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Examining Metabolic Syndrome Definitions in Overweight Hispanic Youth: A focus on insulin resistance

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Abstract

Objective—To examine the prevalence of the metabolic syndrome in overweight Hispanic youth according to three published pediatric definitions. Furthermore, the relationship of each definition to directly measured insulin resistance was examined.

Study design—Secondary data analysis of 218 overweight Hispanic youth with a family history of type 2 diabetes. The metabolic syndrome was defined as $\geq$ three of the following: elevated triglycerides, low HDL-cholesterol, elevated blood pressure, abdominal obesity, and hyperglycemia. The cut-points were derived from updated definitions of Cook et al(1), Cruz et al(2), and Weiss et al(3). Insulin sensitivity was determined via the insulin-modified frequently sampled intravenous glucose tolerance test.

Results—Prevalence of the metabolic syndrome ranged from 25.7% to 39% with moderate to substantial agreement between definitions ($\kappa=0.52-0.7$). Regardless of definition, an inverse relationship between metabolic risk and insulin sensitivity was noted such that children with the metabolic syndrome had 51–60% lower insulin sensitivity compared to those without any risk factors ($p \leq 0.001$ for all definitions).

Conclusion—The metabolic syndrome is prevalent in overweight Hispanic youth and may provide pediatricians with additional clinical insight for identifying the most metabolically at-risk children. Working towards a uniform and practical definition of the metabolic syndrome may improve its clinical implementation.

Keywords

Insulin resistance; Obesity; Child; Latino; Metabolic syndrome

The metabolic syndrome is a clustering of cardiovascular disease and type 2 diabetes risk factors which includes central obesity, hypertension, dyslipidemia, and glucose intolerance. (4) Collectively, these risk factors cluster around a common pathophysiology related to insulin

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resistance and thus may be an early indicator of chronic disease risk.(5) In adults, the metabolic syndrome is predictive of future diabetes, cardiovascular disease and all-cause mortality.(6) Although the predictive value of the metabolic syndrome has not been established in younger populations, evidence indicates that the individual risk factors in children track into adulthood.(7,8) Several recent reports have demonstrated that 30–50% of overweight youth exhibit the metabolic syndrome phenotype.(1-3) These estimates are suggestive of dramatically increased risk for long-term obesity-related health consequences in this population.

To this end, the American Academy of Pediatrics has identified the prevention of pediatric obesity and its metabolic co-morbidities as a critical priority for clinicians with the hopes of improving the current and future health status of overweight youth.(9) The pediatric growth charts have provided pediatricians and researchers with a standardized, population-based tool to assess for overweight and track adiposity changes over time.(10) Unlike the pediatric growth charts, there is no accepted reference for the metabolic syndrome in children. As such, clinicians and researchers are left with the challenge of how to appropriately ascertain the level of metabolic risk in overweight children with multiple cardiovascular disease and diabetes risk factors.

Our research group has previously examined the relationship between the metabolic syndrome and insulin sensitivity in overweight Hispanic youth.(2) We used age-appropriate cut-points to establish a pediatric definition of the metabolic syndrome based upon criteria from the National Cholesterol Education Panel Adult treatment Panel III (ATPIII).(4) Others have used varying pediatric cut-points of the ATP III definition to establish prevalence rates of the metabolic syndrome in adolescents(1) as well as its relationship to obesity.(3) However, comparing data across studies is problematic due to the lack of congruency between definitions. Recently, the National Institute of Child Health and Human Development sponsored a workshop to initiate dialogue amongst researchers and clinicians regarding a pediatric definition of the metabolic syndrome. Collectively the group was asked to analyze existing data cohorts against various published definitions of the metabolic syndrome in youth. Herein we summarize the data presented to the Pediatric Metabolic Syndrome Working Group where the purpose was: 1) to compare the prevalence of the metabolic syndrome phenotype using various published definitions and 2) to examine the association between the metabolic syndrome definitions and insulin sensitivity in a cohort of overweight Hispanic youth at extremely high risk for cardiovascular disease and type 2 diabetes.

