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# Area Characteristics, Individual-Level Socioeconomic Indicators, and Smoking in Young Adults

## The Coronary Artery Disease Risk Development in Young Adults Study

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The 10-year follow-up examination in 1995–1996 to the population-based Coronary Artery Disease Risk Development in Young Adults Study was used to compare the strength with which socioeconomic indicators at the individual and area levels are related to smoking prevalence and to investigate contextual effects of area characteristics. When categories based on similar percentile cutoffs were compared, differences across area categories in the odds of smoking were smaller than differences across categories based on individual-level indicators. In Whites, there was evidence of a significant contextual effect of area characteristics on smoking: Living in the most disadvantaged area quartiles was associated with 50–110% higher odds of smoking, even after controlling for individual-level socioeconomic indicators. Clear contextual effects of area characteristics were not present in Blacks, but there was evidence that contextual effects may emerge at higher levels of individual-level socioeconomic position. Similar results were obtained for census tracts and block groups. Even in the presence of contextual effects, area measures may underestimate associations of individual-level variables with health outcomes. On the other hand, as illustrated by the presence of contextual effects, area- and individual-level measures are likely to tap into different constructs.

racial stocks; smoking; social class

Abbreviation: CARDIA: Coronary Artery Disease Risk Development in Young Adults.

There has been increasing interest in including measures of area socioeconomic characteristics in epidemiologic analyses, both as proxies for unavailable individual-level socioeconomic indicators (1–3) and as measures of area characteristics that may themselves be related to health (3–6). A series of papers have examined the consequences of using area-based measures as proxies for unavailable individual-level indicators to quantify socioeconomic inequalities in health (2, 3, 7–9). A growing separate literature has investigated area measures as indicators of contextual neighborhood characteristics that may be related to health outcomes independently of individual-level variables (3–6, 10). Although these research questions are clearly distinct, they are conceptually and methodologically related since one of the possible reasons for differences between area-based and individual-based estimates of socioeconomic differences in health is precisely the presence of contextual area effects (11).

A recent study reported that the use of area-based proxies for individual-level measures resulted in overestimates of socioeconomic gradients in health and suggested that this could be due to the presence of area contextual effects (7, 11). However, it is unclear whether the magnitude of the area contextual effects likely to be present for health outcomes will systematically result in overestimates of individual-level socioeconomic gradients when area-based proxies are

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**TABLE 1. Sociodemographic, area, and smoking characteristics of the study sample, the CARDIA* Study, 1995–1996**

| | White men | White women | Black men | Black women |
|---|---|---|---|---|
| No. of persons | 836 | 937 | 697 | 1,002 |
| No. of areas (BG*/CT*) | 739/642 | 856/744 | 585/448 | 753/537 |
| Individual-level characteristics | | | | |
| Age (years) (mean (SD*)) | 35.5 (3.4) | 35.6 (3.4) | 34.4 (3.8) | 34.5 (3.9) |
| Smoking status (% distribution) | | | | |
| Current | 19.5 | 18.6 | 36.9 | 27.6 |
| Former | 17.7 | 25.8 | 8.6 | 12.3 |
| Never | 62.8 | 55.6 | 54.5 | 60.1 |
| Income (% distribution) | | | | |
| <$12,000 | 4.2 | 4.4 | 14.2 | 18.6 |
| $12,000–$15,999 | 3.7 | 3.3 | 7.8 | 10.3 |
| $16,000–$24,999 | 7.4 | 6.7 | 15.1 | 12.5 |
| $25,000–$34,999 | 11.8 | 14.8 | 19.9 | 16.5 |
| $35,000–$49,999 | 21.2 | 18.9 | 17.8 | 19.3 |
| $50,000–$74,999 | 23.1 | 24.6 | 15.9 | 16.0 |
| ≥$75,000 | 28.6 | 27.3 | 9.3 | 7.0 |
| Education (% distribution) | | | | |
| Incomplete high school | 2.4 | 1.2 | 7.8 | 4.9 |
| Complete high school or GED* | 19.4 | 16.2 | 38.2 | 32.5 |
| 1–3 years of college | 21.5 | 20.8 | 31.6 | 37.2 |
| 4 years of college | 26.9 | 31.4 | 14.6 | 17.2 |
| Some graduate or professional school | 29.8 | 30.4 | 7.9 | 8.2 |
| Occupation (% distribution)† | | | | |
| I (executive, managerial, and professional) | 47.5 | 48.9 | 19.7 | 21.0 |
| II (technical, sales, and administrative) | 24.5 | 29.8 | 21.1 | 45.0 |
| III (service) | 6.7 | 7.5 | 18.5 | 17.7 |
| IV–V (farming, precision production, craft, and repair) | 12.7 | 2.8 | 11.9 | 2.2 |
| VI (operators, fabricators, and laborers) | 7.2 | 3.5 | 24.0 | 7.9 |
| Homemakers | 0.4 | 4.8 | 0.4 | 2.2 |
| Missing | 1.1 | 2.8 | 4.5 | 4.1 |

Table continues

used. In addition, even the extent to which the use of area-based proxies results in over- or underestimates of socioeconomic gradients remains a subject of debate (7–9). Simultaneous examinations of both the presence of contextual effects and the consequences of using area-based proxies for individual-level indicators may shed light on these interrelated questions, but empirical analyses that address both questions are still rare (11, 12). Resolving these issues is of importance from a methodological perspective and will also contribute to our substantive understanding of the social determinants of health, as it will illustrate the extent to which area-level and individual-level measures may be tapping into distinct constructs.

Investigation of these questions requires population-based samples with information on individual-level health outcomes, individual-level measures of socioeconomic indicators, and measures of area socioeconomic characteristics appended to each person. Using area-level data from the US Census and individual-level data from the Coronary Artery Risk Development in Young Adults (CARDIA) Study, we investigated 1) whether the use of area-based socioeconomic measures results in under- or overestimates of socioeconomic gradients in smoking prevalence derived using individual-level measures and 2) the presence of contextual area effects on smoking. Because there is also ongoing debate regarding the impact of area size and of different area measures, we also investigated two commonly used census areas (census tracts and block groups), as well as several different area-level and individual-level socioeconomic indicators.

