Availability of healthy foods and dietary patterns: the Multi-Ethnic Study of Atherosclerosis[1–3]

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ABSTRACT

Background: Inadequate availability of healthy foods may be a barrier to achieving recommended diets.

Objective: The objective was to study the association between the directly measured availability of healthy foods and diet quality.

Design: We conducted a cross-sectional study of 759 participants from the Baltimore site of the Multi-Ethnic Study of Atherosclerosis. Diet was characterized by using a food-frequency questionnaire and summarized by using 2 empirically derived dietary patterns reflecting low- and high-quality diets. For each participant, the availability of healthy foods was directly assessed by using 3 measures: in all food stores within their census tract, in their closest food store, and in all food stores within 1 mile (1.6 km) of their residence.

Results: Twenty-four percent of the black participants lived in neighborhoods with a low availability of healthy food compared with 5% of white participants ($P < 0.01$). After adjustment for age, sex, income, and education, a lower availability of healthy foods in the tract of residence or in the closest store was associated with higher scores on the low-quality dietary pattern ($P < 0.05$). Less consistent associations were observed for the high-quality dietary pattern.

Conclusions: Healthy foods were less available for black participants. Low availability of healthy foods was associated with a lower-quality diet. The extent to which improvements in the availability of healthy foods results in higher-quality diets deserves further investigation. *Am J Clin Nutr* 2009;89:897–904.

INTRODUCTION

Unhealthy diets underlie many public health problems in the United States, including obesity, type 2 diabetes, and cardiovascular disease (1, 2). The importance of making recommended healthy foods, such as fruit and vegetables, whole grains, and low-fat dairy products (3), available to consumers has been suggested as key to improving diet quality (4, 5). Although it has been shown that living in lower income neighborhoods is associated with lower diet quality (6), few studies have directly examined the association between healthy food availability and diet quality (7, 8). Prior work relating food availability to diet has mostly relied on the presence of different types of stores (8, 9) or the participants' survey responses (10) as measures of healthy food availability. Other studies have directly measured food availability, but these studies have often focused on limited assessments of healthy food availability and small geographic areas (7, 11–13). The recent development of a comprehensive and valid instrument to assess the availability of healthy foods in a systematic and large-scale fashion (14) has now made it possible to include these systematic assessments in large population studies.

Dietary patterns are currently of interest in nutritional epidemiology because foods are not consumed in isolation, and the health effects of multiple foods consumed as part of a given dietary pattern may be greater than the individual effects of single foods and nutrients (15). Numerous epidemiologic studies have shown associations between disease conditions, such as cancer, diabetes, and cardiovascular disease, and empirically derived dietary patterns (16). However, few studies have examined the determinants of these dietary patterns and how they are influenced by food availability.

Using data from the Multi-Ethnic Study of Atherosclerosis (MESA) (17), a population-based study with detailed dietary assessment, we examined the relation between directly measured healthy food availability and dietary patterns (18, 19) in a diverse sample of adults. We hypothesized that a greater availability of

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healthy food options would be associated with better diet quality, as reflected by 2 empirically derived dietary patterns.

SUBJECTS AND METHODS

Subjects

The analyses were based on data from Baltimore participants of MESA. Baltimore is the only MESA site where the availability of healthy foods was directly measured (20). MESA is a cardiovascular cohort study supported by the National Heart, Lung, and Blood Institute (NHLBI); its goal is to identify risk factors for subclinical atherosclerosis and its progression. A total of 1085 men and women aged 45–84 y who identified themselves as white or black and were free of clinically apparent cardiovascular disease were recruited in Baltimore City and Baltimore County, MD. Participants were recruited from locally available sources, including lists of residents, lists of dwellings, and telephone exchanges. The baseline examination of the cohort, on which these analyses are based, took place between August 2000 and August 2002. The institutional review board at Johns Hopkins University approved the study. All participants gave written informed consent.

