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A Structural Model of Social Determinants of the Metabolic Syndrome

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Objectives: The metabolic syndrome (MetS) refers to a cluster of interrelated physiological characteristics that are associated with an increased risk of cardiovascular disease and diabetes. While the clinical usefulness of the MetS has been the subject of controversy for years, increasingly sophisticated methods are being used to measure the concept.

Participants: Study of community health center patients who were not diabetic; study group was evenly divided between Black and White adults.

Methods: Structural equation modeling of MetS incorporating the effects of race/ethnicity, racial discrimination, socioeconomic position (SEP), and selected mediating variables.

Main Outcome Measure: Latent MetS score and MetS status based on the five-point scale developed by the National Cholesterol Education Panel (NCEP).

Results: The largest influences on latent MetS scores were SEP (negative relationship) and male gender (higher scores for men). Two mediating variables, physical activity and stress-related eating, had smaller impacts. Self-reported racial discrimination was associated with cynical hostility but did not influence the MetS level among non-diabetics. Despite higher NCEP scores and MetS prevalence rates for Blacks compared with Whites, race did not have direct effect on MetS levels when adjusted for the other characteristics in our model.

Conclusions: Neither race nor self-reported racial discrimination had direct effects on MetS level in our structural model. The large effects of socioeconomic position and male gender were not mediated by the other variables in the model. *Ethn Dis*. 2020;30(2):331-338; doi:10.18865/ed.30.2.331

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Introduction

The metabolic syndrome (MetS) refers to a cluster of interrelated physiologic characteristics encompassing obesity, insulin resistance, dyslipidemia, and elevated blood pressure. A meta-analysis of 87 studies showed that the MetS is associated with a more than 2-fold increased risk of cardiovascular disease and other cardiovascular outcomes.[1-3] Components of the syndrome are also associated with an increased incidence of diabetes.[4] However, the pathophysiological pathways underlying the syndrome have not been clearly established and some authorities question whether the MetS is more useful than conventional risk factors for predicting and clinically managing cardiovascular disease risk.[5] In the midst of this controversy, the MetS concept continues to evolve.[6]

In the United States, the MetS is most often measured according to the 2003 protocol specified by the National Cholesterol Education Program's Adult Treatment Panel III (NCES/ATP III).[7] The NCEP algorithm establishes threshold values for five physiologic characteristics: waist circumference, triglycerides, HDL-C, systolic blood pressure, and fasting plasma glucose. Patients are assigned one point for each threshold they exceed, producing total scores that may range from zero to five points. Patients are considered to be positive for MetS if their scores are 3 points or higher. While the NCEP protocol is typically used to define prevalent

cases of MetS, the scoring approach has been questioned because research typically indicates that there are no empirically observed threshold effects for the components of the syndrome.[8]

One of the methodological advances made in the last decade has been the application of more sophisticated multivariable techniques to the study of the MetS. In particular, several investigators have used factor analysis in an attempt to clarify the underlying structure of the MetS components. Early studies focused on whether the syndrome should be considered to be multi-factorial or just one factor. Across many different populations and subgroups, this work appears to have converged on a consensus that the syndrome is characterized by a single higher-order MetS latent variable defined by four distinct factors for obesity, lipid factors, insulin resistance, and blood pressure.[9-12] This structure has been found to be consistent across gender and ethnic/racial groups.[10]

While factor analysis is helpful for establishing a latent outcome, little work has been done to place this measurement model in the context of a broader structural model that traces the pathways leading to the MetS construct. The existing studies tend to be narrowly focused on pathogenic mechanisms involving genetics, hormones, oxidative stress, or inflammation processes. A comprehensive model that encompasses social determinants, physiologic, and psychological processes has been lacking. In particular, a recent review has pointed to a paucity of multivariate research regarding the effects of race/ethnicity and socioeconomic position.[6]

In this article, we estimate a structural equation model of the MetS that was designed to address two objectives. Our first objective was to assess the impact of social determinants on syndrome scores and the extent to which effects were mediated by other characteristics. Capitalizing on our unique survey data for a diverse multi-ethnic population, our second objective was to determine the impact of race/ethnicity and racial discrimination on MetS levels.

