Psychological and Physiological Correlates of Insulin Resistance at Fasting and in Response to a Meal in African Americans and Whites

Background: African Americans are more insulin resistant than are Whites. The purpose of this study was to characterize physiologic and psychological (stress coping style) correlates of insulin resistance in African Americans and Whites.

Methods: We examined African American ($n = 67$) and White ($n = 41$) men and women aged 18–45 years with body mass index 18–35 kg/m^2. We used the homeostasis model assessment (HOMA-IR) and area under the curve for insulin (AUC) after a standardized meal as measure of insulin resistance. We obtained anthropometric measures and determined maximal aerobic power (VO_{2max}) by treadmill exercise. We used stress profile to assess stress and coping style.

Results: Postprandial insulin AUCs were higher in African Americans than in Whites. Anthropometric measures and VO_{2max} were related to HOMA-IR and AUC. Although self-reported stress level did not differ between Whites and African Americans, positive appraisal predicted reduced HOMA-IR and negative appraisal coping style predicted increased insulin AUC.

Conclusions: Psychosocial factors may be determinants of health and targets of intervention for obesity-related disorders such as insulin resistance. Existing behavioral intervention programs, designed with a sole emphasis on exercise and nutrition, may fall short of optimal effectiveness. (*Ethn Dis.* 2009;19:104–110)

Key Words: Insulin Resistance, Stress, Ethnicity, Coping Style

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Introduction

Insulin resistance, characterized by a relative lack of physiologic responsiveness to insulin, is a common biological marker for the early identification of type 2 diabetes mellitus.[1] Insulin resistance is more prevalent in obese than healthy weight people,[2,3] and fasting and stimulated insulin and glucose concentrations are higher in obese people as a group, compared with healthy weight controls.[4] In addition, African Americans are more insulin resistant than are Whites.[5–8] High prevalences of insulin resistance in African Americans may parallel obesity in African Americans because excessive body fat is considered the single most important risk factor for insulin resistance and diabetes.[9–12] However, at each body mass index (BMI) category, the glucose and insulin responses of African Americans resemble the metabolic profile of more obese people.[13] Such evidence suggests that African Americans may be more prone to developing metabolic profiles associated with obesity, insulin resistance, and diabetes.

Interethnic differences in the prevalence of insulin resistance may reflect genetic differences, such as genetically determined metabolic differences,[14] but they may also result from environmental exposures. One possible cause for the differential prevalence in insulin resistance between Whites and African Americans may be the experience of and response to chronic stress. African Americans report high levels of chronic stress from factors that disproportionately affect them, including unemployment, low socioeconomic status, limited healthcare access, and racial discrimination.[15] These factors are associated with negative effects on psychological and physical well-being.[16] For example, the release of glucocorticoids during periods of chronic stress increases plasma glucose; this pattern has been associated with decreased insulin sensitivity.[17,18] The appraisal of stress and subsequent coping responses in specific ethnic populations[19] may further contribute to potential disease states, such as diabetes and other metabolic disorders.

The purpose of the current study was to examine the relationships between psychological variables and insulin resistance in an effort to explain the development of metabolic dysregulation.

The high prevalence of insulin resistance, obesity, and diabetes in African Americans demonstrates the need to understand the psychological correlates of insulin resistance in this specific high-risk group. The purpose of the current study was to examine the relationships between psychological variables and insulin resistance in an effort to explain the development of metabolic dysregulation. Specifically, we sought to characterize psychological correlates of insulin resistance with an emphasis on the role of psychological stress and cognitive coping styles and the relationship between insulin resistance and physiologic and anthropometric variables in African Americans and Whites.

METHODS

Participants

Self-identified African American and White men and women aged 18–45 years who had BMI values 18–35 kg/m^2 were recruited via local newspapers and from local universities in the Washington DC metropolitan area. Participants were healthy and medication-free at the time of participation. Participants with one or more of the following conditions were excluded from the study: 1) pregnancy, menopause, diabetes, liver and pancreatic diseases; 2) heart disease; 3) fasting blood glucose $\geq$125 mg/dL and blood pressure $>$140/90 mm Hg; and 4) active suicidal ideation. The study was approved by the institutional review board of the Uniformed Services University of the Health Sciences, and written informed consent was obtained from all participants.

