Association of Neighborhood Characteristics With Cardiovascular Health in the Multi-Ethnic Study of Atherosclerosis

Erin Unger, MD; Ana V. Diez-Roux, MD, PhD; Donald M. Lloyd-Jones, MD, ScM; Mahasin S. Mujahid, PhD; Jennifer A. Nettleton, PhD; Alain Bertoni, MD; Sylvia E. Badon, MS; Hongyan Ning, MD, MS; Norrina B. Allen, PhD, MPH

Background—The concept of cardiovascular health (CVH) was introduced as a global measure of one's burden of cardiovascular risk factors. Previous studies established the relationship between neighborhood characteristics and individual cardiovascular risk factors. However, the relationship between neighborhood environment and overall CVH remains unknown.

Methods and Results—We analyzed data from the Multi-Ethnic Study of Atherosclerosis baseline examination (2000–2002). Mean age was 61.6 years, and 52% were women. Ideal, intermediate, and poor categories of cholesterol, body mass index, diet, physical activity, fasting glucose, blood pressure, and smoking were defined according to the American Heart Association 2020 Strategic Goals, assigned an individual score, and summed to create an overall score. CVH scores were categorized into ideal (11–14 points), intermediate (9–10), and poor (0–8). Neighborhood exposures included favorable food store and physical activity resources densities (by 1-mile buffer), reported healthy food availability, walking/physical activity environment, safety, and social cohesion (by census tract). Multinomial logistic regression was used to determine the association of each characteristic with ideal and intermediate CVH, adjusted for demographics and neighborhood socioeconomic status. Over 20% of Multi-Ethnic Study of Atherosclerosis participants had an ideal CVH score at baseline. In fully adjusted models, favorable food stores (odds ratio=1.22; 1.06–1.40), physical activity resources (odds ratio=1.19; 1.08–1.31), walking/physical activity environment (odds ratio=1.20; 1.05–1.37), and neighborhood socioeconomic status (odds ratio=1.22; 1.11–1.33) were associated with higher odds of having an ideal CVH score.

Conclusions—Neighborhood environment including favorable food stores, physical activity resources, walking/physical activity environment, and neighborhood socioeconomic status are associated with ideal CVH. Further research is needed to investigate the longitudinal associations between neighborhood environment and CVH. (Circ Cardiovasc Qual Outcomes. 2014;7:524-531.)

Key Words: blood pressure ■ cholesterol ■ diet ■ exercise ■ prevention & control ■ risk factors

Cardiovascular disease (CVD) remains the leading cause of death in the United States and was responsible for over 616,000 deaths in 2009.1 The American Heart Association (AHA) 2020 Strategic Impact Goals for 2020 and Beyond introduced the concept of cardiovascular health (CVH) to better characterize an individual’s global CVH profile, including both health factors and health behaviors.2 Substantial data now indicate that having ideal levels of all 7 components of CVH is associated with greater longevity, markedly fewer cardiovascular events, lower healthcare costs, and higher quality of life.3,4 However, <5% of Americans have ideal levels of all 7 components of CVH, and this prevalence is even lower among minority populations.5-6

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From the Department of Medicine, Feinberg School of Medicine, Northwestern University, Chicago, IL (E.U., D.M.L.-J.); Department of Epidemiology, Center for Social Epidemiology and Population Health, University of Michigan School of Public Health, Ann Arbor (A.V.D.-R.); Department of Preventive Medicine, Feinberg School of Medicine, Northwestern University, Chicago, IL (D.M.L.-J., S.E.B., H.N., N.B.A.); Division of Epidemiology, University of California, Berkeley School of Public Health, Berkeley (M.S.M.); The Department of Epidemiology and Disease Control, The University of Texas Health Science Center at Houston (J.A.N); and Department of Epidemiology and Prevention, Wake Forest School of Medicine, Winston-Salem, NC (A.B.).
Correspondence to Norrina Allen, PhD, MPH, Department of Preventive Medicine, Feinberg School of Medicine, Northwestern University, 680 N Lake Shore Dr, Suite 1400-055, Chicago, IL 60611. E-mail norrina-allen@northwestern.edu

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WHAT IS KNOWN

• Individual cardiovascular risk factors such as diabetes mellitus, hypertension, and obesity have been associated with neighborhood characteristics. It remains unknown whether neighborhood characteristics are associated with ideal cardiovascular health as defined by the American Heart Association.

WHAT THIS ARTICLE ADDS

• This study found that neighborhood characteristics including favorable food stores, physical activity resources, walking/physical activity environment, and neighborhood socioeconomic status are associated with ideal cardiovascular health.

