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Prevalence and sociodemographic correlates of metabolic syndrome in school-aged children and their parents in nine Mesoamerican countries

Eduardo Villamor[1,2,*], Caitlin C Finan[1], Manuel Ramirez-Zea[3] and Ana Victoria Roman[3] for the Nine Mesoamerican Countries Metabolic Syndrome Study (NiMeCoMeS) Group
[1]Department of Epidemiology, University of Michigan School of Public Health, 1420 Washington Heights, SPH II, Room M5055, Ann Arbor, MI 48109, USA: [2]Center for Human Growth and Development, University of Michigan, Ann Arbor, MI, USA: [3]INCAP Research Center for the Prevention of Chronic Diseases, Guatemala City, Guatemala, USA

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Abstract

Objective: To ascertain the prevalence and sociodemographic correlates of cardiometabolic risk factors in adults and school-aged children from Mesoamerica.
Design: Cross-sectional study with convenience sampling. In adults, metabolic syndrome was defined according to the National Cholesterol Education Program's Adult Treatment Panel III (ATP III) criteria. In children, we calculated a continuous sex- and age-standardized metabolic risk score using variables corresponding to adult ATP III criteria. Metabolic syndrome prevalence in adults and risk score distribution in children were compared across levels of sociodemographic characteristics with use of Poisson and linear regression, respectively.
Setting: Capital cities of Guatemala, El Salvador, the Dominican Republic, Honduras, Nicaragua, Panama, Costa Rica, the Mexican State of Chiapas (Tuxtla Gutiérrez city) and Belize.
Subjects: Families (*n* 267), comprising one child aged 7–12 years and their biological parents.
Results: The prevalence of metabolic syndrome was 37·9 % among women and 35·3 % among men. The most common component was low HDL cholesterol, 83·3 % in women and 78·9 % in men. Prevalence was positively associated with age. In women, metabolic syndrome was inversely related to education level whereas in men it was positively associated with household food security and height, after adjustment. The metabolic risk score in children was inversely related to parental height, and positively associated with height-for-age and with having parents with the metabolic syndrome.
Conclusions: Metabolic syndrome is highly prevalent in Mesoamerica. The burden of metabolic risk factors disproportionately affects women and children of lower socio-economic status and men of higher socio-economic status.

Keywords
Metabolic syndrome
Metabolic risk score
Mesoamerica
Socio-economic status
Children

Metabolic syndrome is a clustering of risk factors associated with increased risk of CVD[1]. A widely accepted definition of the metabolic syndrome in adults was provided by the National Cholesterol Education Program's Adult Treatment Panel III (ATP III)[2] and involves the presence of three or more of the following conditions: abdominal obesity, high fasting blood glucose, high blood pressure, low HDL cholesterol and high TAG.

The study of the metabolic syndrome is essential in understanding and decreasing the burden of cardiometabolic disease. This is particularly relevant in low- and middle-income countries, where this condition has increasingly contributed to disability and premature death during the past few decades[3]. In Latin America, the prevalence of the metabolic syndrome ranges from 19 to 43 %[4] and may have reached levels comparable to those observed in Europe and the USA. These estimates, however, are from studies conducted in Mexico and a few South American countries[5–8]. The prevalence in Mesoamerica is virtually unknown. The socio-economic patterning of the metabolic syndrome in this region is also understudied. Identifying the groups at highest risk is relevant as it provides clues on aetiology and may inform policy to target preventive or therapeutic interventions.

The metabolic syndrome has been studied primarily in adults, but the importance of identifying children at

*Corresponding author: Email villamor@umich.edu

risk of developing this condition should not be underestimated. Emerging evidence indicates that the prevalence of metabolic syndrome is increasing among adolescents worldwide, driven by the growing childhood obesity epidemic[9–11]. Approximately 20–25 % of Latin Americans under 18 years of age are overweight or obese[12]; thus, a significant proportion of this population is at risk of developing metabolic syndrome. In addition, metabolic syndrome components tend to track from childhood into adulthood[13,14], which highlights the need to characterize and prevent metabolic risk from an early age.

The aim of the present study was to investigate the prevalence and sociodemographic correlates of metabolic syndrome among women, men and school-age children in nine Mesoamerican countries.

Methods

Study design and population

We conducted a cross-sectional study to investigate environmental correlates of the metabolic syndrome among school-age children and their families in nine countries from the Mesoamerican region. Our aim was to recruit thirty families from the capital cities of Guatemala, El Salvador, the Dominican Republic, Honduras, Nicaragua, Panama, Costa Rica, the Mexican State of Chiapas (Tuxtla Gutiérrez city) and Belize. Study recruitment took place between July 2011 and November 2013. During this time, we identified all public primary schools in periurban areas of each city by contacting each country's Ministry of Education. There were between fifty-six (Belize District) and 810 (Tegucigalpa, Honduras) eligible schools per city. We included schools with at least 400 students of both sexes and grouped them by geographic area (North, South, East, West) using virtual maps as references. To reach target enrolment, one to three schools were randomly selected from each geographic area in each city. We included four schools in Nicaragua; five in Guatemala, El Salvador and Mexico; six in the Dominican Republic and Honduras; seven in Belize; nine in Costa Rica; and ten in Panama. Using the lists of enrolled students in each school, the study team identified those aged 7–12 years as potentially eligible for recruitment. Eighty students were randomly selected from these lists in each city and their parents were invited to a meeting with the research team. Attendance rates to this meeting ranged from 50 % (Nicaragua, Panama, Mexico) to 75 % (Guatemala). At this meeting, the study aims and procedures were explained to the families and additional enrolment criteria were confirmed. These criteria included that the children lived with both biological parents, were not pregnant or had a pregnant mother, and did not have a sibling already identified for potential participation in the study. Both parents and the child of each family had to be willing to participate. A team member read the informed consent form out loud and encouraged parents to ask any questions regarding participation in the study. At the end of the meeting, the study teams provided the families with a hard copy of the consent form and asked them to return the form signed after one week if they wished to participate. The team made itself available during this week over the telephone to answer any further questions the families may have had. After this week, study personnel collected the signed consent forms at the schools and verbally confirmed assent to participate among children of consenting parents, using a standard script. The final sample included 267 families (Guatemala, *n* 31; El Salvador, *n* 30; Dominican Republic, *n* 30; Honduras, *n* 30; Nicaragua, *n* 31; Panama, *n* 26; Costa Rica, *n* 27; Mexico, *n* 31; and Belize, *n* 31). The sampling strategy employed did not intend to produce a representative population of the countries.