Methods

Study Participants

Study subjects were recruited between 2008 and 2010 from a random sample of the members of four community health centers (CHCs) in Boston, Mass. for My Body My Story (MBMS), an observational study focused on racial discrimination and risk of chronic disease.[13] Using rosters compiled by each center, a sample of CHC members were initially sent an invitation letter and then screened for eligibility by telephone. Eligibility was restricted to those aged 35 to 64 years who self-identified as US-born and either non-Hispanic Black or White.

Study Protocol

Study participants were interviewed at the health centers using surveys administered by Audio Computer-Assisted Self-Interviewing. The protocol included a physical exam to collect anthropometric and blood pressure data, and a finger stick to collect a blood sample. Details regarding the 75-minute protocol have been published previously.[13] Respondents received a $75 grocery card and a resource booklet that included their physiological measurements. All recruitment and interviewing procedures were approved by the Harvard School of Public Health Office of Human Research Administration and by one health center institutional review board, which did not have a reciprocal agreement with Harvard.

Measures

The primary outcome, the MetS level, was measured as a latent variable derived by factor analysis of seven physiologic indicators. We also computed NCEP/ATP III scores for each respondent.

Two approaches were used to measure exposure to racial discrimination: Explicit discrimination was a latent variable measured by two widely used self-report measures, the Experiences of Discrimination[14] and Everyday Discrimination[15] scales. Implicit discrimination was measured using the computer-administered Implicit Association Test (IAT).[16] The IAT measures how quickly respondents link images that pertain to themselves or their group to images of targets or perpetrators of racial discrimination. We recorded reaction times in milliseconds in two scenarios: Black vs White and me vs them. For both measures, longer differences in reaction times indicate that participants feel more like targets than perpetrators. The IAT measures perceptions of discrimination that are not captured by the explicit self-report measures. Social desirability (the tendency to provide socially acceptable answers during interactions with interviewers) was included to assess potential

Table 1. Measures used in structural equation model

Construct	Measure	Metric	Source
MetS indicator	Fasting glucose	in, mg/dL	Laboratory analysis
MetS indicator	Body mass index (BMI)	kg/m^2	Physical exam
MetS indicator	Waist circumference	cm	Physical exam
MetS indicator	HDL	mg/dL	Laboratory analysis using Cholestech LDX
MetS indicator	Triglycerides	in, mg/dL	Laboratory analysis using Cholestech LDX
MetS indicator	Systolic blood pressure (SBP)	mm Hg	Physical exam
MetS indicator	Diastolic blood pressure (DBP)	mm Hg	Physical exam
MetS	NCEP/ATP III score	Count of 5 thresholds exceeded	Ref. 7
Diabetes	Diabetes status	0=no, 1=yes (affirmative response to told by doctor or elevated glucose or glucose medications)	Self-report
Explicit discrimination	Experience of Discrimination scale (EOD; lifetime)	9 situations; 0-9	Ref. 14
Explicit discrimination	Everyday Discrimination Scale (EDS; race)	5 items; 0-5 (unfair treatment due to race)	Ref. 15
Implicit discrimination	IAT-Me vs Them (IAT-M/T)	Detrended and centered difference in target vs perpetrator matching speed (msec)	Implicit Association Test; ref. 16
Implicit discrimination	IAT-Black vs White (IAT-B/W)	Detrended and centered difference in target vs perpetrator matching speed (msec)	Implicit Association Test; ref. 16
Hostility	Cynicism-related items from Cook Medley Hostility Scale	12 items; 2 forced choice options per item	Ref. 18
Stress-related eating problems	Emotion-and Stress-Related Eating scale (ESRE)	5 Likert items; range = 5-25	Ref. 22
Physical activity	International Physical Activity Questionnaire (short form)	Metabolic equivalents/week	Ref. 24
Social desirability	RAND social desirability scale	5 items; 0-100	Ref. 17.
Socioeconomic position (SEP)	Annual household income	USD; in thousands	Self-report
Socioeconomic position (SEP)	Highest grade completed	in years (10-20)	Self-report
Race/ethnicity	Racial/ethnic group	0=White, 1=Black	Self-report
Gender	Gender	0=female, 1=male	Self-report
Age	Age at time of interview	In years; range=35-64	Self-report