Laboratory Visit

Qualified participants visited the laboratory between 7 and 8 a.m. All participants were required to abstain from caffeine, alcohol, tobacco, and strenuous exercise for at least 12 hours before the laboratory visit. An indwelling catheter was placed in the antecubital vein of a forearm; the catheter line was kept open with a heparin lock.

Next, the participants drank 5 mL/kg of their body weight in water to ensure adequate hydration before exercise. Approximately 40 minutes were allowed for absorption of the water. During this period, the stress profile was administered. After this 40-minute period, participants drank 2 cans of Ensure-Plus as their breakfast meal. A 5-minute period was allotted for the liquid meal ingestion. Approximately 2 hours after ingesting the standardized meal, participants underwent a maximal exercise treadmill test to determine maximal aerobic power. Before the maximal aerobic power test, a medical history, physical examination, and resting 12-lead electrocardiogram were carefully examined by a physician for the participant safety.

Measures

Body weight was measured with a calibrated balance beam metric scale to the nearest 0.1 kg, and height was measured to the nearest 0.1 cm while the participant was wearing light clothing and no shoes. BMI was calculated from height and weight. Percentage body fat was estimated by bioelectric impedance with the portable RJL body composition analyzer (RJL Systems). Waist circumferences were measured with an inelastic tape around the waist and hip by using standard techniques.[20]

The stress profile[21] has 123 items that provide scores in multiple areas related to perceived stress and health risk. Conceptually, the stress profile is based on the framework of stress and coping.[19] Internal consistency is satisfactory (r = .72) and reliability is adequate (r = .76–.86) and has been validated on an ethnically diverse population.[21] The Cronbach α for our sample was .82. Selected subscales used for this study are described below.

The stress subscale (6 items) addressed perceived stress experienced in the last 3 months. Stress is defined as the experience of major and minor irritants, annoyances, and frustrations of daily living such as health, work, financial, family, social, and environmental hassles. Participants are asked how frequently they experience stress in these areas by using a 5-point Likert scale ranging from never to always.

The social support network subscale contains 15 items assessing emotional support, assistance on a regular basis, use of support, and the satisfaction of the support that the respondent receives from the immediate environment.

The stress profile also includes cognitive coping strategy items. The coping style subscales consist of 4 areas (positive appraisal, negative appraisal, threat minimization, and problem-focus) that address specific coping strategies. Coping style is the most common way that people deal with work and life stress. Positive appraisal (5 items) is characterized by employing supportive and encouraging self-talk to cope with a challenging situation. People who employ positive appraisal can often generate favorable outcomes. Negative appraisal (5 items) is the tendency to approach a difficult life situation with self-blame, criticism, or catastrophic thinking. This coping strategy focuses on the worst possible outcome. Threat minimization (5 items), also referred to as avoidance, is a coping strategy that emphasizes the humor in problematic situations and often distracts attention from the stressor. Problem focus (4 items) is the degree to which a person devises a specific course of action for reducing the effect of current problems. This coping style emphasizes the tendency of trying to improve the troublesome situation.

Changes in plasma glucose and insulin were monitored at baseline and 10, 30, 50, and 70 minutes after participants drank 16 oz Ensure-Plus (720 kcal, 56.4% carbohydrates, 29% fat, and 14.6% protein). This liquid meal has been used to stimulate both glucose and insulin responses.[22,23]