Outcome assessment

Usual dietary intake for each participant over the past year was assessed by using a 120-item food-frequency questionnaire (FFQ). The questionnaire was adapted from the Insulin Resistance Atherosclerosis Study instrument, which has comparable validity for multi-ethnic populations (21). To reflect diet quality, we used 2 empirically derived dietary patterns previously identified by Nettleton et al (19). Dietary patterns were derived across all MESA participants by principal components analysis of 47 food groups, and each pattern was named according to its top loading food groups. As seen in **Appendix A**, the fats and processed meats pattern was characterized by a high intake of added fats and oils, processed meats, fried potatoes, salty snacks, and desserts, reflecting a diet of low quality. Scores on this dietary pattern were positively associated with serum concentrations of C-reactive protein, interleukin-6, homocysteine, LDL cholesterol, serum insulin, and waist circumference (19). The whole grains and fruit pattern was characterized by high loadings of whole-grain foods, fruit, low-fat milk, nuts, and green leafy vegetables, reflecting a diet of high quality (*see* Appendix A). Scores on this dietary pattern were inversely associated with C-reactive protein, interleukin-6, homocysteine, LDL cholesterol, serum glucose, serum insulin, and waist circumference (19). These 2 dietary patterns were selected as outcomes because they reflect meaningful variability in diet quality in our study sample.

Availability of healthy foods assessment

The availability of healthy foods for each MESA participant was characterized by using 3 complementary approaches: *1*) availability of healthy foods in the neighborhood (census tract) of the participant's residence, *2*) availability of healthy foods in the closest food store to each participant's residence, and *3*) availability of healthy foods in all of the food stores located within 1 mile (1.6 km) of the participant's residence. A detailed assessment of all food stores in the MESA Baltimore neighborhoods was conducted by one of us (MF) as part of the MESA Neighborhood Study, an ancillary study to MESA. The area assessed encompassed a total of 159 contiguous census tracts, of which 112 were in Baltimore City and 47 were in Baltimore County. We obtained information on all grocery stores, supermarkets, and convenience stores located within these census tracts from InfoUSA, a proprietary information service, in 2004. Food stores were categorized as in previous studies (8, 22). The InfoUSA list of food stores was improved by comparing it with food license records from the city and county health departments and by having data collectors drive through the main thoroughfares and identify omitted stores (20). A total of 226 food stores were assessed within the study area of interest. Any stores that had opened after the end of the MESA examination (after 2002) were omitted from these analyses.

All food stores were visited and systematically assessed by using the previously validated Nutrition Environment Measures Survey in stores (NEMS-S) instrument (14). One of us (MF) was trained in the use of the NEMS-S instrument and then adapted the instrument to the local conditions of Baltimore. More detailed information on the adaptation of the NEMS-S instrument to Baltimore conditions and how the food availability assessment was conducted is published elsewhere (20). Data on the availability of healthy foods were recorded within 8 food groups: low-fat milk, fruit, vegetables, low-fat meat, frozen foods, low-sodium foods, whole-wheat bread, and low-sugar cereals. Items in the instrument were standardized by brand, type, and size. A healthy food availability score for each store was constructed by adding scores for the availability of the different items ranging from 0 to 27 points, where zero points indicate the lack of any healthy food and 27 points indicate that all healthy foods were available and in high proportions (20). The healthy food availability score for each neighborhood (defined as census tract or a 1-mile radius around the home) was estimated as the mean of the availability scores measured in all stores located within the neighborhood.

Availability of healthy food assessments were examined as a continuous variable as well as categorized into tertiles. Fifty-three (33%) of the 159 census tracts in the study had no stores. Participants with no food stores in their census tract or within 1 mile of their residence were categorized separately. For each MESA participant, we also estimated the healthy food availability score for the store closest to the participant's residence. The 3 food availability measures were highly correlated (Pearson's correlation coefficients of $\geq$0.64).

Sociodemographic indicators

Information on age, sex, race-ethnicity, income, and education was obtained from the MESA baseline questionnaire. Race-ethnicity was characterized on the basis of the participants' responses to questions modeled on the 2000 US Census. Family annual income was classified in tertiles (<\$20,000, \$20,000–\$49,999, and $\geq$\$50,000). Education was also stratified in 3 groups: less than high school, completed high school or had a technical school certificate or an Associates degree, and completed college or more.

