolic syndrome and its components among overweight and obese Costa Rican children. Definitions by WHO, the National Cholesterol Education Program's Adult Treatment Panel II (NCEP-ATP

TABLE 2. Prevalence of the metabolic syndrome abnormalities according to the criteria proposed by Tapia-Ceballos [10] and other well-known cardiovascular risk factors[a]

Risk factor	Boys (n = 110)	Girls (n = 104)	p value[b]	Total (n = 214)
Metabolic syndrome	4 (3.6)	8 (7.7)	.314	12 (5.6)
High triglycerides (≥ 1.24 mmol/L)[c]	48 (43.6)	55 (52.9)	.221	103 (48.1)
Low HDL cholesterol (<1.03 mmol/L)[d]	50 (45.4)	67 (64.4)	.008	117 (54.7)
High fasting glucose (≥ 5.55 mmol/L)[e]	8 (7.3)	12 (11.5)	.412	20 (9.3)
Other risk factors				
Sedentarism	35 (31.8)	52 (50.0)	.010	87 (40.6)
Family history of type 2 diabetes	82 (75.2)	75 (72.1)	.809	157 (73.3)
hs-CRP > 8.2 mg/L	9 (8.2)	6 (5.8)	.675	15 (7.0)
LDL cholesterol ≥ 2.84 mmol/L[d]	63 (57.3)	59 (56.7)	.961	122 (57.0)
Castelli index > 4.5	49 (44.5)	54 (51.9)	.344	103 (48.1)
Fasting hyperinsulinemia (> 10.5 μIU/mL)	57 (51.8)	71 (68.3)	.020	128 (59.8)
HOMA-IR ≥ 2.4	55 (50.0)	63 (60.6)	.155	118 (55.1)
Total cholesterol > 4.39 mmol/L[d]	70 (63.6)	60 (57.7)	.457	130 (60.7)

HDL, high-density lipoprotein; HOMA-IR, homeostasis model assessment of insulin resistance; hs-CRP, high-sensitivity C-reactive protein; LDL, low-density lipoprotein

a. Figures represent number (percent) of children.
b. Differences are considered significant if $p < .05$ (Student's t-test).
c. To convert mmol/L triglycerides to mg/dL, multiply by 88.6.
d. To convert mmol/L cholesterol to mg/dL, multiply by 38.7.
e. To convert mmol/L glucose to mg/dL, divide by 0.0555.

III), the European Group for the Study of Insulin Resistance, the American College of Endocrinology, and the International Diabetes Federation are reported in the literature for the diagnosis of metabolic syndrome in adults. **Table 5** shows the various definitions proposed since 2003 for pediatric metabolic syndrome and the diagnostic criteria used in each case. Whereas Cook et al. [24] and de Ferranti et al. [25] modified the adult NCEP-ATP III criteria for adolescents, Viner et al. [26] adapted the WHO criteria for children and used hyperinsulinism and hypercholesterolemia as additional components of the metabolic syndrome. In this study, we used the most recent definition proposed by Tapia-Ceballos [10] in 2007, which includes the new cutoff values for fasting glucose recommended by the American Diabetes Association in 2005 [27].

The reported prevalence data for metabolic syndrome in children and adolescents in different countries vary markedly. Some studies worked with the general population, and others used samples of overweight and obese children. In addition, the inconsistent definition criteria used for metabolic syndrome and slightly different cutoff values for triglycerides, HDL cholesterol, blood pressure, and fasting glucose could explain the discrepancies found in the prevalence data reported worldwide [6, 28], making comparisons very difficult. Hamidi et al. [3] reported a frequency of metabolic syndrome of 20.8% in 505 obese Iranian children aged 7 to 12 years, and Ferreira et al. [29] reported a similar prevalence of 17.3% of metabolic syndrome among 52 obese Brazilian schoolchildren aged 7 to 10 years. Cook et al. [24] analyzed a sample of adolescents aged 12 to 19 years from the Third National Health and Nutrition Examination Survey (NHANES III) using the same components of Ferreira's study but with different cutoff points for the parameters. They found a prevalence of metabolic syndrome of 6.8% and 28.7% among overweight and obese adolescents, respectively. Meanwhile, Caceres et al. [30] found a prevalence of metabolic syndrome of 36% in a group of 61 obese Bolivian children and adolescents aged between 5 and 18 years. In our study, we found a prevalence of metabolic syndrome of