Smoking was selected as the outcome of interest in these analyses because there is abundant evidence that smoking rates are strongly and inversely related to individual-level socioeconomic position (13–15), making the comparison of social inequalities as assessed by individual-level and area-based measures informative. In addition, there are several plausible mechanisms through which a contextual area effect on smoking could be mediated. These mediating mechanisms may include area differences in tobacco advertising and availability, the psychosocial effects of living in disad-

**TABLE 1. Continued**

| | White men | White women | Black men | Black women |
|---|---|---|---|---|
| Area characteristics (mean (SD)) | | | | |
| Median household income‡ | | | | |
| BG | 41,700 (18,800) | 42,600 (19,000) | 27,800 (13,200) | 28,000 (13,300) |
| CT | 39,900 (16,400) | 41,200 (17,200) | 27,500 (12,200) | 27,600 (12,400) |
| Median house value‡ | | | | |
| BG | 153,800 (112,100) | 159,600 (111,700) | 97,300 (72,600) | 97,600 (70,800) |
| CT | 152,500 (112,000) | 157,400 (108,000) | 97,800 (71,900) | 98,800 (72,500) |
| % earning interest income | | | | |
| BG | 52 (16) | 52 (16) | 30 (17) | 29 (17) |
| CT | 51 (15) | 51 (14) | 30 (16) | 29 (16) |
| % with complete high school | | | | |
| BG | 86 (12) | 87 (11) | 74 (16) | 73 (15) |
| CT | 86 (11) | 86 (10) | 73 (14) | 73 (14) |
| % with complete college | | | | |
| BG | 36 (20) | 36 (20) | 19 (15) | 18 (15) |
| CT | 35 (19) | 35 (18) | 19 (14) | 18 (14) |
| % in executive, managerial, and professional occupations | | | | |
| BG | 37 (15) | 37 (15) | 24 (13) | 23 (13) |
| CT | 36 (14) | 36 (13) | 24 (11) | 23 (11) |
| Score | | | | |
| BG | 4.8 (5) | 4.9 (5) | –0.32 (4) | –0.45 (4) |
| CT | 5.0 (5) | 5.2 (4) | –0.08 (4) | –0.25 (4) |

* CARDIA, Coronary Artery Disease Risk Development in Young Adults; BG, block groups; CT, census tracts; SD, standard deviation; GED, general education diploma.

† Occupational categories as follows: I, executive, managerial, and professional specialty occupations; II, technical, sales, and administrative support occupations; III, service occupations; IV, farming, forestry, and fishing occupations; V, precision production, craft, and repair occupations; and VI, operators, fabricators, and laborers. Because of small numbers of participants in category IV, categories IV and V were combined in the analyses.

‡ In US dollars rounded to the nearest 100.

vantaged areas, and "contagion" processes related to the prevalence of smoking itself. These factors make smoking a particularly relevant outcome to investigate with respect to the research questions outlined above.

## MATERIALS AND METHODS

### Study population and data

The CARDIA Study sample consisted of 5,115 adults aged 18–30 years at baseline recruited primarily through telephone contact from community lists in Birmingham, Alabama; Chicago, Illinois; and Minneapolis, Minnesota; as well as from membership in a prepaid health plan in Oakland, California (16). The goal of recruitment was to obtain at each field center nearly equal numbers of Blacks and Whites, females and males, persons less than 25 and 25 or more years of age, and persons with high school education or less and more than high school education. Baseline interviews and examinations were conducted in 1985–1986. Overall retention of the cohort at the year 10 follow-up examination (1995–1996), on which these analyses are based, was 79 percent. Year 10 data were used because earlier addresses were not available for geocoding. At year 10, 68 percent of the sample remained in the original study counties, and the remaining 32 percent were dispersed over 45 US states.

Participants were classified as current smokers if they reported smoking at least five cigarettes per week, almost every week, at the time of the examination. Participants who reported having smoked at least five cigarettes per week almost every week for at least 3 months in the past were classified as former smokers. Smoking self-report was previously validated against biochemical markers in the CARDIA Study, and misclassification was found to be low (17). Participants were asked to select their total combined family income from a list of categories and to report the highest grade or year of school completed. Information on current or most recent occupation was used to assign 1990 US Census occupational codes, and occupations were then categorized into the six summary groupings used in the US Census (18). Homemakers who reported no current or past occupation and persons who reported never having worked were coded as separate categories. Categories for socioeconomic indicators are shown in table 1.

Two census-defined areas were investigated: census tracts and block groups. Census tracts are subdivisions of a county, with an average size of approximately 4,000 residents. When first delineated, census tracts were designed to be homogeneous with respect to population characteristics, economic

status, and living conditions. In the 1990 US Census, census tracts in nonmetropolitan areas are replaced by block-numbering areas. Each census tract (or block-numbering area) is in turn subdivided into clusters of blocks or block groups. On average, each block group includes approximately 1,000 individuals (19). Study participants were linked to their 1990 US Census-defined area of residence using their home address. Six area variables reflecting the dimensions of wealth/income (median household income, median value of housing units, and percentage of households receiving interest, dividend, or net rental income), education (percentage of adults with complete high school, percentage of adults with complete college), and occupation (percentage of persons in managerial or professional specialty occupations) were investigated. These six variables were also combined into a summary score as previously described (20). The summary score was obtained by summing $z$ scores for the six variables, with increasing score signifying increasing neighborhood advantage (20).