Statistical analyses

Of the 1085 Baltimore MESA participants, 883 were geocoded and lived in the set of contiguous census tracts for which healthy food availability was assessed. Of these 883 participants, 124 were excluded because of missing dietary data ($n = 122$) or other covariates (2), which left 759 MESA participants for analysis. The 326 participants excluded from the analyses did not differ significantly from the final sample in terms of race-ethnicity, education, income, sex, or dietary patterns (all $P > 0.05$). Because data collection on healthy food availability occurred in the spring of 2006 and dietary data collection occurred in 2000–2002, healthy food availability scores were based only on stores that reported being open in 2002. All analyses were performed with SAS version 9.1 (SAS Institute Inc, Cary, NC) and Arc GIS version 9.2 (ESRI, Redlands, CA) software.

Differences in healthy food availability in the participants' census tract, closest food store, and all food stores within 1 mile by race-ethnicity, sex, income, and education were tested by using *t* tests and an analysis of variance for continuous measures and by using a chi-square test for categorical measures. Linear regression was used to estimate mean differences in dietary pattern scores before and after adjustment for age, sex, income, education, and race-ethnicity. In categorical analyses, participants with no food stores in their tract or within a mile were included as a separate category. *P* values for linear trends were obtained by including categories of availability of healthy foods as ordinal variables in models (for census tract and 1-mile analyses of participants with no stores were excluded from trend analyses). Given the differences found in the measures of food availability between Baltimore City and Baltimore County (20), we also ran models adjusting for county compared with city residence, and no substantial differences in results were observed.

RESULTS

Demographic characteristics of participants and availability of healthy foods

The distribution of the availability of recommended foods by sociodemographic characteristics of the study participants is shown in **Table 1**. The mean age of the final sample was 63 y. Healthy food availability was strongly patterned by race-ethnicity, income, and education. The most striking differences were observed by race-ethnicity: 24% of black participants lived in census tracts with low healthy food availability compared with only 5% of white participants ($P < 0.01$). In contrast, 46% of white participants lived in census tracts with high healthy food availability compared with 23% of black participants ($P < 0.01$). Low income and less-educated participants were also more likely than high-income and more-educated participants to live in neighborhoods with lower healthy food availability. Differences were larger for income than for education. The percentage of participants living in census tracts with no stores was not substantially different by race-ethnicity, income, or education.

When healthy food availability was examined as a continuous variable, the mean census tract healthy food availability score was 4.64 units lower in blacks than in whites ($P < 0.01$). Similar, although slightly smaller, differences in mean healthy food availability scores were observed when comparing the top and bottom income and education categories (mean difference: 3.9 units and 3.27 units, respectively).

Differences by race-ethnicity, income, and education in the availability of healthy foods in the closest store and for all stores within 1 mile were generally similar to differences observed for availability of healthy foods measured in the census tract (Table 1). The distance in miles from the participants' residence to the closest store was significantly lower for black, low-income, and less-educated participants than for white, high-income, or more-educated participants. Analogously, white, high-income, and more-educated participants were more likely than black, low-income, and less-educated participants to have no stores within 1 mile of their home.

Demographic characteristics of participants and dietary patterns

As shown in **Table 2**, the mean fats and processed meats dietary pattern score was 0.34 (range: −2.25 to 6.25), with higher values indicating a lower-quality diet. The mean whole grains and fruit dietary pattern score was 0.16 (range: −3.28 to 6.59), with higher values indicating a higher-quality diet. Scores for the fats and processed meats dietary pattern were significantly higher in blacks than in whites (mean difference: 0.29 units; $P < 0.01$) and higher in men than in women (mean difference: 0.24 units; $P < 0.01$). Analogously, scores for the whole grains and fruit dietary pattern were significantly higher in whites than in blacks (mean difference: 0.36 units; $P < 0.01$) and higher in women than in men (mean difference: 0.19 units; $P < 0.01$). Neither dietary pattern was consistently associated with income, although the higher income categories had higher mean scores for the whole grains and fruit pattern than did the lowest income category. The fats and processed meats dietary pattern showed no relation with education, whereas the whole grains and fruit dietary pattern was significantly and positively associated with years of education (*P* for trend <0.01).