• These findings suggest that interventions aimed at improving the built environment and health policies to increase healthy food availability and physical activity resources may improve the cardiovascular health of residents.

levels of CVH and characteristics of the neighborhood environment including favorable food stores, physical activity resources, healthy food availability, walking/physical activity environment, safety, and social cohesion among participants of the Multi-Ethnic Study of Atherosclerosis (MESA).

Methods

Study Sample

MESA is a multicenter, prospective cohort study of individuals aged 45 to 84 years and free of clinical CVD at baseline designed to examine the prevalence, correlates, and progression of subclinical CVD. Further details of the study design have been previously published. In brief, 6814 participants were enrolled from July 2000 to September 2002 at 6 field centers (Baltimore; Chicago; Forsyth County, NC; Los Angeles; New York; and St Paul, MN). In the study, 27.7% of study participants were black, 11.8% Chinese-American, 22.0% Hispanic, and 38.5% white. The study protocol was approved by the institutional review boards of all participating institutions as well as the National Heart, Lung, and Blood Institute, and participants gave informed consent. At baseline examination, participants completed questionnaires on demographic and social characteristics, smoking, physical activity, diet, and medications. They underwent a physical examination to determine cardiovascular risk including blood pressure, height, and weight in addition to a fasting blood draw for glucose and cholesterol levels.

The present study included 5649 MESA participants. We excluded participants who did not participate in the ancillary MESA Neighborhood Study (n=623), did not have accurate geocoded information available (n=144), or did not have complete baseline data on education, income, marital status, or CVH components (body mass index [BMI], blood pressure, smoking, physical activity, diet, total cholesterol, and fasting blood glucose; n=398).

Assessment of CVH

CVH, as defined by the AHA 2020 Strategic Impact Goals for 2020 and Beyond, includes 3 health factors (cholesterol, fasting blood glucose, and blood pressure) and 4 health behaviors (BMI, diet, physical activity, and smoking status), each of which was categorized into 3 categories as per the 2020 Strategic Impact Goals—poor, intermediate, and ideal—as defined in Table 1. Physical activity was assessed using the MESA Typical Week Physical Activity Survey, adapted from the Cross-Cultural Activity Participation Study to identify time and frequency spent in activities during a typical week in the past month. The survey has 28 questions covering household chores, lawn/yard/garden/farm, care of children/adults, transportation, walking (not at work), dancing and sport activities, conditioning activities, leisure activities, and occupational and volunteer activities. We included minutes of walking, conditioning, and leisure activities as exercise. Minutes of moderate and vigorous exercise were estimated from the questionnaire. Diet was assessed using a 120-item food frequency questionnaire, modified from the Insulin Resistance Atherosclerosis study. As in prior studies using the food frequency questionnaire, 5 components of healthy diet (high intake of fruit and vegetables, fish, whole grains; low intake of sodium and sugar-sweetened beverages) were defined according to AHA Strategic Goals. Blood sugar and cholesterol were measured from a fasting 75 mL blood sample obtained at the clinical examination. Blood pressure was measured after resting for 5 minutes in the seated position; the average of the second and third readings was used. BMI was calculated using measured height and weight at the clinical examination. Smoking history was obtained using a questionnaire developed from National Health and Nutrition Examination Survey (NHANES) III, the National Health Interview Survey, and Atherosclerosis Risk in Communities (ARIC). Ideal, intermediate, and poor levels of each risk factor and behavior are defined in Table 1 based on the AHA 2020 Strategic Goals, which have previously been published.

For each individual risk factor, poor, intermediate, and ideal risk factor categories were assigned a score of 0, 1, and 2, respectively. As previously described, an overall CVH score (range, 0–14) was established as the sum of each individual component score, with 14 corresponding to the lowest burden of cardiovascular risk. Participants were divided into 3 groups based on overall CVH score: ideal (11–14), intermediate (9–10), and poor (0–8) along natural breaks in the data.

Neighborhood Characteristics

The primary exposures in this study included 6 neighborhood characteristics: (1) densities of favorable food stores, (2) resident-reported healthy food availability, (3) density of physical activity resources, (4) resident-reported walking/physical activity environment, (5) safety, and (6) social cohesion. The densities of favorable food stores (ie, food stores likely to provide fresh fruits and vegetables) and physical activity resources were created from Kernel density estimates generated using Euclidean distances. Kernels using 1-mile and 1/5 mile radius around participants’ home addresses were examined; because prior studies have used 1-mile radius and results were similar using 1/2 mile radius, the results below use the 1-mile density values. Healthy food availability, walking/physical activity environment, social cohesion, and safety were evaluated as part of the MESA Neighborhood Ancillary Study via a questionnaire administered to MESA participants as well as to other neighborhood residents sampled from MESA neighborhoods to serve as informants on their neighborhoods. Specific questions for the survey and further details have previously been reported. Questionnaire responses for all residents of a given tract were aggregated to the census tract level using conditional empirical Bayes estimation using a 3-level hierarchical linear model adjusted for respondent age, sex, source, and site. The models incorporated weights which were proportional to the reliability; thus, census tracts with smaller samples and poorer reliability would have greater shrinkage toward the mean as compared with larger census tract with greater reliability. For all neighborhood measures, a higher score represents a healthier/better environment.

