Distribution and Correlates of the Metabolic Syndrome in Adults Living in the San Juan Metropolitan Area of Puerto Rico

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Objective: This study evaluated correlates of the metabolic syndrome among adults living in Puerto Rico, a Hispanic subpopulation disproportionately affected by diabetes.

Methods: A probability cluster design was used to select a sample of households of the San Juan Metropolitan Area in Puerto Rico. A total of 858 persons aged 21–79 years completed a face-to-face interview, blood pressure and anthropometric measurements, blood sampling and spot urine. Logistic regression was employed to assess correlates of the metabolic syndrome.

Results: Of 368 (42.9%) of adults who met the criteria for metabolic syndrome, elevated fasting glucose (49.8%), abdominal obesity (48.6%), and reduced HDL cholesterol (45.8%) were the most prevalent diagnostic criteria. In a multivariable logistic model that simultaneously adjusted for sociodemographic characteristics and health behaviors, older age, high school educational attainment or less, no alcohol intake, and lack of moderate-to-vigorous physical activity remained significantly ($p<0.05$) associated to the metabolic syndrome. However, the associations for male gender, some college education, and current smoking ≥20 cigarettes/day had borderline significance. Further controlling for inflammatory markers slightly attenuated the strength of most of these associations but remained significantly ($p<0.05$) associated to the metabolic syndrome with only a few exceptions. Middle and upper tertiles of hs-CRP, fibrinogen, and PAI-1 and an elevated albumin-to-creatinine ratio were also associated ($p<0.05$) with the metabolic syndrome.

Conclusion: Enhancing public education regarding modifiable risk factors for the metabolic syndrome and providing optimal medical management of individual metabolic disturbances among those at risk through preventive lifestyle changes should be placed as a public health priority for Puerto Rico. [*P R Health Sci J 2012;3:114-122*]

Key words: Metabolic syndrome, Prevalence, Correlates, Puerto Rican population, Updated NCEP-ATP III

The metabolic syndrome, a clustering of risk factors which include abdominal obesity, atherogenic dyslipidemia, elevated blood pressure, and proinflammatory and prothrombotic states, confers additional risk for cardiovascular disease and type 2 diabetes (1). Using the revised National Cholesterol Education Program Adult Treatment Panel (NCEP-ATP) III criteria, the National Health and Nutrition Examination Survey (NHANES) 2003-2006 found that the age-standardized prevalence of the metabolic syndrome in the population 20 years and over in the United States (US) was 34.3%±1.2%, with Mexican Americans having the highest prevalence at 41.9%±2.0% (2). Despite the lack of a consensus definition for the metabolic syndrome in youth, the prevalence among adolescents aged 12-18 participants of the 1999-2006 NHANES ranged from 4% by the International Diabetes Federation criteria to 15.1% by the de Ferranti criteria (3).

A variety of factors may contribute to the different manifestations of the metabolic syndrome, including body fat distribution, insulin resistance, aging, physical inactivity, hormonal imbalance, and genetics (1, 4). Although the mechanisms underlying the metabolic syndrome are not

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fully understood, insulin resistance is a common feature of obesity and is considered to be an important link between adiposity and the associated risk of metabolic syndrome, type 2 diabetes, cardiovascular disease, and some types of cancers (1, 4, 5-7). Increasing evidence suggests that chronic, low-grade inflammation induced by adipocyte-secreted cytokines may be one of the underlying mechanisms of the metabolic syndrome, diabetes, and cardiovascular disease (5, 7).

Numerous studies have determined the prevalence of the metabolic syndrome and its risk factors in both developed and developing countries (2, 3, 8-12). In the US, the NHANES has been extensively used to document correlates of the metabolic syndrome across racial and ethnic subgroups including Whites, Blacks, and Mexican-Americans (2, 13, 14, 15). However, there are sparse data on the role of socio-demographic characteristics, health behaviors, and emerging cardiovascular risk factors on the metabolic syndrome among Hispanic subgroups in the US. Puerto Ricans, the second largest Hispanic subgroup in the US, are disproportionately affected by diabetes compared to other ethnic groups in the US (16, 17). In contrast, Hispanics in Puerto Rico and in the US have been reported to have a low incidence and mortality of coronary heart disease (CHD). For example, CHD prevalence was two-fold greater in Framingham than in Honolulu and Puerto Rico, whereas CHD incidence was from two to four times as high in Framingham as in Honolulu and Puerto Rico (18). However, data for Puerto Rico were derived from men participating in the Puerto Rican Heart Health Program conducted between 1965 and 1977, and recent cardiovascular disease research, albeit limited, shows that the prevalence of cardiovascular risk factors in Puerto Ricans has increased considerably (17, 19, 20).

