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Neighborhood socio-economic characteristics, African ancestry, and *Helicobacter pylori* sero-prevalence

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Abstract

Purpose—The authors recently reported high *Helicobacter pylori* sero-prevalence among African-Americans of high African ancestry. We sought to determine whether neighborhood-level socio-economic characteristics are associated with *H. pylori* prevalence and whether this helps explain the link between African ancestry and *H. pylori*.

Methods—Antibodies to *H. pylori* proteins were assessed in the serum of 336 African-American and 329 white Southern Community Cohort Study participants. Prevalence odds ratios (ORs) and 95 % confidence intervals (CIs) for CagA+ and CagA− *H. pylori* were calculated using polytomous logistic regression in relation to 10 Census block group-level measures of socio-economic status.

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Results—After adjusting for individual-level characteristics, three neighborhood-level factors were significantly inversely related to CagA+ *H. pylori*: percent completed high school; median house values; and percent employed (comparing highest to lowest tertile, OR, 0.47, 95 % CI, 0.26–0.85; OR, 0.56, 95 % CI, 0.32–0.99; and OR, 0.59, 95 % CI, 0.34–1.03, respectively). However, accounting for these measures did not attenuate the association between African ancestry and CagA+ *H. pylori*, with African-Americans of low, medium, and high African ancestry maintaining two-, seven-, and ninefold increased odds, respectively, compared to whites.

Conclusions—Neighborhood-level measures of education, employment, and house values are associated with CagA+ *H. pylori* sero-prevalence, but do not explain the persistent strong relationship between African ancestry level and CagA+ *H. pylori*. The findings suggest that neighborhood socio-economic status can help to highlight high-risk areas for prevention and screening efforts and that the link between African ancestry and *H. pylori* may have a biological basis.

Keywords

Helicobacter pylori; Education; Income; Neighborhood factors; African ancestry

Introduction

Helicobacter pylori, a gram-negative spiral bacterium that resides in the lining of the stomach of approximately half of the world's population, is one of the leading risk factors for chronic gastritis, peptic ulcer disease, and gastric cancer. While the prevalence of infection with *H. pylori* in the United States (~30 %) has generally been found to be lower than that in countries in Asia, Africa, and South America (60–90 %) [1], individuals of ethnic minorities in the United States have consistently been found to have higher *H. pylori* sero-prevalence [2, 3]. We recently found very high *H. pylori* sero-prevalence among both low-income African-Americans (89 %) and whites (69 %) recruited from community health centers in the southeastern United States [4]. Upon further delineation by African ancestry, even stronger racial differences were observed, with 92 % of individuals in the highest tertile of African ancestry having antibodies to *H. pylori*. Of note, 74 % of high-African-ancestry individuals (compared to 25 % of whites) had antibodies to the *H. pylori* protein cytotoxin-associated antigen (CagA) [4], a gastric cancer virulence factor and the most well-established high-risk marker.

In addition to non-white race, low socio-economic status (SES) has consistently been associated with *H. pylori* infection [5, 6], potentially as a marker of hygiene practices or other lifestyle characteristics (such as household crowding) that would increase transmission rates, and/or related to psychosocial stressors that might impair the immune system. Studies attempting to untangle the effects of race and indicators of SES generally do find a racial disparity in the prevalence of *H. pylori* infection persisting even after adjusting for individual levels of education and income [4, 7], suggesting that the cofactors resulting in a higher risk for racial minorities are still unknown. It has been suggested that these cofactors may be other, unmeasured characteristics related to low SES, possibly those captured by the neighborhood environment. In the United States, a variety of health conditions, including cardiovascular disease [8], atherosclerosis [9], and obesity [10] have been found to be associated with neighborhood-level characteristics. In China, it has also been reported that village education level is more predictive of an individual's *H. pylori* status than the individual's own education level [11]. An important question therefore is whether infection with *H. pylori* in the United States is associated with neighborhood-level factors and whether such associations help to explain the high *H. pylori* sero-prevalence among African-Americans, particularly those of high African ancestry.

To further investigate the relationship between socioeconomic characteristics, race, and *H. pylori* infection in the United States, our aim was to explore, above and beyond individual SES, the association between neighborhood-level socio-economic characteristics and CagA-specific *H. pylori* sero-prevalence within the Southern Community Cohort Study. We also sought to investigate whether the combination of neighborhood-level and individual-level socio-economic characteristics could explain the strong association between higher African ancestry and CagA+ *H. pylori* infection.

Materials and methods

Study population

A detailed description of the Southern Community Cohort Study (SCCS) has previously been published [12]. Briefly, from 2002 to 2009, approximately 86,000 men and women 40–79 years of age from 12 southeastern states were recruited to be participants in the SCCS. The majority (~86 %) were recruited from community health centers, where they completed a comprehensive computer-assisted in-person interview that collected information on demographics, including the individual-level socio-economic status measures of annual household income, educational attainment, marital status, and current occupational status, as well as other lifestyle characteristics, medical history, anthropometrics, and regular diet. The remaining 14 % were recruited by mail, completing the same baseline survey on paper. All participants reported their race using a preprinted card that instructed them to indicate all race/ethnic categories to which they belong. Individuals whose baseline interviews took place at a community health center were asked to donate a venous blood sample (20 mL) that was then refrigerated, shipped overnight to Vanderbilt University, centrifuged the next day, and stored at −80 °C.