Based on prior work, favorable food stores included chain and nonchain supermarkets and fruit and vegetable markets identified using National Establishment Time Series data from Wall’s and Associates. A total of 15 Standardized Industrial Codes were used to identify supermarkets and fruit and vegetable markets. These data were enhanced by adding supermarket data from the Nielsen TDLinx Service Supermarket Retail Category Database. Data corresponding to the year that the individual MESA participant was enrolled were used. For each MESA participant, the density of favorable food stores was defined as the number of food stores within a 1-mile radius around their primary residential address. Data are presented as businesses per square mile. Survey measures to assess healthy food availability were based on 2 questionnaire items. Respondents were asked...
how much they agree with the following statements using a 5-point Likert scale: (1) A large selection of fresh fruits and vegetables is available in my neighborhood; (2) A large selection of low-fat products is available in my neighborhood.

Physical activity resources included the number of total physical activity facilities within a 1-mile radius around each MESA participant’s home address. Physical activity resources were identified using National Establishment Time Series data corresponding to the year the MESA participant was enrolled in the study, and facilities per square mile were calculated. Recreational resources were identified from 114 Standardized Industrial Codes and included indoor conditioning (health clubs/gyms, yoga, karate, etc.), dance, bowling, golf, team and racquet sports, and water activities. Survey-reported neighborhood walking/physical activity environment was assessed using several survey items. Respondents were asked their agreement with the following questions based on a 5-point Likert scale: (1) My neighborhood offers many opportunities to be physically active; (2) Local sports clubs and other facilities in my neighborhood offer many opportunities to get exercise; (3) It is pleasant to walk in my neighborhood; (4) The trees in my neighborhood provide enough space; (5) In my neighborhood, it is easy to walk places; (6) I often see other people walking in my neighborhood; (7) I often see people exercising in my neighborhood. Participants’ agreement with each of the statements was combined into an aggregate score for neighborhood walking/physical activity environment.23

Safety and social cohesion were also assessed via questionnaires. Safety was assessed using the following items: (1) I feel safe walking in my neighborhood, day or night; (2) Violence is not a problem in my neighborhood; (3) My neighborhood is safe from crime. Responses were combined to create a score for neighborhood safety. Social cohesion was assessed based on the following items: (1) People around here are willing to help their neighbors; (2) People in my neighborhood generally get along with each other; (3) People in my neighborhood can be trusted; (4) People in my neighborhood share the same values, and their responses were combined to create a total score for neighborhood social cohesion.

Neighborhood socioeconomic status (SES) based on census tract was represented by a single, summary score adapted from previous work.9 The score combines 6 variables representing wealth and income (log of the median household income; log of median value of housing units; the percentage of households receiving interest, dividend, or net rental income), education (the percentage of adults ≥25 years who had completed high school and the percentage of adults ≥25 years who had completed college), and occupation (the percentage of used persons ≥16 years in executive, managerial, or professional specialty occupations). A higher score indicates greater neighborhood socioeconomic advantage.

**Individual-Level Covariates**

Additional participant covariates included patient demographics such as age, sex, race/ethnicity, education (less than high school, high

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### Table 1. Cardiovascular Health Score Components