The research was conducted in accordance with guidelines laid down by the Declaration of Helsinki. The study protocol and procedures were approved by Institutional Review Boards at all nine collaborating institutions in Mesoamerica and the University of Michigan Health Sciences and Behavioral Sciences Institutional Review Board.

Data collection

Research personnel scheduled morning appointments to visit the homes of enrolled families to perform all data collection procedures. Evaluations took place at health centres for families who preferred this option. Each family member was asked to fast for at least 6 h prior to the scheduled visit. During the appointment, study participants completed self-administered questionnaires that included questions on sociodemographic characteristics such as age, education level, household assets and home ownership; as well as on health and dietary habits. Mothers completed the Latin American and Caribbean Food Security Scale[15], a survey validated for use in this region. The questionnaire comprises sixteen yes/no questions regarding food security experiences in the household during the previous three months.

Next, trained research assistants obtained anthropometric measurements on each participant. Weight was measured in light clothing to the nearest 0·1 kg on digital Tanita scales (Tanita, Tokyo, Japan). Height was measured without shoes to the nearest millimetre with the use of portable Seca stadiometers (Seca, Hamburg, Germany). Waist circumference (WC) was measured at the end of an unforced exhalation to the nearest millimetre at the midpoint between the lower edge of the ribcage and the iliac crest in adults and above the uppermost lateral border of the right ilium in children, with the use of an inextensible metric tape. All anthropometric measures were obtained in triplicate. Blood pressure was measured with the participant seated using Omron HEM-712C digital

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blood pressure monitors (Omron Healthcare, Inc., Lake Forest, IL, USA). Three readings were obtained with at least one minute between measures and the average of the second and third measurements was recorded as the blood pressure value. Biological specimens were collected from each family member towards the end of the visit, including a fasting blood sample which was obtained via venepuncture of the antecubital vein. The median (interquartile range) estimated fasting time at the time of sample collection was 12·9 (12·0–14·0) h. Immediately after collection, samples were placed in portable ice containers that had been pre-cooled with ice packs to 2°C. The containers' temperature was strictly monitored each time samples were deposited throughout a day of home visits. At the end of the last visit, collected samples were taken to each country's collaborating institution laboratories where serum and plasma were separated, aliquoted and cryostored at −20°C. Samples were sent frozen to the Institute of Nutrition of Central America and Panama (INCAP) in Guatemala City, Guatemala, one to twelve weeks after collection, by air courier from the Dominican Republic, Panama and Costa Rica and by land from the other countries using institutional vehicles under the supervision of professionals trained on cold chain procedures.

Laboratory methods

All analyses took place at INCAP. Serum insulin was measured using chemiluminescent immunoassay with an Immulite 1000 system (Siemens Healthcare Diagnostics Products, Tarrytown, NY, USA); plasma glucose concentrations were analysed using an automated chemistry analyser (Cobas c111 system; Roche Diagnostics, Mannheim, Germany); and serum lipid profiles were determined using enzymatic colorimetric assays on an automated chemistry analyser (Cobas c111 system; Roche Diagnostics).

Definition of exposures

Age in years was categorized as <30, 30–34, 35–39, 40–44 or ≥45 in the mothers; and as <35, 35–39, 40–44, 45–54 or ≥55 in the fathers. Parental education level was categorized according to the number of completed years of schooling (incomplete elementary, 1–5 years; complete elementary, 6 years; incomplete secondary, 7–11 years; complete secondary, 12 years; and post-secondary, ≥13 years). The highest parental education level was the maximum achieved by the father or the mother. Food security in the household was defined as a negative answer to all questions in the survey. The number of home assets was determined as the sum of affirmative responses to owning a car, bicycle, refrigerator/freezer, gas stove, electric stove, blender, microwave, washing machine, colour television, sound set, computer or Internet. The sum was categorized into quartiles for analysis. Home ownership and mother's parity were reported on the background questionnaires. Parental smoking status was classified as never, past or current.

We used the median of replicate measures for each anthropometric indicator in the analyses[16]. Height was categorized into quartiles separately for men and women. BMI was calculated and categorized into normal (<25·0 kg/m^2), overweight (25·0–29·9 kg/m^2) or obese (≥30·0 kg/m^2) groups[17]. An underweight category (BMI < 18·5 kg/m^2) was not considered because there were very few adults below this value. In children, we estimated height-for-age and BMI-for-age *Z*-scores with the use of the WHO growth reference[18].

