Neighborhood Characteristics and Components of the Insulin Resistance Syndrome in Young Adults

The Coronary Artery Risk Development in Young Adults (CARDIA) Study

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OBJECTIVE — To examine associations of neighborhood characteristics with six components of the insulin resistance syndrome (IRS) in young adults.

RESEARCH DESIGN AND METHODS — Cross-sectional data from the Coronary Artery Risk Development in Young Adults (CARDIA) Study were used to examine associations of neighborhood characteristics with the IRS in 3,093 nondiabetic adults aged 28–40 years. Measures of BMI, fasting HDL cholesterol, triglycerides, insulin, glucose, and systolic blood pressure were combined into an IRS score. U.S. Census–derived neighborhood characteristics were summarized into a neighborhood socioeconomic score, with an increasing score signifying increasing socioeconomic advantage.

RESULTS — Among white men and women, the IRS score was inversely related to neighborhood socioeconomic score. Neighborhood characteristics remained associated with the IRS score after controlling for personal income and education (adjusted mean differences for 95th vs. 5th percentile of neighborhood score: −0.24 standard deviation units [SE = 0.12] in men and −0.56 standard deviation units [SE = 0.10] in women). Among black participants, neighborhood score was inversely associated with IRS score in persons of high income and education (mean differences 95th vs. 5th percentile −0.54 [SE 0.26] in men and −0.52 [SE 0.26] in women) but positively associated or not associated with IRS score in persons of low income and education (mean differences 0.60 [SE 0.21] in men and 0.00 [SE 0.16] in women).

CONCLUSIONS — The IRS score is associated with neighborhood characteristics as early as young adulthood. Features of residential environments may be related to the development of insulin resistance.

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The insulin resistance syndrome (IRS) (1) has received increasing attention over the past few years because of its role in the complex set of processes leading to cardiovascular disease. The public health importance of the syndrome has been highlighted by high rates of type 2 diabetes in the general population (2) and increasing rates of type 2 diabetes in children (3). The reasons for this increase remain a subject of debate, but its population-wide nature suggests that society-wide factors (possibly related to features of the environments where people live and work) are likely to be involved (4).

As in most cardiovascular disease epidemiology, investigations of risk factors for insulin resistance have focused on personal characteristics such as behaviors (5–7), obesity (7,8), and more recently, genes (9). The role of living environments in shaping the distribution and development of insulin resistance has rarely been examined. Neighborhood environments may provide important contexts for day-to-day activities related to cardiovascular health. Features of neighborhoods may affect the development of insulin resistance through their influence on the adoption and maintenance of health-related behaviors or through psychosocial pathways. Living in disadvantaged neighborhoods has recently been shown to be associated with increased incidence of coronary heart disease, even after controlling for personal income, education, and occupation (10). The reasons for these associations, and the factors mediating these neighborhood differences, remain to be determined.

Using data from the Coronary Artery Risk Development in Young Adults (CARDIA) Study, we investigated whether neighborhood characteristics are associated with components of the IRS in young adults 28–40 years of age sampled from four diverse areas of the U.S. We hypothesized that living in socioeconomically disadvantaged neighborhoods would be associated with a higher prevalence of components of the IRS, even after accounting for personal income and education. We also hypothesized that neighborhood effects would be stronger in persons of low income or education (or equivalently, that the effects of low per-

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Abbreviations: CARDIA, Coronary Artery Risk Development in Young Adults; IRS, insulin resistance syndrome.

A table elsewhere in this issue shows conventional and Système International (SI) units and conversion factors for many substances.

sonal income or education would be greater in disadvantaged neighborhoods), reflecting greater vulnerability of persons of low income or education to neighborhood conditions.

RESEARCH DESIGN AND METHODS

— CARDIA is a cohort study of cardiovascular risk factors in young adults. A total of 5,115 adults aged 18–30 years at baseline were recruited primarily through telephone contact from community lists in Birmingham, Alabama; Chicago, Illinois; and Minneapolis, Minnesota and from membership in a prepaid health plan in Oakland, California (11). The goal of recruitment was to obtain at each field center nearly equal numbers of blacks and whites, women and men, persons <25 and ≥25 years of age, and persons with a high-school education or less and more than a high school education. Baseline interviews and examinations were conducted in 1985–1986. Follow-up examinations were conducted every 2–3 years. Overall retention of the cohort at the year 10 examination (1995–1996), on which these analyses are based, was 79%. Year 10 data were used because earlier addresses for the full cohort were not available for geocoding.