Previously, our group conducted a population-based study in the San Juan Metropolitan Area of Puerto Rico and documented a high prevalence of the metabolic syndrome in the population aged 21-79 years (age-standardized prevalence: 38.1%, 95% CI: 35.0%–41.3%) (20). Our finding that nearly 85% of adults met at least one criteria of the metabolic syndrome suggests the widespread risk of developing metabolic syndrome and related disorders in Puerto Rico. However, assessment of potential correlates of the metabolic syndrome in our population remains to be elucidated. In-depth understanding of the factors associated to the metabolic syndrome is essential to design appropriate public health strategies to address disease risk in Puerto Rico. The present study examined correlates of the metabolic syndrome in a representative sample of adults living in the San Juan Metropolitan Area of Puerto Rico.

Research design and methods

Detailed description of the study design and recruitment has been published previously (20-22). In brief, a three-stage, cluster sampling design for household surveys was used to recruit adults aged 21-79 years who self-identified as Puerto Ricans living in the San Juan Metropolitan Area. Sample selection included a random selection of census block groups, followed by selection of one block per group, and finally all households within the randomly selected block segment. All eligible individuals were invited to undergo a personal interview, physical exam, and biochemical measurements. We identified 1,200 eligible adults, of which, 867 (72.3%) participated in the face-to-face interview, physical exam, and biochemical measurements. Nine participants were excluded because they had missing data needed to define the metabolic syndrome, thus the final analytic sample included 858 participants. They were instructed to fast for at least eight hours prior to attend their morning appointment in a mobile examination center located near their homes. Participants completed a face-to-face interview that covered socio-demographic characteristics, health behaviors, medical history, current medication use, and family history of various chronic diseases.

Definition of study variables

Age was used as a continuous variable as well categorized into three categories: 20-39, 40-59, and ≥60 years. Educational attainment was categorized as high school diploma or less, some college and college graduate or more, whereas annual household income from previous year was classified as <$20,000 and ≥$20,000. However, educational attainment was used as our primary indicator of socioeconomic status since it is stable, is available for all individuals regardless of employment status, and is useful across the age spectrum (23).

Participants were questioned about selected health behaviors. Participants were considered current smokers if they reported having smoked at least 100 cigarettes during their lifetime and were still smoking. Information on daily cigarette consumption was used to define the amount of cigarettes smoked per day (1–9, 10–19, ≥20) among current smokers. Former smokers were defined as those who had previously smoked at least 100 cigarettes in their lifetime and have stopped smoking. The remaining participants were classified as never smokers. Participants who reported no alcohol consumption in their lifetime or who had abstained in the past 30 days were defined as alcohol abstainers. Women consuming no more than one drink per day and men consuming no more than two drinks per day were classified as light-to-moderate alcohol consumers. Those individuals reporting number of drinks that exceeded the American Dietary Guidelines cutoff points were classified as heavy consumers. Respondents were classified as meeting national guidelines on physical activity if they indicated participation in moderate-intensity activities for a minimum of 30 minutes on five days per week or vigorous-intensity activity for a minimum of 20 minutes on three days per week.

The metabolic syndrome was defined based on the American Heart Association/National Heart, Lung, and Blood Institute (AHA/NHLBI) revised definition of the NCEP-ATP III report

(1). Participants who met at least three of the following five criteria had the metabolic syndrome: 1) abdominal obesity determined by elevated waist circumference (≥40 inches in men and ≥35 inches in women); 2) elevated triglyceride level (≥150 mg/dL) or on drug treatment for hypertriglyceridemia; 3) reduced high-density lipoprotein (HDL) cholesterol level (<40 mg/dL in men and <50 mg/dL in women) or on drug treatment for low HDL cholesterol; 4) elevated blood pressure (≥130 mm Hg systolic blood pressure or ≥85 mm Hg diastolic blood pressure) or antihypertensive drug treatment in a patient with a history of hypertension; and 5) elevated fasting glucose level (≥100 mg/dL) or on drug treatment for elevated glucose.