Definition of outcomes

Adults

The primary outcome of interest was the presence of metabolic syndrome according to the National Cholesterol Education Program's ATP III criteria[2]. Abdominal obesity was defined as WC > 102 cm in men or WC > 88 cm in women; high fasting glucose as ≥100 mg/dl; high blood pressure as systolic blood pressure ≥130 mmHg, diastolic blood pressure ≥85 mmHg or treatment with an antihypertensive drug; low HDL cholesterol as serum concentration <40 mg/dl in men or <50 mg/dl in women, or drug treatment for reduced HDL cholesterol; and high TAG as serum concentration ≥150 mg/dl or drug treatment for elevated TAG. Metabolic syndrome was defined as the presence of three or more of these criteria. In supplemental analyses, we also considered the harmonized definition of the metabolic syndrome by the International Diabetes Federation, the National Heart, Lung, and Blood Institute, the American Heart Association, the World Heart Federation, the International Atherosclerosis Society and the International Association for the Study of Obesity[19]. This definition differs from the ATP III's in that the recommended WC cut-off points for the abdominal obesity criterion are population-specific. For the Mesoamerican population, they are ≥90 cm in men and ≥ 80 cm in women.

Children

Because the metabolic syndrome is undefined in children <10 years old, we estimated a continuous metabolic score using values on the same criteria used in adults, as previously recommended[20]. We used the homeostasis model assessment of insulin resistance (HOMA-IR) as the measure of insulin resistance[21] and mean arterial pressure (MAP) as the blood pressure criterion. We first obtained sex- and age-standardized scores for WC, HOMA-IR, MAP, HDL cholesterol and serum TAG by performing the regression of the natural logarithmic transformation of each of these variables *v.* sex and log-transformed age with the use of linear regression models. The standardized regression residuals for WC, HOMA-IR,

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MAP and TAG, plus the HDL cholesterol residual multiplied by −1, were then averaged to create a metabolic risk score, where higher values reflect a worse metabolic profile.

Statistical analyses

All analyses were performed using the statistical software package SAS version 9.4.

Adults

In bivariate analyses, we compared the prevalence of individual ATP III criteria and metabolic syndrome across categories of each sociodemographic characteristic with use of the χ^2 test for nominal predictors and the Cochrane–Armitage test for trend for ordinal predictors. Prevalence ratios and 95% CI were obtained with the use of Poisson regression models in which metabolic syndrome was the dichotomous outcome while predictors included indicator variables for each sociodemographic characteristic. Adjusted prevalence ratios and 95% CI were estimated with use of multivariable Poisson regression. In these models, predictors included variables that remained significantly associated with metabolic syndrome at $P<0{\cdot}05$ or that were considered relevant from an explanatory viewpoint. Among women, models were adjusted for age, education and country; whereas among men they were adjusted for height, food security and country. BMI was not considered as a predictor because it is highly correlated with abdominal obesity, a component of the outcome variable. We conducted tests for linear trend for ordinal correlates by entering into the model a variable that represented ordinal categories of the characteristic as a continuous covariate.

Children

In bivariate analyses, we compared the distribution of the metabolic risk score across categories of each sociodemographic characteristic by estimating means and SD. Mean differences and 95% CI were estimated with use of linear regression models in which the metabolic score was the continuous outcome. Estimates were adjusted for age, height-for-age *Z*-score, maternal and paternal height, parental metabolic syndrome and country. Sex and age were not included in the models because the score is standardized by these characteristics. Robust estimates of variance were specified in each model to account for potential deviations from the multivariate normality assumption[22].

Results

Mean age of mothers, fathers and children was 37·0 (SD 6·3), 40·4 (SD 8·2) and 9·9 (SD 1·7) years, respectively. Of the children, 50·2% were girls. On average, the most highly educated parent in the household had 11·5 (SD 4·8) years of schooling. A majority (69·7%) of families owned their homes but 66·9% of the households were experiencing some degree of food insecurity. Mean BMI of mothers and fathers was 29·2 (SD 5·5) and 28·0 (SD 4·7) kg/m^2, respectively. In adults, the prevalence of obesity (BMI $\geq 30{\cdot}0$ kg/m^2) was 34·2%, whereas only 1·1% had underweight (BMI $<18{\cdot}5$ kg/m^2). These characteristics varied by country (see online supplementary material, Supplemental Table 1).

Metabolic syndrome in women

Among mothers, the prevalence of ATP III metabolic syndrome criteria for abdominal obesity, high fasting glucose, high blood pressure, low HDL cholesterol and high serum TAG was 70·0, 9·8, 15·4, 83·3 and 39·8%, respectively. Dyslipidaemia and insulin resistance were positively associated with age and inversely related to socio-economic status (SES) indicators including education level, number of home assets and food security (see online supplementary material, Supplemental Table 2). The prevalence of metabolic syndrome was 37·9%. In multivariable-adjusted analyses, metabolic syndrome was positively associated with age (Table 1); every year of age was related to an adjusted 2·2% higher prevalence (95% CI −0·1, 4·6%; $P=0{\cdot}06$). On the other hand, it was inversely associated with education level; compared with women with incomplete elementary schooling, those with complete secondary or post-secondary had a 56% ($P=0{\cdot}01$) and 40% ($P=0{\cdot}05$) lower adjusted prevalence, respectively. The prevalence varied by country, but these differences were not statistically significant. According to the harmonized metabolic syndrome definition[19], 90·6% of women had abdominal obesity and 44·3% had metabolic syndrome. The associations of sociodemographic characteristics with metabolic syndrome according to this definition (Supplemental Table 3) did not differ from those with the ATP III definition.