Availability of healthy foods and diet quality

The mean differences in low- and high-quality dietary patterns by categories of food availability after sequential adjustments for age, sex, income, education, and race-ethnicity are shown in **Table 3** and **Table 4**. As shown in Table 3, participants in the lowest category of food availability based on the neighborhood (census tract) or closest store measure had significantly higher values for the fats and processed meats pattern than those in the highest category. This association did not change substantially after adjustment for age, sex, income, and education [adjusted mean ± SE difference between the lowest and highest availability: 0.23 ± 0.11 ($P = 0.049$) and 0.22 ± 0.09 ($P = 0.021$); *P* for linear trend across categories: = 0.08 and 0.02, respectively], but the association was reduced and no longer statistically significant after adjustment for race-ethnicity [mean differences: 0.12 for census tract ($P = 0.314$) and 0.10 for closest store ($P = 0.215$)]. For each SD increase in the continuous measurement of availability of healthy foods in the neighborhood and closest store, the fats and processed meats dietary pattern score decreased by 0.04 and 0.08 units, respectively. These associations also weakened after adjustment for race-ethnicity. Associations of the fats and processed meats score with healthy food availability for all stores within 1 mile were in the same direction and very similar to those reported for the census tract and closest store measures but were not statistically significant.

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TABLE 1
Demographic characteristics and availability of healthy foods for 759 Multi-Ethnic Study of Atherosclerosis (MESA) participants in Baltimore[1]

	Baltimore MESA participants								
	Race-ethnicity		Income			Education			
Availability of healthy foods	Blacks (n = 383)	Whites (n = 376)	Low (n = 129)	Medium (n = 276)	High (n = 329)	Less than high school (n = 71)	Completed high school (n = 374)	College or more (n = 311)	Total (n = 759)
Census tract									
Low (%)	24.0[2]	5.0	24.0[2]	17.7	7.0	23.9[3]	15.0	11.9	14.6
Medium (%)	21.4	20.5	20.9	24.3	19.2	16.9	22.5	20.3	20.9
High (%)	23.2[2]	45.5	30.2[2]	26.4	43.5	25.3[3]	31.8	39.2	34.3
No stores (%)	31.4	28.5	24.0	31.2	30.4	31.0	30.7	28.6	29.9
Continuous[4]	8.40 ± 7.8[2]	13.04 ± 7.5	8.87 ± 7.8[2]	9.47 ± 7.95	12.77 ± 7.69	8.47 ± 7.44[3]	10.31 ± 7.98	11.74 ± 8.06	10.74 ± 8.00
Closest store									
Low (%)	46.2[2]	9.8	44.2[2]	27.2	21.0	43.7[2]	30.0	22.5	28.2
Medium (%)	30.5[2]	46.8	26.4[2]	45.7	38.0	28.2	39.3	39.9	38.6
High (%)	23.2[2]	43.3	29.5[2]	27.2	41.0	28.2	30.7	37.6	33.2
Continuous[4]	7.66 ± 8.38[2]	13.26 ± 9.40	8.68 ± 8.91[2]	9.54 ± 8.79	12.19 ± 9.71	8.04 ± 8.60[3]	10.09 ± 9.23	11.46 ± 9.49	10.43 ± 9.32
Distance to closest store (miles)[5]	0.45 ± 0.32[2]	0.55 ± 0.41	0.35 ± 0.31[2]	0.46 ± 0.33	0.60 ± 0.40	0.37 ± 0.32[3]	0.50 ± 0.37	0.53 ± 0.40	0.50 ± 0.37
One-mile radius									
Low (%)	47.8[2]	8.0	44.2[2]	33.3	16.1	45.1[2]	30.7	20.6	28.1
Medium (%)	22.5[2]	34.8	27.1	30.8	27.6	28.2[3]	24.3	34.1	28.6
High (%)	20.1[2]	39.4	23.3[2]	25.7	36.5	18.3	32.4	28.9	29.6
No stores (%)	9.7[2]	17.8	5.4[2]	10.1	19.8	8.4	12.6	16.4	13.7
Continuous[4]	7.88 ± 6.11[2]	11.98 ± 6.06	8.19 ± 6.24[2]	9.04 ± 6.15	11.45 ± 6.41	8.03 ± 6.12	10.04 ± 6.64	10.00 ± 6.15	9.81 ± 6.41