<table>
<thead>
<tr>
<th>Component</th>
<th>Score</th>
<th>Definition</th>
<th>% of MESA Population (n=5805)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Physical activity</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>No exercise</td>
<td>22.1</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1–149 min of moderate exercise or 1–74 min of vigorous exercise/week</td>
<td>17.4</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>150+ min of moderate exercise or 75+ min of vigorous exercise/week</td>
<td>60.5</td>
<td></td>
</tr>
<tr>
<td><strong>Diet</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>0–1 components of healthy diet</td>
<td>42.8</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>2–3 components of healthy diet</td>
<td>55.7</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>4–5 components of healthy diet</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td><strong>Blood sugar</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>≥126 mg/dL fasting</td>
<td>10.3</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>100–125 mg/dL fasting or treated to &lt;100 mg/dL</td>
<td>14.7</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>&lt;100 mg/dL, unmedicated</td>
<td>75.0</td>
<td></td>
</tr>
<tr>
<td><strong>Blood pressure</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>SBP ≥140 mm Hg or DBP ≥90 mm Hg</td>
<td>36.5</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>SBP 120–139 mm Hg or DBP 80–89 mm Hg or treated to &lt;120/80 mm Hg</td>
<td>28.2</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>&lt;120/80 mm Hg, unmedicated</td>
<td>35.3</td>
<td></td>
</tr>
<tr>
<td><strong>BMI</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>≥30 kg/m²</td>
<td>31.7</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>25.0–29.9 kg/m²</td>
<td>39.5</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>&lt;25.0 kg/m²</td>
<td>28.9</td>
<td></td>
</tr>
<tr>
<td><strong>Cholesterol</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>≥240 mg/dL</td>
<td>13.3</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>200–239 mg/dL or treated to &lt;200 mg/dL</td>
<td>39.5</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>&lt;200 mg/dL, unmedicated</td>
<td>47.3</td>
<td></td>
</tr>
<tr>
<td><strong>Smoking</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>Current smoker</td>
<td>12.5</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Former smoker, quit ≤12 mo ago</td>
<td>1.2</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Never smoker or quit &gt;12 mo ago</td>
<td>86.3</td>
<td></td>
</tr>
</tbody>
</table>

BMI indicates body mass index; DBP, diastolic blood pressure; MESA, Multi-Ethnic Study of Atherosclerosis; and SBP, systolic blood pressure.

*When combining vigorous and moderate exercise, vigorous exercise was weighted double.
school graduate, some college, college graduate, or more than college graduate), marital status (married, not married), income (<$40,000 and ≥$40,000 per year), census tract, and study site as assessed by a study questionnaire.

Statistical Analyses
In descriptive analyses, distributions of each component of the CVH score were summarized. Distributions of participant characteristics including age, sex, race/ethnicity, highest level of education completed, income, and marital status were examined overall and stratified by CVH score group. We calculated mean and standard deviation for continuous variables, and percentage for categorical variables. Components of the CVH score and participant characteristics were compared across CVH score groups using ANOVA for continuous variables and \( \chi^2 \) tests for categorical variables.

We examined the association of each neighborhood characteristic with poor, intermediate, and ideal CVH groups using multinomial logistic regression models. Models were sequentially adjusted for demographics (age, sex, study site, census tract, race/ethnicity, and marital status), individual SES (income, education), and neighborhood SES. Neighborhood characteristics were each examined separately. Model 1 is unadjusted. Model 2 adjusts for sex, age, census tract, and study site. Model 3 adjusts for all variables in model 2 and race and marital status. Model 4 adjusts for all variables in model 3 and education and income. Model 5 adjusts for all variables in model 4 and neighborhood SES.

For the purposes of this study, all neighborhood characteristics were standardized such that the odds ratio represents the odds per each +1 standard deviation difference (higher). Interaction terms were analyzed to assess whether sex, race/ethnicity, or neighborhood SES modified the associations of interest. All analyses were conducted in SAS 9.3 (SAS Institute, Cary, NC).

Results
Of the 5805 MESA participants included in this study, 21.1% were in ideal CVH (scores of 11–14) as we defined it, 33.2% were in the intermediate group (scores of 9–10), and 45.8% were in poor CVH (scores of 0–8). Only 0.14% (n=8) of participants had ideal levels of all 7 components. Table 1 shows the 7 components of CVH, the definitions for the 3 groups within each component, and the percentage of individuals who obtained ideal, intermediate, and poor levels for each of the individual components. For CVH behaviors and factors, ideal smoking status (ie, never smoker or quit >1 year ago) was the most prevalent: 86.3% of participants. MESA participants were least likely to meet the definition of ideal dietary health. Only 1.5% of participants had ideal dietary health, with the largest proportion of individuals (55.7%) in intermediate dietary health (meeting 2–3 components of the healthy diet construct).

Sociodemographic characteristics of participants, both overall and by CVH group, are displayed in Table 2. Fifty-two percent of the study sample were women, and the mean age was 61.7 years. Individuals having ideal CVH were younger, more frequently white, more educated, and wealthier compared with participants in the poor CVH group. All sociodemographic factors included in Table 2, except for sex, were significantly associated with the CVH group (\( P<0.001 \)).

