Acculturation and Socioeconomic Position as Predictors of Coronary Calcification in a Multiethnic Sample

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Background—Coronary calcium has recently emerged as a marker of subclinical coronary heart disease. Although there has been much interest in race differences in calcification, heterogeneity within race or ethnic groups has not been investigated.

Methods and Results—Data from the Multi-Ethnic Study of Atherosclerosis (MESA), a population-based study of coronary calcification, were used to investigate acculturation and socioeconomic position as predictors of coronary calcification within 2553 non-Hispanic whites, 1734 non-Hispanic blacks, 1457 Hispanics, and 797 Chinese residing in the United States. Coronary calcium was assessed by chest CT. Relative risk regression and linear regression were used to estimate adjusted associations of sociodemographic variables with the presence and amount of calcium. Not being born in the United States was associated with a lower prevalence of calcification in blacks (relative prevalence [RP], 0.75; 95% confidence limit [CL], 0.61 to 0.94) and Hispanics (RP, 0.89; 95% CL, 0.81 to 0.98) after adjustment for age, sex, income, and education. Years in the United States was positively associated with prevalence of calcification in non–US-born Chinese (adjusted RP per 10 years in United States, 1.06; 95% CL, 1.01 to 1.11) and non–US-born blacks (RP, 1.59; 95% CL, 1.22 to 2.06). Low education was associated with a higher prevalence of calcification in whites (adjusted RP for no high school versus complete college, 1.17; 95% CL, 1.05 to 1.32) but with lower prevalence of calcification in Hispanics (RP, 0.91; 95% CL, 0.77 to 1.09) (P for interaction=0.02). US birth and time in the United States were also positively associated with the extent of calcification in persons with detectable calcium. These differences did not appear to be accounted for by smoking, body mass index, LDL and HDL cholesterol, hypertension, and diabetes.

Conclusions—Acculturation and socioeconomic factors are associated with differences in the prevalence and amount of coronary calcification within whites, Chinese, blacks, and Hispanics. The presence of this heterogeneity needs to be acknowledged in the quantification and investigation of race/ethnic differences. (***Circulation*. 2005;112:1557-1565.**)

Key Words: atherosclerosis ■ calcium ■ epidemiology ■ population groups ■ risk factors

The presence and amount of coronary calcium have recently emerged as markers of subclinical coronary heart disease. Coronary calcification appears to be a strong predictor of future coronary events.[1–4] Information on sociodemographic predictors of coronary calcification remains scarce. Recently, a growing number of reports have focused on race and ethnic differences in the presence of coronary calcification. Most[5–9] but not all[10–12] of these studies have found a lower prevalence of coronary calcification in US blacks compared with US whites. Hispanics also appear to have lower levels of coronary calcium than non-Hispanic whites.[9,13–15] The reasons for these differences remain unclear.

Heterogeneity within race or ethnic groups has been investigated less frequently than differences between race/ethnic groups. The presence of within-group heterogeneity would suggest that simple race/ethnic comparisons that treat each race/ethnic group as homogeneous may be misleading, and explanations for race/ethnic differences that fail to account for this variability could be incomplete. More generally, identifying factors associated with differences in calcification within race/ethnic groups may shed light on the processes leading to coronary calcification in all persons. These factors may also contribute to between race/ethnic group differences through their main effects or in interaction with genetic background.

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In this report, we use data from a large, population-based, multiethnic study to investigate factors related to place of birth, migration history, and socioeconomic position as predictors of coronary calcification within whites, blacks, Hispanics, and Chinese residing in the United States. We hypothesized that greater acculturation would be associated with higher prevalence of coronary calcification and higher calcium scores within race/ethnic groups. On the basis of prior work,[16] we also hypothesized that low socioeconomic position would be associated with greater calcification in whites but that the strength and direction of association of socioeconomic position with calcification would differ in other race/ethnic groups, especially groups composed of recent immigrants.

Methods

The Multi-Ethnic Study of Atherosclerosis[17] (MESA) is a 10-year longitudinal study supported by the National Heart, Lung, and Blood Institute with the goals of identifying risk factors for subclinical atherosclerosis, for quantitative progression of subclinical atherosclerosis, and for transition from subclinical disease to clinically apparent events. The MESA cohort includes 6814 men and women 45 to 84 years at baseline recruited from 6 field centers: Baltimore, Md; Chicago, Ill; Forsyth County, North Carolina; Los Angeles, Calif; New York, NY; and St Paul, Minn. Approximately 40% of the cohort is white, 30% is black, 20% is Hispanic, and 10% is Chinese. At each site, a probability sample of >1000 (range, 1066 to 1319) participants was selected through a variety of population-based approaches, including lists of area residents (all sites), HCFA lists of area residents (for participants ≥65 of age in all sites), area residents enrolled in a union health plan (in New York City), and random digit dialing (New York City and Los Angeles). Only persons free of clinical cardiovascular disease at baseline were eligible. Non-Hispanic white participants were recruited at all 6 study sites; non-Hispanic black participants were recruited at all sites except St Paul; Hispanic participants were recruited in New York, Los Angeles, and St Paul; and Asian participants were recruited in Los Angeles and Chicago. Each of the 6 field centers recruited approximately equal numbers of men and women. To augment recruitment of elderly minority groups, toward the end of the recruitment period, participants were asked to refer elderly persons to the study. The final sample included 27% who were 45 to 54 years of age, 28% who were 55 to 64 years of age, 30% who were 65 to 74 years of age, and 16% who were ≥75 years of age. The baseline visit for the cohort (on which these analyses are based) took place between July 2000 and September 2002.