Metabolic syndrome in men

In the fathers, the prevalence of abdominal obesity, high fasting glucose, high blood pressure, low HDL cholesterol and high serum TAG was 24·1, 8·1, 29·4, 78·9 and 63·2%, respectively. Dyslipidaemia, insulin resistance and high blood pressure were positively related to SES indicators (see online supplementary material, Supplemental Table 4). The prevalence of metabolic syndrome was 35·3%. In multivariable analyses, metabolic syndrome was positively associated with age, height and food security (Table 2). Every year of age was related to an adjusted 2·6% higher prevalence (95% CI 0·6, 4·6%; $P=0{\cdot}01$). In addition, every centimetre in height was related to a 3·5% higher metabolic syndrome prevalence (95% CI 1·1, 5·9%; $P=0{\cdot}004$). Finally, food security in the household was associated with an adjusted 38% higher prevalence of metabolic syndrome in men ($P=0{\cdot}02$). Using the

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Table 1 Prevalence of metabolic syndrome according to sociodemographic characteristics in adult women from nine Mesoamerican countries, 2011–2013

Characteristic	*n**	Metabolic syndrome (%)	Unadjusted prevalence ratio†	95 % CI	Adjusted prevalence ratio‡	95 % CI
Age (years)						
<30	42	38·1	1·00		1·00	
30–34	57	28·1	0·74	0·42, 1·30	0·79	0·45, 1·38
35–39	89	38·2	1·00	0·63, 1·60	1·22	0·77, 1·94
40–44	48	41·7	1·09	0·66, 1·82	1·34	0·82, 2·21
≥45	28	50·0	1·31	0·77, 2·24	1·25	0·69, 2·25
P, trend§			0·14		0·10	
Education level						
Incomplete elementary	44	56·8	1·00		1·00	
Complete elementary	35	34·3	0·60	0·36, 1·02	0·71	0·41, 1·24
Incomplete secondary	67	43·3	0·76	0·52, 1·11	0·79	0·53, 1·19
Complete secondary	46	21·7	0·38	0·21, 0·70	0·44	0·23, 0·85
Post-secondary	64	28·1	0·50	0·31, 0·79	0·60	0·36, 1·00
P, trend			0·001		0·03	
Height quartile (median, cm)						
Q1 (148·9)	65	41·5	1·00		1·00	
Q2 (153·1)	67	29·9	0·72	0·45, 1·15	0·78	0·48, 1·26
Q3 (157·0)	68	41·2	0·99	0·66, 1·49	1·15	0·75, 1·77
Q4 (162·7)	64	39·1	0·94	0·62, 1·43	1·30	0·80, 2·10
P, trend			0·88		0·15	
BMI (kg/m^2)						
<25·0	63	11·1	1·00		1·00	
25·0–29·9	98	37·8	3·40	1·62, 7·15	4·03	1·91, 8·49
≥30·0	103	54·4	4·89	2·38, 10·06	6·29	3·06, 12·89
P, trend			<0·0001		<0·0001	
Parity						
1	20	35·0	1·00		1·00	
2	87	39·1	1·12	0·58, 2·14	1·07	0·53, 2·16
3	92	33·7	0·96	0·50, 1·87	0·85	0·44, 1·66
≥4	64	43·8	1·25	0·65, 2·42	0·76	0·38, 1·51
P, trend			0·58		0·13	
Smoking						
Never	216	37·0	1·00		1·00	
Past or current	47	40·4	1·09	0·74, 1·61	0·96	0·64, 1·43
P‖			0·66		0·83	
Home ownership						
Yes	185	39·5	1·00		1·00	
No	79	34·2	0·87	0·61, 1·23	0·82	0·57, 1·18
P			0·43		0·29	
Number of home assets¶						
0–4	49	46·9	1·00		1·00	
5–7	99	46·5	0·99	0·69, 1·43	1·17	0·79, 1·73
8–9	51	23·5	0·50	0·28, 0·89	0·76	0·41, 1·40
10–12	65	29·2	0·62	0·38, 1·01	0·96	0·49, 1·87
P, trend			0·007		0·56	
Household's food security						
Secure	87	33·3	1·00		1·00	
Insecure	176	39·8	1·19	0·84, 1·69	0·98	0·64, 1·50
P			0·32		0·92	
Country						
Guatemala	31	45·2	1·00		1·00	
El Salvador	29	44·8	0·99	0·57, 1·74	1·19	0·66, 2·14
Dominican Republic	30	36·7	0·81	0·44, 1·49	1·05	0·56, 1·99
Honduras	30	23·3	0·52	0·24, 1·10	0·70	0·31, 1·58
Nicaragua	31	54·8	1·21	0·73, 2·01	1·29	0·74, 2·23
Panama	26	15·4	0·34	0·13, 0·91	0·46	0·17, 1·29
Costa Rica	27	29·6	0·66	0·33, 1·32	0·71	0·34, 1·46
Mexico	31	38·7	0·86	0·48, 1·54	1·03	0·54, 1·94
Belize	29	48·3	1·07	0·62, 1·84	1·07	0·58, 1·95
P			0·03		0·37	

*Totals may be less than 267 due to missing values.
†From Poisson regression models with metabolic syndrome as the dichotomous outcome and indicator variables for each characteristic as predictors.
‡From multivariable Poisson regression adjusted for age, education level and country.
§Wald test for a variable representing ordinal categories of the predictor that was introduced into the model as continuous.
‖χ^2 score statistic.
¶From a list that included car, bicycle, refrigerator/freezer, gas stove, electric stove, blender, microwave, washing machine, colour television, sound set, computer and Internet.

