Neighbourhood differences in diet: the Atherosclerosis Risk in Communities (ARIC) Study

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Abstract

***Study objective*—To investigate whether neighbourhood characteristics are related to dietary patterns independently of individual level variables.**

***Design*—A cross sectional analysis of the relation between neighbourhood median household income and food and nutrient intakes, before and after adjustment for individual level variables.**

***Setting*—Four United States communities (Washington Co, MD; Suburban Minneapolis, MN; Forsyth Co, NC, and Jackson, MS).**

***Participants*—13 095 adults aged 45 to 64 years participating in the baseline examination of the Atherosclerosis Risk in Communities (ARIC) Study, a prospective study of atherosclerosis.**

***Measurements and main results*—Information on diet and individual level income was obtained from the baseline examination of the ARIC Study. Diet was assessed using a semi-quantitative food frequency questionnaire. Information on neighbourhood (census defined block groups) median household income was obtained from the 1990 US Census. Multilevel models were used to account for the multilevel structure of the data. Living in lower income neighbourhoods was generally associated with decreased energy adjusted intake of fruits, vegetables, fish, and increased intake of meat. Patterns generally persisted after adjustment for individual level income, but were often not statistically significant. Inconsistent associations were recorded for the intake of saturated fat, polyunsaturated fat, and cholesterol. Overall, individual level income was a more consistent predictor of diet than neighbourhood income.**

***Conclusion*—Despite limitations in the definition and characterisation of neighbourhoods, this study found consistent (albeit small) differences across neighbourhoods in food intake, suggesting that more in depth research into potential neighbourhood level determinants of diet is warranted.**

(*J Epidemiol Community Health* 1999;**53**:55–63)

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Accepted for publication 15 July 1998

Over the past three decades, numerous studies conducted in industrialised nations have documented higher coronary heart disease incidence, prevalence, and mortality in the lower than in the higher social classes.[1–8] Diet may be one of the many variables mediating the relation between social class and coronary heart disease, and changes in dietary patterns by social class may partly explain the shift in the social class distribution of coronary heart disease that seems to have occurred during the 1950s and 60s.[9 10] In addition, atherogenic diets may interact with other coronary heart disease risk factors that tend to cluster in the lower social classes, including smoking, hypertension, and psychosocial factors.

A variety of social, economic, educational, and cultural factors may influence the types of foods consumed by people. Income and education have been found to be inversely related to atherogenic diets,[11–15] and trends over time in diet have differed by socioeconomic groups.[16] In recent years, researchers have revitalised the idea that dietary patterns may also differ by area of residence.[17 18] For example, recent data from a study of four contrasting neighbourhoods in Glasgow suggest that there are significant differences across neighbourhoods in the consumption of foods that persist after controlling for individual level variables, including income and occupational class.[17 18]

The idea that area characteristics may be important in shaping dietary habits is by no means new, and was elegantly illustrated by Goldberger *et al*[19] in their study of pellagra in the southern United States: village availability of fresh fruits and vegetables was associated with the incidence of pellagra independently of the income of people. Moreover, the protective effect of high income seemed to be greater in villages with high availability than in those with low availability. Similarly today, neighbourhood cost and availability of low fat foods, or of fruits and vegetables rich in antioxidants, may vary by neighbourhood,[20–25] and area level factors may be related to dietary habits independently of individual level factors. Both individual level factors such as income and education, and neighbourhood level factors may potentially contribute to social class differences in diet.

Using data from the baseline visit of the Atherosclerosis Risk in Communities (ARIC) Study (a prospective study of cardiovascular disease in four United States communities), we investigated whether dietary patterns vary across neighbourhoods. Neighbourhood median household income was selected a priori as a proxy for neighbourhood socioenvironmental characteristics potentially related to diet. The dietary indicators investigated were chosen to reflect different aspects of diet potentially related to cardiovascular disease.

The specific hypotheses investigated were as follows:

1 Persons living in high income neighbourhoods consume more fruits, vegetables, and fish, and less meat than persons living in low income neighbourhoods. Similarly, persons living in high income neighbourhoods have lower intakes of saturated fat and cholesterol, and higher intakes of polyunsaturated fat than those living in low income neighbourhoods.
2 Associations of neighbourhood income with diet persist after controlling for individual level income.
3 The effect of individual level income on diet varies across neighbourhood socioeconomic environments (interaction between neighbourhood characteristics and individual level income).

Methods

Information on demographic characteristics, dietary intake, and income was obtained from the baseline interview and examination of the ARIC Study, conducted between 1987 and 1989. The ARIC study is a prospective investigation of atherosclerosis in four US communities (Forsyth County, NC; Jackson, MS; the northwestern suburbs of Minneapolis, MN; and Washington County, MD). The ARIC cohort is composed of 15 792 persons aged 45 to 64 years at the time of the baseline interview, selected by probability sampling in the four communities.[26] Three samples reflect the demographic composition of the communities from which they were chosen (virtually all white in Washington County and Minneapolis suburbs, and 85% white in Forsyth County). The fourth sample (Jackson, Mississippi) is entirely African-American.