bias in self-reports.[17] Age, gender, race/ethnicity, and socioeconomic position (a latent variable measured by household income and educational attainment) served as covariates.

Three variables that might mediate the relationship between social determinants and MetS were examined. Cynical hostility, measured by a modified 12-item version of the Cook-Medley Hostility scale,[18] has been found to be a leading psychological risk factor for MetS in several studies.[19-21] The Emotion and Stress-Related Eating (ESRE) scale[22] is an indicator of stress reactions. Johnson et al[23] have previously reported that emotional eating behavior was correlated with self-reported racial discrimination in a sample of African American women. A low level of physical activity is a common risk factor for cardiovascular events. It was measured in the MBMS survey by the short form of the International Physical Activity Questionnaire.[24] The measurement of each variable in our model is defined in Table 1.

Statistical Analyses

The prevalence of missing survey responses was <5% for nearly all variables in our model. The only measure with a missingness rate >5% was household income (9.6%). Missing data for a small percentage of respondents were estimated using the multiple imputation algorithm from the Amelia II program[25] which assumes that data are missing at random. Relationships among the study variables were estimated as a structural equation model us-

Table 2. Variable means and (standard deviations) by race/ethnicity, participants without diabetes only, My Body My Story (Boston, Mass., 2008-2010)

Measure	Black, N=391	White, N=426	P
Fasting glucose, in	4.58 (.19)	4.57 (.14)	.366
Body nass index [BMI][a]	31.5 2(7.72)	28.43 (6.37)	.000
Waist circumference[a]	101.9 (15.3)	97.9 (14.5)	.000
HDL	50.7 (16.1)	50.4 (16.5)	.784
Triglycerides, ln[c]	4.63 (.67)	4.72 (.57)	.038
Systolic blood pressure [SBP] [a]	130.5 (15.7)	124.3 (16.0)	.000
Diastolic blood pressure [DBP] [a]	83.2 (10.8)	79.3 (10.3)	.000
NCEP/ATP III score[b]	2.49 (1.29)	2.16 (1.41)	.001
Experience of Discrimination scale [EOD], lifetime [a]	3.72 (2.63)	1.17 (1.68)	.000
Everyday Discrimination scale [EDS], race [a]	1.79 (1.79)	.53 (1.29)	.000
IAT-me vs them [IAT-M/T][b]	.258 (.365)	.189 (.332)	.005
IAT-black vs white [IAT-B/W] [a]	.271 (.313)	.141 (.380)	.000
Hostility	18.7 (6.1)	18.3 (6.1)	.420
Emotion-and Stress-Related Eating scale [ESRE] [a]	10.7 (4.8)	12.9 (5.2)	.000
International Physical Activity Questionnaire	3,035 (3,466)	3,046 (3,352)	.964
RAND social desirability scale [a]	43.9 (30.9)	27.7 (28.7)	.000
Annual household income, $1,000 USD [a]	46.3 (39.0)	58.1 (42.3)	.000
Highest grade completed [a]	13.3 (2.0)	14.3 (2.4)	.000
Male, %	29.9	36.1	.059
Age at time of interview, years	47.8 (7.9)	48.5 (7.9)	.169

a. P<.001.
b. P<.01.
c. P<.05.

ing the maximum likelihood option in Mplus version 5.1.[26] Model fit was assessed by the Comparative Fit Index (CFI), the Tucker-Lewis Index (TLI), the Root Mean Square Error of Approximation (RMSEA), and the Standardized Root Mean Square Residual (SRMR). Current guidelines suggest that CFI and TLI values >.95 indicate excellent model fit, while RMSEA and SRMR values should be below .08.[27] Modification indexes were reviewed for potentially misspecified parameters. To be consistent with the literature, our primary analyses were based on participants who did not have diabetes since the syndrome is generally of less interest for those already diagnosed with diabetes.