Of the 3,950 CARDIA Study participants who attended the year 10 follow-up, 91 percent ($n = 3,593$) were geocoded. Sixty participants were excluded because they matched to very small block groups or census tracts (population, ≤100; housing units, ≤30; and ≥33 percent persons in group quarters) for which area measures were judged to be unreliable. An additional 59 participants were excluded because they were missing information on income, education, or smoking, leaving a total of 3,472 available for analysis. Participants with no information on occupation ($n = 107$) and homemakers ($n = 73$) were retained and included as dummy categories in analyses involving occupation. The 3,472 participants were distributed in 1,761 census tracts and 2,467 block groups. A total of 68 percent of the census tracts and 87 percent of the block groups had only one study participant. Only 9 percent of the census tracts and 2 percent of the block groups had five participants or more.

### Statistical methods

Because of important differences in the distribution of individual-level and area-level socioeconomic indicators by race/ethnicity, analyses were stratified by race/ethnicity and adjusted for age and gender. The first set of analyses focused on the comparison of associations of individual-level and area-level socioeconomic indicators with smoking. For these analyses, individual-level income and education were each categorized into four groups containing as close as possible to 25 percent of the race-specific sample (although the actual percentages in each category varied because of the categories in which the income and education data were collected). Occupation was categorized into only three groups because of the skewed nature of the distribution of the sample. To allow a direct comparison of the effects of individual-level and area-based measures, we constructed categories based on area measures to mimic the percentage of distribution of the corresponding individual-level socioeconomic indicator. For example, if the lowest category of individual-level income contained 20 percent of the sample, the lowest category of area income (e.g., median income for the census tract) was constructed so that it also contained 20 percent of the sample. Categories based on area measures of median household income, median house value, and percentage earning interest income were constructed to match the percentage of distribution of the most directly comparable individual-level measure, that is, income. Categories based on area percentage of complete high school and percentage of complete college were constructed to match the percentage of distribution of individual-level education, and categories based on area percentage of executive, managerial, and professional specialty occupations were constructed to mimic the percentage of distribution of individual-level occupational categories. Age- and gender-adjusted odds ratios of smoking were then estimated for each indicator with the most advantaged category as the reference group. As an alternative, categories based on identical income value cutoffs for individual-level income and area median income were also compared. This could not be done for the other area indicators because comparable absolute measures at both levels were not available. All area-based analyses were repeated for census tracts and block groups.

The second set of analyses investigated the contextual effects of each area indicator after adjustment for individual-level indicators. To allow comparisons across different area measures, we based categories for each area indicator on exact quartiles. Individual-level indicators were included as finer categories (seven categories for income, five categories for education, and six categories for occupation) to minimize residual confounding. The odds ratios of smoking for each area category versus the most advantaged category were estimated before and after adjustment for all three individual-level indicators. Because the vulnerability of individuals to area contextual effects may differ according to individual-level socioeconomic characteristics, we also examined the effects of area characteristics at "high" and "low" levels of individual-level income, education, and occupation, and we tested for interactions by including appropriate interaction terms in the logistic regression equations. For these analyses, individual-level income, education, and occupation were dichotomized as follows: income of <$35,000 versus ≥$35,000; education of complete high school or less versus more than complete high school; and occupation categories of II–VI versus I. Estimates were also adjusted for individual-level socioeconomic indicators within strata.

Because the majority of census tracts and block groups included only one participant, within- and between-area variability in outcomes could not be reliably estimated, and methods to account for possible within-area correlations were not necessary (21). Hence, for contextual analyses of area effects on health, we report fixed effects of area characteristics but do not report estimates of between-area variability in outcomes.

## RESULTS

Table 1 shows individual-level and area characteristics by race and gender. Blacks were more likely to be of low income and low education, to have lower skilled jobs, and to live in more disadvantaged areas than Whites. Area indicators were similar for block groups and census tracts although, as expected (because they are based on smaller-

**TABLE 2. Age- and gender-adjusted odds ratios of smoking by categories of individual-level and area-level socioeconomic indicators based on identical percentile cutoffs in Whites, the CARDIA* Study, 1995–1996**

| | Categories based on income/wealth (% distribution)† | | | | | | |
|---|---|---|---|---|---|---|---|
| | I (28%) | | II (20%) | | III (24%) | | IV (28%) (OR) |
| | OR* | 95% CI* | OR | 95% CI | OR | 95% CI | |
| OR by categories of individual-level income | 4.1 | 2.9, 5.8 | 1.9 | 1.2, 2.8 | 1.8 | 1.2, 2.7 | 1.0 |
| OR by categories of area median household income | | | | | | | |
| BG* | 3.1 | 2.2, 4.3 | 1.3 | 0.9, 2.0 | 1.3 | 0.9, 1.9 | 1.0 |
| CT* | 2.8 | 2.0, 3.8 | 1.6 | 1.1, 2.3 | 1.3 | 0.9, 1.9 | 1.0 |
| OR by categories of area median house value | | | | | | | |
| BG | 2.9 | 2.1, 4.0 | 2.3 | 1.6, 3.4 | 1.2 | 0.8, 1.7 | 1.0 |
| CT | 2.9 | 2.1, 4.2 | 2.9 | 2.0, 4.2 | 1.5 | 1.0, 2.2 | |
| OR by categories of area percentage receiving interest income | | | | | | | |
| BG | 1.9 | 1.4, 2.5 | 0.7 | 0.5, 1.0 | 1.1 | 0.8, 1.5 | 1.0 |
| CT | 1.9 | 1.5, 2.6 | 1.0 | 0.7, 1.3 | 1.2 | 0.9, 1.6 | 1.0 |
| | Categories based on education (% distribution)† | | | | | | |
| | I (19%) | | II (22%) | | III (29%) | | IV (30%) (OR) |
| | OR | 95% CI | OR | 95% CI | OR | 95% CI | |
| OR by categories of individual-level education | 11.8 | 7.6, 18.3 | 7.2 | 4.6, 11.2 | 2.5 | 1.6, 4.0 | 1.0 |
| OR by categories of area percentage with complete high school | | | | | | | |
| BG | 2.9 | 2.1, 4.1 | 1.6 | 1.1, 2.3 | 1.3 | 0.9, 1.8 | 1.0 |
| CT | 3.3 | 2.3, 4.6 | 1.3 | 0.9, 1.9 | 1.4 | 1.0, 2.0 | 1.0 |
| OR by categories of area percentage with complete college | | | | | | | |
| BG | 4.6 | 3.2, 6.7 | 1.9 | 1.3, 2.8 | 2.0 | 1.4, 2.9 | 1.0 |
| CT | 4.1 | 2.9, 5.9 | 2.2 | 1.5, 3.2 | 2.0 | 1.4, 2.9 | 1.0 |
| | Categories based on occupation (% distribution)† | | | | | | |
| | I (21%) | | II (29%) | | III (50%) (OR) | | |
| | OR | 95% CI | OR | 95% CI | | | |
| OR by categories of individual-level occupation | 4.0 | 2.9, 5.5 | 2.2 | 1.6, 3.0 | 1.0 | | |
| OR by categories of area percentage in executive, managerial, and professional occupations | | | | | | | |
| BG | 2.9 | 2.2, 4.0 | 1.8 | 1.4, 2.4 | 1.0 | | |
| CT | 2.6 | 1.9, 3.5 | 1.7 | 1.3, 2.3 | 1.0 | | |

