Maternal Waist Circumference and the Prediction of Children’s Metabolic Syndrome

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Objective: To determine the association between metabolic syndrome (MS) components in 620 children and their mothers.

Design: Cross-sectional assessment.

Setting: Three public elementary schools in Buenos Aires, Argentina.

Participants: A total of 620 students at a mean ± SD age of 9.00 ± 2.07 years and their mothers at a mean ± SD age of 37.69 ± 7.19 years.

Main Outcomes Measures: The association between MS in children and components of MS in their mothers, such as body mass index (BMI) (calculated as weight in kilograms divided by height in meters squared), high-density lipoprotein cholesterol concentration, triglycerides, cholesterol, and glucose and age (odds ratio, 2.11; 95% confidence interval, 1.36-3.26).

Results: Ninety-five (15.3%) of the children were obese (BMI ≥ 95th percentile), 108 (17.4%) were overweight (BMI ≥ 85th percentile and < 95th percentile), and 418 (67.3%) were a healthy weight (BMI < 85th percentile). One hundred twelve (18.1%) of the mothers were obese (BMI ≥ 30), 183 (29.5%) were overweight (BMI ≥ 25 and < 30), and 325 (52.4%) were a healthy weight (BMI < 25). Low concentration of high-density lipoprotein cholesterol (in 46.0% and 56.9% of mothers and children, respectively) and central obesity (in 36.0% and 25.0% of mothers and children, respectively) were common, whereas hypertension (in 10.5% and 1.9% of mothers and children, respectively) and impaired fasting glucose (in 2.9% and 0.3% of mothers and children, respectively) were infrequent. The prevalence of MS was 10.8% in children and 11.0% in mothers. Central obesity was less frequent in mothers of children without MS vs mothers of those with MS (41.2% vs 78.8%, respectively; P < .001). Mothers of children without MS had fewer MS components than did mothers of children with MS (BMI z score, 0.09 vs 0.69, respectively [P < .001]; waist circumference z score, 0.15 vs 0.87, respectively [P < .001]). Mothers’ waist circumference was a significant independent predictor of their children’s MS when adjusted for mothers’ concentrations of triglycerides, cholesterol, and glucose and age (odds ratio, 2.11; 95% confidence interval, 1.36-3.26).

Conclusion: A mother’s waist circumference predicts her child’s MS, consistent with known familial associations of obesity and type 2 diabetes.

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Between 1980 and 2002, the prevalence of obesity in the United States doubled for adults older than 20 years and the prevalence of overweight and obesity (body mass index [BMI] [calculated as weight in kilograms divided by height in meters squared] ≥ 85th percentile for age and sex) tripled in children and adolescents aged 6 to 19 years.¹ Two thirds of children and adolescents aged 6 to 19 years were overweight or obese in 2001 and 2002.² Most type 2 diabetes is attributable to excess weight. Furthermore, approximately 197 million people worldwide have impaired glucose tolerance and associated metabolic syndrome (MS) components, most commonly because of obesity. This number is expected to increase to 420 million people by 2025.³ The increase in type 2 diabetes will be most noticeable in developing countries, where the number of people with diabetes is expected to increase from 84 million to 228 million by 2030.⁴

Childhood obesity has contributed to an increased incidence of type 2 diabetes and MS among children. Metabolic syndrome is associated with diabetes and cardiovascular disease in adults.⁵ There is increasing evidence of MS among obese children and adolescents.⁶ This raises concern about the potential development of not only type 2 diabetes but also early cardiovascular disease in childhood.⁷

Parents are in a key position to shape the environments of children, and there is increasing interest in the contribution of the home environment to health behaviors and their long-term consequences.

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of parenting behaviors to obesity risk. Maternal feeding practices have received particular attention as a risk factor for childhood obesity. Obesity is now considered to be the most prevalent nutritional disease of children and adolescents in the United States, where an estimated 15% of 6- to 11-year-old children are overweight.

This study was performed to determine the association between MS components in elementary school children and in their mothers.

### METHODS

**PARTICIPANTS**

The data were collected cross-sectionally from 620 children (297 boys) aged 5 to 13 years at 5 public elementary schools and from their mothers (mean ± SD age, 37.69 ± 7.19 years) between April 5, 2006, and August 2, 2006, in Buenos Aires, Argentina. The sampling design of the survey was a 2-stage probability sample. The first stage was the selection of the schools, and the second stage consisted of an invitation to all of the students and their mothers to undergo testing. The overall response rate was 80.2% of mothers and students. There was no difference in the mean age (P = .81), BMI (P = .32), sex (P = .82), and socioeconomic class (P = .53) among all of the school children and those who underwent testing.