Coronary calcium was assessed by chest CT using either a cardiac-gated electron-beam CT scanner[18] (Chicago, Los Angeles, and New York field centers) or a multidetector CT system[19] (Baltimore, Forsyth County, and St Paul field centers).[20] All participants were scanned twice over phantoms of known physical calcium concentration. Scans were read centrally at the Los Angeles Biomedical Research Institute at Harbor–UCLA in Torrance (Calif) to identify and quantify coronary calcification, calibrated according to the readings of the calcium phantom. A cardiologist read all CT scans at a central reading center. Scans were read blindly with respect to scan pairs and to other participant data using a computer interactive scoring system similar to that described by Yaghoubi et al.[21] The average Agatston score[22] for the 2 scans was used in all analyses. The presence of calcification was defined as an average Agatston score of >0 (or >0 on either scan).

Questionnaires administered as part of the baseline visit in English, Spanish, or Chinese were used to obtain information on sociodemographic indicators. Race and ethnicity were characterized on the basis of participants' responses to the ethnicity and race questions modeled on the year 2000 US Census. All participants who reported their ethnicity as Hispanic were classified as Hispanic in these analyses. All others were classified into 3 groups (white, black, and Chinese) on the basis of their responses to the race question. Place of birth, time in the United States (for those not born in the United States), and language spoken at home were used as proxy measures of acculturation. Income and education were used as indicators of socioeconomic position. Participants were asked to select their total gross family income from a list of 13 categories: less than $5000; $5000 to $7999; $8000 to $11 999; $12 000 to $15 999; $16 000 to $19 999; $20 000 to $24 999; $25 000 to $29 999; $30 000 to $34 999; $35 000 to $39 999; $40 000 to $49 999; $50 000 to $74 999; $75 000 to $99 999; and $100 000 or more. They also selected the highest level of schooling completed from a list of 8 categories: no schooling; grades 1 to 8; grades 9 to 11; completed high school or GED; some college but no degree; technical school certificate; associate degree; bachelor's degree; and graduate of professional school. The categories of region of residence, place of birth, income, and education used in these analyses are shown in Table 1. Income and education were collapsed into a smaller number of categories for some analyses.

Information on cardiovascular risk factors (smoking history, body mass index [BMI], LDL and HDL cholesterol, hypertension,[23] and diabetes[24]) was also collected as part of the baseline examination. Height and weight were measured with participants wearing light clothing and no shoes. BMI was calculated as weight in kilograms divided by height in meters squared. Resting blood pressure was measured 3 times with participants in the seated position with a Dinamap model Pro 1000 automated oscillometric sphygmomanometer (Critikon). The average of the last 2 measurements was used in the analysis. Hypertension was defined as systolic blood pressure ≥140 mm Hg, diastolic blood pressure ≥90 mm Hg, or current use of antihypertensive medication. HDL cholesterol and glucose levels were measured from blood samples obtained after a 12-hour fast. LDL was calculated with the Friedewald equation.[25] Diabetes was defined as fasting glucose >6.99 mmol/L (126 mg/dL) or use of hypoglycemic medication. Quality assurance and quality control procedures were implemented for all aspects of data collection.

When the outcome is common, odds ratios estimated from cross-sectional data will substantially overestimate prevalence ratios. The presence of coronary calcification is a common outcome in our sample. We therefore used relative risk regression to directly estimate prevalence ratios of the presence of coronary calcification associated with the exposures of interest. Although relative risk regression was first proposed in the context of cohort studies with common outcomes,[26] the method is also applicable to the estimation of relative prevalences (RPs) in cross-sectional studies. RPs can be derived from binomial regression models fitted with Proc Genmod in SAS.[26,27] Because the use of a binomial error resulted in frequent convergence problems, a Gaussian error was used, and robust standard errors were obtained through the use of an approach similar to that proposed by Zou.[28] Analyses of the amount of calcium among persons with calcium modeled the (ln) Agatston score as a function of covariates using linear regression. Exponentiated coefficients derived from these models can be interpreted as relative differences in the amount of calcium associated with the variable of interest. For example, a relative difference of 1.5 represents a 50% increase in the Agatston score. All probability values reported correspond to 2-tailed tests. Of the 6814 MESA participants at baseline, 273 were excluded because they had incomplete information on the key variables of interest (place of birth, income, or education), leaving a total of 6541 participants available for analysis. Agatston scores were slightly higher in excluded than in included participants. Excluded participants also were more likely to be black, but because of the small number of exclusions (only 4%), the race/ethnic distribution and coronary calcium levels of the analysis sample were very similar to those of the full cohort. The study was approved by Institutional Review boards at each site, and all subjects gave written informed consent.

Results

Table 1 shows sociodemographic characteristics and prevalence of coronary calcification in MESA participants. Chi-

TABLE 1. Sociodemographic Characteristics and Coronary Calcium Levels by Sex and Race/Ethnicity: MESA 2000–2002*

	Whites (n=2553)	Chinese (n=797)	Blacks (n=1734)	Hispanics (n=1457)
Median age, y	62.4	62.3	61.6	61.3
Male, %	48.0	48.8	44.1	48.6
Place of residence, %				
South	41.8	0	52.8	0.1
Northeast	8.7	0.3	21.4	33.7
Midwest	44.5	37.8	17.0	30.5
West	5.0	62.0	8.8	35.7
Place of birth, %				
United States	93.3	3.6	90.7	31.5
Other country†	6.7	96.4	9.3	68.5
Generations in the United States, %†				
0	6.7	96.4	9.3	68.5
1	17.3	3.4	2.0	14.8
2	24.1	0.3	1.3	4.7
3	47.5	0	81.2	2.5
Other	4.5	0.1	6.1	9.5
Language spoken at home, %				
English	97.2	6.3	97.7	29.6
Spanish	0.2	0	0.1	53.5
Chinese	0	78.2	0	0
English and Spanish	0.3	0	0.7	16.0
English and Chinese	0	6.3	0.1	0
Other or unknown	2.3	9.9	1.5	0.9
Income, %				
<$12 000	4.0	22.2	11.0	20.4
$12 000–$24 999	12.1	27.4	19.6	29.1
$25 000–$34 999	9.8	12.7	13.8	18.5
$35 000–$49 999	17.0	9.3	18.3	14.3
$50 000–$74 999	20.6	11.5	19.7	10.5
$75 000–$99 999	12.2	6.9	9.2	4.9
≥$100 000	24.3	10.0	8.3	2.4
Education. %				
Grade 8 or less	1.5	16.7	3.6	32.7
Grades 9–11	3.3	8.0	7.7	11.5
Complete high school/GED	16.5	16.2	18.7	20.3
Technical school, associate degree, some college	28.4	20.0	35.2	25.4
Bachelors degree	22.4	22.8	17.9	5.6
Graduate or professional school	27.8	16.3	16.9	4.5
Percent with any coronary calcification, %				
Men	70.1	59.1	51.2	56.6
Women	44.5	41.9	35.5	34.9
Percent with Agatston score ≥400				
Men	20.1	8.0	11.2	12.6
Women	6.9	4.9	5.0	3.9
Median (25th–75th percentile) calcium score in persons with calcium				
Men	159 (33–460)	85 (23–233)	80 (23–302)	92 (25–349)
Women	67 (18–235)	53 (18–153)	53 (17–177)	44 (14–150)