In unadjusted analyses, all neighborhood characteristics, except social cohesion, were associated with the prevalence of an ideal CVH score (Figure 1; Table 3). After sequential adjustment for individual demographics characteristics in models 2, 3, and 4, all neighborhood characteristics except social cohesion remained associated with having ideal CVH (Table 3). Neighborhood SES was associated with 8% and 22% greater odds of having intermediate and ideal CVH, respectively. Favorable food stores, physical activity resources, and walking/physical activity environment remained significantly associated with having ideal CVH after additional adjustment for neighborhood SES. In the fully adjusted model, for every 1 SD increase in favorable food stores, participants had a 22% greater odds of having ideal CVH as compared with poor CVH (odds ratio, 1.22; 95% confidence interval, 1.06, 1.40). Similar findings were seen for the association between physical activity resources and ideal CVH (odds ratio, 1.19; 95% confidence interval, 1.06, 1.31) and between walking/physical

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Overall n=5805</th>
<th>Poor (Score 0–8) n=2657</th>
<th>Intermediate (Score 9–10) n=1925</th>
<th>Ideal (Score 11–14) n=1223</th>
<th>( P ) Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y, mean (SD)</td>
<td>61.7 (10.11)</td>
<td>62.4 (9.65)</td>
<td>61.7 (10.42)</td>
<td>60.2 (10.42)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Women, %</td>
<td>52.4</td>
<td>51.6</td>
<td>52.6</td>
<td>53.5</td>
<td>0.47</td>
</tr>
<tr>
<td>Race/ethnicity, %</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>White</td>
<td>40.0</td>
<td>32.1</td>
<td>44.0</td>
<td>50.8</td>
<td></td>
</tr>
<tr>
<td>Chinese</td>
<td>12.1</td>
<td>6.9</td>
<td>14.6</td>
<td>19.9</td>
<td></td>
</tr>
<tr>
<td>Black</td>
<td>25.8</td>
<td>33.7</td>
<td>21.9</td>
<td>14.9</td>
<td></td>
</tr>
<tr>
<td>Hispanic</td>
<td>22.0</td>
<td>27.3</td>
<td>19.5</td>
<td>14.5</td>
<td></td>
</tr>
<tr>
<td>Education, %</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>&lt;High school education</td>
<td>16.4</td>
<td>21.0</td>
<td>14.7</td>
<td>8.9</td>
<td></td>
</tr>
<tr>
<td>High school education</td>
<td>18.0</td>
<td>21.5</td>
<td>17.0</td>
<td>11.9</td>
<td></td>
</tr>
<tr>
<td>Some college education</td>
<td>28.7</td>
<td>31.2</td>
<td>28.0</td>
<td>24.5</td>
<td></td>
</tr>
<tr>
<td>College education</td>
<td>18.2</td>
<td>14.0</td>
<td>19.9</td>
<td>24.8</td>
<td></td>
</tr>
<tr>
<td>&gt;College education</td>
<td>18.7</td>
<td>12.3</td>
<td>20.4</td>
<td>29.9</td>
<td></td>
</tr>
<tr>
<td>Married, %</td>
<td>62.0</td>
<td>58.8</td>
<td>63.3</td>
<td>67.1</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Income &lt;$40,000/y, %</td>
<td>49.0</td>
<td>56.9</td>
<td>46.4</td>
<td>36.0</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

*For comparison across 3 cardiovascular health score groups.
activity environment and ideal CVH (odds ratio, 1.20; 95% confidence interval, 1.05, 1.37).

The associations of favorable food stores, healthy food availability, walking/physical activity environment, safety, and neighborhood SES with CVH scores were significantly different for men and women (Table 4). Among men, the odds of having an intermediate or ideal CVH as compared with poor CVH were 23% and 36% greater, respectively, for every 1 SD increase in favorable food stores. Among women, favorable food stores were not associated with intermediate or ideal CVH score. In contrast, healthy food availability, walking/physical activity environment, and safety were significantly associated with greater odds of having ideal CVH among women but not in men. Similarly, neighborhood SES was significantly associated with greater odds of having intermediate or ideal CVH among women of 19% and 41%, respectively, but there was no association among men. Physical activity resources were significantly associated with greater odds of ideal CVH in both men (16%) and women (22%) as compared with poor CVH. Sex did not seem to modify the association between social cohesion and CVH scores. There was no evidence that race/ethnicity or neighborhood SES modified the association between any neighborhood characteristics in this study and CVH scores. Correlation between neighborhood characteristics ranged from 0.01 to 0.67.