Usual dietary intake was assessed using a modified version of the semi-quantitative food frequency questionnaire developed by Willett *et al*.[27] The ARIC dietary questionnaire was administered by trained interviewers rather than self reported, as was Willet's original questionnaire. Additional modifications included: (1) splitting a few items into subcategories; (2) adding several new food items; and (3) creation of separate and more detailed questions regarding consumption of beer, wine, and hard liquor. The ARIC questionnaire included 66 food items, as compared with 61 food items in Willet's original version. The validity of Willett's original questionnaire has been assessed in a sample of 173 women. Correlation coefficients between questionnaire results and the means of four one week diet records, after energy adjustment, were 0.59 for saturated fat, 0.61 for cholesterol, and 0.48 for polyunsaturated fat.[27] Participants were asked how often on average they had consumed a specified portion size of each food during the past year. They were instructed to report their usual portion size if it was one half or less of the specified portion size, or if it was at least two times the specified size. The frequency of intake was coded into nine categories ranging from "almost never" to "more than six times per day". These categories were subsequently transformed into servings per day using the following weights: "almost never"=0; "1–3 per month"=0.066; "1 per week"=0.14; "2–4 per week"= 0.43; "5–6 per week"=0.79; "1 per day"=1.0; "2–3 per day"=2.5; "4–6 per day"=5.0; and "more than 6 per day"=7.0. Information on alcohol intake was obtained in the form of average weekly servings of specified amounts of alcoholic beverages and subsequently converted into daily servings. Daily servings of each food item and alcoholic beverage were multiplied by their nutrient content to obtain daily nutrient intake. Nutrient values of foods were computed by Willett *et al* primarily on the basis of data from the US Department of Agriculture.[28]

Food intake measures included daily servings of fruits, vegetable, meats, and fish defined as follows: (1) fruits: apples, pears, oranges, peaches, apricots, plums, bananas, other fruits, orange and grapefruit juices; (2) vegetables: string or green beans, broccoli, cabbage, cauliflower, brussel sprouts, carrots, corn, spinach, collards, greens, peas, lima beans, squash, sweet potatoes, beans or lentils, tomatoes; (3) meats and meat products: hamburgers, hot dogs, processed meats, bacon, beef, pork or lamb; and (4) fish: canned tuna, dark meat fish, other fish, shrimp, lobster, scallops. The nutrient indicators included daily intake of saturated fat, polyunsaturated fat, and cholesterol. Keys score, a measure of the serum cholesterol increasing potential of the diet,[29] was calculated as follows: $1.35(2S-P)+1.5Z$, where S is the per cent of calories from saturated fat, P is the per cent of calories from polyunsaturated fat, and Z is the square root of dietary cholesterol in mg/1000 kcal/day.

Individual level income was assessed by each participant's family income. As part of the home interview, participants were asked to select their total annual family income from a list of eight categories (under 5000 US$; 5000–7999; 8000–11 999; 12 000–15 999; 16 000–23 999; 24 000–34 999; 35 000–40<thin<999; and 50 000 or over). Information on neighbourhood median income was obtained from the 1990 US Census. In the 1990 Census, information on income was collected on a random sample of approximately one in six housing units. Sample data were weighted using an iterative ratio estimation procedure to obtain estimates of the actual figures that would have been obtained from a complete count.[30] In our study, block groups (subdivisions of census tracts comprised on average of approximately 1000 people) were used as proxies for neighbourhoods. ARIC participants were linked to their block group of residence using their home address.

Of the 15 792 persons in the ARIC baseline examination, 14 360 (91%) were linked to block groups in the ARIC Study geographical sites. People were excluded from the analyses if information on 10 or more items of the dietary questionnaire was missing or if their daily energy intake was below the 1st or above the

99th sex specific percentile (n=339) (600 and 4200 kcal/day for men and 500 and 3600 kcal/day for women), under the assumption that the information provided was less valid. People were also excluded from the analyses if they belonged to racial/ethnic groups other than African-American or white (n=42), or if family income information was missing (n=831). The small number of African-Americans in Washington Co and Minneapolis suburbs made centre and race specific analyses unreliable, so an additional 53 African-Americans in these field centres were also excluded. The final study sample was composed of 4597 white men, 5062 white women, 1280 African-American men, and 2156 African-American women. The median number of participants per block group was eight for whites and four for African-Americans.

The associations of neighbourhood median household income with dietary intakes were initially explored stratified by sex, and field centre. Because patterns were generally similar across field centres, final estimates are presented for all field centres combined and adjusted for centre. In addition, because of differences in geographical location and socioeconomic indicators between African-Americans and whites (see table 1), analyses were also stratified by race/ethnicity. To assess differences in dietary composition (rather than absolute differences in food or nutrient intakes), dietary intakes were adjusted for total energy intake using linear regression.[31]

Neighbourhood income was categorised into four groups based on race/ethnic-specific quartiles, and energy adjusted means for the dietary intakes were estimated for each category. Linear trends across categories were tested by including the median neighbourhood income of each category in regression equations. In regression analyses, individual level income was categorised into three groups based on race/ethnic specific income distributions as follows: < 25 000 US$, 25 000–49 999, and ⩾50 000 for whites; and <12 000, 12 000–24 999, and ⩾25 000 for African-Americans. The per cent of persons in these categories were 26%, 43%, and 31% respectively for whites, and 41%, 30%, and 29% respectively for African-Americans. These cut offs were selected to ensure sufficient subjects in each category to allow reasonably precise estimates. Trends by individual level income were tested by including the income categories as an ordinal covariate in the regression equations.

Heterogeneity in the effects of individual level income across neighbourhood categories was explored using stratified analyses and tested by including interaction terms in the appropriate regression models. Energy adjusted dietary intake means were estimated for each category of individual level income stratified by the four neighbourhood categories. Only two categories of neighbourhood income (above and below the median) were used in these analyses for African-Americans because of sample size limitations. If no interactions were present, regression models including age, field centre, energy intake, neighbourhood income, and individual level income were used to estimate the independent effects of neighbourhood income, and individual level income on dietary intakes. To compare the distribution of extreme intake values, the odds of having an intake at or below the 10th sex specific percentiles compared with having an intake at or above the 50th percentile were estimated by neighbourhood categories after adjustment for individual level income (for foods or nutrients for which high intakes are presumed unhealthy we estimated the odds ratio of having an intake at or above the 90th percentile compared with having an intake at or below the 50th percentile). For example, for fruits, vegetables, and fish the odds of "unhealthy" intake were defined as the odds of having an intake at or below the sex specific 10th percentile compared with having an intake at or above the 50th percentile. For meat, the odds of