*For race/ethnic differences, $P<0.0001$ for all variables except age ($P=0.002$), percent male ($P=0.03$), percent with calcium >400 in women ($P=0.02$), and Agatston score in women with calcium ($P=0.17$).

†Generation 0 means participant was not born in the United States; first generation, 1 or both parents were not born in the United States; second generation, both parents were born in the United States but ≥2 grandparents were not born in the United States; and third generation, both parents were born in the United States and ≥3 grandparents were born in the United States. The "other" category includes participants who could not be classified in the previous categories.

TABLE 2. Sociodemographic Characteristics and Cardiovascular Risk Factors* in US- and Non–US-Born Participants by Race/Ethnicity: MESA 2000–2002

	Whites		Chinese		Blacks		Hispanic	
	US-Born (n=2383)	Non–US-Born (n=170)	US-Born (n=29)	Non–US-Born (n=768)	US-Born (n=1572)	Non–US-Born (n=162)	US-Born (n=459)	Non–US-Born (n=998)
Male, %	48.4	42.9	58.6	48.4	43.9	46.3	52.7	46.7
P†	0.2		0.3		0.6		0.03	
Mean age, y	62.4	63.6	61.5	62.3	62.0	58.2	61.7	61.1
P†	0.1		0.7		0.0001		0.3	
Income, %								
<$20 000	10.8	11.2	3.5	43.1	21.6	23.5	25.5	45.7
$20 000–$49 999	32.1	31.2	34.5	29.7	41.0	40.1	45.8	41.6
≥$50 000	57.0	57.7	62.1	27.2	37.3	36.4	28.8	12.7
P†	0.9		<0.0001		0.8		<0.0001	
Education, %								
No high school diploma	4.7	6.5	3.5	25.5	11.1	13.0	20.4	55.4
Complete high school	45.5	37.1	31.0	36.3	53.3	59.9	67.8	35.6
Complete college	49.8	56.5	65.5	38.2	35.6	27.2	12.2	9.0
P†	0.08		0.004		0.1		<0.0001	
Mean HDL cholesterol, mg/dL	52.3	53.5	53.6	49.4	52.0	53.3	48.0	47.9
P†	0.3		0.07		0.3		0.9	
Mean LDL cholesterol, mg/dL	116.9	119.5	107.0	115.4	116.3	118.2	116.9	120.9
P†	0.3		0.1		0.5		0.03	
Mean BMI, kg/m^2	27.8	27.2	25.8	23.9	30.2	29.4	30.6	28.8
P†	0.2		0.003		0.1		0.0001	
Percent smokers	10.8	14.0	4.0	3.9	18.1	4.8	11.9	10.3
P†	0.2		0.9		0.0001		0.3	
Percent diabetic	6.3	7.6	9.8	14.3	19.1	20.4	22.0	17.8
P†	0.5		0.5		0.7		0.06	
Percent hypertensive	36.5	29.6	34.1	35.0	58.8	51.3	41.3	41.4
P†	0.08		0.9		0.08		0.9	

*Means and proportions for cardiovascular risk factors are adjusted to the mean age (62 years) and sex distribution (53% female) of the full sample.
†Probability value for difference between US- and non–US-born individuals.

nese and Hispanics were less likely than whites and blacks to have been born in the United States. Among persons not born in the United States, the median time lived in the United States was longest for whites and shortest for Chinese (median, 41 years in whites [n=132], 18 years in Chinese [n=717], 28 years in blacks [n=126], and 31 years in Hispanics [n=885] [data not shown in the table]). Nearly half of the whites and 81% of the blacks were third generation in the United States. In contrast, virtually all Chinese and most (83%) of the Hispanics were either first generation in the United States or immigrants. Virtually all whites and blacks spoke English at home, but most Chinese (78%) spoke Chinese at home, and >50% of Hispanics spoke Spanish at home. Whites were generally of higher income and education than the other 3 groups. The prevalence of coronary calcification and the amount of calcium in persons with calcification were higher in whites than in the 3 other ethnic groups, but these race/ethnic differences were more pronounced in men than in women.

Chinese and Hispanics not born in the United States were generally of lower income and education than the those born in the United States (Table 2). Mean BMI was significantly higher in US-born Chinese and Hispanics than in their non–US-born counterparts. Similar, albeit smaller, differences in BMI were observed by place of birth in whites and blacks. US-born Hispanics had significantly lower LDL cholesterol than non–US-born Hispanics. US-born blacks were significantly more likely to smoke than non–US-born blacks. US-born Hispanics were more likely to have diabetes than non–US-born Hispanics. No other consistent differences in cardiovascular risk factors by place of birth were observed. Language and place of birth were strongly associated: 88.7% of non–US-born Hispanics spoke Spanish at home (versus 27.9% for US-born Hispanics) and 86.6% of non–US-born Chinese spoke Chinese at home (versus 27.6% for US-born Chinese) (not shown in the table).