In sensitivity analyses, the fully adjusted findings were consistent, although slightly attenuated, when we examined the number of favorable food stores and physical activity resources within a smaller (1/2 mile as opposed the 1 mile) radius, and the odds ratios for having an ideal CVH score as compared with a poor CVH score were 1.10 (0.92–1.23) and 1.16 (1.06–1.27) for 1 SD increase in favorable food stores and physical activity resources, respectively. Intraneighborhood correlation was low (the median number of individuals per census tract was 2); thus, when we used a multilevel GEE model to account for the clustering, findings were not changed substantially although the standard errors were increased; therefore, as in previous studies of MESA Neighborhood data, we present the simpler model. In the Generalized Estimating Equations (GEE) models, favorable food stores, walking/physical activity environment, and neighborhood SES were all positively related to having an ideal CVH score, although they were no longer significant. The association of physical activity resources with ideal CVH as compared with poor CVH remained significant with an adjusted odds ratio of 1.12 (95% confidence interval, 1.00–1.26).

Discussion

In this cross-sectional analysis of an ethnically diverse, population-based cohort of US adults, we found that neighborhood characteristics, including the density of favorable food stores, physical activity facilities, resident-reported walking/physical activity environment, and neighborhood SES were positively associated with having ideal CVH, even after adjusting for individual sociodemographic factors. The density of favorable food stores seemed to greatly affect CVH among men, whereas neighborhood SES was more strongly associated with having ideal CVH among women.

The present study is the first to report the relationship between neighborhood characteristics and overall CVH, as introduced in the 2020 AHA Strategic Goals. These findings are consistent with prior studies that have examined the relationship between neighborhood characteristics and the individual CVD risk factors that are components of the CVH score. However, an examination of overall CVH, as opposed to individual components, provides a more holistic representation of overall health and may suggest that neighborhood interventions could affect CVH and CVD outcomes more meaningfully and efficiently than approaches targeting single risk factors.
Although findings have not always been consistent, and casual inferences are limited by cross-sectional designs, a number of studies have reported associations between local neighborhood resources, cardiovascular outcomes, and health behaviors. For example, healthy food availability has been found to be associated with a significantly lower BMI, including healthy food density in multiple studies.25 Rundle et al.26 found that BMI was 0.80 U lower in the highest healthy food density quintile compared with the lowest density group. Similarly, Morland et al.26 examined the associations of proximity to supermarkets and other neighborhood resources with selected CVD risk factors in the Atherosclerosis Risk in Communities study using food stores. The study found that there was a 9% lower prevalence of overweight and 12% lower prevalence of hypertension in areas with ≥1 supermarket compared with areas without any supermarkets. Previous studies have also shown a positive association between physical activity resources and increased physical activity15,30 potentially resulting in lower BMI and blood pressure. Individuals with 4 to 6 recreational facilities within a 5-minute walk from their home were 1.3 times more likely to meet physical activity recommendations than those without recreation facilities.14 In this study, we found a positive association between the density of favorable food stores and physical activity resources and the availability of healthy foods with CVH. The present study expands on this prior work by showing how neighborhood resources are related to a global measure of CVH, including the biomedical risk factors influenced by behaviors.

There is little research investigating the importance of social cohesion in a neighborhood context for cardiovascular risk factors. Yet, there is evidence to suggest that social support at the individual level may impact physical activity and smoking cessation. Trierbe et al.31 examined 3 prior studies assessing the relationship between social support and physical activity and found that social support for exercise positively correlated with physical activity, but this varied significantly based on sociodemographic characteristics. Further, previous studies have demonstrated that low social support may be an independent CVD risk factor. Orth-Gomer et al.32 examined both social attachment (to close individuals) and social integration (to larger society) in relationship to coronary heart disease for 6 years in 700+ Swedish men. In their study, they found that men with coronary heart disease were twice as likely to lack social integration rather than at the level of neighborhoods. Consistent with previous studies, we found that neighborhood SES was significantly associated with CVD risk.5–11,33–35 In this study, we found that the