Data for BMI, waist circumference (WC), blood pressure, Tanner stage, serum glucose levels, and serum lipid levels were obtained. Argentinians are an ethnically mixed population with a high prevalence of white individuals, a low prevalence of Hispanic individuals, and a very low prevalence of African individuals. Sociodemographic characteristics included age and level of education. Mothers were asked to define their level of formal education as having no formal education, having completed elementary school, having completed high school, or having a university degree. Participants (mothers and children) were asked to estimate the frequency of their own participation in physical activity during a 1-week period. The questionnaire was preexamined by a statistician (C.G.) and a psychologist (Alejandra Acosta, MS) and was validated by administering it twice in 2 weeks to a pilot group of 20 mothers and children. A high level of concordance was observed between test and retest results, ie, 98.0% for the questions described earlier.

Exclusion criteria included the following: missing BMI information; self-reported pregnancy at the time of the examination; not in the fasting state for at least 8 hours; having known diabetes or other chronic diseases; and the use of medication that alters blood pressure or glucose or lipid metabolism. All of the subjects were examined by the same physician (V.H.). The study was approved by the human rights committee of Durand Hospital, Buenos Aires. Each subject and parent gave written informed consent after an explanation of the study and before its initiation.

Height and weight were measured with subjects wearing light clothing and no shoes. Height was recorded to the nearest 0.1 cm with a wall-mounted stadiometer. Weight was measured to the nearest 0.1 kg on a medical balance scale. The BMI was calculated. Healthy weight in children was defined as having a BMI lower than the 85th percentile. Overweight was defined as a BMI between the 85th and 94th percentiles and obesity as greater than the 95th percentile for age and sex according to the Centers for Disease Control and Prevention standards for US children. The BMI z score was also determined.

Measurement of the WC was taken at the level of the umbilicus and recorded to the nearest 0.1 cm. A nonelastic flexible tape measure was used with the subject standing without clothing covering the waist area. Because WC varies according to age and sex, we standardized values for age and sex by converting them to z scores. Central obesity was defined for children as a WC greater than the 75th percentile based on 5000 healthy Argentinian children (V.H., M.L.C., Graciela Clemente, MD, and Ana Clemente, MD, unpublished data, August 2004) and for their mothers as a WC greater than 88 cm.

Three separate blood pressure measurements were recorded by a trained technician (Alba Dileva, MS) using a random-zero sphygmomanometer after the participant was seated at rest for 5 minutes. The averages of the last 2 measurements of systolic and diastolic blood pressures were used. Because normal pediatric blood pressure varies significantly, we used the National Heart, Lung, and Blood Institute’s recommended cut point for age, sex, and height.

Children had fasting glucose, lipid profile, and insulin assays. Insulin resistance was assessed by homeostasis model assessment (HOMA-IR), which was validated in children and adolescents and strongly correlated with insulin resistance. The following equation for HOMA-IR was used: fasting insulin concentration (international units per liter) × fasting glucose concentration (millimoles per liter) divided by 22.5.

Insulin resistance was defined as the upper quartile of HOMA-IR. The upper quartile of insulin resistance for all of the children was greater than 2.05 and for all of the mothers was greater than 1.79.

### DEFINITION OF MS

Metabolic syndrome is a constellation of metabolic abnormalities that predicts premature coronary artery disease and type 2 diabetes. The National Cholesterol Education Program Adult Treatment Panel III definition for MS was used for mothers. Briefly, MS was defined as the presence of 3 or more of the following 5 conditions: (1) abdominal obesity (WC > 102 cm [≥ 40 in] in men and > 88 cm [≥ 35 in] in women); (2) fasting triglycerides concentration of 150 mg/dL or higher (to convert to millimoles per liter, multiply by 0.0113); (3) high-density lipoprotein cholesterol (HDL-C) concentration lower than 40 mg/dL in men and lower than 50 mg/dL in women (to convert to millimoles per liter, multiply by 0.0259); (4) blood pressure of 130 mm Hg or higher systolic or 85 mm Hg or higher diastolic or the use of antihypertensive medications; and (5) fasting glucose concentration of 100 mg/dL or higher (to convert to millimoles per liter, multiply by 0.0555) or the use of diabetes medications. Criteria analogous to those of the Adult Treatment Panel III were used for children (Table 1).
STATISTICAL ANALYSIS