* CARDIA, Coronary Artery Disease Risk Development in Young Adults; OR, odds ratio; CI, confidence interval; BG, block group; CT, census tract.

† Percentile cutoffs of the categories are determined by the race-specific distribution of the categorical individual-level indicators in the sample. Categories range from I (lowest socioeconomic category) to IV (highest socioeconomic category). Individual-level income categories are <$35,000, $35,000–$49,999, $50,000–$74,999, and ≥$75,000. Individual-level educational categories are complete high school or less, 1–3 years of college, 4 years of college, and some graduate or professional school. Individual-level occupational categories are groups III–VI, group II, and group I (as shown in table 1). In order to allow a direct comparison, cutoffs for the continuous area measures were selected to mimic the percentile distribution of the corresponding individual-level indicator. Cutoffs for the block-group categories were as follows: $30,100, $37,500, and $49,800 for median household income; $79,700, $110,400, and $190,600 for median house value; 43%, 52%, and 63% for percentage earning interest income; 78%, 87%, and 94% for percentage with complete high school; 15%, 28%, and 48% for percentage with complete college; and 23% and 35% for percentage in executive, managerial, and professional occupations. Cutoffs for the census tract categories were as follows: $30,500, $36,400, and $46,900 for median household income; $78,300, $108,600, and $188,300 for median house value; 43%, 52%, and 60% for percentage earning interest income; 78%, 86%, and 93% for percentage with complete high school; 17%, 28%, and 46% for percentage with complete college; and 23% and 35% for percentage in executive, managerial, and professional occupations.

sized units), standard deviations were slightly greater for block groups than for census tracts. The prevalence of current smoking was higher in Blacks than in Whites.

Table 2 and table 3 show odds ratios of smoking by categories of individual-level and area characteristics based on identical percentile cutoffs. Overall, associations were stron-

**TABLE 3. Age- and gender-adjusted odds ratios of current smoking by categories of individual-level and area-level socioeconomic indicators based on identical percentile cutoffs in Blacks, the CARDIA* Study, 1995–1996**

| | Categories based on income/wealth (% distribution)† | | | | | | |
|---|---|---|---|---|---|---|---|
| | I (26%) | | II (32%) | | III (18%) | | IV (24%) (OR) |
| | OR* | 95% CI* | OR | 95% CI | OR | 95% CI | |
| OR by categories of individual-level income | 5.1 | 3.7, 7.0 | 2.5 | 1.8, 3.4 | 1.4 | 0.9, 2.0 | 1.0 |
| OR by categories of area median household income | | | | | | | |
| BG* | 2.2 | 1.6, 2.9 | 1.7 | 1.3, 2.3 | 1.2 | 0.9, 1.7 | 1.0 |
| CT* | 2.0 | 1.5, 2.7 | 1.5 | 1.1, 2.0 | 1.0 | 0.7, 1.4 | 1.0 |
| OR by categories of area median house value | | | | | | | |
| BG | 1.7 | 1.3, 2.3 | 1.5 | 1.1, 2.0 | 1.3 | 1.0, 1.8 | 1.0 |
| CT | 1.7 | 1.2, 2.2 | 1.5 | 1.1, 2.1 | 1.5 | 1.1, 2.1 | |
| OR by categories of area percentage receiving interest income | | | | | | | |
| BG | 2.1 | 1.6, 2.8 | 1.6 | 1.2, 2.1 | 1.1 | 0.8, 1.6 | 1.0 |
| CT | 1.8 | 1.3, 2.4 | 1.3 | 1.0, 1.8 | 1.0 | 0.7, 1.4 | 1.0 |
| | Categories based on education (% distribution)† | | | | | | |
| | I (41%) | | II (35%) | | III (16%) | | IV (8%) (OR) |
| | OR | 95% CI | OR | 95% CI | OR | 95% CI | |
| OR by categories of individual-level education | 7.0 | 4.0, 12.3 | 3.2 | 1.8, 5.6 | 1.5 | 0.8, 2.9 | 1.0 |
| OR by categories of area percentage with complete high school | | | | | | | |
| BG | 1.5 | 1.0, 2.2 | 1.1 | 0.7, 1.6 | 0.9 | 0.6, 1.4 | 1.0 |
| CT | 1.3 | 0.9, 2.0 | 1.0 | 0.7, 1.5 | 0.8 | 0.5, 1.3 | 1.0 |
| OR by categories of area percentage with complete college | | | | | | | |
| BG | 1.6 | 1.1, 2.5 | 1.2 | 0.8, 1.8 | 0.8 | 0.5, 1.4 | 1.0 |
| CT | 1.5 | 1.0, 2.2 | 1.2 | 0.8, 1.8 | 0.8 | 0.5, 1.3 | 1.0 |
| | Categories based on occupation (% distribution)† | | | | | | |
| | I (41%) | | II (38%) | | III (21%) (OR) | | |
| | OR | 95% CI | OR | 95% CI | | | |
| OR by categories of individual-level occupation | 3.3 | 2.4, 4.6 | 1.8 | 1.2, 2.4 | 1.0 | | |
| OR by categories of area percentage in executive, managerial, and professional occupations | | | | | | | |
| BG | 1.6 | 1.2, 2.1 | 1.3 | 1.0, 1.7 | 1.0 | | |
| CT | 1.6 | 1.2, 2.2 | 1.3 | 1.0, 1.8 | 1.0 | | |