Each participant completed a progressive maximal exercise test to determine maximal aerobic power (VO_{2max}). The exercise test was carried out on a treadmill (Quinton ST-65, Quinton Instrument Company, Seattle, Wash) and involved a 5-minute warm-up (3.0 mph, 2% grade) followed by walking (or running) at 2.5–7.0 mph (depending on heart rate during the warm-up), as grade increased by 2.5% every 2 minutes until the subject reached volitional exhaustion. Participants were instrumented with electrodes (Quinton Q-4500) and a portable metabolic unit for continuous monitoring of heart rate and electrocardiogram, and oxygen uptake, carbon dioxide production, and respiratory exchange ratio by open-circuit spirometry (KB20-CosMed, Rome, Italy). A 5-minute cool-down (2.5 mph, 0% grade) followed the maximal exercise testing. Verification that each volunteer actually achieved maximum VO_{2max} criteria was determined by plateau of VO_{2max} or meeting at least 3 of the following 4 criteria: respiratory exchange ratio ≥1.1, age-predicted maximal heart rate, a score ≥17 on the Borg perceived exertion scale rating, or a blood lactate value ≥8 mmol/L. Spotters and trained medical personnel were present during the exercise test.

Blood for hormones was collected in EDTA, immediately placed on ice, and then centrifuged within 30 minutes of collection. Insulin levels were measured by standard radioimmunoassay (Diagnostic Systems Laboratories Incorporated, Webster, Texas). All plasma was stored at −70°C and assayed in duplicate and in batch to minimize interassay variability. Intraassay and interassay coefficients of variation were <10%.

Statistical Analysis

Fasting IR was calculated by the homeostasis model assessment method of insulin resistance (HOMA-IR)[24] by using morning fasting plasma insulin and glucose samples. The area under the curve (AUC)[25] for insulin was used for a stimulated insulin resistance measure. Fasting insulin, HOMA-IR, and AUC were natural log transformed.

Independent *t* tests and χ^2 analyses were used to examine the participant characteristics and baseline measures. Multivariate analyses of variance were used to examine the anthropometric measures and stress profile data between African American and White partcipants. Postprandial metabolic measures were examined by using repeated measures of analysis of variance, and fasting and summarized postprandial glucose and insulin measures were analyzed by using multivariate analysis of variance. Relationships among insulin resistance, anthropometric and psychological measures, and VO_{2max} were examined by using the correlations and hierarchical linear regressions. All data analyses were conducted by using SPSS version 15.0 (SPSS Inc, Chicago, Ill). Differences were considered significant at $P < .05$.

RESULTS

Demographics and Baseline Physiologic Measures

Of the 160 participants who visited the laboratory for the original study, 11 were excluded for not meeting the inclusion criteria. After excluding 41 more people with missing or incomplete data, a total of 108 participants were included in the study. White and African American participants were comparable in sex, education, income, and anthropometric measures, but African Americans were older and had significantly lower cardiorespiratory fitness levels than did Whites (Table 1). VO_{2max} remained significantly lower for African Americans even after accounting for age difference and BMI, $P = .005$. Eight Whites (20%) and 12 African Americans (18%) were smokers.

Metabolic Measures

There was no difference in fasting glucose concentrations between African Americans and Whites, but African Americans had higher fasting insulin concentrations, $P = .014$, and higher HOMA-IR values, $P = .03$ (Table 1). However, after adjusting for age and VO_{2max}, fasting insulin and HOMA-IR did not differ between the ethnic groups. Sex did not make a difference in fasting insulin or the HOMA-IR.

Figure 1 shows the plasma concentrations of insulin for a 70-minute period after a meal. African Americans and Whites did not differ in plasma glucose in response to a meal, but insulin response was higher in African Americans than in Whites, $P < .001$. African Americans had higher insulin concentrations even after accounting for the age and VO_{2max} difference, $P = .013$. The higher postprandial insulin concentrations in African Americans was further confirmed in total insulin AUC, $P < .001$ (Table 1). The difference remained even after accounting for age and VO_{2max}, $P = .014$. Glucose AUC did not differ by ethnicity.

Stress and Coping Strategies

African Americans did not report higher level of stress than did Whites. However, African Americans reported more frequent use of positive appraisal as a coping mechanism than did Whites, $P = .003$. African Americans and Whites did not differ on social support (trend $P = .066$), negative appraisal, threat minimization, and problem-focused coping.