*Table 1 Income and dietary variables by sex, race/ethnicity, and field centre**

	White men		African-American men			White women		African-American women		
	F	*M*	*W*	*J*	*F*	*F*	*M*	*W*	*J*	*F*
Number	1423	1689	1485	1110	170	1607	1764	1691	1910	246
Individual level income in US$ (% distribution)										
under 8000	2.0	0.4	3.2	21.0	12.4	4.4	1.2	7.2	33.5	28.0
8000–15 999	6.5	3.0	10.9	24.6	16.5	12.3	6.5	15.3	27.1	19.1
16 000–24 999	10.8	8.2	17.6	19.4	18.8	15.8	12.4	18.3	16.8	17.9
25 000–34 999	20.7	16.8	22.0	13.4	18.8	19.0	18.4	21.9	10.7	13.0
35 000–49 999	20.6	28.3	23.9	12.0	20.0	19.0	26.7	19.6	7.2	14.2
50 000 or over	34.5	43.5	22.4	9.6	13.5	29.5	34.9	17.7	4.7	7.7
Neighbourhood median household income in US$ mean (SD)	37 657 (12 788)	44 408 (12 221)	31 547 (7330)	19 808 (10 932)	25 797 (9606)	37 400 (12 996)	43 225 (11 747)	31 605 (7363)	18 747 (9714)	24 475 (8784)
Energy intake in kcal/day mean (SEM)	1714 (16)	1800 (15)	1862 (18)	1701 (20)	2000 (58)	1432 (13)	1485 (12)	1560 (14)	1477 (13)	1687 (42)
Food intake in servings/day mean (SEM)										
Vegetables	1.9 (0.03)	1.4 (0.03)	1.7 (0.03)	1.9 (0.03)	2.1 (0.08)	1.9 (0.03)	1.6 (0.03)	1.8 (0.03)	1.8 (0.02)	2.3 (0.07)
Fruits	1.7 (0.04)	1.9 (0.03)	2.0 (0.04)	1.6 (0.04)	2.2 (0.11)	2.2 (0.04)	2.1 (0.03)	2.3 (0.04)	2.0 (0.03)	2.4 (0.09)
Meats	1.3 (0.02)	1.3 (0.02)	1.3 (0.02)	1.4 (0.02)	1.4 (0.05)	0.9 (0.01)	0.9 (0.01)	0.9 (0.01)	1.1 (0.01)	0.9 (0.04)
Fish	0.3 (0.01)	0.2 (0.01)	0.3 (0.01)	0.4 (0.01)	0.4 (0.02)	0.3 (0.01)	0.3 (0.01)	0.3 (0.01)	0.4 (0.01)	0.5 (0.02)
Daily nutrient intake mean (SEM)										
Saturated fat in g/day	24.2 (0.2)	24.9 (0.1)	25.1 (0.2)	22.9 (0.2)	22.6 (0.5)	19.6 (0.13)	20.8 (0.12)	20.3 (0.13)	19.4 (0.12)	18.4 (0.33)
Cholesterol in mg/day	276 (2.9)	259 (2.7)	264 (2.9)	321 (3.3)	317 (8.5)	225 (2.1)	219 (2.0)	218 (2.1)	253 (1.9)	246 (5.4)
Polyunsaturated fat in g/day	9.9 (0.1)	10.2 (0.1)	10.0 (0.1)	9.5 (0.1)	9.1 (0.2)	8.3 (0.1)	8.5 (0.1)	8.6 (0.1)	8.0 (0.1)	8.2 (0.2)
Keys score	42.1 (0.3)	42.7 (0.2)	43.3 (0.3)	42.7 (0.3)	42.8 (0.7)	41.1 (0.2)	42.9 (0.2)	42.0 (0.2)	42.3 (0.2)	40.9 (0.6)

*F: Forsyth M: Minneapolis W: Washington J: Jackson. Foods as defined in text. All dietary variables except total energy intake and Keys score are adjusted to the sex specific mean energy intake.

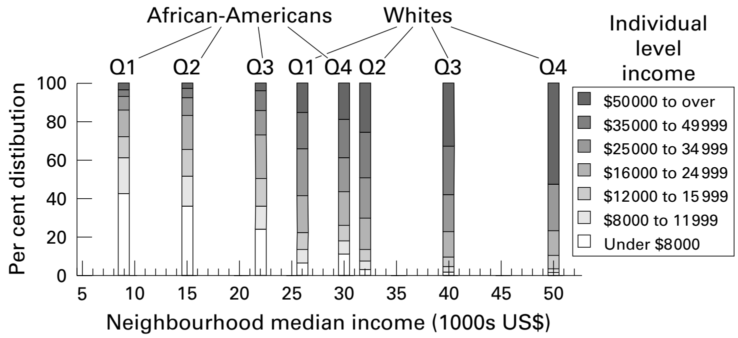

Figure 1 Per cent distribution of individual level income by categories of neighbourhood income. Neighbourhood categories (Q1–Q4) based on race specific distribution of neighbourhood income (US$) as follows: whites: poorest quartile (Q1): <$30 300; lower-middle quartile (Q2): $30 300–35 900; upper-middle quartile (Q3): $35 901–43 800; richest quartile (Q4): >$43 800. African-Americans: Q1: <$12 300; Q2: $12 300–16 600; Q3: $16 601–26 500; Q4: >$26 500. Bars are placed at the median for each neighbourhood category.

KEY POINTS

- Persons living in lower income neighbourhoods consumed less fruits, vegetables, and fish, and more meat than those living in higher income neighborhoods.
- Associations of neighbourhood income with food intake persisted after adjustment for individual level income, but associations were weak and often not statistically significant.
- Individual level income was generally a more consistent predictor of diet than neighbourhood income.
- Public health efforts to change dietary habits may benefit from further investigation of possible neighbourhood level determinants of diet.