Waist circumference was determined with a measuring tape at the high point of the iliac crest at minimal respiration. A Cardinal Detecto digital scale (Cardinal/Detecto, Webb City, MO) was used to measure current body weight in kilograms, and a portable Seca stadiometer (Seca Corporation, Hanover, MD) was used to determine height in meters. Body mass index (BMI) categories were defined as underweight (<18.5 kg/m^2), normal (18.5-24.9 kg/m^2), overweight (25.0-29.9 kg/m^2), and obese (≥30.0 kg/m^2). Blood pressure was measured three times, at 10-minute intervals using an appropriate cuff size and a standard aneroid sphygmomanometer. Prior to the measurement, participants were asked to seat quietly in a chair for at least five minutes, with feet on the floor and arm supported at the chest level. Blood pressure status was based on the average of the three measurements. Self-reported information on physician-diagnosed hypertension and diabetes and their treatment regimens were collected.

Blood was drawn from an antecubital vein and was sent for analysis within four hours of blood collection. Concentrations of total cholesterol, triglycerides, HDL cholesterol, fasting plasma glucose, and hemoglobin A1c were determined using commercial enzymatic colorimetric kits (Bayer Diagnostics, Tarrytown, NY). Levels of low density lipoprotein (LDL) cholesterol were estimated indirectly using the Friedewald equation. A two site immunoassay for measuring human fibrinogen in plasma was used (DiaPharma Group Inc., West Chester, OH). Plasminogen activator inhibitor 1 (PAI-1) levels were determined by the use of Imubind enzyme-linked immunosorbent assay (American Diagnostica Inc., Stamford, CT). The high-sensitive C reactive protein (hs-CRP) was measured using the ultrasensitive assay (Kamiya Biomedical, Seattle, WA). A random untimed urine sample was also obtained from all participants to measure albumin and creatinine with a Bayer ADVIA® 1650 Chemistry analyzer (Bayer HealthCare, Tarrytown, NY). Elevated urinary albumin excretion was defined as an albumin-to-creatinine ratio of 30 mg/g or higher. The study was approved by the Institutional Review Board of the University of Puerto Rico Medical Sciences Campus, and written informed consent was given by all participants.

Statistical analysis

Continuous random variables that showed evidence of normal distribution were summarized in terms of arithmetic means and standard deviations, whereas those that had a skewed distribution were described in terms of their medians and 25th and 75th percentiles. Categorical variables were summarized with frequency distributions. Comparisons of proportions and means were based on chi-square and Student's t-test distributions, respectively; medians were contrasted with the use of Mann-Whitney-Wilcoxon test. Inflammatory markers were categorized by tertiles, and the lowest category was used as the reference group. Logistic regression models were used to examine the associations between socio-demographic characteristics, health behaviors and inflammatory markers and the binary outcome of metabolic syndrome by use of the prevalence odds ratio (POR) and 95% confidence intervals (95% CI). These analyses were based on three models. The first model estimated the crude prevalence odds ratio between individual characteristics and the presence of metabolic syndrome; the second model adjusted simultaneously for sociodemographic characteristics and health behaviors; and the third model additionally adjusted for inflammatory markers and albumin-to-creatinine ratio. Since the definition of the metabolic syndrome includes abdominal obesity as determined by waist circumference, BMI, a marker of overall adiposity, was excluded from the logistic regression models due to the significant positive correlation observed between BMI and waist circumference ($r=0.78$, $p<0.05$).

First-order interactions were assessed in the model with the use of the likelihood ratio test. Parameter estimation in this model was performed using the generalized estimating equations to control the intra-class correlation between subjects selected from the same household block (24). A sandwich estimate of variance was used to determine the standard errors of the logistic regression parameters (24). Extension of the Hosmer and Lemeshow goodness of fit test statistic indicated no evidence of lack of fit of the logistic models to the data ($p>0.10$). All statistical analyses were performed incorporating the sampling weights to obtain unbiased estimates from the complex sampling design using Stata for Windows release 11.0 (StataCorp, College Station, Texas).

Results

A total of 858 adults participated in the study, with a mean age of 49.4±16.1 years (Table 1). Over one-third of the participants were men, nearly 54% reported a secondary-level education or less, and more than two-thirds indicated an annual income below $20,000. Less than 40% of participants had ever smoked, 30.3% reported light-to-moderate or heavy alcohol consumption, 61.3% did not meet physical activity recommendations, and a significant proportion of adults were overweight or obese (79%) or had abdominal obesity (48.6%). Elevated fasting glucose,

abdominal obesity, and reduced HDL cholesterol were the most prevalent diagnostic criteria of the metabolic syndrome.