Table 3 shows multivariable-adjusted RPs of calcification by place of birth, education, and income. After adjustment for socioeconomic indicators, non-US birth was significantly associated with a reduced probability of calcification in blacks and Hispanics. The probability of having calcification was 25% lower in non–US-born compared with US-born

TABLE 3. RPs of Coronary Calcification by Sociodemographic Characteristics and Race/Ethnicity: MESA 2000–2002*

	RP (95% CI)			
	Whites	Chinese	Blacks	Hispanics
Place of birth†				
Country other than United States	1.01 (0.90–1.12)	0.92 (0.68–1.25)	0.75 (0.61–0.94)	0.89 (0.81–0.98)
United States	1.0	1.0	1.0	1.0
Education†				
No high school diploma	1.17 (1.05–1.32)	0.98 (0.83–1.16)	0.98 (0.84–1.14)	0.91 (0.77–1.09)
Complete high school	1.10 (1.03–1.17)	1.02 (0.88–1.18)	1.00 (0.89–1.11)	0.99 (0.85–1.17)
Complete college or graduate school	1.0	1.0	1.0	1.0
Income†				
<$20 000	1.02 (0.93–1.12)	1.01 (0.84–1.22)	1.12 (0.97–1.29)	1.08 (0.92–1.26)
$20 000–$49 999	1.02 (0.96–1.09)	1.03 (0.86–1.23)	1.00 (0.89–1.13)	1.01 (0.87–1.17)
≥$50 000	1.00	1.0	1.0	1.0
Years in United States among non–US-born†				
Each 10 y in United States	1.09 (0.97–1.21)	1.06 (1.01–1.11)	1.59 (1.22–2.06)	1.00 (0.96–1.04)
Sample size, n	133	717	126	885
Region of birth				
Africa	...	...	0.44 (0.21–0.95)	...
Caribbean/Central America	...	...	0.83 (0.66–1.04)	0.87 (0.77–0.99)
Mexico	...	...	...	0.93 (0.83–1.07)
South America	...	...	...	0.87 (0.73–1.03)
United States	...	...	1.00	1.00

*RPs for place of birth, education, and income are adjusted for sex, age (continuous), and each other. There was no statistically significant ($P<0.05$) heterogeneity by sex in the effects of place of birth, income, or education in any race group. Age-by-sex interactions were statistically significant and retained in all models. RPs for years in the United States and for region of birth are each adjusted for sex, age (continuous), education (3 categories), and income (3 categories).

†For effect modification by race/ethnicity (comparing association in each group to the association observed in whites) for non-US birth: $P=0.4$ for Chinese, $P=0.009$ for blacks, $P=0.004$ for Hispanics; for no high school diploma, $P=0.2$ for Chinese, $P=0.6$ for blacks, $P=0.02$ for Hispanics; for income <$20 000, $P=0.5$ for Chinese, $P=0.06$ for blacks, $P=0.6$ for Hispanics; and for years in the United States, $P=0.6$ for Chinese, $P=0.009$ for blacks, $P=0.7$ for Hispanics.

blacks and 11% lower in non–US-born Hispanics compared with US-born Hispanics. Non-US birth was also associated with lower probability of calcification in Chinese, but the confidence interval was wide because of the small sample size in this group. Low education was independently and significantly associated with increased probability of calcification in whites: The probability of having calcification was 17% higher in persons with incomplete high school compared with those with complete college. In contrast, low education appeared to be associated with lower probability of calcification among Hispanics (RP, 0.91; 95% confidence limit [CL], 0.77 to 1.09; $P=0.3$; $P=0.02$ for difference in education association in Hispanics versus whites). Income appeared to be inversely associated with calcification in blacks: Blacks in the lowest income categories had a 12% higher probability of calcification than those in the highest category (RP, 1.12; 95% CL, 0.97 to 1.29; $P=0.1$; $P=0.06$ for difference in income association in blacks versus whites). Adjustment for study site did not modify these patterns.

Years in the United States was positively associated with the prevalence of calcification in all groups except Hispanics. In non–US-born Chinese, each 10 years lived in the United States was significantly associated with a 6% increase in the probability of calcification (RP per 10 years in the United States, 1.06; 95% CL, 1.01 to 1.11). An especially strong association was observed in blacks (RP, 1.59; 95% CL, 1.22 to 2.06). A positive but not statistically significant association was also observed in whites. Examination of country of birth among the non–US-born showed that the prevalence of having coronary calcification was reduced in both African-born and in Caribbean- or Central America–born blacks compared with US-born blacks. The reduction was especially pronounced in the African-born group (multivariate-adjusted RP, 0.44; 95% CL, 0.21 to 0.95). The probability of having calcification was similarly reduced for Hispanics born in Mexico, Central America, the Caribbean (including Puerto Rico), or South America.

Associations of acculturation and socioeconomic variables with coronary calcification after adjustment for smoking, LDL and HDL cholesterol, hypertension, diabetes, and BMI are shown in Table 4. Comparison of point estimates in Tables 3 and 4 shows that associations between place of birth and years in the Unites States and calcification were very similar before and after adjustment. The association of low education with lower probability of calcification was not modified by risk factor adjustment. In contrast, in whites, the

TABLE 4. RPs of Coronary Calcification by Sociodemographic Characteristics and Race/Ethnicity Adjusted for Cardiovascular Risk Factors: MESA 2000–2002*