The BMI was converted to age- and sex-standardized percentiles based on the Centers for Disease Control and Prevention 2000 growth charts, which are not race specific. The χ² test was used to compare proportions. When more than 20% of the cells had expected frequencies of less than 5, Fisher exact test was used. The fit to normal distribution of continuous variables was assessed using the Shapiro-Wilks test. When comparing 2 groups with normally distributed data, a t test was performed. The primary focus of the analysis was to determine the maternal risk factors associated with MS in children. Multiple logistic regression analysis was done to examine the relationship between MS in children and components of their mothers’ MS, and observed associations are expressed as odds ratios with 95% confidence intervals. P < .05 was considered statistically significant. Data are presented as mean±SD and observed prevalences are expressed as percentages with 95% confidence intervals. Analyses were done using SPSS version 10.0 statistical software (SPSS, Inc, Chicago, Illinois).

RESULTS

CHARACTERISTICS OF CHILDREN

Physical and metabolic profiles are presented in Table 2. Ninety-five (15.3%) of the children were obese, 108 (17.4%) were overweight, and 418 (67.3%) were a healthy weight. The prevalence of obesity was higher in boys (n=58; 19.5%) than in girls (n=37; 11.4%) (P=.007). The mean±SD BMI z scores of these 3 groups were as follows: obese, 2.03±0.28; overweight, 1.33±0.17; and healthy weight, 0.33±0.81. Among the children, 72.0%, 18.4%, 9.1%, and 0.6% were at Tanner stages I, II, III, and IV, respectively. The frequency of participation in physical activity during a 1-week period was none for 62 children (10.0%), once a week for 122 children (19.8%), twice a week for 141 children (22.9%), and 3 or more times a week for 292 children (47.3%). There was no significant difference in the participation in physical activity between the obese, overweight, and healthy-weight groups (P=.54).

Approximately 70.2% of children had at least 1 risk factor for cardiovascular disease and 32.0% had 2 or more risk factors. The risk factors of low HDL-C concentration (in 353 of 620 children [56.9%]) and central obesity (in 155 of 620 children [25.0%]) were common, whereas hypertension (in 12 of 620 children [1.9%]) and impaired fasting glucose (in 2 of 620 children [0.3%]) were infrequent. No children had diabetes. Metabolic syndrome was present in 10.8% of children overall, 1.0% of those with a healthy weight, 10.7% of those who were overweight, and 43.9% of those who were obese (P<.001). No children had all of the 5 risk factors. There was no significant difference in the prevalence of individual risk factors (P=.53) or in the prevalence of MS between boys and girls (P=.46). There was no significant difference in the distribution of Tanner stages (P=.73) or in the participation in physical activity (P=.90) between the groups with and without MS. The mean±SD BMI z score was higher (P<.001) in the MS group (1.85±0.41) than in the group without MS (0.52±0.18). The number of MS features was significantly related to BMI adjusted for HOMA-IR, age, and sex (b coefficient=0.18; P<.001; R²=0.35).