* CARDIA, Coronary Artery Disease Risk Development in Young Adults; OR, odds ratio; CI, confidence interval; BG, block group; CT, census tract.

† Percentile cutoffs of the categories are determined by the race-specific distribution of the categorical individual-level indicators in the sample. Categories range from I (lowest socioeconomic category) to IV (highest socioeconomic category). Individual-level income categories are <$16,000, $16,000–$34,999, $35,000–$49,999, and ≥$50,000. Individual-level educational categories are complete high school or less, 1–3 years of college, 4 years of college, and some graduate or professional school. Individual-level occupational categories are groups III–VI, group II, and group I (as shown in table 1). In order to allow a direct comparison, cutoffs for the continuous area measures were selected to mimic the percentile distribution of the corresponding individual-level indicator. Cutoffs for the block-group categories were as follows: $19,100, $27,700, and $35,100 for median household income; $52,100, $82,400, and $128,600 for median house value; 15%, 31%, and 42% for percentage earning interest income; 70%, 86%, and 93% for percentage with complete high school; 12%, 26%, and 44% for percentage with complete college; and 19% and 33% for percentage in executive, managerial, and professional occupations. Cutoffs for the census tract categories were as follows: $19,400, $27,600, and $34,000 for median household income; $52,000, $82,400, and $132,300 for median house value; 16%, 31%, and 43% for percentage earning interest income; 70%, 84%, and 92% for percentage with complete high school; 12%, 25%, and 41% for percentage with complete college; and 19% and 32% for percentage in executive, managerial, and professional occupations.

gest when individual-level socioeconomic indicators were used, although substantial and statistically significant effects were observed with area-based measures as well. There were no important or consistent differences between census-tract and block-group measures. When individual-level and area median household income categories based on identical absolute value cutoffs were compared (table 4), associations were also weaker for area-based than for individual-based

**TABLE 4. Odds ratios of current smoking by categories of individual-level and area-level income based on identical absolute income cutoffs, the CARDIA* Study, 1995–1996**

| | Income categories | | | | | | |
|---|---|---|---|---|---|---|---|
| | <$35,000 | | $35,000–$49,999 | | $50,000–$74,999 | | ≥$75,000 (OR) |
| | OR* | 95% CI* | OR | 95% CI | OR | 95% CI | |
| Whites | | | | | | | |
| OR by categories of individual-level income | 4.1 | 2.9, 5.8 | 1.9 | 1.2, 2.8 | 1.8 | 1.2, 2.7 | 1.0 |
| OR by categories of block-group median household income | 4.8 | 2.2, 10.5 | 2.4 | 1.1, 5.4 | 2.1 | 0.9, 4.9 | 1.0 |
| OR by categories of census tract median household income | 2.7 | 1.2, 6.0 | 1.8 | 0.8, 4.0 | 1.2 | 0.5, 2.8 | 1.0 |
| | Income categories | | | | | | |
| | <$16,000 | | $16,000–$34,999 | | $35,000–$49,999 | | ≥$50,000 (OR) |
| | OR | 95% CI | OR | 95% CI | OR | 95% CI | |
| Blacks | | | | | | | |
| OR by categories of individual-level income | 5.1 | 3.7, 7.0 | 2.5 | 1.8, 3.4 | 1.4 | 0.9, 2.0 | 1.0 |
| OR by categories of block-group median household income | 3.1 | 1.8, 5.3 | 2.0 | 1.2, 3.2 | 1.4 | 0.8, 2.4 | 1.0 |
| OR by categories of census tract median household income | 2.4 | 1.4, 4.1 | 1.5 | 0.9, 2.5 | 1.1 | 0.6, 1.9 | 1.0 |

* CARDIA, Coronary Artery Disease Risk Development in Young Adults; OR, odds ratio; CI, confidence interval.

indicators, with the exception of block-group measures in Whites.

The contextual effects of area characteristics on smoking are shown in table 5. Approximately similar results were obtained regardless of whether census-tract or block-group measures were used, so only block-group results are shown. In Whites, living in disadvantaged areas was associated with higher odds of smoking even after controlling for all three individual-level indicators. Among all the area indicators investigated, the percentage in the top occupational category, with complete college, and the summary area score showed the strongest associations before and after adjustment. In Blacks, however, differences in the odds of smoking by area characteristics usually did not persist after controlling for individual-level indicators. Of all the area indicators investigated, the strongest associations (before adjustment) were observed for median household income, percentage earning interest income, and area score. Individual socioeconomic indicators remained associated with smoking after controlling for quartiles of area score (not shown); for example, the adjusted odds ratios for the four individual-level income categories shown in table 2 and table 3 from lowest income to highest income were 2.6, 1.3, and 1.4 in Whites and 4.6, 2.3, and 1.3 in Blacks, after controlling for area score.