A total of 368 (42.9%) adults met the criteria for metabolic syndrome. Those with the metabolic syndrome were significantly ($p<0.05$) older and achieved less years of education than participants without the syndrome (Table 1). The metabolic syndrome was significantly ($p<0.05$) more common among former smokers, alcohol abstainers, and those who reported lack of moderate-to-vigorous physical activity. Mean values of BMI and waist circumference were significantly ($p<0.0001$) higher among individuals with the metabolic syndrome than those without the condition. These individuals also exhibited significantly ($p<0.05$) higher mean levels of systolic and diastolic blood pressures, fasting plasma glucose, hemoglobin A1c, total cholesterol, LDL cholesterol, and triglycerides; however, mean HDL cholesterol levels were significantly ($p<0.0001$) lower in subjects with the metabolic syndrome. Median levels of hs-CRP, fibrinogen, PAI-1, and albumin-to-creatinine ratio were also significantly ($p<0.001$) higher among individuals with the metabolic syndrome than among those without the syndrome.

Prevalence of the metabolic syndrome was significantly ($p<0.05$) higher among older individuals, those with lower educational attainment, former smokers, those who reported no alcohol intake or lack of moderate-to-vigorous physical activity, individuals classified in the middle and upper tertiles of hs-CRP, fibrinogen, and PAI-1, and subjects with an elevated albumin-to-creatinine ratio (Table

Table 1. Sociodemographic, health behaviors and clinical characteristics of 858 participants according to metabolic syndrome status

	Overall sample (n=858)	Metabolic syndrome present (n=368)	Metabolic syndrome absent (n=490)	P value
Sociodemographic characteristics				
Mean age, y	49.4±16.1	55.4±13.6	44.8±16.4	<0.0001
Male gender, %	34.4	36.4	32.9	0.28
Educational attainment, %				
High school or less	53.6	57.3	50.8	0.007
Some college	26.8	28.0	25.9	
College or more	19.6	14.7	23.3	
Annual income <$20,000, %	67.2	68.7	65.9	0.43
Lifestyle factors				
Tobacco use, %				
Never smokers	61.5	59.3	63.2	0.004
Former smokers	18.9	24.3	14.8	
Current smokers				
1-9 cigarettes/day	8.0	5.7	9.6	
10-19 cigarettes/day	5.5	4.6	6.2	
≥20 cigarettes/day	6.1	6.1	6.2	
Alcohol consumption, %				
None	69.7	77.2	64.1	<0.001
Light-to-moderate	10.1	6.5	12.9	
Heavy	20.2	16.3	23.0	
Lack of moderate-to-vigorous physical activity, %	61.3	69.0	55.5	<0.001
Clinical features				
BMI, kg/m^2	29.7±6.6	33.2±6.5	27.0±5.4	<0.0001
BMI, kg/m^2, %				
<25.0	21.0	4.9	33.5	<0.001
25.0-29.9	37.5	31.8	42.0	
≥30.0	41.5	63.3	24.5	
Waist circumference, inches	36.6±5.8	40.3±5.0	33.9±4.8	<0.0001
Increased waist circumference, %	48.6	80.7	24.5	<0.001
Systolic blood pressure, mm Hg	120.1±21.1	129.2±19.7	113.2±19.4	<0.0001
Diastolic blood pressure, mm Hg	73.0±11.1	77.5±11.2	69.6±9.8	<0.0001
Blood pressure ≥130/85 mm Hg, %	45.6	77.7	21.4	<0.001
Diagnosed hypertension, %	40.7	63.6	23.5	<0.001
Treatment for hypertension, %	29.7	52.5	12.7	<0.001
Fasting plasma glucose, mg/dL	113.4±48.3	136.0±64.3	96.4±17.5	<0.0001
Fasting glucose >100 mg/dL, %	49.8	84.8	23.5	<0.001
Hemoglobin A1c, %	6.3±1.5	7.0±2.0	5.8±0.8	<0.0001
Hemoglobin A1c ≥6.5%, %	23.4	43.3	8.4	<0.001
Diagnosed diabetes, %	15.9	29.9	5.3	<0.001
Treatment for diabetes, %	12.6	25.3	3.1	<0.001
Family history of diabetes, %	49.7	59.1	42.6	<0.001
Total cholesterol, mg/dL	191.3±43.7	199.4±49.1	185.1±38.0	<0.0001
HDL cholesterol, mg/dL	49.4±13.0	44.4±9.3	53.1±14.1	<0.0001
Reduced HDL cholesterol, %	45.8	66.6	30.2	<0.001
LDL cholesterol, mg/dL	117.5±39.1	123.2±44.7	113.3±33.8	0.0002
Triglycerides, mg/dL	141.7±106.5	186.3±112.2	108.4±88.4	<0.0001
Triglycerides ≥150 mg/dL, %	31.2	59.8	9.8	<0.001
Treatment for lipids, %	1.9	3.5	0.6	0.002
hs-CRP*, mg/L	0.3 (0.1, 0.7)	0.5 (0.2, 0.9)	0.2 (0.1, 0.4)	<0.001
Fibrinogen*, mg/L	316 (277, 365)	325 (290, 385)	308 (260, 350)	<0.001
PAI-1*, ng/L	7 (2, 18)	13 (5, 26)	4 (0, 11)	<0.001
Albumin:creatinine ratio, mg/g	8.9 (5.6, 16.4)	11.6 (6.8, 27.2)	7.7 (5.1, 12.3)	<0.001
Albumin:creatinine ratio≥30 mg/g, %	15.5	24.0	9.1	<0.001