"unhealthy"intake were defined as the odds of having an intake at or above the 90th percentile compared with intake at or below the 50th percentile. All cut points were selected a priori.

Because of the multilevel structure of the data (individuals nested within neighbourhoods) and the potential for residual correlation between persons within neighbourhoods, multilevel models with a random intercept for each neighbourhood were used.[32–35] Models were fitted using SAS Proc Mixed for continuous dependent variables and the SAS GLIMMIX macro for binary dependent variables.[36] The ARIC Study has been approved by the ethics boards of all participating sites.

Results

Table 1 shows income and dietary intake variables by sex, race/ethnicity, and field centre. White participants generally had higher incomes than African-American participants, and also tended to live in higher income neighbourhoods.

As expected, mean energy intake was greater for men than for women. Overall there were no systematic or important differences in energy adjusted food intake by race/ethnicity or field centre. Fish consumption was higher in African-Americans than in whites in both men and women ($p < 0.05$), but differences were small. The energy adjusted intake of saturated fat and polyunsaturated fat was slightly higher

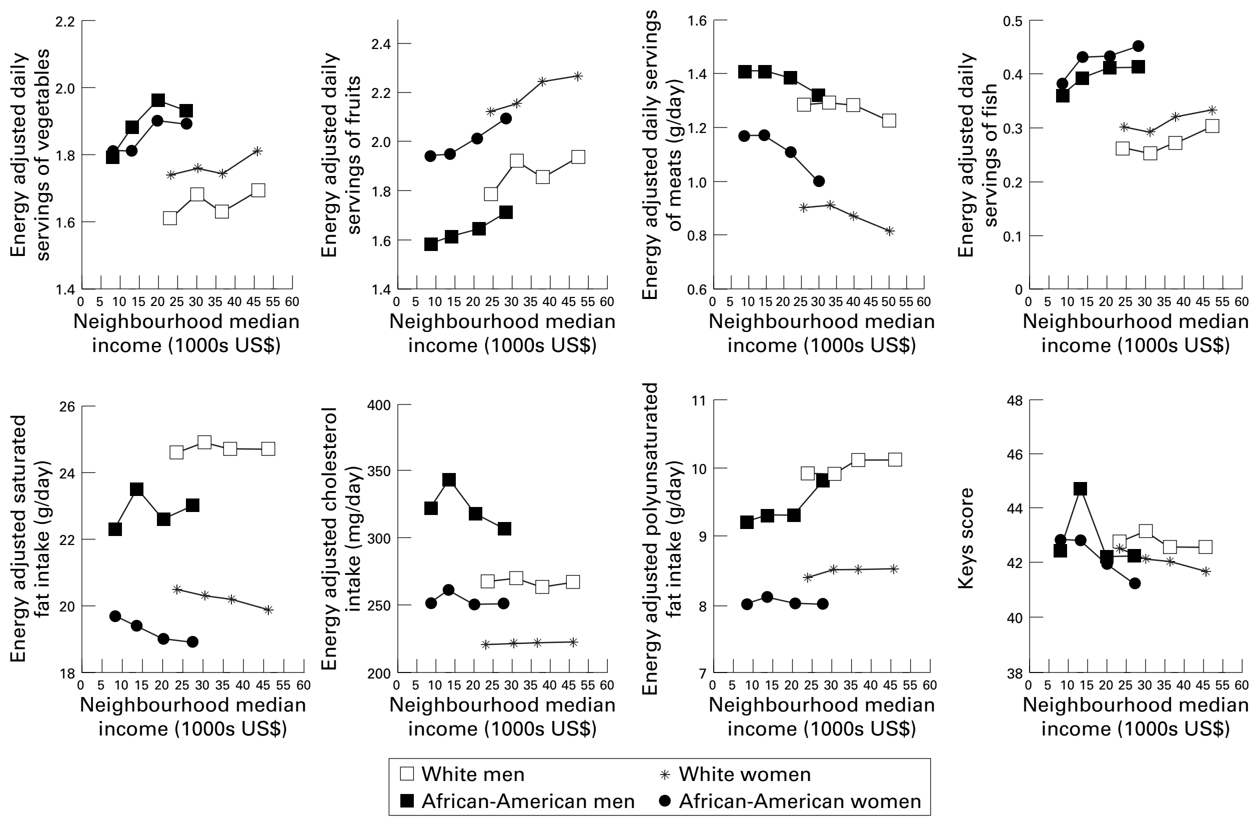

Figure 2 Energy adjusted food and nutrient intakes by categories of neighbourhood income. Categories based on race specific distributions (<25%;25–49%;50–74%;>74%). Means are plotted at the median for each category. All estimates are adjusted for field centre. Food and nutrient intakes adjusted to the sex specific mean energy intake.

Table 2 Adjusted mean (SEM) differences in dietary intake associated with neighbourhood and family income†: men