METHODS

Participants

Data from 218 children from the University of Southern California (USC) SOLAR (Study of Latino Adolescents at Risk) Diabetes Project were analyzed. The study was designed to explore risk factors for the development of type 2 diabetes in at-risk youth.(11) Participants were recruited from the greater Los Angeles County through community health clinics, health fairs, and word of mouth. They were required to meet the following inclusion criteria at baseline: 1) Latino ethnicity (all four grandparents of Latino descent), 2) age 8–13 years; 3) a family history of type 2 diabetes (sibling, parent, or grandparent), and 4) age and sex BMI $\geq$ 85th percentile based on the standards of the Centers for Disease Control and Prevention. Children were excluded if they had a prior major illness, including type 1 or type 2 diabetes, took medications or had a condition known to influence body composition, insulin action, or insulin secretion. This study was approved by the USC Institutional Review Board. Written informed consent and assent were obtained from all parents and children prior to any testing procedures. Data from this cohort have been reported previously(2,12).

Protocol

Children arrived at the USC General Clinical Research Center (GCRC) in Los Angeles County Hospital at approximately 0800 h after an overnight fast. Physical maturation was assessed by a pediatrician according to the criteria of Marshall and Tanner.(13) Height was measured to the nearest 0.1 cm using a wall-mounted stadiometer and weight was measured to the nearest 0.1 kg using a medical balance beam scale. Subjects ingested 1.75 g of oral glucose solution / kg body weight (to a maximum of 75 g). Blood samples were taken via antecubital vein catheter for measurement of glucose before and 2 hours after glucose load.

At least 7 days after the initial visit, children were admitted for an overnight stay to the GCRC where they underwent a brief physical exam, completed body composition (see below), and anthropometric measures. At ~0730 h the following morning, flexible intravenous catheters were placed in both arms. Fasting blood was drawn for analysis of plasma lipids as well as insulin and glucose concentrations. At time zero, glucose (25% dextrose, 0.3 g/kg body weight) was administered intravenously. Blood samples were then collected at the following time points: 2, 4, 8, 19, 22, 30, 40, 50, 70, 100, and 180 min. Insulin [0.02 U/kg body weight; Humulin R (regular insulin for human injection; Eli Lilly, Indianapolis, IN)] was injected at 20 min. Plasma was analyzed for glucose and insulin and values were entered into the Minmod Millennium 2003 computer program (version 5.16) for determination of insulin sensitivity.

Anthropometry and Blood Pressure

Waist circumference (at the umbilicus) was recorded to the nearest 0.1 cm by a trained technician. Sitting blood pressure was measured on two separate days using the right arm after the subject had rested quietly for 5 min. On each occasion, three readings of blood pressure were obtained and the average of the 6 measures was recoded and used for analysis.(14)

Body Composition

Total body composition (fat mass and fat-free mass i.e. soft lean tissue mass) was determined by a whole-body dual-energy x-ray absorptiometry (DEXA) scan using a Hologic QDR 4500W (Bedford, MA).

Definition of the Metabolic Syndrome

In adults, the presence of the metabolic syndrome is defined as having at least three of the following risk factors: abdominal obesity measured via waist circumference, triglycerides ≥ 150 mg / dl, HDL-cholesterol < 40 mg / dl in men and < 50 mg / dl in women, blood pressure $\geq 130/85$ mm Hg, and a serum fasting glucose ≥ 100 mg / dl.(15) Three pediatric variations (Cook et al,(1) Cruz et al,(2) and Weiss et al(3)) based upon the ATP III definition were employed. All defined metabolic syndrome as 3 or more risk factors but incorporated different cut-points depending on age, sex, and ethnicity (Table I). The original manuscripts used either available pediatric criteria for each risk factors or in the case of Cook et al.(1) cut-points derived from the dataset. The original manuscripts were published in 2003 – 2004 and since that time, revised cut-points for several of the individual metabolic syndrome risk factors have been released. In order to incorporate the most up to date evidence, our analyses utilized current cut-points rather than what was available at the time of original publication. For example, Cook et al utilized a fasting glucose ≥ 110 mg/dl to define impaired fasting glucose (IFG). Since the original publication, the American Diabetes Association has redefined IFG as a fasting glucose ≥ 100 mg / dl,(16) thus the current value was used. Other notable updates included the Fourth Report on the Diagnosis, Evaluation, and Treatment of High Blood Pressure in Children and Adolescents,(14) as well as the publication of waist circumference percentiles in a nationally representative sample of children and adolescents.(17)

Assays

Blood samples taken during the oral glucose tolerance test were separated for plasma and immediately transported on ice to the Los Angeles County - USC Medical Center Core Laboratory where glucose was analyzed with a Dimension clinical chemistry system using the *in vitro* hexokinase method (Dade Behring, Deerfield, IL). During the overnight stay, fasting blood samples were taken and centrifuged immediately to obtain plasma and aliquots were frozen at -70°C until assayed. Fasting triglycerides and HDL cholesterol were measured using the Vitro chemistry DT slides (Johnson and Johnson Clinical Diagnostics Inc., Rochester, NY).