	RP (95% CI)			
	Whites	Chinese	Blacks	Hispanics
Place of birth†				
Country other than the United States	0.99 (0.89–1.10)	0.96 (0.70–1.32)	0.82 (0.66–1.01)	0.91 (0.82–1.00)
United States	1.0	1.0	1.0	1.0
Education†				
No high school diploma	1.08 (0.96–1.22)	0.97 (0.82–1.15)	0.96 (0.83–1.12)	0.91 (0.77–1.08)
Completed college or graduate school	1.0	1.0	1.0	1.0
Income†				
<$20 000	0.97 (0.89–1.07)	1.01 (0.85–1.22)	1.07 (0.93–1.24)	1.03 (0.88–1.20)
≥$50 000	1.00	1.0	1.0	1.0
Years in United States among non–US-born†				
Each 10 y in United States	1.11 (0.98–1.25)	1.05 (1.00–1.11)	1.56 (1.22–2.00)	1.00 (0.96–1.04)
Region of birth				
Africa	...	...	0.42 (0.18–0.96)	...
Caribbean/Central America	...	...	0.91 (0.73–1.14)	0.90 (0.79–1.02)
Mexico	...	...	...	0.97 (0.84–1.11)
South America	...	...	...	0.86 (0.72–1.03)
United States	...	...	1.00	1.00

* Models are identical to those reported in Table 3 with the addition of current and former smoking, LDL and HDL cholesterol, BMI, hypertension, and diabetes as defined in the Methods section. Intermediate categories of income and education are not shown.

†For effect modification by race/ethnicity (comparing association in each group to the association observed in whites), for non-US birth: $P=0.6$ for Chinese, $P=0.04$ for blacks, $P=0.1$ for Hispanics; for no high school diploma, $P=0.4$ for Chinese, $P=0.9$ for blacks, $P=0.08$ for Hispanics; for income <$20 000, $P=0.8$ for Chinese, $P=0.04$ for blacks, $P=0.5$ for Hispanics; and for years in the United States, $P=0.7$ for Chinese, $P=0.005$ for blacks, $P=0.3$ for Hispanics.

increased probability of calcification associated with low education was reduced by ≈50% after risk factor adjustment (from an RP of 1.17 to 1.08). A similar reduction was observed for the association between low income and calcification in blacks (from an RP of 1.12 to 1.07).

Non-US birth and time in the United States were also associated with the amount of calcification in persons with detectable calcium. Among Hispanics, non-US birth was associated with having ≈30% less calcium (relative difference, 0.71; 95% CL, 0.53 to 0.94), and each 10 years in the US was associated with 18% more calcium (relative difference, 1.18; 95% CL, 1.05 to 1.33) (Table 5). Non-US birth was also associated with less calcium in whites, Chinese, and blacks; years in the United States was positively associated with the amount of calcium in Chinese and blacks, but confidence intervals were wide (Table 5). Low education was associated with more calcium in blacks and with less calcium in Hispanics, and low income was associated with more calcium in whites and blacks; however, confidence intervals of these associations were very wide. Point estimates for relative differences in amount of calcium were not substantially modified by risk factor adjustment (not shown).

Discussion

As reported elsewhere,[9] the prevalence of calcification in MESA participants was higher in white non-Hispanics than in the other 3 groups studied. However, our analyses show that there is also important variation within race/ethnic groups. Not being born in the US was associated with lower prevalence of calcification and less calcium in blacks and Hispanics. Years in the United States was positively associated with the presence of calcium or with the amount of calcium in Chinese, blacks, and Hispanics. These differences did not appear to be accounted for by smoking, BMI, LDL and HDL cholesterol, hypertension, and diabetes.

There is a long tradition of research on the potential effects of acculturation on cardiovascular risk. A series of studies of Japanese migrants to the United States carried out >25 years ago showed that greater incorporation into Western culture (acculturation) was related to higher levels of cholesterol, greater prevalence of coronary heart disease, and higher incidence and mortality resulting from coronary heart disease.[29–32] Recent work on ethnic minorities residing in the United States has also found that acculturation (as assessed by place of birth, duration of residence in the US, language, and ethnic self-identification) is associated with higher prevalence of cardiovascular risk factors or greater prevalence of coronary heart disease in South Asians,[33] Chinese,[34] and Hispanics,[35–40] although findings have not always been consistent.[41]

To the best of our knowledge, no studies have examined associations between indicators of acculturation and measures of subclinical disease. Our results are consistent with lower prevalence of subclinical disease in less acculturated members of minority groups. Associations between acculturation and greater prevalence of calcification were present

TABLE 5. Relative Differences in the Amount of Coronary Calcification by Sociodemographic Characteristics Among Persons With Detectable Calcification: MESA 2000–2002*

	Relative Difference (95% CI)			
	Whites	Chinese	Blacks	Hispanics
Place of birth†				
Country other than United States	0.77 (0.54–1.09)	0.87 (0.38–2.02)	0.63 (0.37–1.07)	0.71 (0.53–0.94)
United States	1.0	1.0	1.0	1.0
Education†				
No high school diploma	1.06 (0.72–1.57)	0.70 (0.45–1.09)	1.53 (0.99–2.36)	0.79 (0.49–1.29)
Complete high school	1.07 (0.88–1.30)	0.70 (0.47–1.03)	1.00 (0.75–1.34)	0.98 (0.62–1.55)
Complete college or graduate school	1.0	1.0	1.0	1.0
Income†				
<$20 000	1.28 (0.95–1.74)	1.08 (0.67–1.75)	1.26 (0.86–1.83)	0.85 (0.55–1.31)
$20 000–$49 999	0.98 (0.80–1.21)	0.99 (0.63–1.57)	1.18 (0.86–1.61)	0.95 (0.63–1.41)
≥$50 000	1.00	1.0	1.0	1.0
Years in United States among non–US-born†				
Each 10 y in United States	0.84 (0.62–1.16)	1.05 (0.92–1.21)	1.58 (0.90–2.76)	1.18 (1.05–1.33)
Region of birth				
Africa	...	...	0.23 (0.06–0.82)	...
Caribbean/Central America	...	...	0.74 (0.40–1.35)	0.87 (0.77–0.99)
Mexico	...	...	...	0.93 (0.82–1.07)
South America	...	...	...	0.87 (0.72–1.03)
United States	...	...	1.00	1.00

*Relative differences for place of birth, education, and income are adjusted for sex, age (continuous), and each other. Relative differences for years in the United States and for region of birth are each adjusted for sex, age (continuous), education (3 categories), and income (3 categories).