	Daily food intake (servings)				*Daily nutrient intake*			
	Vegetables	*Fruits*	*Meats*	*Fish*	*Saturated fat (g)*	*Cholesterol (mg)*	*Polyunsaturated fat (g)*	*Keys score*
Whites								
Individual level income (US$)								
⩾50 000	reference	reference	reference	reference	reference	reference	reference	reference
25–49 999	−0.07* (0.04)	−0.13** (0.05)	0.11*** (0.02)	−0.05*** (0.01)	0.5* (0.2)	3.0 (3.6)	0.1 (0.1)	1.1*** (0.3)
<25 000	−0.07 (0.05)	−0.19** (0.06)	0.06 (0.03)	−0.06*** (0.01)	0.5 (0.3)	7.2 (4.7)	0.0 (0.1)	1.3** (0.4)
p value trend		**	*	***	*			***
Neighbourhood median income								
Richest quartile	reference	reference	reference	reference	reference	reference	reference	reference
Upper-middle	−0.06 (0.05)	−0.07 (0.06)	0.04 (0.03)	−0.02* (0.01)	0.0 (0.3)	−5.4 (4.5)	0.0 (0.1)	−0.3 (0.4)
Lower middle	−0.02 (0.05)	0.00 (0.07)	0.04 (0.03)	−0.04** (0.01)	0.1 (0.3)	1.6 (4.8)	−0.2 (0.1)	0.3 (0.4)
Poorest quartile	−0.08 (0.05)	−0.12 (0.07)	0.04 (0.03)	−0.02 (0.01)	−0.3 (0.3)	−2.0 (5.0)	−0.1 (0.2)	−0.3 (0.5)
p value trend	*							
African-Americans								
Family income (US$)								
⩾25 000	reference	reference	reference	reference	reference	reference	reference	reference
12–24 999	−0.02 (0.08)	−0.28** (0.10)	0.03 (0.05)	−0.05* (0.02)	−0.4 (0.4)	8.5 (9.2)	−0.2 (0.2)	0.0 (0.6)
<12 000	−0.18* (0.09)	−0.49*** (0.10)	0.02 (0.05)	−0.05* (0.02)	−0.2 (0.4)	19.9 (9.8)	−0.2 (0.2)	0.7 (0.7)
p value trend	*	***		*		*		
Neighbourhood median income								
Richest quartile	reference	reference	reference	reference	reference	reference	reference	reference
Upper-middle	0.01 (0.10)	0.01 (0.11)	0.09 (0.06)	0.01 (0.03)	−0.4 (0.4)	6.3 (12.2)	−0.5* (0.2)	−0.2 (0.7)
Lower middle	−0.02 (0.12)	0.02 (0.12)	0.09 (0.07)	−0.01 (0.03)	0.5 (0.5)	25.9* (13.4)	−0.5* (0.2)	2.1** (0.8)
Poorest quartile	−0.10 (0.12)	0.04 (0.12)	0.08 (0.07)	−0.04 (0.03)	−0.7 (0.5)	6.4 (13.2)	−0.5* (0.2)	−0.2 (0.8)
p value trend							**	

*p <0.05 **p <0.01 ***p <0.001. For individual categories, p values correspond to the test of the null hypothesis that the mean difference (with respect to the reference category) equals 0. For trends, p values correspond to the test of the null hypothesis that the slope equals 0.

†Adjusted differences were obtained from models including age, field centre, energy intake (except models for total calory intake and Keys score), individual level income (categories as shown), and neighbourhood median household income (in four categories from poorest to richest as follows: whites: <$30300; $30301–35900; $35901–43800; and >$43800; and African-Americans: <$12300; $12301–16600; $16601–26500; >$26500). Models included a random intercept for each neighbourhood. p Value for trend corresponds to p value for neighbourhood median household income when it is included in the regression equations as a continuous variable.

in whites than in African-Americans in both sexes ($p < 0.05$). On the other hand, the energy adjusted intake of cholesterol was higher in African-Americans than in whites ($p < 0.05$). There were no clear patterns in Keys score by race/ethnicity or field centre.

Figure 1 shows the relation between individual level and neighbourhood level income measures by race/ethnicity. Although as expected, individual level income increased as neighbourhood income increased, there was variation in individual level income within neighbourhood categories. Spearman correlation coefficients between median household income as a continuous variable and individual level income (as an ordinal variable representing the eight categories described above) were 0.35 for whites and 0.41 for African-Americans.

Figure 2 shows energy and centre adjusted food and nutrient intakes by categories of neighbourhood income stratified by race/ethnicity and sex. Overall, energy adjusted daily servings of vegetables, fruits, and fish increased, and daily servings of meat decreased, with increasing neighbourhood income, although trend tests were not always statistically significant at the 0.05 level ($p < 0.05$ in six of eight tests in whites, and in two of eight tests in African-Americans). Patterns for nutrient intakes were less consistent than those observed for foods. Among white men, neighbourhood income was not related to saturated fat intake, cholesterol intake or Keys score (fig 2). Among African-American men, saturated fat intake, cholesterol intake, and Keys score were highest in the lower-middle income category. Polyunsaturated fat intake increased slightly with increasing neighbourhood income in both white ($p < 0.2$) and African-American men ($p < 0.01$). Among white and African-American women, saturated fat intake and Keys score decreased with increasing neighbourhood income ($p < 0.05$). Among African-American women, cholesterol intake was higher in the lower-middle income category than in the other categories (as it was for African-American men). No consistent patterns were observed for cholesterol in white women or for polyunsaturated fat intake in white or African-American women. In stratified analyses, there was no consistent evidence of heterogeneity in the effects of individual level income across neighbourhood categories in whites or African-Americans (results not shown).

Tables 2 and 3 show mean differences in dietary intake variables associated with individual level and neighbourhood level income, adjusted for each other as well as for age, field centre, and energy intake (when appropriate). The residual correlation between people within neighbourhoods (residual intraclass correlation coefficient) was small and did not differ significantly from 0, after inclusion of individual level variables in the models, for any of the outcomes examined. Consequently, standard errors estimated using random effects models did not differ substantially from those obtained using standard regression techniques. In general, patterns by neighbourhood income described above for energy, fruits, vegetables, meat, and fish intake persisted after adjustment for individual level income, but mean differences by neighbourhood category were small, and often not statistically significant. In contrast with patterns observed in the other race-sex groups, among African-American men the lowest income neighbourhoods were associated with

Table 3 Adjusted mean (SEM) differences in dietary intake associated with neighbourhood and family income†: women