Stress, Coping Style, Anthropometric Measures, and Insulin Resistance

Correlational analyses revealed significant associations among anthropometric measures, $P < .001$, and all anthropometric measures were positively correlated with HOMA-IR and insulin AUC (Table 2). Increased anthropometric measures were related to reduced VO_{2max} as well as increased HOMA-IR and insulin AUC. African Americans and Whites had similar patterns.

Increased stress was associated with increased BMI, percentage body fat, and postprandial insulin AUC. Increased stress was associated with reduced VO_{2max}. Increased social support was related to reduced abdominal obesity, and positive appraisal was related to reduced BMI and HOMA-IR. Negative appraisal was only related to increased insulin AUC.

The role of stress and coping strategies for HOMA-IR and insulin AUC were examined by using a hierarchical regression analysis (Table 3). The contributions on HOMA-IR and insulin AUC were examined along with demographic and physiologic variables.

Table 1. Demographic, anthropometric, and metabolic characteristics of 108 White and African American participants

Variable	*n* or mean (SD)	
	White (*n* = 41)	African American (*n* = 67)
Demographic characteristics		
Age, years*	28.2 (5.3)	31.3 (8.3)
Sex (women/men)	18/23	32/35
Education		
Less than high school	0	1
High school	0	3
Some college	16	33
College graduate	25	30
Annual Income, $		
<25,000	5	20
25,000–50,000	15	28
50,001–80,000	11	12
>80,000	6	5
Missing data	4	2
Anthropometric measures		
BMI (kg/m^2)	26.6 (4.5)	26.8 (3.9)
BMI category (healthy weight/overweight/obese)	15/15/11	22/28/17
Waist circumference (cm)	86.0 (14.3)	85.5 (11.2)
Body fat (%)	28.8 (8.7)	30.5 (7.7)
VO_{2max} (mL/kg/min)†	43.9 (9.1)	37.0 (10.0)
Metabolic measures		
Fasting glucose (mmol/L)	5.2 (.62)	5.1 (.70)
Fasting insulin (µIU/mL)	8.7 (5.78)	11.4 (6.60)
Ln fasting insulin*	2.0 (.55)	2.3 (.56)
HOMA	2.0 (1.33)	2.7 (1.75)
Ln HOMA*	.54 (.56)	.80 (.60)
Glucose peak (mmol/L)	6.6 (.98)	6.7 (1.48)
Glucose AUC (mmol/L•80 min)	456.7 (60.81)	456.7 (101.51)
Insulin peak (µIU/mL)	121.4(99.77)	193.29 (150.41)
Ln insulin peak†	4.5 (.72)	5.0 (.70)
Insulin AUC (µIU/mL•80 min)	5068.9(3670.2)	8513.9 (6453.1)
Ln insulin AUC‡	8.3 (.62)	8.8 (.69)

SD = standard deviation, BMI = body mass index, VO_{2max} = maximum oxygen consumption, HOMA = homeostasis model assessment of insulin resistance, AUC = area under the curve.
* $P < .05$.
† $P < .01$.
‡ $P < .001$.

These predictor factors were entered in 4 separate models.

The overall model accounted for 38% of the variance of HOMA-IR, and the model was significant, $R^2 = .384$, P $< .001$. In this model, sex, VO_{2max}, and positive appraisal were significant predictors of HOMA-IR. Men had higher HOMA-IR, and higher cardiovascular fitness reduced HOMA-IR. Positive appraisal of stress reduced HOMA-IR, and ethnicity was not a contributor in HOMA-IR.

The overall model for insulin AUC was significant, $R^2 = .528$, P $< .001$. Higher fasting insulin concentrations predicted higher postprandial insulin concentrations. Furthermore, ethnicity (being African American) significantly contributed to higher postprandial insulin response, and negative appraisal of stress also predicted higher insulin AUC.