Statistics

Sex differences in physical and metabolic characteristics were examined using independent sample T-tests. Variables that were not normally distributed were log transformed (insulin sensitivity, total fat mass, total fat-free mass, BMI percentile, systolic blood pressure, diastolic blood pressure, waist circumference, triglycerides, HDL-cholesterol, and fasting glucose). Descriptive characteristics presented as untransformed data for ease of interpretation. Agreement among cut-points between definitions for prevalence of individual risk factors as well as the metabolic syndrome was examined using chi-squared analysis and Kappa statistics. Interpretation of Kappa scores were taken from Landis and Koch(18) and were as follows: 0–0.19 = poor agreement, 0.2–0.39 = fair agreement, 0.4–0.59 = moderate agreement, 0.6–0.79 = substantial agreement, and 0.8–1 = almost perfect agreement. Analysis of variance was used to establish differences in insulin sensitivity according to definition across children who exhibited zero, one, two, or $\geq$ three risk factors of the metabolic syndrome. Results are presented as estimated means $\pm$ standard error for insulin sensitivity. All analyses were performed using SPSS version 14.0 (SPSS Inc., Chicago, IL) with a type I error set at 0.05.

RESULTS

Physical and metabolic profiles of the children are presented in Table II. Girls had significantly lower fasting glucose levels and diastolic blood pressure but had significantly higher percent fat compared to boys. Data from both sexes were combined for further analyses.

The prevalence of the individual features of the metabolic syndrome by the three definitions is presented in Table III. In general, the definitions showed substantial to almost perfect agreement (Kappa statistic between 0.6 – 1). However, the measure of hyperglycemia from the Cook et al definition showed poor agreement (Kappa = 0.13) with both the Cruz et al and the Weiss et al definitions. Furthermore, the Cook et al definition of the metabolic syndrome (≥ 3 features) showed only moderate agreement with either the Cruz et al or Weiss et al definitions (both Kappa = 0.52). The Cruz et al definition of the metabolic syndrome and the Weiss et al definition showed substantial agreement with each other (Kappa = 0.7).

The Figure displays the mean insulin sensitivity $\pm$ SE according to the number of abnormal features for each definition. Regardless of definition, insulin sensitivity was significantly lower in children with either two or three abnormal features compared to those with zero features. Moreover, children with the metabolic syndrome (≥ 3 features) had very similar insulin sensitivity levels across the definitions (metabolic syndrome via Cook et al = 1.6 ± 0.15 , via Cruz et al = 1.6 ± 0.16 , via Weiss et al = $1.6 \pm 0.17 \times 10^{-4} \text{ min}^{-1}/\mu\text{U/ml}$).

DISCUSSION

Obesity has become the most prevalent chronic disorder affecting today's youth.(19) Furthermore, pediatricians are diagnosing and treating several obesity-related conditions (e.g., type 2 diabetes and dyslipidemia) that were once thought to be exclusively adult disorders.

Several recent reports have described a large proportion of overweight youth with multiple metabolic derangements in the form of the metabolic syndrome.(1-3) Unfortunately, variations in the definition and the cut-points employed have hindered comparison across studies. Our current findings suggest that despite differences in cut points, the three definitions examined have substantial to almost perfect agreement for most of the metabolic syndrome risk factors. However, when clustered together, the metabolic syndrome defined by Cook et al. only showed moderate agreement with either Cruz et al. or Weis et al. definitions ($\kappa = 0.52$). This is most likely a function of the poor agreement ($\kappa = 0.13$) noted between the IFG and IGT criteria for hyperglycemia. We did note that regardless of definition, children with the metabolic syndrome consistently had lower insulin sensitivity compared to those children void of any risk factor. Therefore, the metabolic syndrome may represent a useful clinical indicator of youth who are at greatest risk for the development of obesity-related chronic diseases such as cardiovascular disease and type 2 diabetes.