[1] Tertiles of healthy food availability scores were used to define low, medium, and high levels of healthy food availability measurements in the census tract, closest store, and all food stores within a 1-mile (1.6 km) radius of each participant.
[2] $P < 0.01$ for differences in healthy food availability by race-ethnicity, income, and education.
[3] $P < 0.05$ for differences in healthy food availability by education.
[4] Healthy food availability score as a continuous variable; all values are means ± SDs.
[5] 1 mile = 1.6 km.

TABLE 2
Mean fat and processed meats and whole grains and fruit dietary pattern scores for 759 Multi-Ethnic Study of Atherosclerosis (MESA) participants in Baltimore, by sociodemographic characteristics

	Fat and processed meats[1]		Whole grains and fruit[2]	
Demographic characteristics	Mean ± SD	Median (25th–75th percentiles)	Mean ± SD	Median (25th–75th percentiles)
Total (n = 759)	0.34 ± 1.03	0.16 (−0.39 to 0.84)	0.16 ± 0.99	0.05 (−0.45 to 0.69)
Race-ethnicity				
Blacks (n = 383)	0.48 ± 1.15[3]	0.26 (−0.32 to 1.02)[3]	−0.02 ± 0.95[3]	−0.13 (−0.65 to 0.50)[3]
Whites (n = 376)	0.19 ± 0.87	0.05 (−0.45 to 0.69)	0.34 ± 0.99	0.27 (−0.41 to 0.98)
Sex				
Male (n = 362)	0.46 ± 1.05[3]	0.29 (−0.27 to 0.96)[3]	0.06 ± 0.94[3]	−0.02 (−0.58 to 0.61)[3]
Female (n = 397)	0.22 ± 1.00	−0.05 (−0.48 to 0.71)	0.25 ± 1.01	0.16 (−0.46 to 0.84)
Income				
<$20,000 ($n$ = 129)	0.22 ± 129	0.11 (−0.40 to 0.84)	0.09 ± 0.96	0.02 (−0.55 to 0.63)
$20,000–$50,000 (n = 276)	0.35 ± 1.10	0.13 (−0.40 to 0.79)	0.21 ± 1.01	0.13 (−0.50 to 0.74)
>$50,000 ($n$ = 329)	0.34 ± 0.97	0.16 (−0.39 to 0.87)	0.17 ± 0.96	0.05 (−0.52 to 0.67)
Education				
Less than high school (n = 71)	0.14 ± 0.83	−0.02 (−0.42 to 0.60)	0.02 ± 0.78[3]	0.02 (−0.56 to 0.38)[3]
Completed high school (n = 374)	0.47 ± 1.13	0.26 (−0.32 to 0.97)	0.07 ± 1.03	−0.07 (−0.62 to 0.64)
College or more (n = 311)	0.22 ± 0.93	0.03 (−0.47 to 0.76)	0.30 ± 0.96	0.23 (−0.39 to 0.84)

[1] Possible scores range from −2.25 to 6.25; lower values indicate a better-quality diet.
[2] Possible scores range from −3.28 to 6.59; higher values indicate a better-quality diet.
[3] $P < 0.01$ for differences in means by race-ethnicity and sex and for trend of linear trends for categories of education.

Participants in the low healthy food availability tertile had lower scores for the whole grains and fruit pattern than did those in the highest category (mean differences: −0.16 and −0.07 for the availability in the census tract and closest store, respectively) after adjustments for age, sex, income, and education (Table 4), but the differences were not statistically significant. As in the case of the fats and processed meats pattern, these differences were further reduced after adjustment for race-ethnicity. Food availability within 1 mile was not associated with the whole grains and fruit dietary pattern.