Table 6 summarizes the area effects on smoking stratified by categories of individual-level income. In Whites, the multiplicative effects of area characteristics were slightly stronger at higher than at lower levels of individual-level socioeconomic indicators, although the absolute differences between the top and bottom quartiles were comparable in both strata. In Blacks, no effect was observed in the lower income stratum, but an inverse association of area score with smoking was observed in persons with annual incomes of $35,000 or more. Associations were also slightly stronger for persons of higher socioeconomic position than for persons of lower socioeconomic position when strata were based on individual-level education or occupation (not shown), although differences were less pronounced than they were for income. However, multiplicative interactions were not statistically significant for any of the indicators.

## DISCUSSION

Previous evidence on the extent to which the use of area measures leads to under- or overestimates of individual-level socioeconomic differences is conflicting. Some work has found larger estimates of effects with individual-level than with area-level socioeconomic indicators (3, 22), but the opposite difference (larger area effects) has been reported in recent studies (7, 11, 12). In our analyses, although associations of smoking with area socioeconomic characteristics were present (and were substantial and often statistically significant), they were weaker than associations of smoking with individual-level measures, when categories based on identical percentile cutoffs were compared.

Comparing associations of health outcomes with socioeconomic indicators at both levels raises issues regarding the variables or categories to be compared. Some previous studies compared continuous measures at the individual and area levels (e.g., individual-level income and area median income or individual years of education and mean area years of education) (7, 11, 12, 22). Others have compared different categories at both levels (e.g., less than high school vs. high school or more for individuals and <25 percent complete high school vs. ≥25 percent complete high school for areas) (3). We compared categories at both levels because indi-

**TABLE 5. Odds ratios of current smoking by quartiles of block-group indicators before and after adjustment for individual-level variables, the CARDIA* Study, 1995–1996**

| Variable† | Whites | | | | Blacks | | | |
|---|---|---|---|---|---|---|---|---|
| | Adjusted for age and gender | | Adjusted for age, gender, income, education, and occupation‡ | | Adjusted for age and gender | | Adjusted for age, gender, income, education, and occupation‡ | |
| | OR* | 95% CI* | OR | 95% CI | OR | 95% CI | OR | 95% CI |
| Median household income | | | | | | | | |
| Quartile 1 | 2.9 | 2.0, 4.1 | 1.5 | 1.0, 2.2 | 2.2 | 1.6, 2.9 | 1.2 | 0.8, 1.6 |
| Quartile 2 | 1.4 | 1.0, 2.1 | 0.9 | 0.6, 1.4 | 1.7 | 1.3, 2.3 | 1.0 | 0.7, 1.4 |
| Quartile 3 | 1.1 | 0.7, 1.6 | 0.8 | 0.5, 1.2 | 1.3 | 1.0, 1.8 | 1.0 | 0.7, 1.4 |
| Quartile 4 | 1.0 | | 1.0 | | 1.0 | | 1.0 | |
| *p* for trend | | <0.001 | | 0.02 | | <0.001 | | 0.3 |
| Median house value | | | | | | | | |
| Quartile 1 | 3.2 | 2.2, 4.7 | 1.8 | 1.2, 2.7 | 1.8 | 1.3, 2.4 | 0.9 | 0.6, 1.3 |
| Quartile 2 | 2.7 | 1.9, 3.9 | 2.0 | 1.3, 2.9 | 1.6 | 1.2, 2.1 | 0.9 | 0.6, 1.2 |
| Quartile 3 | 1.3 | 0.9, 1.9 | 1.0 | 0.7, 1.6 | 1.4 | 1.0, 1.9 | 1.1 | 0.8, 1.6 |
| Quartile 4 | 1.0 | | 1.0 | | 1.0 | | 1.0 | |
| *p* for trend | | <0.001 | | <0.001 | | <0.001 | | 0.3 |
| % earning interest | | | | | | | | |
| Quartile 1 | 2.9 | 2.0, 4.1 | 1.5 | 1.0, 2.3 | 2.1 | 1.6, 2.9 | 1.3 | 0.9, 1.8 |
| Quartile 2 | 2.3 | 1.6, 3.3 | 1.4 | 0.9, 2.1 | 1.6 | 1.2, 2.2 | 1.2 | 0.9, 1.7 |
| Quartile 3 | 1.5 | 1.0, 2.3 | 1.2 | 0.8, 1.9 | 1.3 | 1.0, 1.8 | 1.0 | 0.8, 1.5 |
| Quartile 4 | 1.0 | | 1.0 | | 1.0 | | 1.0 | |
| *p* for trend | | <0.001 | | 0.04 | | <0.001 | | 0.09 |
| % completed high school | | | | | | | | |
| Quartile 1 | 3.0 | 2.1, 4.2 | 1.5 | 1.0, 2.2 | 1.8 | 1.3, 2.4 | 1.1 | 0.8, 1.6 |
| Quartile 2 | 1.4 | 0.9, 2.0 | 0.9 | 0.6, 1.4 | 1.4 | 1.0, 1.8 | 1.0 | 0.7, 1.4 |
| Quartile 3 | 1.6 | 1.1, 2.3 | 1.3 | 0.8, 1.9 | 1.2 | 0.9, 1.6 | 1.0 | 0.7, 1.4 |
| Quartile 4 | 1.0 | | 1.0 | | 1.0 | | 1.0 | |
| *p* for trend | | <0.001 | | 0.2 | | <0.001 | | 0.4 |
| % completed college | | | | | | | | |
| Quartile 1 | 4.8 | 3.2, 7.2 | 2.1 | 1.3, 3.2 | 1.9 | 1.4, 2.6 | 1.2 | 0.9, 1.6 |
| Quartile 2 | 2.8 | 1.8, 4.2 | 1.6 | 1.0, 2.6 | 1.4 | 1.0, 1.9 | 1.0 | 0.7, 1.4 |
| Quartile 3 | 2.5 | 1.6, 3.8 | 1.7 | 1.1, 2.6 | 1.4 | 1.0, 1.8 | 1.1 | 0.8, 1.6 |
| Quartile 4 | 1.0 | | 1.0 | | 1.0 | | 1.0 | |
| *p* for trend | | <0.001 | | 0.005 | | <0.001 | | 0.5 |
| % in executive, managerial, and professional occupations | | | | | | | | |
| Quartile 1 | 4.3 | 2.9, 6.3 | 1.8 | 1.2, 2.8 | 1.7 | 1.3, 2.3 | 1.1 | 0.8, 1.5 |
| Quartile 2 | 2.7 | 1.8, 4.0 | 1.5 | 0.9, 2.3 | 1.4 | 1.1, 2.0 | 1.0 | 0.7, 1.4 |
| Quartile 3 | 2.1 | 1.4, 3.2 | 1.4 | 0.9, 2.2 | 1.3 | 1.0, 1.7 | 1.1 | 0.8, 1.5 |
| Quartile 4 | 1.0 | | 1.0 | | 1.0 | | 1.0 | |
| *p* for trend | | <0.001 | | 0.01 | | <0.001 | | 0.8 |
| Summary score | | | | | | | | |
| Quartile 1 | 4.5 | 3.1, 6.7 | 2.0 | 1.3, 3.1 | 2.0 | 1.5, 2.7 | 1.1 | 0.7, 1.5 |
| Quartile 2 | 2.8 | 1.9, 4.1 | 1.7 | 1.1, 2.6 | 1.8 | 1.4, 2.5 | 1.1 | 0.8, 1.5 |
| Quartile 3 | 1.8 | 1.2, 2.8 | 1.2 | 0.8, 1.9 | 1.3 | 1.0, 1.8 | 1.0 | 0.7, 1.3 |
| Quartile 4 | 1.0 | | 1.0 | | 1.0 | | 1.0 | |
| *p* for trend | | <0.001 | | <0.001 | | <0.001 | | 0.6 |