Results

Response Rates

A total of 3,420 health center patients were successfully contacted for the study; 2,065 were screened; 1,219 were found to be eligible; and 1,005 completed the study protocol (82.4% of those confirmed eligible). The sample included nearly equal numbers of Black (n=504) and White (n=501) respondents.

Respondent Characteristics

Of the total sample, 817 respondents (84.1%) did not have a diabetes diagnosis. Mean values for this group are presented by race/ethnicity in Table 2. Blacks had significantly higher mean NCEP scores than Whites (2.49 vs 2.16) and were more often classified by the NCEP thresholds as positive for MetS (50.7% vs 38.5%). As previously reported,[13] compared with Whites, Black respondents had significantly higher scores for both explicit and implicit racial discrimination and for social desirability. In spite of being drawn from the same health centers, Blacks had lower values for the SEP measures.

MetS Factor Model

We initially attempted to replicate the hypothesized four-factor measurement structure for the MetS, but the analysis generated a negative variance for one error term. This may have been due to the lack of a measure of fasting insulin in our data,

which is needed to fully identify the insulin resistance factor. As a result, we allowed all 7 available indicators to load separately on the MetS factor. We also allowed for correlated errors between the blood pressure indicators and the obesity indicators.

Structural Model Results

Standardized path estimates for the full structural model are shown in Figure 1 (all displayed paths have P<.01). The RMSEA (.066; 95%CI=.060-.071) and SRMR (.054) values indicated more than adequate model fit, while the CPI was .889 and the TLI was .831. Consistent with previous research,[9] the factor loadings indicate that the blood pressure measures have less influence on the underlying MetS latent variable than the other components. The two variables with the strongest direct effects on the latent MetS outcome were SEP (negative relationship) and male gender (men had higher scores compared with women). Emotion and Stress-Related Eating (ESRE) had a small positive impact (beta -.12) on the MetS and mediated the influence of several demographic variables. Blacks had lower ESRE scores than Whites (beta=-.20). IPAQ physical activity was associated with lower syndrome scores (beta=-.14) and partially mediated the effect of gender. Syndrome scores also rose with increasing age. The model explained 24.5% of the variance in the latent syndrome factor.

As expected, explicit discrimination scores were much higher for Blacks than Whites. Neither explicit nor implicit discrimination, which were relatively uncorrelated in our data, exerted direct effects on the MetS. The model also reveals multiple influences on many of the mediating measures. Reports for hostility, stress-