TABLE 3. Number and percentage of children with none, one, two, or three of the risk factors for the metabolic syndrome according to the criteria proposed by Tapia-Ceballos [10]

No. of risk factors	Boys (n = 110)	Girls (n = 104)	p value[a]	Total (n = 214)
0	52 (47.3)	31 (29.8)	.014	83 (38.8)
1[b]	48 (43.6)	55 (52.9)	.221	103 (48.1)
2[c]	6 (5.5)	10 (9.6)	.379	16 (7.5)
3[d]	4 (3.6)	8 (7.7)	.314	12 (5.6)

a. All differences are significant at $p < .05$ (Student's t-test test).
b. Only high serum triglycerides (≥ 1.24 mmol/L) (to convert mmol/L triglycerides to mg/dL, multiply by 88.6).
c. High serum triglycerides and low serum HDL cholesterol (< 1.03 mmol/L) (to convert mmol/L cholesterol to mg/dL, multiply by 38.7).
d. High serum triglycerides, low serum HDL cholesterol, and high fasting glucose (≥ 5.55 mmol/L) (to convert mmol/L glucose to mg/dL, divide by 0.0555).

3.8% and 6.9%, respectively, among 214 overweight and obese schoolchildren from 8 to 10 years of age. Independently of the definition used to establish pediatric metabolic syndrome, it seems that its prevalence in overweight and obese children is increasing to worrisome limits in many countries [31, 32].

In our study, insulin resistance (estimated by HOMA-IR index) and mean serum concentrations of insulin were higher and HDL cholesterol levels were lower in girls than in boys and in obese than in overweight children. These results are consistent with other studies that have shown that obesity is associated with type 2 diabetes, dyslipidemia, and long-term vascular complications [33, 34]. Likewise, it has been reported that girls have higher basal insulin levels than boys and that the levels in girls increase with age [35], a condition that makes girls more liable than boys to develop insulin resistance and type 2 diabetes. In addition, half of the girls in our study had a sedentary lifestyle, and the prevalence of low levels of HDL cholesterol was higher in girls than in boys (50.0% vs. 31.8%, $p = .010$); these results suggest that encouraging increased physical activity should be an important intervention among girls.

Many studies have shown that physical activity lowers serum cholesterol, serum triglycerides, serum glucose, and blood pressure and improves serum HDL cholesterol and insulin sensitivity. Physical activity also reduces body weight, modifies body composition, and improves cardiovascular fitness and skeletal and mental health [36–41]. Recent data also suggest that weight reduction can decrease serum levels of C-reactive protein [2].

Nine of the 12 children diagnosed with metabolic syndrome in our study (75%) were obese, a result showing the important participation of obesity in this condition. Furthermore, children with metabolic syndrome had higher serum glucose and triglyceride levels and lower HDL cholesterol levels than children without this condition, findings that are consistent with other investigations [42, 43]. Obese children should be

TABLE 4. Sociodemographic, anthropometric, and biochemical characteristics of Costa Rican schoolchildren with and without metabolic syndrome[a]