DISCUSSION

The present study examined physiologic and psychological correlates of fasting and stimulated insulin resistance in African American and White men and women. Insulin AUCs in response to a meal were significantly higher in African Americans than in Whites, and this hyperinsulinimic postprandial response in African Americans could not be completely explained by any one or combination of baseline characteristics (eg, age, sex, anthropometric measures, VO_{2max}). This finding was interesting considering African Americans and Whites had comparable plasma glucose concentrations at all times. This study confirmed that African Americans may require more insulin to remove the same amount of glucose from the bloodstream

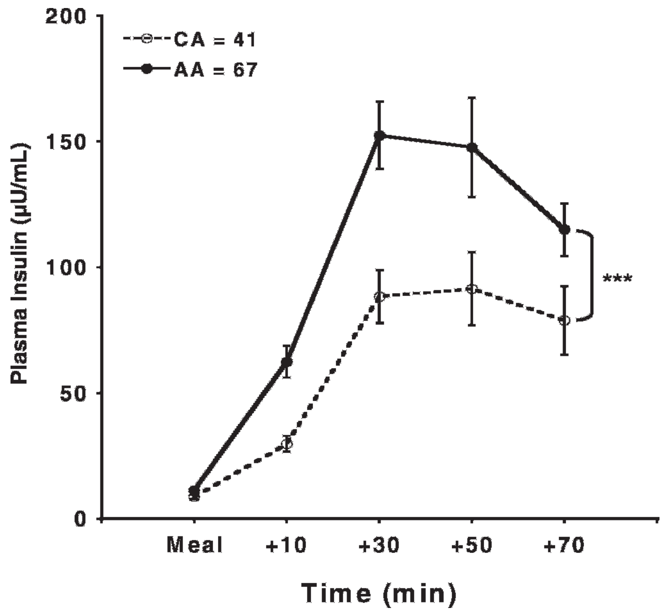

Fig 1. Postprandial insulin concentrations after a meal by ethnicity. ***$P < .001$.

This study confirmed that African Americans may require more insulin to remove the same amount of glucose from the bloodstream than do Whites.[6]

than do Whites.[6] Hyperinsulinemia is associated with obesity; however, in this study, even after accounting for age, BMI, and cardiovascular fitness, African Americans released more insulin than did Whites after a meal.

Of particular note was the finding that cardiovascular fitness (VO_{2max}) was significantly higher in Whites than in African Americans, regardless of their age. Moreover, VO_{2max} was negatively correlated with both fasting and stimulated insulin resistance and all anthropometric measures. In the regression, VO_{2max} was the only significant physiologic predictor for HOMA-IR.

Psychological and behavioral variables contribute to the development of insulin resistance differently in African Americans as compared with Whites. Previous studies reported high levels of chronic stress in African Americans from factors that are disproportionately common in African Americans, such as low socioeconomic status. This difference in socioeconomic status may serve as a daily stressor in African Americans. However, in the current study, overall self-reported chronic stress did not differ by group. Comparable levels of stress between Whites and African Americans may be in part explained by comparable socioeconomic status of the 2 groups. In this study, almost all participants had received at least a partial college education, and the annual income was comparable between African Americans and Whites. Interestingly, when the financial hassle item from the stress subscale was

Table 2. Correlation of HOMA and insulin AUC with anthropometric and stress measures and VO_{2max}

	BMI	Waist	Body fat	VO_{2max}	Stress	Social Support	Positive Appraisal	Negative Appraisal	Threat Minimization	Problem Focus	LnHOMA
BMI	1										
Waist	.84‡	1									
Body fat	.60‡	.39‡	1								
VO_{2max}	−.50‡	−.38‡	−.75‡	1							
Stress	.24*	.12	.25†	−.22*	1						
Social Support	−.19	−.25†	−.09	.13	−.19	1					
Positive Appraisal	−.21*	−.13	−.14	.03	−.22*	.22*	1				
Negative Appraisal	.19	.08	.13	−.02	.52‡	−.19*	−.25†	1			
Threat Minimization	.04	.11	−.03	.04	−.03	.25†	.50‡	−.05	1		
Problem Focus	−.13	−.05	−.02	.14	−.09	.27†	.44‡	−.20*	.52‡	1	
LnHOMA	.44‡	.43‡	.32†	−.48‡	.13	−.11	−.20*	.07	−.06	−.19	1
Ln In AUC	.29†	.30†	.27†	−.43‡	.21*	−.01	−.08	.23*	.01	−.09	.66‡

HOMA = homeostasis model assessment of insulin resistance, AUC = area under the curve, VO_{2max} = maximum oxygen consumption, BMI = body mass index.
* $P < .05$.
† $P < .01$.
‡ $P < .001$.