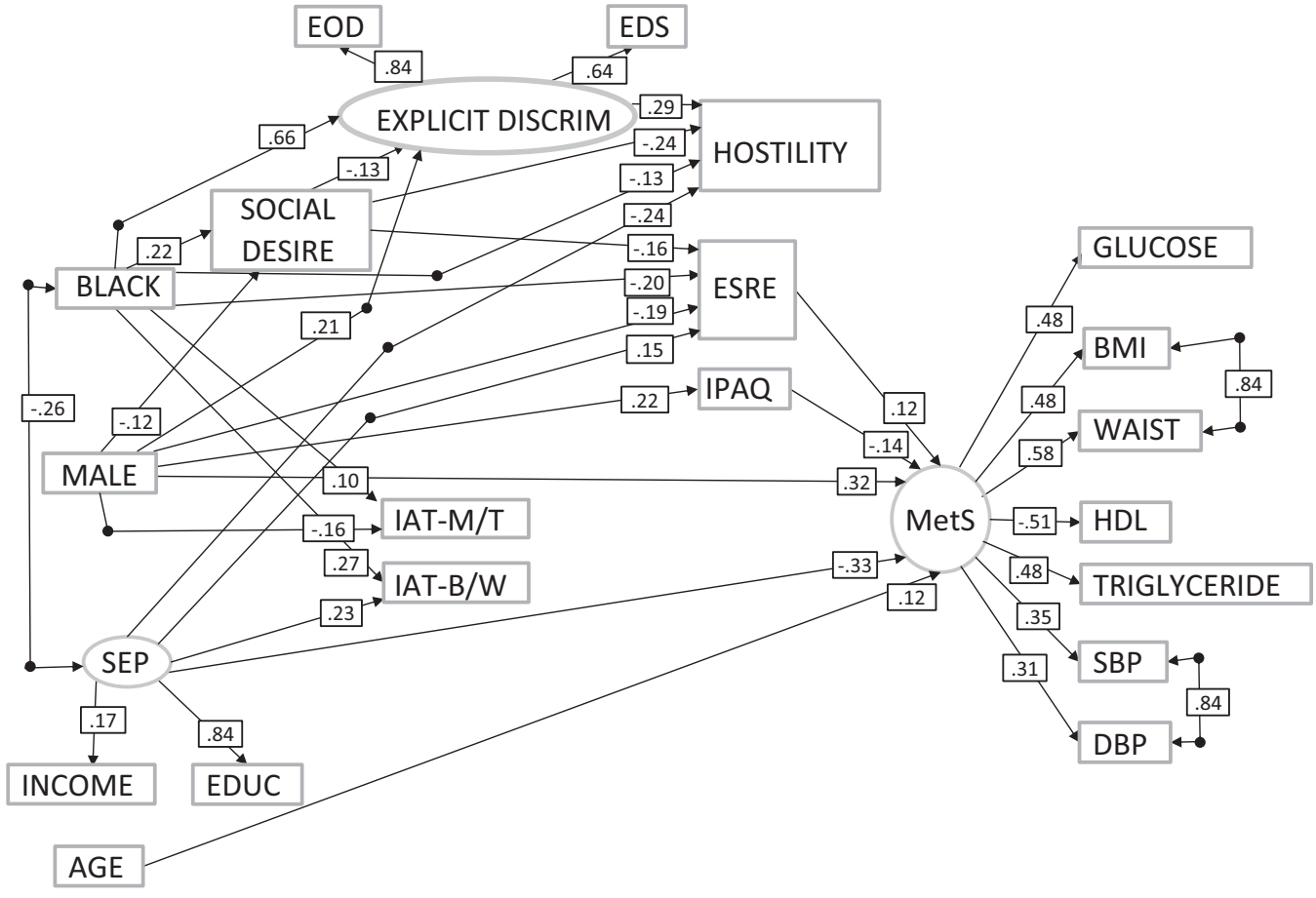

Figure 1.Structural model of the metabolic syndrome for participants without diabetes
N=817, CFI=.889, TLI=.831, RMSEA=.066; SRMR=.054; coefficients are standardized path values; all displayed paths significantly different from zero at P<.01.

related eating, and explicit discrimination were affected by social desirability, SEP, gender, and race/ethnicity.

Discussion

In this analysis, we used structural equation modeling to explore social determinants of the metabolic syndrome in the My Body My Story study. We created a latent MetS factor formed by 7 common indicators of the syndrome. The strongest direct effects on the syndrome were found for SEP, which was inversely associated, and gender, with higher MetS levels for men. A small positive age effect is consistent with nationally representative surveys.[28] Socioenonomic disadvantage has also been shown to be an important determinant of the syndrome in longitudinal studies.[29,30]

Our model contained three potential mediating variables. Two of the mediating variables – IPAQ physical activity and stress-related eating—had small, but statistically significant, impacts on MetS. The ESRE was the only stress-related measure included in the MBMS survey, and it is conceivable that a more general measure of stress would have a greater impact on the MetS. As expected, physical activity was negatively associated with syndrome scores.