These findings are particularly interesting given our population which represents a comparatively understudied minority group with one of the highest lifetime risks for developing type 2 diabetes.(20) It is important to note that all of our participants had a family history of type 2 diabetes. Although we cannot determine the impact of family history on our results, others have shown that adults with a family history of type 2 diabetes are more likely to exhibit multiple metabolic risk factors. (21) Whether the same holds true for younger populations has not been determined.

Recent guidelines recommend that overweight youth undergo an in-depth medical evaluation for the metabolic co-morbidities associated with increasing levels of adiposity.(22) A comprehensive examination including a fasting blood draw would provide clinicians with sufficient information to identify youth with the metabolic syndrome and potentially refer these youth for appropriate care or counseling. However, a recent report showed that clinicians routinely fail to adequately screen for obesity in youth let alone the metabolic syndrome.(23) Perhaps the challenges of implementing current guidelines among pediatric providers is an indication that a complex algorithm for defining the metabolic syndrome is clinically impractical and is thus less likely to be executed.

The three definitions we examined represented varying levels of complexity. For example, all used an age, height, and sex adjusted cut-point for defining elevated blood pressure,(14) but only the Cruz et al. and Weiss et al. definitions utilized an age and sex adjusted cut-point for dyslipidemia (elevated triglycerides or low HDL-cholesterol).(24) Although Cook et al. used age and sex data to establish their criteria for dyslipidemia; they extrapolated those data to come up with a universal cut-point for all ages and both sexes (Table I). Perhaps the most dramatic difference between the definitions and arguably the cut-point that would be most difficult to implement in the clinic was the criteria for hyperglycemia. Both Cruz et al. and Weiss et al. defined hyperglycemia by impaired glucose tolerance (2-hour glucose ≥ 140 mg/dl)(16) and Cook et al used impaired fasting glucose. In order to ascertain whether a child has IGT, a provider must administer a 2-hour oral glucose tolerance test initiated under fasting conditions. Establishing IFG can be accomplished with a simple fasting glucose measure. Although very little is known about the metabolic differences in risk between youth with IGT and those with IFG,(25) we have previously shown that both forms of prediabetes (IFG and IGT) convey similar diabetes risk via reduced pancreatic beta cell function.(11,26) Given our findings that the metabolic syndrome (regardless of criteria) seemed to identify the most at-risk youth and the overwhelming need for clinicians to identify and track these youth, it stands to reason that a clinically practical definition of the syndrome be established (i.e. similar to that of Cook et al).

The epidemic of pediatric obesity and related metabolic disorders will dramatically impact the future of our healthcare system. Although longitudinal data are lacking, it is likely that a high proportion of youth with the metabolic syndrome will go on to develop cardiovascular disease and type 2 diabetes. In adults, lifestyle interventions have been shown to improve the metabolic syndrome phenotype(27) as well as prevent the progression from impaired glucose tolerance to frank type 2 diabetes.(28) A growing body of literature in the pediatric population suggests that similar improvements in cardiovascular disease and type 2 diabetes risk factors can be achieved via lifestyle modification.(29,30) Therefore, establishing a unified definition of the metabolic syndrome will allow clinicians to appropriately identify high-risk youth who may benefit from intensive therapeutic lifestyle modifications or pharmacologic treatments. Given that we have yet to determine all of the factors associated with increased disease risk in youth (e.g. obesity, insulin resistance, family history, physical activity, dietary intake, etc) and it is almost certainly multi-factorial in nature, it is likely that no one intervention may be ideal. Ultimately, the goal of a pediatric definition of the disorder may provide for improvements in the quality of care and eventual quality of life of overweight youth.

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Figure.

Insulin Sensitivity and the Metabolic Syndrome

Mean insulin sensitivity $\pm$ SE according to pediatric adaptations by a) Cruz et al, b) Weiss et al, and c) Cook et al of the ATP III definition of the metabolic syndrome in overweight Hispanic youth with 0, 1, 2, or ≥ 3 risk factors. Youth with 0 risk factors for each respective definition serve as reference for comparisons. * $P < 0.05$, † $P < 0.01$.