BMI: body mass index; HDL: high density lipoprotein; LDL: low density lipoprotein; hs-CRP: high sensitive C reactive protein; PAI-1, plasminogen activator inhibitor 1. *Median (25th and 75th percentiles)

2). As expected, the prevalence of the metabolic syndrome increased significantly (p<0.05) with BMI (data not shown). While 22.8% of normal weight individuals had at least three components of the metabolic syndrome, 43.2% of overweight and 62.7% of obese individuals met the definition of metabolic syndrome.

In a multivariable logistic model that simultaneously adjusted for sociodemographic characteristics and health behaviors, older age (POR=3.91 for age group 40-59; POR=5.98 for age group 60-79), high school educational attainment or less (POR=1.93), no alcohol intake in the previous month (POR=1.95), and lack of moderate-to-vigorous physical activity (POR=1.55) remained significantly (p<0.05) associated to the metabolic syndrome (Table 2). However, the associations for male gender (POR=1.39), some college education (POR=1.57), and current smoking of at least 20 cigarettes/day (POR=2.10) had borderline significance (0.05≤p<0.10).

Further controlling for inflammatory markers and albumin-to-creatinine ratio only slightly attenuated the strength of most of these associations but remained significantly (p<0.05) associated to the metabolic syndrome with only a few exceptions. The associations with current smoking of at least 20 cigarettes/day and lack of moderate-to-vigorous physical activity were weakened and attenuated to non-significance. In contrast, the association for male gender strengthened toward a positive association and achieved statistical significance (POR=1.60, 95% CI: 1.09-2.37). This model also showed that the metabolic syndrome was significantly (p<0.05) associated with middle and upper tertiles of hs-CRP (POR=1.62 for middle tertile; POR=3.38 for upper tertile), fibrinogen (POR=1.79 for middle tertile; POR=1.80 for upper tertile), and PAI-1 (POR=2.04 for middle tertile; POR=6.32 for upper tertile), and an albumin-to-creatinine ratio ≥30 mg/g (POR=1.77).

Table 2. Prevalence and prevalence odds ratios of metabolic syndrome among 858 adults aged 21-79 years by selected characteristics: San Juan Metropolitan Area, Puerto Rico, 2005-2007