	Daily food intake (servings)				*Daily nutrient intake*			
	Vegetables	*Fruits*	*Meats*	*Fish*	*Saturated fat (g)*	*Cholesterol (mg)*	*Polyunsaturated fat (g)*	*Keys score*
Whites								
Individual level income (US$)								
≥50 000	reference	reference	reference	reference	reference	reference	reference	reference
25–49 999	−0.12** (0.04)	−0.11* (0.05)	0.05** (0.02)	−0.05*** (0.01)	0.5** (0.2)	0.3 (2.8)	0.2 (0.1)	0.7* (0.3)
<25 000	−0.10* (0.04)	−0.19*** (0.06)	0.10*** (0.02)	−0.05*** (0.01)	0.9*** (0.2)	6.0 (3.2)	0.1 (0.1)	1.5*** (0.4)
p value trend	*	***	***	***	***	*		***
Neighbourhood median income								
Richest quartile	reference	reference	reference	reference	reference	reference	reference	reference
Upper-middle	−0.05 (0.04)	−0.01 (0.06)	0.04 (0.02)	0.01(0.01)	0.3 (0.2)	−0.2 (3.3)	0.0 (0.1)	0.3 (0.4)
Lower middle	−0.03 (0.05)	−0.11 (0.07)	0.09*** (0.02)	−0.03* (0.01)	0.3 (0.2)	0.0 (3.4)	0.0 (0.1)	0.4 (0.4)
Poorest quartile	−0.05 (0.05)	−0.13* (0.07)	0.07** (0.03)	−0.02 (0.01)	0.4 (0.2)	−1.9 (3.6)	−0.1 (0.1)	0.7 (0.4)
p value trend			**					
African-Americans								
Family income (US$)								
≥25 000	reference	reference	reference	reference	reference	reference	reference	reference
12–24 999	0.01 (0.07)	−0.32*** (0.09)	0.06 (0.04)	−0.07** (0.02)	0.1 (0.3)	−4.5 (6.0)	0.2 (0.1)	−0.4 (0.5)
<12 000	−0.10 (0.07)	−0.31*** (0.09)	0.14*** (0.04)	−0.08*** (0.02)	0.3 (0.3)	−1.3 (5.9)	−0.3 (0.1)	0.6 (0.5)
p value trend		**	***	***			*	
Neighbourhood median income								
Richest quartile	reference	reference	reference	reference	reference	reference	reference	reference
Upper-middle	0.02 (0.07)	−0.01 (0.10)	0.02 (0.04)	0.00 (0.03)	0.0 (0.3)	−0.7 (6.2)	0.0 (0.2)	0.5 (0.6)
Lower middle	−0.07 (0.08)	−0.06 (0.11)	0.08 (0.04)	0.02 (0.03)	0.3 (0.3)	10.9 (6.7)	0.2 (0.2)	1.2* (0.6)
Poorest quartile	−0.06 (0.08)	−0.08 (0.11)	0.07 (0.04)	−0.03 (0.03)	0.5 (0.3)	0.6 (6.7)	0.1 (0.2)	1.1 (0.6)
p value trend								

*p <0.05 **p <0.01 ***p <0.001. For individual categories, p values correspond to the test of the null hypothesis that the mean difference (with respect to the reference category) equals 0. For trends, p values correspond to the test of the null hypothesis that the slope equals 0.
†Adjusted differences were obtained from models including age, field centre, energy intake (except models for total calory intake and Keys score), individual level income (categories as shown), and neighbourhood median household income (in four categories from richest to poorest as follows: whites: <$30300; $30301–35900; $35901–43800; and >$43800; and African-Americans: <$12300; 12301–16600; $16601–26500; >$26500). Models included a random intercept for each neighbourhood. p Value for trend corresponds to p value for neighbourhood median household income when it is included in the regression equations as a continuous variable.

slight increases, rather than decreases, in the intake of fruits. Individual level income was associated with energy and food intakes in a direction that was consistent with neighbourhood income. Associations were more likely to be statistically significant for individual level measures than for neighbourhood measures.

The patterns described above for nutrient intakes by neighbourhood categories remained similar (and inconsistent) after adjustment for individual level income. With some exceptions (polyunsaturated fat in white men and women, saturated fat in African-American men, and cholesterol in African-American women), lower individual level income tended to be associated with more adverse dietary patterns. As in the case of food intakes, associations with individual level income were more likely to be statistically significant than associations with neighbourhood income.

Table 4 shows adjusted odds ratios of extreme intakes of fruits, vegetables, meats, and fish by neighbourhood characteristics. Odds ratios of "unhealthy" dietary intakes for those living in the poorest neighbourhoods were greater than 1 for all outcomes except meats in white men, and fruits and meat in African-American men, although consistent dose response trends were not always present.

Table 4 Adjusted odds ratios of "unhealthy" dietary intakes (95% confidence intervals) by neighbourhood income categories stratified by sex and race†