CHARACTERISTICS OF MOTHERS

Physical and metabolic profiles are presented in Table 2. The mean±SD maternal BMI was 25.82±5.04, which indicates that as a group the mothers were overweight. One hundred twelve (18.1%) of the mothers were obese (BMI ≥ 30), 183 (29.5%) were overweight (BMI ≥ 25 and <30), and 325 (52.4%) were a healthy weight (BMI <25). The mean±SD BMIs of these 3 groups were as follows: obese, 34.31±3.76; overweight, 27.05±1.40; and healthy weight, 22.17±1.88. The educational backgrounds of the mothers were as follows: 2 (0.3%) had no formal education, 184 (29.6%) had completed elementary school, 259 (41.7%) had completed high school, and 170 (26.7%) had university and/or advanced degrees. Participants came from low and middle-low socioeconomic classes. Overweight and obesity were more common in mothers with a lower level of education (divided into high school or less and more than high school) (P=.003). The frequency of participation in physical activity during a 1-week period was as follows: none for 404 mothers (65.1%); once a week for 76 mothers (12.3%); twice a week for 54 mothers (8.7%); and 3 or more times a week for 86 mothers (13.9%).
Approximately 70.0% of mothers had at least 1 risk factor for cardiovascular disease and 32.3% had 2 or more risk factors. The risk factors of low HDL-C (in 285 of 620 mothers [46.0%]) and central obesity (in 223 of 620 mothers [36.0%]) were common, whereas hypertension (in 59 of 620 mothers [10.5%]) and impaired fasting glucose (in 18 of 620 mothers [2.9%]) were less frequent. None had diabetes. Metabolic syndrome was present in 11.0% of the mothers overall, 0.7% of those who were overweight, and 33.8% of those who were obese (P <.001). Only 1 mother had all of the 5 risk factors. There were no significant differences in the educational backgrounds (P = .76) and in the participation in physical activity (P = .15) in the groups with and without MS. The group with MS as compared with the group without MS had a higher mean ± SD BMI (32.95 ± 4.92 vs 25.64 ± 4.62, respectively) and older mean ± SD age (41.5 ± 8.3 years vs 35.6 ± 6.5 years, respectively). There was a higher prevalence of overweight and obese mothers in the group with MS than in the other group (97.0% vs 46.8%, respectively; P < .001). The number of MS features was significantly related to BMI adjusted for HOMA-IR, age, and sex (b coefficient = 0.11, P < .001; R² = 0.39).

### RELATIONSHIP BETWEEN CHILDREN AND THEIR MOTHERS

The prevalence of MS in mothers was not substantially higher than in their children, but the prevalences of hypertension (10.5% in mothers vs 1.9% in children) and glucose abnormalities (2.9% in mothers vs 0.3% in children) were 5- to 10-fold higher in mothers. For mothers and their children, the risk factors of low HDL-C concentration (46.0% and 36.9%, respectively) and central obesity (36.0% and 25.0%, respectively) were common, whereas hypertension (10.5% and 1.9%, respectively) and impaired fasting glucose (2.9% and 0.3%, respectively) were much less frequent (Figure). There was a lower prevalence of central obesity for mothers of children without MS than for those whose children had MS (41.7% vs 78.8%, respectively; P < .001). There were no significant differences in the educational level (P = .27) and physical activity (P = .82) for mothers of children with or without MS.

Mothers of children without MS had mean values of MS components that were significantly different from those for the mothers of children with MS (BMI z score, 0.09 vs 0.69, respectively [P < .001]; WC z score, 0.15 vs 0.87, respectively [P < .001]; triglycerides concentration, 89 vs 108 mg/dL, respectively [P = .04]; HDL-C concentration, 52 vs 47 mg/dL, respectively [P = .01]; and glucose concentration, 79 vs 83 mg/dL, respectively [P = .03]). In contrast, mean values for mothers' HOMA-IR were not significantly different between the groups (1.46 for mothers of children without MS vs 1.48 for mothers of children with MS [P = .96]). Multiple logistic regression analysis using MS as the dependent variable showed that mothers' WC was the only significant independent predictor for their children's MS after adjusting for mothers' concentrations of triglycerides, cholesterol, and glucose and systolic blood pressure (odds ratio, 2.11; 95% confidence interval, 1.36-3.26) (Table 3). We observed a strong association between children's MS and central obesity of their mothers.

The epidemic of childhood obesity, early onset of type 2 diabetes, and clustering of cardiovascular risk factors have important public health implications, awareness of which has led to increasing attention to the presence of MS in children. Obesity is commonly familial.20,21 Parental obesity greatly increases the risk of a child becoming obese,22 and the parent-child association is stronger when both parents rather than one are obese.23 An overweight school-aged child with an obese parent has greater than a 70% chance of being obese in young adulthood.23 Two important determinants of MS are obesity and physical activity. We found an unusually high prevalence of MS (10.8%) in this young age group (mean age, 9.00 years), which was similar to that in their mothers (11.0%). Approximately 70.0% of the children had at least 1 MS abnormality. This could be due to the high prevalence of overweight and obesity in mothers. Of the mothers, 18.1% were obese and 29.5% were overweight. There was a high prevalence of maternal central obesity as measured by WC (36.0%). In this cross-sectional analysis of