†For effect modification by race/ethnicity (comparing association in each group to the association observed in whites), for non-US birth: $P=0.9$ for Chinese, $P=0.5$ for blacks, $P=0.3$ for Hispanics; for no high school diploma, $P=0.2$ for Chinese, $P=0.9$ for blacks, $P=0.02$ for Hispanics; for income <$20 000, $P=0.2$ for Chinese, $P=0.9$ for blacks, $P=0.02$ for Hispanics; for years in the United States, $P=0.8$ for Chinese, $P=0.07$ for blacks, $P=0.5$ for Hispanics.

despite the fact that more acculturated members of each ethnic group often had higher incomes than less acculturated ones. Particularly intriguing is the substantially lower prevalence of calcification in African-born blacks and the strong, positive association between years in the United States and coronary calcium in non–US-born blacks. However, these results are based on a small number of non–US-born blacks and need to be confirmed in other studies.

A standard set of cardiovascular risks factors did not appear to account for the patterns we observed. Although it is tempting to conclude that other factors must therefore be involved, our ability to investigate the mediating role of these factors is limited by the fact that we had measures only at 1 point in time, rather late in adulthood, which may not reflect the lifetime history of exposures likely to be relevant to the development of atherosclerosis.

We also found differences in the prevalence of coronary calcium by socioeconomic indicators within race/ethnic groups. The socioeconomic patterning of clinical coronary heart disease in non-Hispanic whites and non-Hispanic blacks is well-established,[42–45] but socioeconomic differences in subclinical indicators of coronary atherosclerosis such as coronary calcium have been investigated less frequently. A small study of 149 men and women 30 to 40 years of age living in London found that being in the manual social class and having left full-time education before 19 years of age were associated with increased odds of having coronary calcification.[46] Education was also inversely associated with having coronary calcium in the top quintile of the sample of 308 postmenopausal women living in the United States.[47] Consistent with these reports, we found that low education was associated with greater prevalence of calcification in whites. In contrast, low education appeared to be associated with lower prevalence of calcification and with less calcium in Hispanics, even after accounting for place of birth. Adjustment for a standard set of contemporaneously measured risk factors reduced some but not all of these associations, suggesting that factors earlier in life or other unmeasured factors may partly contribute to these differences. Other studies have also found that socioeconomic indicators are not always similarly associated with cardiovascular risk across different race/ethnic groups.[16,48] Further investigation of the processes generating the opposite association of education with coronary calcium in whites and Hispanics may shed light on the origin of coronary calcification generally.

A limitation of our study in investigating socioeconomic differences in subclinical disease is that socioeconomic factors were measured only once in middle or late adulthood. Adult measures are only limited proxies for socioeconomic trajectories over the life course that are clearly more relevant

to the development of a chronic disease like atherosclerosis than a single measure late in life. Moreover, the exclusion of persons with a prior history of cardiovascular disease (which may be associated with calcification and is known to be strongly associated with socioeconomic factors)[43] is likely to have resulted in underestimates of socioeconomic differences in the prevalence and amount of calcium.

The within-ethnic group differences associated with acculturation and socioeconomic factors were substantial and comparable to the magnitude of differences between race/ethnic groups. For example, from estimated adjusted prevalence ratios and the overall prevalence of calcification in each gender and race/ethnic group, the estimated absolute difference in the adjusted prevalence of calcification between non–US-born and US-born persons is equivalent to ≈12.8 percentage points in black men and 8.9 percentage points in black women compared with an overall difference of 18.9 percentage points between white and black men overall and 9.0 percentage points between white and black women overall. The estimated absolute differences between persons with no high school diploma and persons with complete college was ≈11.9 percentage points in white men and 7.6 percentage points in white women. Several associations observed for income, education, and place of birth were comparable, for example, to the effects of diabetes and hypertension observed in the fully adjusted models reported in Table 3 (RP for diabetics versus non diabetics, 1.11 in whites, 1.10 in Chinese, 1.09 in blacks, and 1.08 in Hispanics; RP for hypertensives versus nonhypertensives, 1.08 in whites, 1.23 in Chinese, 1.17 in blacks, and 1.23 in Hispanics).

A clear strength of our study is the population-based, multiethnic sample. Although the sample size for the different race/ethnic groups may be large compared with other studies, stratification within race/ethnic groups sometimes resulted in small groups and wide confidence intervals for some estimates and limited our power to detect some associations. The factors we investigated are only a small subset of a complex set of factors involved in the causal processes leading to coronary atherosclerosis and calcification. For example, socioeconomic factors clearly do not explain why white men have significantly higher prevalence of calcium than men of other ethnic groups.

We documented substantial heterogeneity in coronary calcification associated with acculturation and socioeconomic indicators within race/ethnic groups. The reasons for these differences, which did not appear to be accounted for by a set of standard cardiovascular risk factors, require additional analyses. More generally, however, our results highlight the complexity of understanding the reasons for differences in coronary calcification between what are often internally heterogeneous race/ethnic groups. Overall, between race/ethnic group differences are likely to involve complex interactions between social and biological processes and perhaps even countervailing influences of genetic and social factors. The presence of this heterogeneity needs to be acknowledged in the quantification and investigation of race/ethnic differences.