	Whites				*African-Americans*			
	Vegetables	*Fruits*	*Meats*	*Fish*	*Vegetables*	*Fruits*	*Meats*	*Fish*
Men								
Categories of neighbourhood income								
Richest quartile	reference	reference‡	reference	reference	reference	reference	reference	reference
Upper-middle	1.08 (0.75, 1.54)	0.98 (0.70, 1.38)	1.04 (0.65, 1.66)	1.30 (0.95, 1.79)	1.58 (0.63, 3.98)	1.22 (0.71, 2.10)	1.32 (0.48, 3.66)	1.72 (0.67, 4.39)
Lower middle	1.14 (0.78, 1.66)	1.11 (0.78, 1.58)	1.21 (0.75, 1.95)	1.28 (0.91, 1.79)	1.67 (0.60, 4.64)	1.14 (0.62, 2.07)	1.37 (0.46, 4.09)	2.32 (0.85, 6.32)
Poorest quartile	1.20 (0.81, 1.79)	1.67 (1.18, 2.37)	0.93 (0.56, 1.53)	1.27 (0.90, 1.79)	1.60 (0.58, 4.46)	0.98 (0.54, 1.78)	0.90 (0.29, 2.76)	1.41 (0.49, 4.10)
p value for trend	0.3	0.01	0.9	0.1	0.3	0.4	0.9	0.07
Women								
Categories of neighbourhood income								
Richest quartile	reference	reference	reference	reference	reference	reference	reference	reference‡
Upper-middle	1.00 (0.70, 1.43)	0.89 (0.61, 1.30)	1.40 (0.86, 2.29)	1.15 (0.78, 1.70)	0.99 (0.50, 1.98)	1.56 (1.00, 2.47)	0.91 (0.54, 1.53)	0.59 (0.21, 1.63)
Lower middle	1.10 (0.76, 1.59)	1.11 (0.76, 1.62)	2.12 (1.31, 3.45)	1.45 (1.00, 2.13)	1.34 (0.65, 2.75)	1.46 (0.90, 2.36)	1.22 (0.71, 2.11)	0.74 (0.26, 2.05)
Poorest quartile	1.11 (0.75, 1.64)	1.41 (0.95, 2.08)	1.53 (0.92, 2.54)	1.36 (0.91, 2.02)	1.29 (0.62, 2.64)	1.91 (1.18, 3.10)	1.42 (0.82, 2.45)	1.41 (0.55, 3.58)
p value for trend	0.3	0.07	0.05	0.04	0.2	0.05	0.2	0.22

†For fruits, vegetables, and fish the odds of "unhealthy" intake were defined as the odds of having an intake at or below the sex specific 10th percentile compared with having an intake at or above the 50th percentile. For meat, the odds of "unhealthy" intake were defined as the odds of having an intake at or above the 90th percentile compared with having an intake at or below the 50th percentile. The 10th and 50th percentiles were as follows: vegetables: 0.5, 1.5 servings/day in men, 0.6, 1.6 in women; fruits: 0.3, 1.6 servings/day in men and 0.5, 1.9 in women; fish: 0, 0.2 servings/day in men and 0, 0.3 in women. The 50th and 90th percentiles for meat were 1.2, 2.4 servings/day in men and 0.8, 1.9 in women. Odds ratios were adjusted for age, energy intake, field centre and individual level income as described in tables 2 and 3. Models included a random intercept for each neighbourhood. p Value for trend corresponds to p value for neighbourhood median household income when it is included in the regression equations as a continuous variable. ‡Estimates correspond to standard logistic regression because of non-convergence of the random effects models.

Discussion

Overall, neighbourhood median household income was found to be associated with the intake of selected foods in the direction expected. People living in higher income neighbourhoods had generally higher energy adjusted intakes of fruits, vegetables, and fish, and lower intakes of meat, than those living in lower income neighbourhoods. These findings were consistent across sex, race/ethnicity, and field centre (with the exception of fruit intake in African-American men). These patterns generally persisted after adjustment for individual level income, although they were often not statistically significant. Findings for other nutrients were often inconsistent: associations were present for some nutrients but not others or in some subgroups but not in others. On the other hand, consistently with patterns previously reported for education in the ARIC cohort,[11] decreased individual level income was generally associated with less healthy dietary intakes. Individual level income was strongly and often significantly associated with dietary intake even after controlling for neighborhood income, suggesting that it is an important predictor of diet regardless of area of residence. The effects of individual level income on diet did not seem to vary significantly across neighbourhood contexts.

Over the past few years, several studies have suggested that area socioenvironmental characteristics may be related to health outcomes independently of individual level variables.[37–43] In addition, area socioeconomic characteristics have been found to be related to the decline of coronary heart disease mortality.[44 45] Multilevel analyses of the ARIC cohort[35] and of the Scottish Heart Health Study[46] have also suggested that neighbourhood socioeconomic indicators may be related to the distribution of coronary heart disease risk factors independently of individual level indicators of social class.

Recently, analyses based on the comparison of contrasting neighborhoods in Glasgow have found significant differences in the consumption of "healthy" foods (fruits, vegetables, cereals, fish, and "brown" bread) across neighbourhoods, which persisted after accounting for individual level indicators, including income and occupational class.[18] Several different factors may lead to differences in food consumption across neighbourhoods. On the one hand, neighbourhoods may differ in the cost and availability of different types of foods. For example, Sooman *et al*[20] found that a "healthy" food basket (including several low fat and high fibre products) was more costly in the poorer than in the richer neighbourhood, and healthy foods were also less likely to be available in the poorer neighbourhood. Another study conducted in London also suggested that the availability of healthy food choices may be reduced in deprived communities.[21] Although limited in scope, reports from the United States have also documented differences in the availability and cost of foods across neighbourhoods,[22–25] and at least one study has suggested that the availability of healthy (low fat and high fibre) products (as assessed by shelf space occupied in community stores) is related to the consumption of healthful foods by people living in the area.[47] In addition, cultural factors may also play a part in shaping neighbourhood consumption patterns, and neighbourhood consumption patterns may in turn influence food availability and cost.[17 47] Despite suggestive evidence of differences in the cost and availability of foods across neighbourhoods, only one study of which we are aware has examined the possible role of neighbourhood environments in shaping dietary patterns in the United States: Diehr *et al* found little variation in the per cent of calories from saturated fat across the 15 communities in their study, after accounting for individual level variables.[48]

Our findings are not conclusive regarding the effects of neighbourhood environments on diet in the ARIC cohort. The absence of residual correlation between the diets of people within neighbourhoods after accounting for individual level variables is not supportive of a strong neighbourhood effect. Associations with neighbourhood income were often not statistically significant after adjustment for individual level income, differences were often small, and were not present for some of the nutrients studied. However, the energy adjusted intakes of vegetables, fruits, meat, and fish were consistently associated with neighbourhood income in the expected direction in nearly all subgroups studied, and patterns were still present after adjustment for individual level income. The fact that estimates of neighbourhood effects were virtually unchanged when income was adjusted for in the form of eight categories instead of three categories (data not shown), suggests that residual confounding by individual level income (or other individual level variables strongly correlated with income) is an unlikely explanation for associations with neighbourhood income. Adjustment for individual level education did not substantially change the patterns observed (data not shown). In addition, if lower socioeconomic status (SES) persons consume less healthy diets in part because they live in deprived neighbourhoods, unadjusted estimates may be better estimates of true neighbourhood effects than SES adjusted estimates.