Table I**Metabolic Syndrome Definitions**

Feature	Cook et al	Cruz et al	Weiss et al
Elevated Triglycerides	≥ 110 (mg/dl)	$\geq 90^{\text{th}}$ % for Age and Sex ^A	$\geq 95^{\text{th}}$ % for Age, Sex, and Ethnicity ^A
Low HDL-cholesterol	≤ 40 (mg/dl)	$\leq 10^{\text{th}}$ % for Age and Sex ^A	$\leq 5^{\text{th}}$ % for Age, Sex, and Ethnicity ^A
Abdominal adiposity	$\geq 90^{\text{th}}$ % for Age and Sex ^B	$\geq 90^{\text{th}}$ % for Age Gender, and Ethnicity ^C	BMI-Z ≥ 2
Hyperglycemia	Impaired Fasting Glucose ^D	Impaired Glucose Tolerance	Impaired Glucose Tolerance
Elevated Blood Pressure	$\geq 90^{\text{th}}$ % for Age, Sex, and Height ^E	$\geq 90^{\text{th}}$ % for Age, Sex, and Height ^E	$\geq 95^{\text{th}}$ % for Age, Sex, and Height ^E

^A Hickman et al(24)

^B Cook et al used original dataset to define waist circumference cut-point

^C Cruz et al originally used unpublished data which has since been published. The published data has been used in the current manuscript.(17)

^D Cook et al originally used fasting glucose ≥ 110 mg/dl to define Impaired Fasting Glucose. The criteria for Impaired Fasting Glucose has been updated by the American Diabetes Association as a fasting glucose ≥ 100 mg/d.(16) The revised cut-point has been used.

^E All three variations for defining elevated blood pressure have been updated.(14)

Table II
Descriptive and Metabolic Characteristics of Sample

Characteristic	Boys	Girls	Total
n	123	95	218
Age (years)	11.2 ± 1.6	11 ± 1.8	11.1 ± 1.7
Height (cm)	149.5 ± 11	148.7 ± 11.7	149.3 ± 11.2
Weight (kg)	64 ± 18.9	63.6 ± 20.6	63.9 ± 19.6
BMI %ile	96.9 ± 4.4	96.7 ± 4.6	97.8 ± 4.5
Total Fat Mass (kg)	24.1 ± 10.2	25.6 ± 10.4	24.8 ± 10.3
Total Lean Tissue (kg)	37.6 ± 9.9	35.7 ± 10.4	36.7 ± 10.2
Percent Fat (%)	37.2 ± 6.9	39.9 ± 5.5 [†]	38.4 ± 6.5
Systolic BP (mmHg)	110 ± 10	110 ± 10	110 ± 10
Diastolic BP (mmHg)	64 ± 6	62 ± 5 [*]	63 ± 6
Triglycerides (mg/dl)	114.4 ± 66.7	99.6 ± 42.3	108 ± 57.9
HDL-cholesterol (mg/dl)	37.4 ± 8.8	37.8 ± 8.3	37.6 ± 8.6
Waist Circumference(cm)	88.9 ± 13.4	86.9 ± 13.8	88 ± 13.6
Fasting Glucose (mg/dl)	92.9 ± 6.3	89.8 ± 6.7 [†]	91.5 ± 6.6
2-Hour Glucose (mg/dl)	125.4 ± 17.4	128.3 ± 17.8	126.7 ± 17.6
Insulin Sensitivity (×10 ⁻⁴ min ⁻¹ /μU/ml)	2.2 ± 1.5	2.1 ± 1.5	2.1 ± 1.5

Data are Means ± SD

* P < 0.05

[†] P < 0.01

Table III
Prevalence of Metabolic Syndrome Phenotype by Definition

Feature	Cook et al	Cruz et al	Weiss et al	Average un-weighted kappa
Elevated Triglycerides (%)	85/218 (39%)	45/218 (20.6%)	53/218 (24.3%)	0.68
Low HDL-cholesterol (%)	145/218 (66.5%)	125/218 (57.3%)	132/218 (60.6%)	0.8
Abdominal adiposity (%)	157/218 (72%)	153/218 (70.2%)	138/218 (63.3%)	0.74
Hyperglycemia (%)	26/218 (11.9%)	55/218 (25.2%)	55/218 (25.2%)	0.42
Elevated Blood Pressure (%)	44/218 (20.1%)	44/218 (20.1%)	27/218 (12.4%)	0.86
Metabolic Syndrome ≥ 3 features (%)	85/218 (39%)	67/218 (30.7%)	56/218 (25.7%)	0.58