Table 3. Hierarchical multiple linear regression analysis

LN HOMA-IR	R	R^2 Change	β	LN Insulin AUC	R	R^2 Change	β
Sex (male)	.158	.025	.057	Sex (male)	.119‡	.014	.088
Age			.153	Age			−.073
Sex (male)	.593‡		.257†	Sex (male)	.475‡		−.169
Age			−.170	Age			.119
BMI		.326***	.212*	BMI		.212‡	.091
VO_{2max}			−.564‡	VO_{2max}			−.518‡
Sex (male)	.597‡		.241*	Sex (male)	.700‡		−.090
Age			−.177	Age			−.043
BMI			.232*	BMI			.031
VO_{2max}			−.526‡	VO_{2max}			−.101
Ethnicity (AA)		.005	.075	Ethnicity (AA)		.264‡	.182*
				Fasting insulin			.573‡
Sex (male)	.620‡		.258*	Sex (male)	.726‡		−.056
Age			−.146	Age			.032
BMI			.196	BMI			−.026
VO_{2max}			−.521‡	VO_{2max}			−.167
Ethnicity (AA)			.139	Ethnicity(AA)			.176*
				Fasting Insulin			.554‡
Stress		.028	−.007	Stress		.038	.022
Social support			.076	Social Support			.129
Positive appraisal			−.187*	Positive Appraisal			−.007
Negative appraisal			.005	Negative Appraisal			.178*

Note: * $P < .05$; † $P < .01$; ‡ $P < .001$.

examined alone, African Americans reported more frequent financial hassles than did Whites, P = .003.

African Americans also reported more positive appraisal than did Whites, and positive appraisal had influence on reducing HOMA-IR. Cognitive appraisal mediates responses to stress.[19] Situations that threaten physical or psychological well-being can be appraised as either positive or negative. Positive appraisal minimizes the stressor by resulting in an optimistic perspective about the situation; in contrast, negative appraisal is defined by a reliance on catastrophic thinking.[21] Catastrophic thinking adversely affects mood states and is more likely to exacerbate the stress response.[19] Previous research has suggested that maladaptive (passive or negative) coping strategies are associated with an increased health risk.[26–28] In our study, negative appraisal increased insulin AUC after a meal.

The current investigation has several weaknesses. First, perceived racial and ethnic discrimination or racism-specific coping responses were not directly measured in this study. The environmental hassle included stress associated with prejudice, but no language was used to address race-related prejudice or associated stress. It may be important to quantify these episodes of racism in order to understand their effect on mental and physical health outcomes. Second, our study included healthy people of BMI 18–35 kg/m^2. The negative effect of stress may be more pronounced in severely obese people or those with health problems. However, because of the physical demand of VO_{2max} exercise protocol and to safeguard our participants against any injury, we used only healthy participants. Generalizability of the findings may be limited to relatively healthy people with BMI <35 kg/m^2.

In summary, in addition to cardiovascular fitness, the significant associations between psychological factors and insulin resistance among participants implies that stress and adaptive coping mechanisms, such as positive appraisal, may be indicators of health risks and targets of intervention for obesity-related disorders, to include insulin resistance. The implication from this study is that existing behavioral intervention programs with a sole emphasis on exercise and nutrition may fall short of optimal effectiveness in targeting groups at high risk for insulin resistance and obesity. Positive coping strategies seem to be complements to a well-managed exercise and nutrition program to reduce the risk of insulin resistance in both African Americans and Whites, on the basis of this particular sample. Future studies are warranted to determine whether these findings are applicable to other ethnic minorities - particularly those at risk for metabolic disorders, such as some Latino and Native American subgroups.

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