Associations of neighbourhood income with diet were more consistent for foods than for nutrients. The reasons for these differences are unclear. Different degrees of measurement error in the estimation of food and nutrient intakes could potentially contribute. If nutrient intakes are measured with less precision than food intakes (because of in part the assumptions involved in estimating nutrient intakes from food intakes), non-differential misclassification of nutrient outcomes may bias our estimates of neighbourhood effects for nutrients towards the null. On the other hand, it is also possible that food intake varies by neighbourhood despite relatively constant nutrient intake. At least one study has suggested that the relative contribution of different foods to the intake of fibre, total fat, saturated fat, and cholesterol may differ by household income.[13]

Patterns for African-Americans (particularly for African-American men) sometimes differed from those observed for whites. The high Keys score observed in the lower-middle neighbourhood income category in men is consistent with patterns previously documented for serum cholesterol in the same dataset.[35] In African-American men, the associations of neighbourhood income with fruit intake were the opposite of those observed in other groups: living in poorer neighbourhoods was associated with increased, rather than decreased, fruit intake after adjustment. The majority of the African-American participants were from the city of Jackson, Mississippi, and African-Americans in the study sample had significantly lower incomes and lived in poorer neighbourhoods than whites. Therefore, no direct race/ethnic comparisons are possible with these data. However, our results do suggest that some of the associations observed may differ for low SES African-Americans living in poor neighbourhoods in the urban South, emphasising the need to examine neighbourhood effects in more detail within regional and sociocultural contexts.

Two important limitations of our study related to the definition of neighbourhoods and their characterisation may have hindered our ability to investigate neighbourhood effects. Because the ARIC cohort is dispersed over a large geographical area, we relied on census-based measures as proxies for neighbourhoods. Although it has been suggested that block group measures may be better indicators of the immediate socioeconomic environment than other census measures (such as census tracts),[49] block groups may not correspond to socially defined neighbourhoods. A more appropriate study of neighbourhood effects requires definition of neighbourhoods based on detailed sociological information on the areas studied, as has been done in other studies of neighbourhood effects on diet.[17 20] In addition, neighbourhood income is undoubtedly a poor proxy for many of the potential neighbourhood level factors directly related to diet. A more detailed characterisation of neighbourhoods combining both qualitative and quantitative measures of food availability, cost, and prevalent cultural norms related to diet, would lead to a better test of the hypothesis that neighbourhood level factors influence diet.

An additional limitation relates to the use of food frequency questionnaires to characterise the dietary patterns of people. Although food frequency questionnaires may not adequately assess absolute intakes (for example they tend to underestimate total energy intake), they are useful for ranking persons according to relative intake within a study population.[50] The measurement error associated with the version of the questionnaire of Willett *et al* used in the ARIC Study is unknown. In a subsample of 418 ARIC participants, the reliability of nutrient intakes was found to be lower in African-Americans than in whites, and lower in persons with less than 12 years of education than in those with more than 12 years of education.[51] The imprecisions that undoubtedly exist in the assessment of diet may make it more difficult to tease apart the effects of variables such as neighbourhood and individual level income (which may themselves be subject to measurement error). This may partly explain our failure to document stronger or statistically significant associations.

An important strength of our study is its reliance on a large, population-based sample with detailed standardised dietary assessment. To our knowledge, this study is the first to investigate neighbourhood differences in diet systematically within a large cohort using multilevel models and after controlling for individual level factors. Despite its limitations, our study suggests that dietary patterns, particularly the consumption of different types of foods, may be related not only to individual level variables, but also to neighbourhood environments. Public health efforts to change dietary habits may benefit from further research into possible community level determinants of diet.

ARIC Study is carried out as a collaborative study supported by National Heart, Lung, and Blood Institute contracts N01-HC-55015, N01-HC-55016, N01-HC-55018, N01-HC-55019, N01-HC-55020, N01-HC-55021, and N01-HC-55022. Dr Diez-Roux is supported in part by a FIRST award from NHLBI (R29 HL59386–01). The authors thank the staff at the ARIC centres: University of North Carolina, Chapel Hill NC: Phyllis Johnson, Marilyn Knowles, Catherine Paton; University of North Carolina, Forsyth County, NC: Jeanette Bensen, Kay Burke, Wilhelmenia Cheeks, Revitha Cook; University of Mississippi Medical Center, Jackson MI: Virginia L Overman, Stephanie A Parker, Liza B Sullivan, Cora L Walls; University of Minnessota, Minneapolis MN: Todd Avant, Joe Bjorklund, Carolyne Campbell, Collett Cosgriff; The Johns Hopkins University, Baltimore MD: Joan Nelling, Dorothy Nixon, Thelma Oliver, Rodney Palmer; University of Texas Medical School, Houston TX: Valerie Stinson, Pan Pfile, Hoang Pham, Teri Trevino; The Methodist Hospital, Atherosclerosis Clinical Laboratory, Houston TX: Wanda Alexander, Doris J Harper, Charles E Rohdes, Sela M Soyal; Bowman-Gray School of Medicine, Winston-Salem NC: Suzanne Pillsbury, Tiffany Robertson, Anne Safrit, Melanie Wilder; University of North Carolina at Chapel Hill Coordinating Center: Patsy Tacker, Lily Wang, Climmon Walker, Kiduk Yang.
Conflicts of interest: none.

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