Characteristic	Metabolic syndrome ($n = 12$)	No metabolic syndrome ($n = 202$)	p value[b]	Total ($n = 214$)
Age—yr	9.67 ± 0.49	9.11 ± 0.81	.019	9.14 ± 0.80
No. males/no. females	4/8	106/96	NS	110/104
No. obese/no. overweight	9/3	124/78	NS	133/81
No. in private schools/no. in public schools	1/11	44/158	NS	45/169
Weight—kg	46.06 ± 11.06	43.23 ± 8.12	.252	43.40 ± 8.30
Height—m	1.37 ± 0.09	1.39 ± 0.23	.765	1.39 ± 0.22
BMI—kg/m^2	24.45 ± 4.86	22.54 ± 3.11	.047	22.65 ± 3.24
Body fat—%	36.43 ± 7.07	33.46 ± 7.19	.166	33.6 ± 7.2
Sedentarism—no. (%)	5 (41.7)	82 (40.6)	.820	87 (40.7)
Family history of type 2 diabetes—no. (%)	8 (66.7)	149 (73.8)	.838	157 (73.4)
Glucose—mmol/L[c]	5.84 ± 0.46	4.89 ± 0.43	< .001	4.94 ± 0.49
Insulin—μIU/mL	16.18 ± 8.11	14.24 ± 9.32	.482	14.35 ± 9.25
hs-CRP—mg/L	2.57 ± 1.41	3.11± 2.56	.470	3.08 ± 2.51
Total cholesterol—mmol /L[d]	5.10 ± 1.23	4.65 ± 0.88	.094	4.68 ± 0.91
HDL cholesterol—mmol/L[d]	0.81 ± 0.12	1.05 ± 0.25	.001	1.04 ± 0.25
LDL cholesterol—mmol/L[d]	3.04 ± 1.28	3.14 ± 2.49	.891	3.13 ± 2.44
Triglycerides—mmol/L[e]	2.97 ± 1.34	1.37 ± 0.81	< .001	1.46 ± 0.92
Castelli index	6.35 ± 1.47	5.87 ± 10.51	.875	5.9 ± 10.2
HOMA-IR	4.21 ± 2.09	3.11 ± 2.08	.077	3.20 ± 2.10

BMI, body mass index; HDL, high-density lipoprotein; HOMA-IR, homeostasis model assessment of insulin resistance; hs-CRP, high-sensitivity C-reactive protein; LDL, low-density lipoprotein; NS, not significant

a. Plus–minus values are means ± SD.

b. Differences are considered significant if $p < .05$ (Mann–Whitney test).

c. To convert mmol/L glucose to mg/dL, divide by 0.0555.

d. To convert mmol/L cholesterol to mg/dL, multiply by 38.7.

e. To convert mmol/L triglycerides to mg/dL, multiply by 88.6.

considered a high-risk group for the development of insulin resistance, hyperinsulinemia, and cardiovascular disease at young ages. Physical activity should be encouraged among children and adolescents to prevent these chronic diseases [41, 44].

The overall high prevalence rates of other risk factors for the development of cardiovascular disease and type 2 diabetes found among the studied population, such as sedentarism (40.6%), family history of type 2 diabetes (73.3%), high serum LDL cholesterol levels (57%), hyperinsulinemia (59.8%), and high serum total cholesterol concentrations (60.7%), are alarming, particularly if we consider that these factors are associated with cardiovascular disease in adults in the next 25 years of life [45] and that in Costa Rica coronary artery disease has been the main cause of death among the adult population since the 1970s [46].

Finally, in our study we determined the serum levels of hs-CRP as a marker of subclinical inflammation. This acute-phase protein has also been associated in the literature with insulin resistance, adiposity, atherosclerosis, and metabolic syndrome [47, 48]. In our study, obese children had significantly higher mean serum concentrations of hs-CRP than overweight children (3.52 ± 2.70 vs. 2.04 ± 1.54, $p< .001$). In addition, this protein had a mild positive correlation with BMI ($r = 0.296$) and with percentage of body fat ($r = 0.320$), findings that are consistent with other investigations. Adipose tissue secretes interleukin-6, the main stimulant of the hepatic synthesis of CRP. Available evidence supports the hypothesis that CRP correlates with endothelial dysfunction and that physical exercise and diet can reduce the inflammatory response by reducing body fat and subsequently CRP levels [49]. hs-CRP is used today as a valuable marker of inflammation and predictor of coronary events [49].

Application of the metabolic syndrome concept in children and adolescents is controversial; in fact, multiple definitions of the metabolic syndrome have been proposed for children, adolescents, and adults [50]. However, our data clearly demonstrate that the metabolic syndrome and its components are present in

TABLE 5. Pediatric metabolic syndrome definitions found in the literature as of April 2008