Six components of the IRS were investigated as outcomes in these analyses: BMI; fasting plasma HDL cholesterol, triglycerides, insulin, and glucose; and systolic blood pressure. BMI was estimated as weight (in kilograms) divided by height in meters squared. Body weight and height were measured with the participant in light clothing and without shoes. HDL cholesterol was measured using an enzymatic method after dextran sulfate-magnesium precipitation (12), and triglyceride levels were determined using enzymatic procedures (13). Fasting insulin was measured by radioimmunoassay (14). Fasting glucose was measured by the hexokinase-ultraviolet method. Blood pressure was measured on the right arm in a sitting position after a 5-min rest using a random-zero sphygmomanometer. The mean of the second and third measurements was used in the analyses.

The six components were investigated separately as well as combined into a summary IRS score. For each variable, a Z score was calculated by subtracting the sample mean and dividing by the sample standard deviation. Triglycerides and insulin were log transformed before the calculation of Z scores because of their skewed distribution. Z scores for the six variables were then summed and divided by 6 to obtain an average Z score (HDL cholesterol Z scores were multiplied by −1 before summing). The average Z score was then divided by its standard deviation to obtain a standardized normal deviate score. This score (the IRS score) was the outcome variable investigated in analyses. An increasing score signifies increasing levels of components of the insulin resistance syndrome. The absolute value of the score reflects deviations from the mean score in standard deviation units. For example, a score of 1 means that the average Z score of the six components is 1 standard deviation above the average score for the sample as a whole. Values of the IRS score may be transformed into an average percentile ranking of the six variables using a table of the standard normal distribution. The use of this summary score allows investigation of how exposures are related to the syndrome as a single continuous variable and affords more power to detect associations (especially in relatively young populations) than the use of arbitrary cut-off points. The use of summary scores is appropriate when dealing with multiple intercorrelated variables. These six factors have been shown to be correlated with each other in other samples (15) and in CARDIA participants (16).

Census-defined block groups (mean population 1,000) were used as proxies for neighborhoods (17). Study participants were linked to their census-defined area of residence using their year 10 home address. Six area variables collected by the 1990 U.S. Census reflecting the dimensions of wealth/income, education, and occupation were investigated (Table 1). The 1990 U.S. Census currently provides the most appropriate socioeconomic data available to characterize residential areas at the time of the year 10 CARDIA visit. For each of the census variables, a Z score was estimated by subtracting the mean for the total sample of block-groups and dividing by the standard deviation. These six variables were then combined into a neighborhood summary score constructed by summing Z scores for each of the six variables, with increasing neighborhood score signifying increasing neighborhood advantage (18). Neighborhood scores for the year 10 CARDIA sample used in these analyses ranged from −11.4 to 17.4. Baseline residence information was available for 96% of the Chicago sample; the correlation between baseline and year 10 neighborhood socioeconomic score was high (Pearson's correlation 0.70, $P < 0.0001$). Information on personal income and education was reported by study participants as part of the year 10 exam and categorized as shown in Table 1. Categories for income and block-group score differed for blacks and whites because of large differences in the distribution of these variables in both groups.

Of the CARDIA participants who attended the year 10 follow-up, 89% (3,531) were matched to block-group data. An additional 181 participants were excluded for missing information on income, education, BMI, HDL cholesterol, triglycerides, fasting insulin, fasting glucose, or systolic blood pressure. An additional 257 individuals were excluded because they were diabetic (on diabetes medication or with fasting glucose ≥126 mg/dl and not pregnant) or had not been fasting at least 8 h. The total of 3,093 participants included in these analyses resided in 2,260 different block groups dispersed in 45 U.S. states. Seventy-nine percent of the block groups had only one study participant, and only 2% had five or more participants.