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References

1. Greenland P, LaBree L, Azen SP, Doherty TM, Detrano RC. Coronary artery calcium score combined with Framingham score for risk prediction in asymptomatic individuals. *JAMA*. 2004;291:210–215.
2. Arad Y, Spadaro LA, Goodman K, Newstein D, Guerci AD. Prediction of coronary events with electron beam computed tomography. *J Am Coll Cardiol*. 2000;36:1253–1260.
3. O'Malley PG, Taylor AJ, Jackson JL, Doherty TM, Detrano RC. Prognostic value of coronary electron-beam computed tomography for coronary heart disease events in asymptomatic populations. *Am J Cardiol*. 2000;85:945–948.
4. Raggi P, Callister TQ, Shaw LJ. Progression of coronary artery calcium and risk of first myocardial infarction in patients receiving cholesterol-lowering therapy. *Arterioscler Thromb Vasc Biol*. 2004;24:1272–1277.
5. Lee TC, O'Malley PG, Feuerstein I, Taylor AJ. The prevalence and severity of coronary artery calcification on coronary artery computed tomography in black and white subjects. *J Am Coll Cardiol*. 2003;41:39–44.
6. Doherty TM, Tang W, Detrano RC. Racial differences in the significance of coronary calcium in asymptomatic black and white subjects with coronary risk factors. *J Am Coll Cardiol*. 1999;34:787–794.
7. Newman AB, Naydeck BL, Whittle J, Sutton-Tyrrell K, Edmundowicz D, Kuller LH. Racial differences in coronary artery calcification in older adults. *Arterioscler Thromb Vasc Biol*. 2002;22:424–430.
8. Tang W, Detrano RC, Brezden OS, Georgiou D, French WJ, Wong ND, Doherty TM, Brundage BH. Racial differences in coronary calcium prevalence among high-risk adults. *Am J Cardiol*. 1995;75:1088–1091.
9. Bild D, Detrano R, Peterson D, Guerci AD, Liu K, Shahar E, Ouyang P, Jackson S, Saad MF. Ethnic differences in coronary calcification: the Multi-Ethnic Study of Atherosclerosis (MESA). *Circulation*. 2005;111:1313–1320.
10. Bild DE, Folsom AR, Lowe LP, Sidney S, Kiefe C, Westfall AO, Zheng ZJ, Rumberger J. Prevalence and correlates of coronary calcification in black and white young adults: the Coronary Artery Risk Development in Young Adults (CARDIA) Study. *Arterioscler Thromb Vasc Biol*. 2001;21:852–857.
11. Khurana C, Rosenbaum CG, Howard BV, Adams-Campbell LL, Detrano RC, Klouj A, Hsia J. Coronary artery calcification in black women and white women. *Am Heart J*. 2003;145:724–729.
12. Jain T, Peshock R, McGuire DK, Willett D, Yu Z, Vega GL, Guerra R, Hobbs HH, Grundy SM. African Americans and Caucasians have a similar prevalence of coronary calcium in the Dallas Heart Study. *J Am Coll Cardiol*. 2004;44:1011–1017.
13. Reaven PD, Thurmond D, Domb A, Gerkin R, Budoff MJ, Goldman S. Comparison of frequency of coronary artery calcium in healthy Hispanic versus non-Hispanic white men by electron beam computed tomography. *Am J Cardiol*. 2003;92:1198–1200.
14. Reaven PD, Sacks J. Reduced coronary artery and abdominal aortic calcification in Hispanics with type 2 diabetes. *Diabetes Care*. 2004;27:1115–1120.
15. Budoff MJ, Yang TP, Shavelle RM, Lamont DH, Brundage BH. Ethnic differences in coronary atherosclerosis. *J Am Coll Cardiol*. 2002;39:408–412.
16. Marmot M. Coronary heart disease: rise and fall of a modern epidemic. In: Marmot MGEP, ed. *Coronary Heart Disease Epidemiology: From Aetiology to Prevention*. Oxford, UK: Oxford University Press; 1992:3–19.
17. Bild D, Bluemke D, Burke G, Detrano R, Diez Roux A, Folsom A, Greenland P, Jacobs D, Kronma R, Liu L, Clark Nelson J, O'Leary D, Saad MF, Shea S, Szklo M, Tracy RP. The Multi-Ethnic Study of Atherosclerosis (MESA): objectives and design. *Am J Epidemiol*. 2002;156:871–881.
18. Breen JF, Sheedy PF 2nd, Schwartz RS, Stanson AW, Kaufmann RB, Moll PP, Rumberger JA. Coronary artery calcification detected with