### Table 3. Odds Ratios of Having Ideal or Intermediate (Compared With Poor) Cardiovascular Health Associated With a 1 Standard Deviation Difference in Neighborhood Characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
<th>Model 4</th>
<th>Model 5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OR 95% CI OR 95% CI OR 95% CI OR 95% CI OR 95% CI OR 95% CI</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Favorable food stores</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intermediate</td>
<td>1.01 0.95, 1.07</td>
<td>1.14* 1.02, 1.29*</td>
<td>1.13 0.99, 1.28</td>
<td>1.13 0.99, 1.29</td>
<td>1.12 0.99, 1.27</td>
</tr>
<tr>
<td>Ideal</td>
<td>1.13* 1.06, 1.21*</td>
<td>1.35* 1.19, 1.54*</td>
<td>1.27* 1.11, 1.45*</td>
<td>1.26* 1.10, 1.44*</td>
<td>1.22* 1.06, 1.40*</td>
</tr>
<tr>
<td>Healthy food availability</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intermediate</td>
<td>1.16* 1.09, 1.23*</td>
<td>1.15* 1.04, 1.26*</td>
<td>1.05 0.94, 1.16</td>
<td>1.01 0.92, 1.12</td>
<td>0.98 0.88, 1.09</td>
</tr>
<tr>
<td>Ideal</td>
<td>1.58* 1.47, 1.69*</td>
<td>1.54* 1.37, 1.72*</td>
<td>1.28* 1.13, 1.45*</td>
<td>1.19* 1.05, 1.35*</td>
<td>1.10 0.97, 1.26</td>
</tr>
<tr>
<td>Physical activity resources</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intermediate</td>
<td>1.16* 1.09, 1.25*</td>
<td>1.19* 1.10, 1.29*</td>
<td>1.12* 1.03, 1.22*</td>
<td>1.08 0.99, 1.18</td>
<td>1.05 0.96, 1.16</td>
</tr>
<tr>
<td>Ideal</td>
<td>1.44* 1.35, 1.55*</td>
<td>1.46* 1.35, 1.58*</td>
<td>1.32* 1.21, 1.44*</td>
<td>1.25* 1.14, 1.36*</td>
<td>1.19* 1.08, 1.31*</td>
</tr>
<tr>
<td>Walking/physical activity environment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intermediate</td>
<td>1.24* 1.17, 1.32*</td>
<td>1.24* 1.14, 1.35*</td>
<td>1.17* 1.07, 1.28*</td>
<td>1.09 0.99, 1.19</td>
<td>1.06 0.94, 1.18</td>
</tr>
<tr>
<td>Ideal</td>
<td>1.6* 1.49, 1.71*</td>
<td>1.66* 1.51, 1.83*</td>
<td>1.48* 1.34, 1.65*</td>
<td>1.29* 1.16, 1.44*</td>
<td>1.20* 1.05, 1.37*</td>
</tr>
<tr>
<td>Safety</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intermediate</td>
<td>1.19* 1.12, 1.26*</td>
<td>1.25* 1.17, 1.34*</td>
<td>1.11* 1.03, 1.19*</td>
<td>1.06 0.98, 1.14</td>
<td>1.02 0.93, 1.12</td>
</tr>
<tr>
<td>Ideal</td>
<td>1.35* 1.26, 1.45*</td>
<td>1.56* 1.44, 1.70*</td>
<td>1.27* 1.16, 1.38*</td>
<td>1.16* 1.06, 1.27*</td>
<td>1.05 0.94, 1.17</td>
</tr>
<tr>
<td>Social cohesion</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intermediate</td>
<td>1.09* 1.03, 1.16*</td>
<td>1.20* 1.10, 1.30*</td>
<td>1.12* 1.03, 1.22*</td>
<td>1.05 0.96, 1.15</td>
<td>1.01 0.91, 1.12</td>
</tr>
<tr>
<td>Ideal</td>
<td>1.09* 1.02, 1.17*</td>
<td>1.46* 1.32, 1.62*</td>
<td>1.27* 1.14, 1.41*</td>
<td>1.11 0.99, 1.24</td>
<td>0.99 0.87, 1.12</td>
</tr>
<tr>
<td>Neighborhood SES</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intermediate</td>
<td>1.34* 1.26, 1.43*</td>
<td>1.34* 1.25, 1.43*</td>
<td>1.18* 1.10, 1.27*</td>
<td>1.08 0.99, 1.17</td>
<td>… …</td>
</tr>
<tr>
<td>Ideal</td>
<td>1.79* 1.67, 1.92*</td>
<td>1.78* 1.64, 1.92*</td>
<td>1.44* 1.33, 1.57*</td>
<td>1.22* 1.11, 1.33*</td>
<td>… …</td>
</tr>
</tbody>
</table>

Odds ratios (ORs) represent ideal or intermediate cardiovascular health group (reference is poor cardiovascular health group) per 1 SD increase in neighborhood characteristic. Model 1 is unadjusted. Model 2 is adjusted for sex, age, study site, and census tract. Model 3 is adjusted for all variables in model 2 and race and marital status. Model 4 is adjusted for all variables in model 3 and education and income. Model 5 is adjusted for all variables in model 4 and neighborhood socioeconomic status (SES). CI indicates confidence interval.*Indicates P value was <0.05 when compared with those with a poor CVH score.
impact of neighborhood SES was stronger for women as compared with men. Sex differences in the effects of neighborhood environment have been previously identified.36,37 However, the reasons for these differences remain unclear.