Characteristics	Unadjusted prevalence	Crude POR (95% CI)	Multivariable-adjusted POR (95% CI)*	Multivariable-adjusted POR (95% CI)†
Age, years				
21-39	19.4	1.00	1.00	1.00
40-59	50.6	3.94 (2.66-5.83)	3.91 (2.54-6.04)	3.06 (1.95-4.81)
60-79	56.9	5.01 (3.35-7.50)	5.98 (3.73-9.58)	4.15 (2.56-6.73)
Gender				
Female	41.6	1.00	1.00	1.00
Male	45.4	1.11 (0.83-1.49)	1.39 (0.95-2.02)	1.60 (1.09-2.37)
Educational attainment				
High school or less	45.9	2.12 (1.42-3.16)	1.93 (1.17-3.18)	1.90 (1.13-3.19)
Some college	44.8	1.80 (1.17-2.78)	1.57 (0.99-2.46)	1.55 (0.96-2.49)
College or more	32.1	1.00	1.00	1.00
Tobacco use				
Never smokers	41.4	1.00	1.00	1.00
Former smokers	55.3	1.74 (1.22-2.48)	1.38 (0.89-2.12)	1.30 (0.82-2.06)
Current smokers				
1-9 cigarettes/day	30.9	0.68 (0.40-1.17)	1.07 (0.55-2.08)	1.00 (0.50-1.97)
10-19 cigarettes/day	36.2	0.81 (0.44-1.50)	1.60 (0.76-3.39)	0.91 (0.40-2.09)
≥20 cigarettes/day	42.3	1.10 (0.62-1.96)	2.10 (0.95-4.65)	1.06 (0.50-2.28)
Alcohol intake, %				
None	47.5	2.49 (1.47-4.20)	1.95 (1.07-3.56)	1.96 (1.04-3.67)
Light-to-moderate	27.6	1.00	1.00	1.00
Heavy	34.7	1.37 (0.75-2.48)	1.12 (0.57-2.22)	0.97 (0.47-2.00)
Moderate-to-vigorous physical activity				
Yes	34.3	1.00	1.00	1.00
No	48.3	1.64 (1.22-2.20)	1.55 (1.10-2.18)	1.35 (0.94-1.93)
hs-CRP tertiles, mg/L				
1 (≤0.16)	22.8	1.00		1.00
2 (0.17-0.48)	43.2	2.37 (1.63-3.46)		1.62 (1.04-2.52)
3 (≥0.49)	62.7	5.61 (3.83-8.20)		3.38 (2.10-5.43)
Fibrinogen tertiles, mg/L				
1 (≤288)	30.1	1.00		1.00
2 (289-350)	44.8	1.97 (1.38-2.82)		1.79 (1.15-2.78)
3 (≥351)	56.0	3.03 (2.10-4.38)		1.80 (1.12-2.86)
PAI-1 tertiles, ng/mL				
1 (≤3)	24.5	1.00		1.00
2 (4-13)	42.0	2.21 (1.52-3.21)		2.04 (1.34-3.11)
3 (≥14)	65.9	6.21 (4.25-9.07)		6.32 (4.03-9.90)
Albumin-creatinine ratio, mg/g				
<30.0	38.5	1.00		1.00
≥30.0	66.4	3.06 (2.03-4.62)		1.77 (1.09-2.87)

hs-CRP: high sensitive C reactive protein; PAI-1, plasminogen activator inhibitor 1. *Indicates the POR of each variable after adjustment for sociodemographic characteristics and health behaviors. †Indicates the POR of each variable after adjustment for sociodemographic characteristics, health behaviors, inflammatory markers, and albumin-to-creatinine ratio.

Discussion

To the best of our knowledge, this is the first population-based study to describe the socio-demographic characteristics and selected health behaviors and inflammatory markers that are associated with the metabolic syndrome among adults residing in the San Juan Metropolitan Area of Puerto Rico. Our findings

align with those from other reports showing that older age, male gender, low educational attainment, smoking, no alcohol intake, lack of moderate-to-physical activity, elevated levels of hs-CRP, fibrinogen, and PAI-1, and elevated albumin-to-creatinine ratio are associated with the metabolic syndrome (2, 8-15).

As expected, the adjusted odds of metabolic syndrome in this study increased steeply with age, which is consistent with previous studies (2, 9-15, 25). Aging is associated with increased risk for insulin resistance, other hormonal alterations, and increase in visceral adipose tissue, affecting multiple components of the metabolic syndrome. Although the effect of gender on the metabolic syndrome is not consistent throughout studies (2, 10, 12, 14, 25-27), male participants in our study had a higher adjusted odds of metabolic syndrome, possibly reflecting the greater age-adjusted prevalence of elevated blood pressure, triglycerides, and fasting glucose among Puerto Rican men as compared to women (20). Educational attainment, an individual-level marker of socioeconomic status, was also associated with the metabolic syndrome, a finding consistent with other studies that suggest that socioeconomic disadvantage early in life and across the life course influences the risk of the metabolic syndrome (28). In our study sample, participants with lower educational attainment had a greater prevalence of physical inactivity, alcohol abstinence, tobacco use, and overweight and obesity, behaviors that could affect parameters of the metabolic syndrome. More research is needed to identify factors that mediate socioeconomic differences in the metabolic syndrome, especially in Puerto Rico, where an estimated 44.8% of our population had an income below the poverty threshold during 2007 (29).