We first estimated age-adjusted means for the summary IRS score and its components by race-specific quartiles of neighborhood score. Linear regression was then used to estimate mean differences in the IRS score by neighborhood characteristics after adjustment for personal income and education. Before adjustment, however, we used stratified analyses to determine whether associations of personal income and education with the IRS score were similar across neighborhood categories (i.e., whether there was interaction between neighborhood and personal socioeconomic indicators). These interactions were tested by including appropriate interactions in regression models. Final estimates of neighborhood differences after controlling for personal income and education were obtained from models including neighborhood characteristics, personal income and education, and their interactions when appropriate. Neighborhood characteristics and personal socioeconomic indicators were investigated as both categorical and continuous variables. The

Table 1—*Individual-level and neighborhood characteristics by sex and race: the CARDIA Study 1995–1996*

	Men		Women	
	Whites	Blacks	Whites	Blacks
n	782	599	852	860
Individual-level characteristics				
Age (years)	35.5 ± 3.4	34.2 ± 3.8	35.7 ± 3.4	34.5 ± 3.9
IRS score	0.28 ± 0.89	0.30 ± 0.99	−0.50 ± 0.89	0.03 ± 1.02
BMI (kg/m^2)	26.5 ± 4.3	27.8 ± 5.6	25.4 ± 5.9	30.0 ± 7.8
HDL cholesterol (mg/dl)	43.0 ± 11.0	48.4 ± 14.3	55.0 ± 13.4	53.3 ± 13.4
Triglycerides (mg/dl)	117.8 ± 95.2	95.0 ± 71.0	82.2 ± 55.6	71.2 ± 40.6
Fasting insulin (μU/ml)	12.6 ± 7.8	14.6 ± 9.1	11.0 ± 5.2	15.4 ± 8.9
Fasting glucose (mg/dl)	88.4 ± 7.9	88.3 ± 9.1	83.4 ± 7.5	85.0 ± 9.1
Systolic blood pressure (mmHg)	111.3 ± 10.3	115.2 ± 11.2	103.1 ± 9.7	110.5 ± 14.2
Income (% distribution)*				
<$16,000	—	21.8	—	29.7
$16,000–$34,999	26.3*	34.9	29.2*	28.2
$35,000–$49,999	20.6	17.9	18.5	20.0
$50,000–$74,999	23.9	25.6*	24.4	22.2*
≥$75,000	29.3	—	27.8	—
Education (% distribution)				
High school diploma or less	20.6	45.6	16.3	36.6
1–3 years college	21.0	32.2	21.2	37.2
4 years college	28.3	14.2	31.7	17.7
Some graduate or professional school	30.2	8.0	30.8	8.5
Neighborhood (block-group) characteristics				
Neighborhood score	4.8 (1.5–8.3)	−0.67 (−3.7–2.7)	5.1 (1.7–8.3)	−0.80 (−3.8–2.3)
Median household income (1,000s US$)	38.3 (28.5–51.6)	25.6 (18.6–35.1)	39.5 (29.8–51.7)	26.1 (18.9–34.8)
Median house value (1,000s US$)	112.7 (71.8–211.6)	66.1 (51.0–118.8)	114.1 (77.3–210.7)	67.7 (49.6–120.5)
Percent earning interest income	53 (41–64)	28 (15–43)	52 (41–64)	27 (14–41)
Percent complete high school	90 (81–95)	76 (64–87)	90 (81–95)	74 (63–85)
Percent complete college	35 (19–51)	16 (8.0–27)	34 (19–51)	14 (7.4–25)
Percent exec., manag., occup.†	36 (25–49)	22 (14–31)	36 (25–48)	21 (14–31)

Data are means ± SD or medians (25th–75th percentile). *Because of small numbers, the two highest income categories were combined in whites and the two lowest categories were combined in blacks. †Percent in executive, managerial, or professional specialty occupations as defined by the U.S. Census.

use of socioeconomic categories as continuous variables allows estimation of the "average" difference in the outcome across categories. As the vast majority of block-groups had only one study participant, no special methods were needed to account for within-neighborhood correlations in outcomes. Adjustment for original study site did not modify the results.