DISCUSSION

It has been proposed that the availability of healthy foods may be an important contributor to poor diet quality (12, 23–27). By directly measuring the availability of a comprehensive list of recommended foods (3) in all stores located in the residential areas of the MESA participants, we were able to study the associations between the availability of healthy foods and 2 dietary patterns. We found that lower healthy food availability in the census tract or in the closest store was associated with the consumption of a poorer-quality diet in a population sample of adults. Similar results were observed when food availability was characterized based on the stores within 1 mile, although the differences were not statistically significant.

Associations between food availability and dietary patterns remained after adjustment for income and education but were attenuated and became nonsignificant after adjustment for race-ethnicity. Race-ethnicity and food availability were strongly associated in this sample, so it was difficult to assess the 2 independently: for example, in 48% of black participants, availability of healthy foods in all stores within 1mile of their residence was in the lowest category compared with only 8% of white participants. Thus, when added to regression models, race-ethnicity may simply serve as a proxy for food availability, obscuring any association between food availability and diet quality.

Although associations were present in the same direction for both dietary patterns examined, they were not statistically significant for the whole grains and fruit pattern. This may have to do with differences in the measurement properties of each of the summary scores. The whole grains and fruit pattern may be less precisely measured, resulting in misclassification and bias toward the null; alternatively, the components of the whole grains and fruit pattern may be less affected by food availability than the components of the fats and processed meats pattern.

Unfortunately, there is very little empirical information on which to base the area definition (or spatial scale) most relevant for food purchasing behavior. One of the strengths of our study was that we investigated a variety of healthy food availability measures for each participant: the stores in the census tract, the closest store, and the stores within a mile. Findings for healthy food availability in the census tract and in the closest store were the most consistent. Food store data were collected for all census tracts represented in the sample. However, some of the 1-mile buffers fell outside our study area (covering areas for which we had no availability data). This may have introduced measurement error into this measure. There were no consistent associations between living in an area with no stores and dietary patterns, possibly because this is a very heterogeneous group, often including residents of suburban areas who are able to access distant resources.

Another major innovation of our study over prior work was the direct measurement of the availability of healthy foods in stores. Using types of food stores as a proxy for food availability, Morland et al (8) showed that the presence of supermarkets was associated with higher intake of recommended foods, and Zenk et al (9) observed that women shopping at supermarkets in the city of Detroit had a higher intake of fruit and vegetables. However, neither study obtained information on the types of

TABLE 3
Adjusted differences in the low-quality dietary pattern (fats and processed meats) per 3 different food availability assessments (n = 759)[1]

	Difference in fats and processed meats dietary pattern scores			
Availability of healthy foods assessment	Crude	Age + sex	Income + education	Race-ethnicity
Census tract of healthy food availability				
Low	0.19 ± 0.12[2,3]	0.25 ± 0.11[3]	0.23 ± 0.11[3]	0.12 ± 0.12
Medium	0.01 ± 0.10	0.04 ± 0.10	0.02 ± 0.10	−0.02 ± 0.10
High	Ref	Ref	Ref	Ref
P for trend[4]	0.14	0.05	0.08	0.50
No stores	0.11 ± 0.09	0.14 ± 0.09	0.11 ± 0.09	0.07 ± 0.09
Continuous measure of healthy food availability (per 1-SD increase)	−0.04 ± 0.04	−0.05 ± 0.04	−0.04 ± 0.04	−0.002 ± 0.04
Closest store food availability				
Low	0.23 ± 0.10[3]	0.25 ± 0.09[3]	0.22 ± 0.09[3]	0.12 ± 0.10
Medium	0.09 ± 0.09	0.12 ± 0.09	0.10 ± 0.09	0.09 ± 0.09
High	Ref	Ref	Ref	Ref
P for trend[4]	0.02	0.008	0.02	0.19
Continuous measure of healthy food availability (per 1-SD increase)	−0.08 ± 0.04[3]	−0.10 ± 0.04[3]	−0.08 ± 0.04[3]	−0.05 ± 0.04
All stores within 1 mile				
Low	0.14 ± 0.10	0.17 ± 0.10	0.15 ± 0.10	0.03 ± 0.10
Medium	−0.02 ± 0.10	−0.02 ± 0.10	−0.01 ± 0.10	−0.03 ± 0.10
High	Ref	Ref	Ref	Ref
P for trend[4]	0.25	0.13	0.17	0.73
No stores	−0.12 ± 0.12	−0.17 ± 0.12	−0.15 ± 0.12	−0.15 ± 0.12
Continuous measure of healthy food availability (per 1-SD increase)	−0.03 ± 0.04	−0.04 ± 0.04	−0.04 ± 0.04	−0.01 ± 0.04