Several cross-sectional and prospective studies have found a high burden of metabolic syndrome among current and ex-smokers; however, conflicting evidence also exists (2 ,9, 11-13, 25, 30-32). In this study, current smokers who used at least 20 cigarettes per day had a marginally significant higher odds of metabolic syndrome compared to never smokers. The higher triglyceride levels and lower HDL cholesterol observed among current smokers who used at least 20 cigarettes per day might partially explain this observation rather than the presence of abdominal obesity, high blood pressure, or abnormal fasting glucose, a finding consistent with a previous publication by our group (22). Thus, health-care providers should strongly provide smoking cessation advice to reduce the harmful effects of tobacco use on overall health. Interventions among former and current smokers should be intensified to reduce their risk of metabolic syndrome, especially by encouraging weight management and physical activity, whereas counseling and medication should be considered among individuals willing to quit smoking.

Although the proposed mechanism is still a matter of research, light to moderate alcohol intake has been inversely associated to the metabolic syndrome, probably due to improvements in HDL cholesterol and increases in insulin sensitivity (34-36). In our study, the prevalence odds for the metabolic syndrome among participants who abstained from alcohol relative to light-to-moderate drinkers was elevated, a finding consistent with several cross-sectional and longitudinal studies (9, 13, 33-36). However, we failed to show a positive association with heavy alcohol intake. It is plausible that the absence of an association between heavy alcohol intake and metabolic syndrome could be attributable to the limited number of participants who were classified into the heavy alcohol consumption category. Other potential explanations include exposure misclassification due to the self-report nature of alcohol consumption and the potential for uncontrolled confounding. In view of the large percentage (20.2%) of participants who reported alcohol consumption in excess of the U.S. dietary guidelines, public health messages should emphasize the potential risks associated with heavy drinking in excess of national guidelines and focus on limiting alcohol consumption to light-to-moderate amounts among those who drink alcohol.

This study found that lack of moderate-to-vigorous physical activity significantly increased the odds of metabolic syndrome independently of age, sex, education, smoking, and alcohol intake. Participants who reported lack of moderate-to-vigorous physical activity had significantly higher BMI, waist circumference, triglycerides, and blood pressure levels. This finding is consistent with previous epidemiologic studies showing the beneficial effects of increased physical activity on visceral adipose tissue loss, insulin sensitivity, HDL cholesterol, triglycerides, and blood pressure, which in turn, would be expected to reduce the metabolic syndrome and related sequelae (9-11, 13, 14, 30, 37, 38). Attenuation of the observed association by inflammatory markers suggests that inflammation is an important mediator of the benefit conferred by moderate and vigorous physical activity on the metabolic syndrome. Since nearly two-thirds of our study population did not meet physical activity recommendations and a large proportion had either general (79%) or abdominal (49%) adiposity, public health interventions approaches at the individual, community, and environmental levels that promote regular physical activity and reduce sedentary behaviors are necessary to improve metabolic health, especially in the least active individuals.

In agreement with previous studies, upper tertiles of hs-CRP, fibrinogen, and PAI-1 were independently associated to the metabolic syndrome in this population (2, 39, 40). CRP, a biomarker of low grade inflammation, is a predictor of incident cardiovascular disease and correlates with several metabolic syndrome components, particularly with obesity (2, 5, 7, 10, 15, 39, 41, 42). On the other hand, coagulation products, such as PAI-1 and fibrinogen, have been found elevated in individuals with the metabolic syndrome, especially those who are obese or diagnosed with atherosclerosis and type 2

diabetes (2, 40-42). Obesity is the critical determinant that leads to insulin resistance in the metabolic syndrome. Adipose tissue cells function as endocrine glands producing a variety of molecules and substrates including cytokines and free fatty acids that allows this tissue to influence energy balance and glucose homeostasis (7). These substrates are considered to play a role in decreased insulin stimulated glucose transport and metabolism in adipocytes and skeletal muscle and may also promote an impaired suppression of hepatic glucose output (42). Adipose tissue contributes to inflammatory process in vascular and nonvascular tissue in overweight subjects since these cells release pro-inflammatory (such as CRP, TNFα, IL-6, IL-1β, and IL-18) and pro-coagulant (such as PAI-1, fibrinogen, and P selectin) mediators with local and systemic effect promoting development of atherosclerosis and increasing the risk of plaque rupture and thrombosis that leads to vascular events (41, 42). Studies have found associations of treatment with statins with reductions in cardiovascular events in individuals with elevated CRP even without elevated baseline LDL cholesterol levels. Measurement of some of these biomarkers as supplemental tools to assess cardiovascular risk in subjects with the metabolic syndrome in the clinical setting awaits further evidence.