RESULTS — The mean IRS score was similar in white and black men but was higher in black women than in white women ($P < 0.0001$) (Table 1). Black participants were more likely to be of lower income and educational attainment than white participants and were also more likely to live in neighborhoods with lower socioeconomic scores (Table 1).

The mean IRS score was inversely associated with neighborhood socioeconomic characteristics in white men and women and in black women (Table 2). For the most part, patterns were consistent across IRS score components. The strongest and most consistent associations were observed in white women. In black men, neighborhood characteristics were not clearly associated with neighborhood score. In fact, patterns for HDL cholesterol, triglycerides, and fasting glucose were the opposite of those observed in the other three groups: HDL cholesterol tended to decrease, and triglycerides and fasting glucose generally increased, with increasing neighborhood score.

In white men and women, increasing personal income and education were associated with decreasing IRS score across categories of neighborhood score (Table 3). In black men, however, personal income and education were inversely associated with the IRS score in the "better-off" neighborhoods but positively associated with the IRS score in the "worse-off" neighborhoods. In black women, the inverse associations of income and education with the IRS score were consistently weaker in "worse-off" than in "better-off" neighborhoods (Table 3).

In white men and women, neighborhood score remained inversely associated with IRS score after adjustment for personal income and education (mean differences in IRS score ± SE per unit increase in neighborhood score: −0.016 ± 0.008 in men and −0.038 ± 0.007 in women). When extrapolated to the 95th percentile of neighborhood score compared to the 5th percentile, differences were −0.24 standard deviation units (SE 0.12) in men and −0.56 standard deviation units (SE 0.10) in women. Patterns were weaker and less consistent in men than in women (Table 4).

Table 2—*Age-adjusted means for components of the IRS and summary IRS score by neighborhood categories: the CARDIA study 1995–1996*

	BMI (kg/m²)	HDL cholesterol (mg/dl)	Triglycerides (mg/dl)	Fasting insulin (μU/ml)	Fasting glucose (mg/dl)	Systolic blood pressure	IRS score
Quartiles of neighborhood score (median score)							
White men (n = 782)							
Q1 (−0.40)	27.4	41.9	131.8	14.5	89.1	111.6	0.44
Q2 (3.1)	26.0	42.5	119.3	12.2	87.2	110.9	0.21
Q3 (6.5)	26.6	43.5	116.2	11.7	88.6	111.5	0.27
Q4 (10.6)	25.9	44.2	103.5	12.1	88.7	111.2	0.20
P trend	0.003	0.03	0.004	0.002	0.9	0.9	0.02
White women (n = 852)							
Q1 (−0.40)	27.6	51.8	95.0	12.3	85.1	103.4	−0.18
Q2 (3.1)	25.7	53.9	83.0	11.3	83.1	104.1	−0.44
Q3 (6.5)	25.0	55.8	78.0	10.7	83.2	103.2	−0.56
Q4 (10.6)	23.2	58.2	73.3	9.6	82.5	101.7	−0.80
P trend	<0.0001	<0.0001	<0.0001	<0.0001	0.0008	0.04	<0.0001
Black men (n = 599)							
Q1 (−5.4)	27.9	48.8	87.3	14.5	86.9	113.8	0.18
Q2 (−2.1)	27.4	51.2	94.9	14.9	87.7	114.9	0.20
Q3 (0.73)	28.4	46.7	96.9	15.1	89.4	117.0	0.47
Q4 (5.0)	27.5	46.9	100.6	14.1	89.1	115.3	0.33
P trend	0.9	0.05	0.1	0.7	0.01	0.1	0.05
Black women (n = 860)							
Q1 (−5.4)	30.3	52.5	76.7	16.0	84.6	111.8	0.11
Q2 (−2.1)	30.5	52.5	70.9	15.8	84.4	111.0	0.07
Q3 (0.73)	30.1	53.9	69.9	16.2	86.1	110.8	0.08
Q4 (5.0)	28.9	54.1	66.8	13.7	85.0	108.1	−0.15
P trend	0.06	0.1	0.01	0.02	0.3	0.01	0.01

Quartiles are race-specific. Median corresponds to the median value for each category. *P* values for linear trends across categories were investigated by including the four categories as ordinal variables in regression equations (i.e., assigning score values 1–4 to the four categories).