* CARDIA, Coronary Artery Disease Risk Development in Young Adults; OR, odds ratio; CI, confidence interval.

† For each variable, quartile 1 corresponds to the most disadvantaged areas (e.g., lowest quartile of median block-group income), and quartile 4 (the reference category) corresponds to the most advantaged quartile.

‡ Adjusted for seven categories of income, five categories of education, and six categories of occupation as described in Materials and Methods.

**TABLE 6. Odds ratios of smoking by race-specific quartiles of block-group score stratified by individual-level income, the CARDIA* Study, 1995–1996**

| | Individual-level income of <$35,000 | | | | Individual-level income of ≥$35,000 | | | |
|---|---|---|---|---|---|---|---|---|
| | No. | % smokers† | OR*,‡ | 95% CI* | No. | % smokers† | OR‡ | 95% CI |
| Whites | | | | | | | | |
| Quartile 1 | 223 | 40.0 | 2.2 | 1.1, 4.6 | 220 | 20.9 | 3.2 | 1.8, 5.5 |
| Quartile 2 | 129 | 25.6 | 1.2 | 0.6, 2.7 | 314 | 19.4 | 3.0 | 1.8, 5.0 |
| Quartile 3 | 100 | 20.3 | 0.9 | 0.4, 2.0 | 344 | 13.4 | 2.0 | 1.2, 3.3 |
| Quartile 4 | 49 | 23.2 | 1.0 | | 394 | 6.8 | 1.0 | |
| *p* for trend | | <0.001 | <0.001 | | | <0.001 | <0.001 | |
| Blacks | | | | | | | | |
| Quartile 1 | 319 | 41.8 | 0.9 | 0.6, 1.3 | 106 | 24.5 | 1.8 | 1.0, 3.2 |
| Quartile 2 | 281 | 41.5 | 0.9 | 0.6, 1.3 | 142 | 24.1 | 1.8 | 1.1, 3.1 |
| Quartile 3 | 220 | 37.4 | 0.8 | 0.5, 1.3 | 206 | 18.2 | 1.3 | 0.8, 2.1 |
| Quartile 4 | 156 | 40.2 | 1.0 | | 269 | 14.0 | 1.0 | |
| *p* for trend | | 0.5 | 0.8 | | | 0.004 | 0.02 | |

* CARDIA, Coronary Artery Disease Risk Development in Young Adults; OR, odds ratio; CI, confidence interval.

† Proportions are adjusted for age and gender.

‡ Odds ratios are adjusted for age, gender, and finer categories (as noted in Materials and Methods) of individual-level income within strata.

vidual-level data (as well as census data on education) had been collected in a categorical fashion.

We attempted to construct "comparable" categories at both levels by basing categories on identical percentile cutoffs. Distribution-based categories are often used in epidemiology when there is no a priori theoretical reason for choosing absolute value cutoffs. In a comparison of area-level and individual-level measures, the use of similar percentile cutoffs accounts for the fact that the dispersion of individual and aggregate measures is different. In addition, this approach is the only way to compare effects when the individual-level measure is categorical (e.g., educational categories) and the area measure is the percentage of persons in the area within a certain category (percentage of people with complete high school). An important limitation of this approach for continuous variables such as income is that the absolute values to which the cutoffs correspond (e.g., for individual-level income and area-level median income categories) may obviously be very different at both levels.

Another alternative is to construct "comparable" categories using identical absolute cutoffs of the indicator in question at the individual level and at the area level. This approach, however, is possible only for indicators that are continuous measures at the individual level (e.g., income or years of education) and for which mean or median area measures are also available (e.g., median area income or median years of education). The limitation of comparing categories based on identical absolute cutoffs is that, although the categories may appear identical, both their relative size and relative location with respect to the distribution in the sample may differ. For example, the top and bottom categories may be more extreme for the aggregate measure than for the individual-level measure because the top and bottom aggregate measure-based categories will necessarily contain a smaller percentage of the sample than the analogous individual-level categories, even though the same absolute value cutoffs were used in both cases. Similarly, because the spread in aggregate variables is necessarily smaller than the spread in individual-level variables (by virtue of aggregate variables' being constructed by "aggregating" the characteristics of individuals), a one-unit difference in aggregate variables may imply a much larger relative difference than a one-unit change in the corresponding individual-level variable (9).