Finally, our finding on the strong association between an elevated albumin-to-creatinine ratio and the metabolic syndrome is in line with previous studies (1, 2, 8, 43, 44); this association might partially be explained by the higher prevalence of elevated urinary albumin excretion among individuals with elevated blood pressure and blood glucose. Chen and colleagues showed that microalbuminuria was significantly associated with the metabolic syndrome and its individual components, and the odds for microalbuminuria increased with the number of components (44). Reductions in urinary albumin-to-creatinine ratio with appropriate interventions and treatment for hypertension and diabetes reduce the risk for cardiovascular mortality, stroke, and myocardial infarction. Taken this into consideration, monitoring of urinary albumin-to-creatinine ratio during treatment for hypertension and diabetes should be an integrated part of patient management and risk reduction.

Limitations to the current study should be acknowledged. First, self-reported lifestyles may be subject to recall bias. Any misclassification of lifestyles' categories may have tended to dilute the associations between these and metabolic syndrome. Although the prevalence of lifestyles in this study was similar to estimates yielded by other large-scale epidemiological surveys conducted in the island, detailed information on daily patterns of tobacco use, alcohol consumption, physical activity, and nutrient intake was not available and limited our ability to assess the complex relation among these factors. Thus, the possibility of residual confounding due to measurement error resulting from broad categorization of these variables cannot be excluded. In addition, the small sample size within relevant subgroups limited our ability to detect some associations of interest. Because of the cross-sectional design of our study, the associations observed in this study cannot be established to be causal in nature. However, appropriate analysis of cross-sectional data represents a useful initial step in identifying correlates of the metabolic syndrome. Since our study was restricted to the San Juan Metropolitan Area, caution should be exercised when generalizing the results to the overall population of Puerto Rico. These limitations must be balanced against the strengths of this study, which include a random, population-based study of a Hispanic subgroup across a broad age range, an adequate response rate, precise methods used for assays and body composition measurements, extensive data from the face-to-face interview in both men and women aged 21-79 years and biological plausibility with most of the findings.

In conclusion, this cross-sectional data showed that socio-demographic characteristic, selected lifestyles and biochemical parameters correlate significantly with the metabolic syndrome in this population. Enhancing public education regarding modifiable risk factors for the metabolic syndrome and providing optimal medical management of individual metabolic disturbances among those at risk through preventive lifestyle changes including weight reduction and maintenance, physical activity, and smoking cessation, should be placed as a public health priority for Puerto Rico.

Resumen

Objetivo: Este estudio evaluó características asociadas al síndrome metabólico en adultos residentes en Puerto Rico, un subgrupo hispano afectado desproporcionalmente por la diabetes. Métodos: Se utilizó un diseño de muestreo por conglomerados para seleccionar una muestra de viviendas en el área metropolitana de San Juan, Puerto Rico. Un total de 858 personas entre las edades de 21 y 79 años completaron una entrevista personal y mediciones de presión arterial y antropométricas y proveyeron muestras de sangre y de orina. La evaluación de características asociadas al síndrome metabólico se realizó mediante modelos de regresión logística. Resultados: De 368 (42.9%) adultos que cumplieron con los criterios del síndrome metabólico, la azúcar elevada en ayuna (49.8%), la obesidad abdominal (48.6%), y las lipoproteínas de alta densidad reducidas (45.8%) fueron los criterios diagnósticos más prevalentes. En el modelo de regresión logística que controló simultáneamente por características sociodemográficas y conductuales, las variables edad, educación secundaria o menor nivel, y la ausencia de consumo de alcohol y actividad física moderada-vigorosa se asociaron significativamente ($p<0.05$) con el síndrome metabólico. Sin embargo, las asociaciones con el género masculino, algunos años de educación pos-secundaria y hábito de fumar alcanzaron significancia marginal. El control

adicional de marcadores de inflamación en el modelo de regresión redujo la fuerza de asociación de la mayoría de estas asociaciones pero retuvieron la significancia estadística con algunas excepciones. Niveles elevados de proteína C reactiva de alta sensibilidad, fibrinógeno, e inhibidor del activador del plasminógeno 1, y la excreción urinaria de albúmina elevada se asociaron significativamente ($p<0.05$) con el síndrome metabólico. Conclusión: La educación al público sobre los factores de riesgo modificables para el síndrome metabólico y el manejo óptimo de los disturbios metabólicos en individuos de alto riesgo mediante la adopción de estilos de vida saludables deben considerarse áreas de prioridad de la salud pública en Puerto Rico.

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