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Table 2 Prevalence of metabolic syndrome according to sociodemographic characteristics in adult men from nine Mesoamerican countries, 2011–2013

Characteristic	*n**	Metabolic syndrome (%)	Unadjusted prevalence ratio†	95 % CI	Adjusted prevalence ratio‡	95 % CI
Age (years)						
<35	67	26·9	1·00		1·00	
35–39	75	30·7	1·14	0·68, 1·92	1·17	0·70, 1·96
40–44	58	51·7	1·93	1·21, 3·07	1·91	1·15, 3·18
45–54	44	36·4	1·35	0·78, 2·36	1·44	0·82, 2·52
≥55	16	31·3	1·16	0·51, 2·66	1·77	0·77, 4·09
P, trend§			0·12		0·03	
Education level						
Incomplete elementary	29	31·0	1·00		1·00	
Complete elementary	40	25·0	0·81	0·38, 1·73	0·81	0·39, 1·72
Incomplete secondary	87	37·9	1·22	0·67, 2·24	1·09	0·57, 2·09
Complete secondary	34	29·4	0·95	0·45, 2·01	0·81	0·36, 1·84
Post-secondary	67	43·3	1·39	0·76, 2·56	0·90	0·46, 1·77
P, trend			0·13		0·80	
Height quartile (median, cm)						
Q1 (159·0)	65	18·5	1·00		1·00	
Q2 (165·0)	66	33·3	1·81	0·98, 3·34	1·95	1·07, 3·55
Q3 (169·7)	65	44·6	2·42	1·36, 4·31	2·44	1·35, 4·41
Q4 (176·4)	65	44·6	2·42	1·36, 4·31	2·42	1·34, 4·38
P, trend			0·0005		0·002	
BMI (kg/m^2)						
<25·0	67	11·9	1·00		1·00	
25·0–29·9	118	28·0	2·34	1·15, 4·77	2·51	1·29, 4·86
≥30·0	76	67·1	5·62	2·88, 10·97	6·29	3·29, 12·00
P, trend			<0·0001		<0·0001	
Smoking						
Never	115	35·7	1·00		1·00	
Past	102	33·3	0·94	0·65, 1·35	1·22	0·83, 1·79
Current	43	39·5	1·11	0·71, 1·73	1·43	0·83, 2·44
P‖			0·78		0·39	
Home ownership						
Yes	182	36·3	1·00		1·00	
No	79	32·9	0·91	0·63, 1·31	0·91	0·64, 1·30
P			0·60		0·60	
Number of home assets¶						
0–4	48	25·0	1·00		1·00	
5–7	97	36·1	1·44	0·83, 2·52	1·48	0·83, 2·66
8–9	51	25·5	1·02	0·52, 2·01	0·93	0·46, 1·87
10–12	65	49·2	1·97	1·14, 3·41	1·52	0·75, 3·09
P, trend			0·03		0·58	
Household's food security						
Secure	86	47·7	1·00		1·00	
Insecure	174	29·3	0·61	0·45, 0·85	0·62	0·42, 0·91
P			0·003		0·02	
Country						
Guatemala	30	30·0	1·00		1·00	
El Salvador	29	24·1	0·80	0·35, 1·87	0·55	0·24, 1·25
Dominican Republic	30	50·0	1·67	0·87, 3·20	0·88	0·45, 1·72
Honduras	29	34·5	1·15	0·55, 2·41	0·66	0·32, 1·34
Nicaragua	31	38·7	1·29	0·64, 2·61	1·06	0·51, 2·18
Panama	26	34·6	1·15	0·54, 2·47	0·60	0·28, 1·28
Costa Rica	27	51·9	1·73	0·90, 3·33	0·79	0·38, 1·63
Mexico	31	35·5	1·18	0·57, 2·44	0·76	0·35, 1·68
Belize	28	17·9	0·60	0·23, 1·56	0·41	0·16, 1·02
P			0·15		0·30	

*Totals may be less than 267 due to missing values.
†From Poisson regression models with metabolic syndrome as the dichotomous outcome and indicator variables for each characteristic as predictors.
‡From multivariable Poisson regression adjusted for age, height, food security and country.
§Wald test for a variable representing ordinal categories of the predictor that was introduced into the model as continuous.
‖χ^2 score statistic.
¶From a list that included car, bicycle, refrigerator/freezer, gas stove, electric stove, blender, microwave, washing machine, colour television, sound set, computer and Internet.

harmonized definition of metabolic syndrome[19], the prevalence of abdominal obesity and metabolic syndrome was 67·2 and 55·2 %, respectively. The associations with sociodemographic characteristics (Supplemental Table 5) did not differ from those using the ATP III definition.