Diagnostic Criteria	Cook et al[a] (2003)	de Ferranti et al[b] (2004)	Viner et al[d] (2005)	Tapia-Ceballos[e] (2007)
Abnormal fasting glucose homeostasis	Glucose ≥ 6.1 mmol/L	Glucose 5.6–7.0 mmol/L[c]	Presence of diabetes mellitus type 2 or impaired fasting glucose (≥ 6.1 mmol/L) or impaired glucose tolerance (≥ 7.8 mmol/L at 2h) or insulin resistance estimated by HOMA-IR Hyperinsulinaemia (additional component)	Presence of glucose intolerance or diabetes mellitus type 2
Obesity	Waist perimeter ≥ P_{90}	BMI above the 95th percentile for age and sex	BMI above the 95th percentile for age and sex	Waist perimeter ≥ P_{90}
Dyslipidemia:				
High levels of triglycerides	≥ 1.24 mmol/L	≥ 1.24 mmol/L	≥1.75 mmol/L	≥ 1.24 mmol/L
Low levels of HDL-cholesterol	< 1.04 mmol/L	≤ 0.98 mmol/L	<0.90 mmol/L	< 1.04 mmol/L
High total cholesterol	—	—	> 95th percentile (additional component)	—
Arterial hypertension	≥ P_{90}	(Diastolic or systolic) > 95th percentile adjusted for age, height and sex	Systolic > 95th percentile adjusted for age and sex	≥ P_{90}

HOMA-IR, homeostasis model assessment for insulin resistance; HDL, high density lipoprotein; BMI, body mass index; P90, percentile

a. Modified version of the National Cholesterol Education Program's Adult Treatment Panel III (NCEP-ATP III) and must fulfill three of the criteria established in the table [10].

b. Modified version of the National Cholesterol Education Program's Adult Treatment Panel III (NCEP-ATP III) and must fulfill three of the criteria established in the table [25].

c. In accordance with American Diabetes Association recommendations (2005) [27].

d. Modified version of the World Health Organization (WHO) and must fulfill glucose intolerance or diabetes mellitus type 2 or insulin resistance estimated by HOMA-IR and two more criteria [26].

e. Modified version of Cook's et al definition of MS and must fulfill three of the criteria established in the table [10].

a large proportion of overweight and obese Costa Rican children. Alterations in glucose metabolism, lipid profile, and insulin sensitivity appear early in childhood when BMI increases, leading to an early onset of type 2 diabetes, hypertension, and cardiovascular disease [29, 51]. Grundy stated recently that persons with metabolic syndrome have twice the risk of cardiovascular disease and five times the risk of type 2 diabetes as those without the syndrome [52]. As stated by the National Cholesterol Education Program's Adult Treatment Panel III (NCEP-ATP III), obesity should be the primary target of intervention for metabolic syndrome [2]. Therefore, weight reduction, dietary modification, control of BMI, and increasing physical activity should become a public health priority in overweight and obese children, and these intervention actions should be promoted and encouraged in the family, school, and community in order to prevent the development of chronic diseases in a short time. Primary prevention programs are required to identify obesogenic environments, and children must be taught to develop healthy food habits and increase their physical activity [41, 53].

Several limitations of these data should be considered. First, because the study design was cross-sectional, hs-CRP was measured in only one sample. Second, insulin resistance was estimated mathematically with HOMA-IR because the gold standard method of the euglycemic-hyperinsulinemic clamp is too expensive and invasive. Third, body-fat measurements were performed with bioimpedance equipment. Although this technique is used by many investigators, it is not very accurate. Fourth, the sample of boys and girls in this study is not representative of the population of 8- to 10-year-old overweight and obese urban schoolchildren, which limits the inferences that can be drawn with respect to the prevalence of metabolic syndrome and its components in this population. Finally, we did not measure waist circumference (abdominal obesity) in the study population, because at the time we collected data, and even today, there is a lack of a standardized technique for measuring waist circumference in children, so that caution needs to be taken when comparing waist circumference percentile reference data between studies. Several cutoff values for waist circumference in children have been suggested, such as the age- and sex-specific 75th percentile to define moderate waist values [54, 55] and the 90th percentile [55–57] or the 95th percentile [54, 58] to define high waist values or abdominal obesity. However, a possible limitation of these cutoff values is the lack of a gold standard research method, such as cross-sectional computed tomography to compare the waist circumference measures in children. In any case, our results do not support the need to measure waist circumference in addition to BMI to identify those at increased risk for metabolic syndrome in childhood.

In summary, this study reported a prevalence of metabolic syndrome of 5.6% in a sample of overweight and obese prepuberal Costa Rican children. Lifestyle interventions focused on reducing weight and increasing physical activity should be promoted by education and health authorities in order to avoid the early development and onset of type 2 diabetes and atherosclerosis.

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