[1] Ref, reference.
[2] Mean ± SD (all such values).
[3] $P < 0.05$ for the comparison of the lowest with the highest tertile of healthy food availability.
[4] Refers to the linear trend across the low, medium, and high categories of healthy food availability.

foods that were actually available in stores. In prior work we showed that healthy food availability may differ substantially across the same type of stores located in different neighborhoods (20). Although some studies measured food availability in small areas (11, 28), our study is among the first to do such in an extended geographic area with a large population sample using the previously validated NEMS-S instrument (14).

Our study had several important limitations. Dietary data were collected at baseline (2000–2002), but food availability data were collected in 2006 and therefore we could not include stores open

TABLE 4
Adjusted differences in the high-quality dietary pattern (whole grains and fruit) per 3 different food availability assessments (n = 759)[1]

	Difference in whole grains and fruit dietary pattern scores			
Availability of healthy foods assessment	Crude	Age + sex	Income + education	Race-ethnicity
Census tract of healthy food availability				
Low	−0.15 ± 0.11[2]	−0.20 ± 0.11	−0.16 ± 0.11	−0.02 ± 0.12
Medium	−0.12 ± 0.10	−0.14 ± 0.10	−0.13 ± 0.10	−0.08 ± 0.10
High	Ref	Ref	Ref	Ref
P for trend[3]	0.12	0.15	0.12	0.54
No stores	−0.08 ± 0.09	−0.10 ± 0.09	−0.09 ± 0.09	−0.03 ± 0.09
Continuous measure of healthy food availability (per 1-SD increase)	0.08 ± 0.04	0.09 ± 0.04	0.08 ± 0.04	0.03 ± 0.04
Closest store food availability				
Low	−0.10 ± 0.09	−0.12 ± 0.09	−0.07 ± 0.09	0.08 ± 0.10
Medium	−0.06 ± 0.08	−0.09 ± 0.08	−0.09 ± 0.08	−0.08 ± 0.08
High	Ref	Ref	Ref	Ref
P for trend[3]	0.26	0.11	0.38	0.45
Continuous measure of healthy food availability (per 1-SD increase)	0.04 ± 0.03	0.05 ± 0.03	0.04 ± 0.04	−0.003 ± 0.04
All stores within 1 mile				
Low	−0.002 ± 0.09	−0.03 ± 0.09	0.01 ± 0.09	0.20 ± 0.10
Medium	0.16 ± 0.09	0.16 ± 0.09	0.14 ± 0.09	0.21 ± 0.09
High	Ref	Ref	Ref	Ref
P for trend[3]	0.41	0.63	0.49	0.29
No stores	0.01 ± 0.11	0.06 ± 0.11	0.04 ± 0.11	0.03 ± 0.11
Continuous measure of healthy food availability (per 1-SD increase)	−0.03 ± 0.04	−0.02 ± 0.04	−0.04 ± 0.04	−0.09 ± 0.04

[1] Ref, reference. *P* values for the comparison of the lowest with the highest tertile of healthy food availability were not significant.
[2] Mean ± SD (all such values).
[3] *P* values for linear trends across healthy food availability categories were not significant.