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Metabolic score in children

Mean age- and sex-standardized scores for WC, HOMA-IR and MAP were positively related to height-for-age and parental BMI and education level (see online supplementary material, Supplemental Table 6). WC was also positively associated with maternal height, the number of home assets and food security in the household. Each individual component of the metabolic score was positively related to having both parents with metabolic syndrome. Guatemalan and Mexican children had the highest scores for insulin resistance and dyslipidaemia, whereas Nicaraguan and Panamanian children had the highest scores for blood pressure. In multivariable-adjusted analyses, the overall metabolic score was positively associated with height-for-age (Table 3). Every *Z*-score in height was related to an adjusted 0·09 higher metabolic score (95% CI 0·07, 0·12; $P<0·0001$). By contrast, maternal and paternal height was each inversely related to the children's metabolic score. Also, children whose parents both had metabolic syndrome had an adjusted 0·17 higher metabolic score than children whose parents did not have metabolic syndrome ($P=0·0003$). Finally, the metabolic score differed substantially between countries. The lowest mean adjusted metabolic score was for children from Honduras, followed by those from El Salvador, Belize, Nicaragua and Panama. The highest was for children from Guatemala, followed by Mexico, Costa Rica and the Dominican Republic.

Discussion

In the nine Mesoamerican countries included in the present study, the overall prevalence of metabolic syndrome was 37·9% among women and 35·3% among men. It was positively related to age, regardless of sex. Metabolic syndrome was inversely associated with education level in women and positively related to food security and height in men.

Although the burden of the nutrition transition has not been characterized using the prevalence of metabolic syndrome, recent changes in the prevalence of obesity indicate that Latin America is transitioning rapidly. For example, women in Latin America have experienced one of the steepest relative percentage annual increases in obesity prevalence between 1990 and 2010: 11·4 and 6·2% in rural and urban areas, respectively[23]. These increases are not occurring homogeneously within the region. In our study, the prevalence of metabolic syndrome overall was substantially higher than the values reported for the Latin American region in a recent comprehensive review: 25·3% in women and 23·2% in men[4]. However, of the nine countries in our study only Mexico was included in the review. The prevalence estimate from a nationwide investigation in Mexico, 36·8%[8], was comparable to ours (38·7% in women and 35·5% in men). This provides indirect evidence of external validity to our results, even though they were not intended to be representative of each country. Compared with the estimates in other countries, our results suggest that the prevalence of metabolic syndrome in Mesoamerica may be higher than that in the rest of Latin America. This is consistent with previous estimates of the prevalence of obesity in women of reproductive age, which were substantially higher in Central America, 31·5%, compared with South America, 19·5%[24]. Even within Mesoamerica, the prevalence appears to vary substantially by country, although the sample sizes in our investigation were small to allow for robust statistical inference. These between-country and regional differences highlight the importance of identifying the aetiology of the metabolic syndrome in Mesoamerica. Although the differences may be due to chance given that our samples were not representative, they could also be explained by variability in the prevalence of risk factors. Indeed, we found that socio-demographic characteristics associated with the metabolic syndrome varied substantially by country. The most frequent component of the metabolic syndrome was low HDL cholesterol, in line with results from the review of Latin American data[4]. Nevertheless, the prevalence of low HDL cholesterol was much higher for Mesoamerica (83·3% in women and 78·9% in men) than for the rest of Latin America (62·9%).

Consistent with previous studies, the prevalence of metabolic syndrome was somewhat higher among women than men[6–8,25]. Also, the prevalence of some of the metabolic syndrome components varied by sex; whereas abdominal obesity was over twice as prevalent in women as in men, prevalences of high blood pressure and hypertriacylglycerolaemia were higher in men than in women. Hence, the aetiology of metabolic syndrome is likely to differ between sexes. There are some explanations for these differences; for example, childbearing is strongly involved in the aetiology of abdominal obesity[26] and androgens are implicated in the incidence of high blood pressure[27]. Additional research is warranted on the ways through which environmental exposures including diet and physical activity affect the risk of metabolic syndrome differently between Mesoamerican men and women. This variation may have relevant implications for the prevention and treatment of the metabolic syndrome, because different efforts would need to be targeted to the components that are more prevalent in each sex group.

We also found that the associations of the metabolic syndrome with SES indicators differed by sex. Whereas the prevalence of metabolic syndrome was inversely related to education level in women, in men it was positively associated with food security and height, two indicators of SES in low- and middle-income countries. The differential association with food security by sex could represent differences in the perception of this variable in men *v.* women, since both parents would share the same level of exposure. Nevertheless, it is also possible that the

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Table 3 Cardiometabolic score according to sociodemographic characteristics in children from nine Mesoamerican countries, 2011–2013