In black participants, mean differences by neighborhood characteristics are shown stratified by income and education because (as shown in Table 3) there was evidence of interaction between neighborhood characteristics and personal socioeconomic indicators. For illustrative purposes, associations of neighborhood score with the IRS score are shown for extreme categories of income and education. In men, neighborhood score was positively associated with IRS score in men in the lowest categories of income and education (mean difference 0.048 ± 0.017 per unit increase in neighborhood score, 0.60 ± 0.21 standard deviation units when extrapolated to 95th vs. 5th percentile of neighborhood score) but negatively associated with IRS score in the highest categories of income and education (mean difference −0.047 ± 0.023 per unit increase and −0.54 ± 0.26 standard deviation units for 95th vs. 5th percentile). In black women, no association between neighborhood score and IRS score was observed in the lower income and education categories (mean difference 0.00 ± 0.16), but an inverse association was apparent in the higher income and education categories (mean difference per unit increase −0.037 ± 0.018, −0.52 ± 0.25 standard deviation units for 95th vs. 5th percentile). All results were similar when BMI was replaced by waist-to-hip ratio in the IRS score. Dropping individual items from the score one at a time did not substantially modify results.

CONCLUSIONS — Among young white men and women, the summary IRS score was inversely related to neighborhood socioeconomic score. There was no evidence that associations differed in persons of high or low income or education. In white women, neighborhood score remained inversely and significantly associated with the summary IRS score after controlling for personal income and education. Strikingly different patterns were observed in young black men: neighborhood score was inversely associated with the IRS score in black men of relatively high income and education but positively associated with the IRS score in black men of relatively low income and education. Similar interactions appeared to be present in black women, although differences were not as great as they were in black men.

Numerous studies have examined socioeconomic differences in cardiovascular risk factors (19), but the social patterning of the IRS has been infrequently investigated (20,21). Although neighborhood deprivation has been linked to cardiovasular risk factors and mortality in persons with diabetes (22–24), the relation of neighborhood characteristics to the IRS has not been examined.

Our study is unique in focusing on components of the IRS in young, asymptomatic adults and in demonstrating associations with neighborhood char-

Table 3—*Age-adjusted mean differences in IRS score per unit increase in personal income and education categories* stratified by neighborhood characteristics: the CARDIA study 1995–1996*

	White men (n = 782)		White women (n = 852)	
	Mean difference per unit increase in income category	Mean difference per unit increase in education category	Mean difference per unit increase in income category	Mean difference per unit increase in education category
Neighborhood quartiles I–II (score <4.99)	−0.045 ± 0.044	−0.131 ± 0.040	−0.088 ± 0.039	−0.198 ± 0.038
Neighborhood quartiles III–IV (score ≥4.99)	−0.051 ± 0.041	−0.051 ± 0.043	−0.101 ± 0.038	−0.099 ± 0.045
P value for interaction	0.92	0.17	0.81	0.09
	Black men (n = 599)		Black women (n = 860)	
	Mean difference per unit increase in income category	Mean difference per unit increase in education category	Mean difference per unit increase in income category	Mean difference per unit increase in education category
Neighborhood quartiles I–II (score <−0.71)	0.135 ± 0.058	0.116 ± 0.070	−0.044 ± 0.048	−0.028 ± 0.059
Neighborhood quartiles III–IV (score ≥−0.71)	−0.031 ± 0.054	−0.048 ± 0.056	−0.118 ± 0.044	−0.154 ± 0.048
P value for interaction	0.04	0.07	0.25	0.10

Data are mans ± SE. *Categories correspond to those shown in Table 1. Mean difference per unit increase in income category corresponds to average change per unit difference in category obtained by including income and education categories in separate regression equations as ordinal covariates. *P* value for interaction corresponds to interaction between neighborhood score (in two categories as shown) and the ordinal income or education variable.

acteristics, after controlling for personal measures of income and education.