### Table 3. Multiple Logistic Regression Analysis With Children’s Metabolic Syndrome as the Dependent Variable

<table>
<thead>
<tr>
<th>Independent Variable</th>
<th>OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mother’s WC</td>
<td>2.11 (1.36-3.26)</td>
</tr>
<tr>
<td>Cholesterol concentration</td>
<td>0.99 (0.98-1.00)</td>
</tr>
<tr>
<td>Triglycerides concentration</td>
<td>1.00 (0.99-1.00)</td>
</tr>
<tr>
<td>Glucose concentration</td>
<td>1.01 (0.97-1.04)</td>
</tr>
<tr>
<td>Age</td>
<td>1.01 (0.96-1.07)</td>
</tr>
<tr>
<td>Constant</td>
<td>0.96</td>
</tr>
</tbody>
</table>

Abbreviations: CI, confidence interval; OR, odds ratio; WC, waist circumference.

[Figure. Prevalence of metabolic syndrome (MS) components in mothers and their children. HDL-C indicates high-density lipoprotein cholesterol; TG, triglycerides; and BP, blood pressure.]
schoolchildren and their mothers, we found that mothers’ central obesity was significantly and independently associated with their children’s MS. Furthermore, the mean values of all of the MS components were significantly higher for mothers of children with MS than for mothers of children without MS. The most common phenotype in mothers of children with MS was central obesity. Remarkably, maternal WC was found to be more closely related to children’s MS status than any maternal risk factor for MS, including maternal MS.

Excessive weight gain during childhood is related to several interacting factors, including poor diet and exercise habits. Dietary preferences and physical activity patterns are probably shaped early in childhood, influenced by parental practices and familial environment. Garn and Clark and Garn et al suggest that childhood eating and exercise patterns are modeled after parental behaviors and that parental behaviors serve as the basis for developing and changing the health habits of children. Experimental research suggests that parent modeling can influence child eating behaviors and that parental reinforcement can alter children’s eating behavior and exercise behavior. Several limitations of this study should be acknowledged. This study evaluated mothers’ and children’s physical activity by questionnaire and found no association between mothers’ physical activity and children’s MS. This could be owing to the questionnaire not being specific enough. Little is known about other components of physical activity such as occupational and transportation-related physical activity. Many mothers belonging to a lower socioeconomic class do not practice any programmed physical activity but work in physically demanding occupations, for example, as housemaids. Because many housemaids in Argentina receive state welfare, which they would lose by revealing that they are working, they were reluctant to be forthcoming about their occupational status. The employment activity information might thus be unreliable, which is why it was not used. There was also no significant difference in the participation of children in physical activity between the groups with and without MS. Most of the children of these mothers are alone during the entire afternoon and play unorganized sports in the street without considering this part of an exercise program. Even though the questionnaire inquired about physical play, mothers may not have known that their children played during the afternoon in the streets instead of doing their homework. These uncertainties might account for the lack of association between physical activity and children’s MS.

This study was a cross-sectional analysis and no causal inferences could be made. In addition, the definition used for MS was developed for older children. In our study, more than 70% of the children were prepubertal; thus, our findings can only be viewed as MS rates. Prospective long-term studies are needed to validate the power of this definition. Moreover, the use of the Adult Treatment Panel III guidelines adapted to adolescents with a unique cutoff value for concentrations of triglycerides and HDL-C during childhood may lead to misclassification of dyslipidemia. Also, physical activity questionnaires may not have been sensitive enough.

Our analyses show that the increase in mothers’ WC accounted for much of the prevalence of the children’s MS. Because MS is common and increasing, health care professionals are likely to find patients with this syndrome in their practice. It remains unknown to what extent health care professionals have adopted the recommendations concerning MS made by the National Cholesterol Education Program and the Adult Treatment Panel III and are examining their patients for this syndrome. Measurements of blood pressure and concentrations of triglycerides, HDL-C, and glucose are commonly collected in clinical practice. Whether WC is routinely measured at present is unknown. This study showed that mothers’ WC is the most important component related to children’s MS and should always be determined because it is cheap and easily measured.

These findings may have implications for both public health and clinical interventions directed at this high-risk group. To halt the rising tide of obesity and associated cardiovascular risk factors, comprehensive approaches for improving nutrition and physical activity are required. Health care professionals have a critical role in preventing the development of MS through weight management and the achievement of proper physical activity levels. These findings provide clues for content development of programs for prevention of childhood MS and for targeting at-risk children for intensive intervention.

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