Characteristic	*n**	Metabolic score† Mean	SD	Unadjusted difference‡	95 % CI	Adjusted difference§	95 % CI
Height-for-age *Z*-score‖							
<–1	65	–0·08	0·18	–0·15	–0·23, –0·07	–0·22	–0·29, –0·15
–1 to <0	100	–0·04	0·21	–0·12	–0·19, –0·04	–0·14	–0·22, –0·07
0 to <1	65	0·08	0·25		Reference		Reference
≥1	37	0·14	0·20	0·06	–0·02, 0·15	0·08	–0·01, 0·17
P, trend¶					<0·0001		<0·0001
BMI-for-age *Z*-score‖							
<–1	38	–0·14	0·13	–0·10	–0·16, –0·04	–0·06	–0·12, 0·00
–1 to <0	58	–0·14	0·15	–0·10	–0·16, –0·04	–0·08	–0·13, –0·02
0 to <1	77	–0·04	0·18		Reference		Reference
≥1	94	0·18	0·21	0·22	0·16, 0·28	0·19	0·14, 0·25
P, trend					<0·0001		<0·0001
Mother's age at child's birth (years)							
<20	33	–0·05	0·20		Reference		Reference
20 to <25	61	0·03	0·20	0·08	–0·01, 0·17	0·06	–0·03, 0·14
25 to <30	98	0·00	0·23	0·05	–0·04, 0·14	0·03	–0·06, 0·11
30 to <35	48	0·03	0·24	0·08	–0·02, 0·18	0·01	–0·09, 0·10
≥35	27	–0·02	0·25	0·03	–0·09, 0·15	–0·06	–0·16, 0·05
P, trend					0·67		0·14
Mother's parity							
1	20	0·01	0·30		Reference		Reference
2	88	0·04	0·24	0·03	–0·12, 0·18	0·02	–0·11, 0·15
3	93	–0·01	0·22	–0·02	–0·18, 0·13	–0·03	–0·15, 0·10
≥4	65	–0·02	0·18	–0·03	–0·18, 0·12	0·02	–0·11, 0·14
P, trend					0·21		0·85
Mother's height quartile (median, cm)							
Q1 (148·8)	66	0·02	0·23		Reference		Reference
Q2 (153·1)	67	0·02	0·25	0·01	–0·08, 0·09	0·00	–0·07, 0·07
Q3 (157·0)	68	–0·02	0·22	–0·03	–0·11, 0·04	–0·07	–0·14, 0·00
Q4 (162·4)	66	–0·01	0·20	–0·03	–0·10, 0·05	–0·11	–0·19, –0·04
P, trend					0·35		0·0005
Mother's BMI (kg/m^2)							
<25·0	63	–0·03	0·21		Reference		Reference
25·0–29·9	100	–0·04	0·21	–0·02	–0·09, 0·05	0·00	–0·06, 0·07
≥30·0	104	0·07	0·24	0·09	0·02, 0·17	0·05	–0·02, 0·13
P, trend					0·003		0·12
Father's age at child's birth (years)							
<25	67	–0·03	0·20		Reference		Reference
25 to <30	71	0·02	0·24	0·05	–0·03, 0·13	0·01	–0·06, 0·08
30 to <35	63	0·02	0·21	0·05	–0·03, 0·12	0·02	–0·05, 0·10
≥35	60	0·02	0·25	0·05	–0·04, 0·13	–0·01	–0·08, 0·06
P, trend					0·29		0·90
Father's height quartile (median, cm)							
Q1 (159·0)	66	0·02	0·22		Reference		Reference
Q2 (165·0)	66	–0·05	0·22	–0·07	–0·15, 0·01	–0·07	–0·14, 0·00
Q3 (169·7)	65	0·05	0·24	0·02	–0·06, 0·11	–0·01	–0·08, 0·07
Q4 (176·4)	65	0·00	0·22	–0·03	–0·10, 0·05	–0·09	–0·17, –0·01
P, trend					0·91		0·16
Father's BMI (kg/m^2)							
<25·0	67	0·00	0·23		Reference		Reference
25·0–29·9	118	–0·03	0·21	–0·03	–0·10, 0·04	–0·05	–0·11, 0·02
≥30·0	77	0·05	0·24	0·05	–0·03, 0·13	0·00	–0·09, 0·09
P, trend					0·23		0·98
Highest parental education level							
Incomplete elementary	22	–0·04	0·20		Reference		Reference
Complete elementary	32	0·00	0·23	0·04	–0·09, 0·16	0·04	–0·07, 0·15
Incomplete secondary	71	0·02	0·21	0·06	–0·04, 0·16	0·03	–0·07, 0·13
Complete secondary	48	0·00	0·24	0·04	–0·07, 0·15	0·03	–0·09, 0·15
Post-secondary	94	0·01	0·23	0·05	–0·05, 0·14	0·02	–0·08, 0·12
P, trend					0·60		0·94
Parental smoking history							
Neither parent ever smoked	103	0·03	0·22		Reference		Reference
One parent ever smoked	125	0·00	0·23	–0·03	–0·10, 0·03	–0·06	–0·11, 0·00
Both parents ever smoked	32	–0·05	0·22	–0·08	–0·18, 0·01	–0·06	–0·15, 0·03
*P***					0·20		0·14

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Table 3 *Continued*

Characteristic	*n**	Metabolic score† Mean	SD	Unadjusted difference‡	95 % CI	Adjusted difference§	95 % CI
Parental metabolic syndrome							
Neither mother nor father	110	−0·06	0·21	Reference		Reference	
Mother only	58	0·01	0·21	0·07	0·00, 0·14	0·06	0·00, 0·12
Father only	52	0·01	0·22	0·06	−0·01, 0·13	0·03	−0·03, 0·10
Both mother and father	39	0·17	0·23	0·22	0·13, 0·31	0·17	0·08, 0·26
P				0·0005		0·01	
Home ownership							
Yes	186	−0·01	0·22	Reference		Reference	
No	81	0·03	0·24	0·03	−0·03, 0·10	0·04	−0·02, 0·10
P				0·35		0·16	
Number of home assets††							
0–4	49	−0·03	0·21	Reference		Reference	
5–7	100	0·04	0·22	0·06	−0·01, 0·14	0·04	−0·03, 0·10
8–9	52	−0·03	0·24	−0·01	−0·10, 0·09	0·02	−0·06, 0·10
10–12	66	0·01	0·23	0·03	−0·05, 0·12	0·00	−0·09, 0·08
P, trend				0·99		0·74	
Household's food security							
Secure	88	0·02	0·24	Reference		Reference	
Insecure	178	−0·01	0·22	−0·03	−0·09, 0·03	0·03	−0·02, 0·09
P				0·34		0·26	
Country							
Guatemala	31	0·06	0·20	Reference		Reference	
El Salvador	30	−0·04	0·26	−0·10	−0·21, 0·02	−0·13	−0·24, −0·02
Dominican Republic	30	0·06	0·20	0·00	−0·10, 0·10	−0·06	−0·17, 0·04
Honduras	30	−0·08	0·27	−0·14	−0·26, −0·02	−0·17	−0·28, −0·06
Nicaragua	31	0·00	0·17	−0·06	−0·15, 0·04	−0·10	−0·19, 0·00
Panama	26	−0·04	0·17	−0·09	−0·20, 0·01	−0·09	−0·20, 0·02
Costa Rica	27	0·02	0·25	−0·04	−0·17, 0·09	−0·05	−0·19, 0·08
Mexico	31	0·10	0·26	0·04	−0·08, 0·16	−0·03	−0·15, 0·09
Belize	31	−0·05	0·19	−0·11	−0·21, −0·01	−0·13	−0·23, −0·03
P				0·08		0·10	