The MESA study is a population-based study composed of an ethnically diverse group of individuals. Additionally, the study includes detailed and validated information about participants' health status and risk factors. Further, the study uses detailed assessments of neighborhood environments for analysis. There are some limitations, which must be considered. As described above, multiple variables including both demographic characteristics as well as neighborhood characteristics are self-reported and thus subject to misclassification. Although MESA is a large population-based cohort composed of individuals from 6 different national sites, it was not designed to be nationally representative. Further, individuals were not sampled by neighborhood, which may limit geographic representation from sites. Because this is a cross-sectional study, we cannot address causality. Prior literature suggests that people self-select into neighborhoods, which complicates the relationship between neighborhood environment and CVH. In addition, our analyses did not examine the extent to which the various neighborhood resources act synergistically to promote CVH.

This study shows that the prevalence of ideal CVH is associated with multiple, different neighborhood characteristics, suggesting the importance of local environment. Neighborhood characteristics including favorable food stores, physical activity resources, walking/physical activity environment, and neighborhood SES were significantly associated with having ideal CVH. Longitudinal studies examining neighborhood characteristics and CVH are needed to better understand whether the associations we describe are causal. However, the patterns observed suggest that future efforts to improve CVH should include a consideration of neighborhood factors. Both structural changes to the built environment as well as healthy policies could potentially impact the CVH of residents. Further understanding of how neighborhood interventions can increase the prevalence of ideal CVH is clearly needed.

### Acknowledgments

We thank the other investigators, the staff, and the participants of the Multi-Ethnic Study of Atherosclerosis (MESA) study for their valuable contributions. A full list of participating MESA investigators and institutions can be found at http://www.mesa-nhlbi.org.

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### Table 4. Odds Ratios by Sex of Having Ideal or Intermediate (Compared With Poor) Cardiovascular Health Associated With a 1 Standard Deviation Difference in Neighborhood Characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>OR (95% CI)*</th>
<th>P Value for Interaction by Sex</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Favorable food stores</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intermediate</td>
<td>1.06 (0.93, 1.22)</td>
<td>1.23 (1.06, 1.43)†</td>
</tr>
<tr>
<td>Ideal</td>
<td>1.13 (0.97, 1.31)</td>
<td>1.36 (1.16, 1.61)†</td>
</tr>
<tr>
<td><strong>Healthy food availability</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intermediate</td>
<td>1.05 (0.93, 1.19)</td>
<td>0.91 (0.81, 1.04)</td>
</tr>
<tr>
<td>Ideal</td>
<td>1.18 (1.02, 1.38)†</td>
<td>1.02 (0.88, 1.19)</td>
</tr>
<tr>
<td><strong>Physical activity resources</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intermediate</td>
<td>1.05 (0.93, 1.17)</td>
<td>1.06 (0.95, 1.19)</td>
</tr>
<tr>
<td>Ideal</td>
<td>1.22 (1.08, 1.36)†</td>
<td>1.16 (1.03, 1.31)†</td>
</tr>
<tr>
<td><strong>Walking/physical activity environment</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intermediate</td>
<td>1.10 (0.97, 1.26)</td>
<td>1.00 (0.88, 1.14)</td>
</tr>
<tr>
<td>Ideal</td>
<td>1.31 (1.13, 1.52)†</td>
<td>1.08 (0.93, 1.26)</td>
</tr>
<tr>
<td><strong>Safety</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intermediate</td>
<td>1.09 (0.98, 1.22)</td>
<td>0.96 (0.86, 1.08)</td>
</tr>
<tr>
<td>Ideal</td>
<td>1.17 (1.02, 1.33)†</td>
<td>0.93 (0.82, 1.07)</td>
</tr>
<tr>
<td><strong>Social cohesion</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intermediate</td>
<td>1.04 (0.92, 1.17)</td>
<td>0.90 (0.78, 1.05)</td>
</tr>
<tr>
<td>Ideal</td>
<td>1.06 (0.92, 1.23)</td>
<td>0.98 (0.87, 1.11)</td>
</tr>
<tr>
<td><strong>Neighborhood SES</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intermediate</td>
<td>1.19 (1.07, 1.31)†</td>
<td>0.98 (0.89, 1.09)</td>
</tr>
<tr>
<td>Ideal</td>
<td>1.41 (1.26, 1.59)†</td>
<td>1.04 (0.92, 1.17)</td>
</tr>
</tbody>
</table>

CI indicates confidence interval; OR, odds ratio; and SES, socioeconomic status.

*Model adjusted for age, education, race/ethnicity, income, study site, marital status, census tract, and neighborhood SES (model 5).
†Indicates P value was <0.05 when compared with those with a poor CVH score.
Disclosures

None.

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