in 2002 but closed by 2006. Thus, our analyses assumed the relative stability of both food environments and dietary practices over time. Changes in diet or food environments over time may have led us to underestimate true associations between food availability and diet. Our analyses are cross-sectional and the presence of cross-sectional associations does not necessarily imply a causal relation between availability of healthy foods and diet quality as reflected by dietary patterns. The relation between food availability and diet quality is likely to be bidirectional, with food availability affecting diet quality and dietary choices of residents affecting what is sold in stores. Although changing the food environment may on its own be insufficient to change behavior, our results suggest that adopting a healthier diet may be very difficult in some environments, even for those highly motivated to change, simply because healthy options are unavailable.

Another limitation was the sample size of the study, which made it difficult to draw reliable conclusions from race-stratified analysis. Larger studies with greater exposure variability within each race group are necessary to study whether associations differ within race-ethnicity groups. Our study area was limited to the areas in Baltimore City and Baltimore County from which MESA participants were sampled. Studies recruiting participants over larger and more diverse areas, including a broader spectrum of race-ethnicity and socioeconomic conditions and perhaps greater variation in food environments are needed to better study the relations between the food environment and diet quality and the complex influence of race-ethnicity on both of these factors. An important determinant of dietary patterns is the price of food, which was not investigated in these analyses. As explained by Drewnowski et al (29, 30), healthy recommended foods, such as fruit and vegetables, are relatively expensive compared with less-healthy food choices. This factor may particularly affect the food choices of low-income populations. Analyses of the effect of food prices on dietary patterns are needed.

We found that less availability of healthy foods was associated with lower dietary quality. We also documented large racial disparities in food availability and diet quality. Whether changes in the availability of healthy foods will improve diet quality and reduce disparities in diet deserves further investigation in studies using quasi-experimental or experimental designs.

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APPENDIX A

Food group factor loadings for 2 dietary patterns derived by principal components analysis in the Multi-Ethnic Study of Atherosclerosis[1]

	Fats and processed meats (low-quality diet)	Whole grains and fruit (high-quality diet)
Fats and oils	0.65	0.18
Processed meats	0.64	−0.13
Fried potatoes	0.60	—
Salty snacks	0.50	—
Desserts	0.48	—
High-fat cheeses and cheese/cream sauces	0.42	—
Red meat	0.42	−0.13
Pizza	0.41	—
Pasta and/or potato salads	0.41	0.29
Sweet breads	0.41	—
Ice cream	0.40	—
Vegetables–white potatoes	0.38	—
Poultry	0.36	—
Nondiet soft drinks	0.36	−0.16
Sweet extras	0.36	—
Eggs and omelets	0.34	—
Chicken, tuna, and/or egg salads	0.30	0.29
Coffee	0.29	0.17
Cream soups and chowders	0.29	—
Refined grain cereal, bread, rice, pasta	0.28	−0.20
Coffee and tea creamer	0.23	—
Beer	0.19	—
Fish	—	—
Seeds, nuts, and peanut butter	—	0.46
Whole milk	—	—
Cottage and ricotta cheese	—	0.31
Wine and spirits	—	0.17
Tomatoes	—	0.25
Other soups	—	—
Diet soft drinks and mineral water	—	—
Hot chocolate	—	—
Fruit juices	—	0.23
High-fat Chinese dishes	—	−0.21
Vegetables–other	—	0.27
Meal-replacement drinks	—	—
Low-fat dairy desserts	—	0.28
Vegetables–green leafy	—	0.38
Yogurt	—	0.21
Low-fat milk	—	0.33
Whole-grain cereals, bread, rice, and pasta	—	0.59
Tea	—	—
Beans	—	—
Vegetables–dark yellow	−0.14	0.21
Soyfoods and beverages	−0.15	—
Avocados and guacamole	−0.15	—
Fruit	−0.16	0.55
Vegetables–cruciferous	−0.18	—

[1] Positive loadings <0.15 and negative loadings ≥0.10 were omitted for simplicity. The order of presentation follows the loading pattern of the fats and processed meats dietary pattern.

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