WC, waist circumference; HOMA-IR, homeostasis model assessment of insulin resistance; MAP, mean arterial pressure.
*Totals may be less than 267 due to missing values.
†Sum of residuals from regression *v.* ln(age) and sex for ln(WC), ln(HOMA-IR), ln(MAP), −1 × [ln(HDL cholesterol)] and ln(serum TAG); divided by 5.
‡From linear regression models with the metabolic score as a continuous outcome and indicator variables for each characteristic as predictors. Empirical estimates of variance were used in all models.
§From multivariable linear regression adjusted for height-for-age, maternal height, paternal height, parental metabolic syndrome and country.
‖According to the WHO growth reference for children and adolescents[18].
¶Wald test for a variable representing ordinal categories of the predictor that was introduced into the model as continuous.
**χ^2 score statistic.
††From a list that included car, bicycle, refrigerator/freezer, gas stove, electric stove, blender, microwave, washing machine, colour television, sound set, computer and Internet.

mechanisms to cope with a household-level exposure differ between mothers and fathers. Previous studies have found that the burden of chronic disease shifts from the better-off towards groups of lower SES as countries undergo economic development[28–30]. This 'epidemiological transition' tends to occur first among women than among men[28,30]. Because the burden of the metabolic syndrome is currently greatest among the least educated women whereas in men it is still highest for those of food-secure households, our data indicate that the Mesoamerican region is at a relatively early stage of the transition. A similar pattern was reported for other Latin American countries in the past decade[6]. It is possible that, as these countries continue to develop, the burden of metabolic syndrome will shift to men of lower SES.

We found a strong association between the children's metabolic score and the presence of metabolic syndrome in their parents. This highlights the influence of genes and environment that are shared by families. It also provides indirect evidence of the internal validity of the score to rank children according to their metabolic risk. We did not find statistically significant associations between conventional SES indicators and the metabolic score in children. Nevertheless, parental height was inversely related to the metabolic score. Adult height is strongly, positively related to SES indicators in low- and middle-income countries[31] and could serve as a proxy for SES in this region since poverty affects linear growth[32]. Thus, the inverse association of parental height and the metabolic score could indicate that the burden of early risk factors for chronic disease in Mesoamerican children is disproportionately affecting those of the lowest SES. As the nutrition transition progresses, these groups may be experiencing greater exposure to lifestyles that increase chronic disease risk,

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including intake of processed foods and physical inactivity. The metabolic score was also related to the children's height-for-age but in a positive direction. Some evidence suggests that rapid linear growth early in life may be associated with the development of obesity later in childhood[33]. If rapidly growing infants become tall in middle childhood, this could explain the positive relationship between height-for-age and the metabolic score that we observed. Whether this association has a causal explanation remains to be determined. There was some between-country variability in the metabolic score of children. Although statistical power was limited, these differences suggest that there may be relevant country-level exposures contributing to the aetiology of early metabolic alterations which are not necessarily captured by variables measured at the individual or family level.

The study has a number of strengths, including the use of standardized methods to measure metabolic risk parameters across many countries where these data were not previously available. The design involving families allows the examination of study questions separately in adults and children. There are also some limitations. First, the cross-sectional design prevents the making of causal inferences. Second, the samples were not intended to be representative of any underlying population. This could result in selection bias if the probability of inclusion was not independent of the specific exposures and outcomes under study. It also hampers the generalizability of results. Third, although metabolic scores have been reported in studies of children and adolescents from Latin America[34–36], their absolute values cannot be compared with those from our study because the components used in their estimation differed and each study standardized the score to its own population. Using scores from log-transformed variables is advantageous from a statistical viewpoint but also limits the comparability of absolute values across populations. Because the score is standardized by age and sex according to the same population's distributions, it is not possible to examine its associations with these two variables. Finally, the relatively small sample sizes prevented country-specific analyses.

Conclusion

In conclusion, the prevalence of metabolic syndrome is high among adults of the Mesoamerican region. The metabolic syndrome is inversely related to SES indicators in women and children but positively in men. Additional research is warranted to characterize specific individual-, family- and country-level predictors of the metabolic syndrome in this region, including the effects of diet, energy balance, and exposure to environmental toxicants and the built environment. Inclusion of measures of the burden of metabolic syndrome in future nationally representative surveys is urgently needed.

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Supplementary material

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