There are several proximate mechanisms through which neighborhood characteristics could be hypothesized to influence the development of components of the IRS. Recent reviews have highlighted the possible role of residential environments in influencing behaviors linked to diet and physical activity (25–26), both of which may be related to insulin resistance (5–7). Although evidence in humans is not yet conclusive, chronic stress may be related to the development of the IRS through endocrine pathways involving the hypothalamo-pituitary-adrenal (HPA) axis (27–29) or activation of the sympathetic nervous system (28,30). Because sources of chronic stress (such as noise, violence, and poverty itself) are also likely to vary across neighborhoods, this proximate pathway may also be involved in linking residential environments to the development of components of the IRS.

Contrary to our second hypothesis, the inverse associations of neighborhood socioeconomic characteristics with the IRS score were not stronger in persons of low income or education. In fact, among

Table 4—*Mean differences in IRS score by categories of neighborhood score**

	White men (n = 782)	White women (n = 852)	Black men (n = 599)		Black women (n = 860)	
			Income < 16,000 and high school diploma or less	Income > 50,000 and some graduate school	Income < 16,000 and high school diploma or less	Income > 50,000 and some graduate school
Quartiles of neighborhood score						
Q1 (lowest)	0.14 ± 0.10	0.44 ± 0.10	−0.45 ± 0.22	0.36 ± 0.33	0.09 ± 0.18	0.41 ± 0.26
Q2	−0.06 ± 0.09	0.25 ± 0.09	−0.41 ± 0.21	0.28 ± 0.29	0.07 ± 0.19	0.38 ± 0.24
Q3	0.01 ± 0.09	0.16 ± 0.08	−0.001 ± 0.23	0.18 ± 0.25	0.26 ± 0.19	0.14 ± 0.22
Q4 (highest)	Reference	Reference	Reference	Reference	Reference	Reference
P trend across quartiles	0.27	<0.0001	0.006	0.16	0.81	0.04
Mean difference per unit increase in score	−0.016 ± 0.008	−0.038 ± 0.007	0.048 ± 0.017	−0.047 ± 0.023	−0.0003 ± 0.014	−0.037 ± 0.018

Data are means ± SE. *In whites, estimates are adjusted for the income and education categories shown in Table 1 as ordinal covariates. In blacks, estimates are shown stratified by personal income and education because of the interactions observed. Mean differences in black men and women were predicted from regression models including interactions between neighborhood score and income, and neighborhood score and education. Income and education included as ordinal covariates representing the categories shown in Table 1. To simplify the presentation, only the two extreme groups (lowest category for both income and education, and highest category for both income and education) are shown.

black men the opposite was true: neighborhood socioeconomic advantage was positively, rather than negatively, associated with the IRS score in persons of low income and education (and personal income and education were positively associated with the IRS score in disadvantaged neighborhoods). We have observed similar interactions between neighborhood characteristics and personal socioeconomic indicators for other cardiovascular risk factors in black men in other samples (31). Explanations for this finding remain speculative. It is plausible that among young black men living in the most disadvantaged neighborhoods, the behavioral and psychosocial correlates of higher personal income are different from those in other groups. These differences in socioeconomic gradients based on the larger context are reminiscent of differences in the socioeconomic patterning of cardiovascular risk in rich and poor countries, as well as over time (32). Consistently with some (33,34) but not all (20) previous work, we found stronger and more consistent socioeconomic gradients for components of the IRS syndrome in women than in men. The reasons for this sex difference remain to be determined.

Our findings are cross-sectional and need to be confirmed in longitudinal analyses relating neighborhood characteristics over a lifetime to the development of insulin resistance before conclusions can be drawn regarding causal relations between neighborhood characteristics and insulin resistance. However, the high correlation between baseline and year 10 neighborhood scores for the subsample with available baseline residence information suggests that the cross-sectional associations we observed are likely to be representative of associations of past place of residence with current outcomes. Our study is also limited by the use of the neighborhood socioeconomic score as an indirect proxy for the specific features of neighborhoods that may be relevant. These results highlight the need to identify specific features of neighborhood environments that may be important and empirically test their effects. Overall, our findings suggest that residential environments may play a role in facilitating recent increases in diabetes, and that broad-based, multidisciplinary strategies for disease prevention (ranging from medical care to urban planning) may be necessary.

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