The third potential mediator, cynical hostility, was not significantly associated with the MetS. The absence of this pathway was unexpected given the literature regarding this relationship. However, Everson et al[31] found that hostility effects can be greatly reduced when adjusted for behavioral risk factors. Hostility was the only variable linked to explicit discrimination. Both of these self-report measures were affected by social desirability. One interpretation of this is that Blacks may underreport racial discrimination due to their greater tendency to give socially desirable responses.

The study sample consisted of nearly equal numbers of White and non-Hispanic Blacks, and one of our primary objectives was to examine the effects of race/ethnicity and racial discrimination. In the National Health and Nutrition Examination Survey, MetS prevalence was highest among Black women and White men and lowest among Black men.[32] In our model, we did not find that either conventional measures of explicit racial discrimination or novel measures of implicit discrimination influenced the MetS. Race/ethnicity did not directly influence the syndrome in our data. Instead, the race/ethnicity effect was indirect, transmitted primarily through its negative correlation with SEP. Explicit discrimination was associated with higher levels of hostility, but hostility did not in turn affect the syndrome.

Recent studies using the Everyday Discrimination Scale have found a significant impact of reported discrimination on incident MetS (hazard ratio=1.33) among US women,[33] but only a weak association (OR=1.06) for ethnic groups living in the Netherlands.[34]

Racial discrimination is one of many possible forms of unfair treatment, and new research emphasizes the need to consider the joint effects of multiple types of discrimination, both to gauge overall exposure and also to identify loci of unfair treatment relevant to prevention.[35,36] Underscoring the importance of unfair treatment, in their large prospective study of British civil servants, DeVogli et al[37] found that a global measure of unfairness was associated with the prevalence of MetS nearly six years later.

The indexes we used gave somewhat differing assessments of the overall fit of our model. The RMSEA and SRMR values indicate adequate fit, while the CFI and TLI values were considerably below the recommended guideline of .95 for excellent fit. Both of these incremental fit indexes penalize complex models with many parameters like ours. Other than correlated errors among the MetS indicators, we did not selectively parse other paths that might have improved the fit measures.

Our results are subject to several potential limitations associated with the available MBMS study measures that may have affected the magnitude of the effects in the model. First, our protocol did not measure fasting insulin, one of the two values conventionally used to define an insulin resistance factor. This may have produced an underestimate of the role of this factor in the latent MetS variable. Second, we used the lifetime version of the EOD scale. This may have contained events occurring many years earlier which may be less salient for assessing explicit discrimination or for MetS risk. Third, we used the Me vs Them and Black vs White comparisons in the IAT, which we felt were the most relevant for the objectives of this study. There are many ways to measure IAT values, and it is possible that the results would be different if other comparisons had been used.

Conclusion

Future research might focus on identifying other important mediators of the MetS. Clarifying the pathophysiologic mechanism that transmits SEP effects would seem to be particularly important. Chronic stress,[38] inflammation,[12] or allostatic load,[39,40] for example, may be important pathways to consider. It would also be important to better understand the role of economic deprivation, which had such a strong impact on syndrome scores in our study.

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Conflict of Interest

No conflicts of interest to report.

Author Contributions

Research concept and design: Smith, Krieger, Williams, Carney, Chen, Bennett, Freeman; Acquisition of data: Krieger, Kosheleva, Urato, Waterman; Data analysis and interpretation: Smith, Krieger, Kosheleva, Urato, Waterman, Williams, Carney, Chen, Bennett; Manuscript draft: Smith, Krieger, Waterman, Williams, Carney, Chen, Bennett; Statistical expertise: Krieger, Kosheleva, Urato; Administrative: Smith, Freeman; Supervision: Krieger, Waterman,

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