The two recent analyses reporting stronger gradients when area-based socioeconomic indicators were used compared the effects of a one-unit change in continuous variables at both levels (11, 12). For income (the only variable in our data for which this comparison was possible), the use of area-based categories based on identical absolute value cutoffs also underestimated associations using individual-level indicators (with the exception of block-group measures in Whites), although differences were smaller than they were for distribution-based categories. However, the size of the categories was strikingly different at both levels: For example, although 28 percent of White participants had incomes of $75,000 or more, only 6 percent lived in block groups with median household incomes of $75,000 or more. Unfortunately, because data on individual-level income were collected in a categorical fashion, the effects of a one-unit change at both levels could not be compared.

As previously noted (11), the extent to which the use of area-based proxies leads to over- or underestimates of individual-level socioeconomic differences results from the balance of two factors: 1) the type and extent of misclassification of individuals inherent in using the aggregate variable

as a proxy for its individual-level namesake (sometimes referred to as "errors-in variables bias") and 2) the magnitude of the contextual effect (sometimes referred to as "aggregation bias"). It has been suggested that the presence of a contextual effect may result in overestimates of individual-level socioeconomic gradients when aggregate proxies are used (7, 11). In our analyses, however, area-based measures were less strongly associated with smoking than individual-based measures even in the presence of significant contextual area effects in White participants.

The presence of contextual area effects on smoking is itself of substantive interest. There are several a priori reasons why area effects on smoking can be hypothesized. A number of reports have documented area differences in tobacco advertising (23–25), and exposure to advertising has been linked to smoking in youth (26). Availability and access to tobacco products may also differ across areas. Psychosocial stress related to living in disadvantaged areas could also play a role. Social norms and attitudes regarding smoking may differ by residential areas (27). The prevalence of smoking itself (which is likely to be higher in disadvantaged neighborhoods because of the well-established relation between low individual-level socioeconomic position and smoking) may itself affect a person's likelihood of smoking. Thus, persons who live in more disadvantaged neighborhoods may be more likely to smoke merely because they are routinely exposed to smokers. In addition, persons of low socioeconomic position may be more vulnerable to the effects of living in disadvantaged neighborhoods, because of the lack of resources to buffer the potential smoking-enhancing effects of residential environments.

Several studies have found some evidence of contextual area effects on smoking (28–35) although others have not (36, 37). We documented a contextual effect of area characteristics on smoking prevalence in White participants: Living in the most disadvantaged area quartiles was associated with 50–110 percent higher odds of smoking, even after controlling for individual-level income, education, and occupation. However, contextual effects were not present in Blacks overall. Several factors may have hampered our ability to detect contextual effects in Black CARDIA Study participants generally. Blacks participating in the study tended to come from much more disadvantaged areas than Whites, thus limiting the types and range of area characteristics across which the effects could be investigated. Selection factors (related to participation in the study or follow-up) may have hampered our ability to detect contextual effects if persons not included in the sample were selected based on both smoking status and area characteristics. The impact of these factors cannot be directly tested with available data. Although year 10 follow-up rates were slightly lower for Black participants (75 percent vs. 79 percent for the whole cohort) and for persons of low education (75 percent vs. 79 percent for the whole cohort), differences were small.

However, area effects did emerge in Black participants with incomes of $35,000 or more (similarly, in Whites, the multiplicative effects of area characteristics were slightly greater in persons with incomes of $35,000 or more compared with those with incomes under $35,000). Contrary to expectation, persons of lower income were not more vulnerable to area affects on smoking than those of higher income. Few previous studies have investigated interactions between area-level and individual-level characteristics, and no consistent evidence of interactions has been found (30, 33). The interactions we observed need to be confirmed in other samples. In theory, they are compatible with at least two distinct processes: Improved neighborhood conditions on their own are not sufficient to prevent smoking in persons already at a disadvantage because of their low socioeconomic position, or alternatively, something about having a low income but living in a "better-off" neighborhood may be conducive to smoking. This multiplicative interaction may have hampered our ability to detect overall (multiplicative) contextual effects in Blacks, who were more likely than Whites to be in the lower socioeconomic groups. More generally, although our analyses did demonstrate the presence of significant area contextual effects in young White adults and possibly in young Black adults with incomes of $35,000 or more, we were unable to examine the processes generating these contextual effects and the specific area characteristics that may be relevant.

All of our findings regarding area effects were similar regardless of whether block groups or census tracts were used. There is inconsistent evidence on the extent to which aggregate measures based on smaller areas provide better estimates of associations between individual-level socioeconomic indicators and health than those based on larger areas. Some studies have suggested that estimates are similar regardless of area size (7, 38, 39), and others have suggested that smaller areas may be more appropriate (3, 40). Contextual effects for different area sizes have rarely been compared. Reijneveld et al. (41) found no clear differences in the contextual effects of area deprivation for geographic areas of mean population size ranging from about 8,000 to 32,800. We found no important differences between census-tract and block-group measures in comparisons of area-level and individual-level measures or in the estimation of contextual effects. There were also no consistent patterns regarding differences across the six different area indicators that we investigated.

Taken together with previous work, our results suggest that generalizations regarding the consequences of using area-based measures to proxy individual-level socioeconomic indicators may not be possible. Differences in estimates derived using aggregate proxies and individual-level measures may depend on the types of variables used (e.g., categorical vs. continuous measures, distribution-based cutoffs vs. identical absolute value cutoffs for categories), on the presence and magnitude of contextual effects, and on the variability in individual-level indicators within areas. Our results show that, in some circumstances, area-based measures may underestimate associations of individual-level variables with the outcomes even in the presence of contextual effects. A more fundamental problem (illustrated by the presence of area contextual effects) is that individual-level and area-level measures are likely to be tapping into different constructs, thus limiting the utility of using one as a proxy for the other.

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