ultrafast CT as an indication of coronary artery disease. *Radiology*. 1992;185:435–439.
19. Carr JJ, Crouse JR, 3rd, Goff DC Jr, D'Agostino RB Jr, Peterson NP, Burke GL. Evaluation of subsecond gated helical CT for quantification of coronary artery calcium and comparison with electron beam CT. *AJR Am J Roentgenol*. 2000;174:915–921.
20. Carr JJ, Nelson JC, Wong ND, McNitt-Gray M, Arad Y, Jacobs DR Jr, Sidney S, Bild DE, Williams OD, Detrano RC. Calcified coronary artery plaque measurement with cardiac CT in population-based studies: standardized protocol of Multi-Ethnic Study of Atherosclerosis (MESA) and Coronary Artery Risk Development in Young Adults (CARDIA) study. *Radiology*. 2005;234:35–43.
21. Yaghoubi S, Tang W, Wang S, Reed J, Hsiai J, Detrano R, Brundage B. Offline assessment of atherosclerotic coronary calcium from electron beam tomograms. *Am J Card Imaging*. 1995;9:231–236.
22. Agatston AS, Janowitz WR, Hildner FJ, Zusmer N, Viamonte M Jr, Detrano R. Quantification of coronary artery calcium using ultrafast computed tomography. *J Am Coll Cardiol.* 1990;15:827–832.
23. Committee JN. The sixth report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure. *Arch Intern Med*. 1997;157:2413–2446.
24. Report of the Expert Committee on the Diagnosis and Classification of Diabetes Mellitus. *Diabetes Care*. 1997;20:1183–1197.
25. Friedewald WT, Levy RI, Fredrickson DS. Estimation of the concentration of low-density lipoprotein cholesterol in plasma, without use of the preparative ultracentrifuge. *Clin Chem*. 1972;18:499–502.
26. Robbins AS, Chao SY, Fonseca VP. What's the relative risk? A method to directly estimate risk ratios in cohort studies of common outcomes. *Ann Epidemiol*. 2002;12:452–454.
27. *SAS/STAT Software, Version 8.02*. Cary, NC: SAS Institute; 1999.
28. Zou G. A modified Poisson regression approach to prospective studies with binary data. *Am J Epidemiol*. 2004;159:702–706.
29. Marmot MG, Syme SL. Acculturation and coronary heart disease in Japanese-Americans. *Am J Epidemiol*. 1976;104:225–247.
30. Marmot MG, Syme SL, Kagan A, Kato H, Cohen JB, Belsky J. Epidemiologic studies of coronary heart disease and stroke in Japanese men living in Japan, Hawaii and California: prevalence of coronary and hypertensive heart disease and associated risk factors. *Am J Epidemiol*. 1975; 102:514–525.
31. Robertson TL, Kato H, Rhoads GG, Kagan A, Marmot M, Syme SL, Gordon T, Worth RM, Belsky JL, Dock DS, Miyanishi M, Kawamoto S. Epidemiologic studies of coronary heart disease and stroke in Japanese men living in Japan, Hawaii and California: incidence of myocardial infarction and death from coronary heart disease. *Am J Cardiol*. 1977; 39:239–243.
32. Robertson TL, Kato H, Gordon T, Kagan A, Rhoads GG, Land CE, Worth RM, Belsky JL, Dock DS, Miyanishi M, Kawamoto S. Epidemiologic studies of coronary heart disease and stroke in Japanese men living in Japan, Hawaii and California: coronary heart disease risk factors in Japan and Hawaii. *Am J Cardiol*. 1977;39:244–249.
33. Mooteri SN, Petersen F, Dagubati R, Pai RG. Duration of residence in the United States as a new risk factor for coronary artery disease (the Konkani Heart Study). *Am J Cardiol*. 2004;93:359–361.
34. Shelley D, Fahs M, Scheinmann R, Swain S, Qu J, Burton D. Acculturation and tobacco use among Chinese Americans. *Am J Public Health*. 2004;94:300–307.
35. Neuhouser ML, Thompson B, Coronado GD, Solomon CC. Higher fat intake and lower fruit and vegetables intakes are associated with greater acculturation among Mexicans living in Washington State. *J Am Diet Assoc*. 2004;104:51–57.
36. Sundquist J, Winkleby MA. Cardiovascular risk factors in Mexican American adults: a transcultural analysis of NHANES III, 1988–1994. *Am J Public Health*. 1999;89:723–730.
37. Dixon LB, Sundquist J, Winkleby M. Differences in energy, nutrient, and food intakes in a US sample of Mexican-American women and men: findings from the Third National Health and Nutrition Examination Survey, 1988–1994. *Am J Epidemiol*. 2000;152:548–557.
38. Winkleby MA, Albright CL, Howard-Pitney B, Lin J, Fortmann SP. Hispanic/white differences in dietary fat intake among low educated adults and children. *Prev Med*. 1994;23:465–473.
39. Popkin BM, Udry JR. Adolescent obesity increases significantly in second and third generation U.S. immigrants: the National Longitudinal Study of Adolescent Health. *J Nutr*. 1998;128:701–706.
40. Gordon-Larsen P, Harris KM, Ward DS, Popkin BM. Acculturation and overweight-related behaviors among Hispanic immigrants to the US: the National Longitudinal Study of Adolescent Health. *Soc Sci Med*. 2003; 57:2023–2034.
41. Woodruff SI, Zaslow KA, Candelaria J, Elder JP. Effects of gender and acculturation on nutrition-related factors among limited-English proficient Hispanic adults. *Ethn Dis*. 1997;7:121–126.
42. Diez-Roux AV, Nieto FJ, Tyroler HA, Crum LD, Szklo M. Social inequalities and atherosclerosis: the Atherosclerosis Risk in Communities study. *Am J Epidemiol*. 1995;141:960–972.
43. Kaplan GA, Keil JE. Socioeconomic factors and cardiovascular disease: a review of the literature. *Circulation*. 1993;88:1973–1998.
44. Keil JE, Loadholt CB, Weinrich MC, Sandifer SH, Boyle E Jr. Incidence of coronary heart disease in blacks in Charleston, South Carolina. *Am Heart J*. 1984;108:779–786.
45. Barnett E, Williams CR, Moore L, Chen F. Social class and heart disease mortality among African Americans. *Ethn Dis.* 2002;12:S3-76–S3-81.
46. Colhoun HM, Rubens MB, Underwood SR, Fuller JH. Cross sectional study of differences in coronary artery calcification by socioeconomic status. *BMJ*. 2000;321:1262–1263.
47. Gallo LC, Matthews KA, Kuller LH, Sutton-Tyrrell K, Edmundowicz D. Educational attainment and coronary and aortic calcification in postmenopausal women. *Psychosom Med*. 2001;63:925–935.
48. Jacobs DR Jr, Burke GL, Liu K, Cutter G, Hughes G, Hulley S, Sidney S. Relationships of low density lipoprotein cholesterol with age and other factors: a cross-sectional analysis of the CARDIA study. *Ann Clin Res.* 1988;20:32–38. Coronary calcium has recently emerged as a marker of subclinical coronary heart disease. Although there has been much interest in race differences in calcification, heterogeneity within race or ethnic groups has not been investigated. Using data from a large, multiethnic, population-based study of coronary calcification, we documented important differences in the degree of calcification by measures of socioeconomic position and acculturation within race/ethnic groups. For example, not being born in the United States was associated with lower prevalence of calcification and less calcium in blacks and Hispanics, even after risk factors were controlled for. Compared with the most educated group, low education was associated with higher prevalence of calcification in whites but with lower prevalence of calcification in Hispanics. Race/ethnic differences in coronary calcification coexist with important heterogeneity within groups. The presence of this heterogeneity needs to be acknowledged in clinical practice. Membership in a particular race/ethnic group is not sufficient to characterize a patient's probability of having coronary calcification.