For initial studies of biomarkers in the SCCS, 792 individuals were selected from the 12,162 participants who enrolled in the SCCS from March 2002 to October 2004 and donated a blood sample at baseline, based on a 2 × 2 × 3 × 3 factorial design, leading to 22 individuals in each of the 36 strata defined by self-reported race (African-American/white), sex, smoking status (current/never/former), and body mass index (18–24.9/25–29.9/30–45 kg/m^2). This design was selected so that there would be a balanced distribution across these factors in consideration of the studies of several blood biomarkers measured, including *H. pylori*.

Genetic analysis and ancestry estimation

Laboratory personnel blinded to the status of the samples extracted genomic DNA from buffy coat using QIAamp DNA kits (Qiagen, Valencia, CA) according to manufacturer's instructions and carried out genotyping using the Illumina GoldenGate genotyping platform (Illumina Inc., San Diego, CA). The inclusion of blinded quality control samples (n = 29) and pairs of duplicate samples (n = 171) revealed a consistency rate of 99.9 %. Using a Bayesian clustering approach within STRUCTURE software (version 2.2.3) [13], a set of 276 single-nucleotide polymorphisms were selected to estimate African and European ancestry levels. For each individual in the present study, STRUCTURE generated an admixture estimate (from 0.00 to 1.00) for both African ancestry and European ancestry.

H. pylori multiplex serology

In preparation for *H. pylori* assaying, serum samples for each study subject were aliquoted into 50 μL portions. *H. pylori* multiplex serology was performed using an antibody detection technology based on fluorescent polystyrene beads (Luminex) and recombinant glutathione *S*-transferase (GST) fusion protein capture [14–16]. All sera were analyzed once within a single assay day. Antigen-specific cut-point values previously determined in a

validation study were applied to 15 *H. pylori* proteins used as antigens (UreA, Catalase, GroEL, NapA, CagA, CagM, Cagδ, HP0231, VacA, HpaA, Cad, HyuA, Omp, HcpC, HP0305), using a bridging panel of 78 previously characterized sera containing 38 *H. pylori*-negative sera and 40 *H. pylori*-positive sera. *H. pylori* sero-positivity was defined as sero-positivity to four or more *H. pylori* proteins, as this cutoff has shown good agreement with commercial serological assay classification [16].

Neighborhood measures of socio-economic status

To determine neighborhood measures of SES, participant home addresses, provided at study entry, were geocoded and linked to the US Census 2000 block group. Briefly, most (80.2 %) addresses were geocoded with ArcMap 9.3.1 (ESRI, Redlands, CA), using either the ESRI StreetMap USA [17] or TIGER/Line 2008 shapefiles as the reference database [18]. For those addresses that did not geocode by either method, an online geocoding vendor was used to geocode the street address, if possible, or the better of the delivery-weighted centroid of the ZIP+4, ZIP+2, or 5-digit ZIP code. All remaining addresses (9.4 %) were manually processed using the above resources as well as Google Earth. Nearly all (97.6 %) of the non-post office box addresses of SCCS participants were geocoded to the street level. Geocoded participant addresses were then spatially joined to Census 2000 block groups, which are generally comprised of 600–3,000 individuals, and are the lowest level of the census geographic hierarchy for which demographic data are routinely available. The ten block group-level characteristics chosen from the Census to represent the SES of the neighborhood include the measures of the following: income or wealth (median household income, percentage of households in poverty, median value of owner-occupied housing units, and percentage of housing units that are owner-occupied); education (percentage of adults who completed high school and percentage of adults who completed college); occupation or employment (percentage employed and percentage employed in executive, managerial, or professional occupations); and crowding (population density and mean number of occupants per room).

Data analysis

Of the 792 individuals selected for the initial SCCS bio-marker studies, 665 (84.0 %) were included in the present analyses. Reasons for exclusion include the following: depletion of the available serum from previous assays performed ($n = 77$); unusable samples due to serum handling issues ($n = 3$); testing sero-positive to CagA but sero-negative to *H. pylori* ($n = 8$); missing information on antibiotic use ($n = 3$); ancestry estimates highly discordant with self-reported race ($n = 23$); and missing block group-level census information ($n = 13$). All individuals were classified into the ancestry categories of white (no or minimal African ancestry: 0–17 % African); low African ancestry (50–<85 % African); medium African ancestry (85–<95 % African); and high African ancestry (≥95 % African), based on previously utilized cut-points [19].

To assess differences in demographic and lifestyle characteristics between individuals of differing race or ancestry categories, crude linear regression was used for all ten continuous neighborhood-level measures as well as the individual-level continuous variables of age and years residing in current home. The Mantel–Haenszel chi-square test was used for the remaining individual-level categorical variables.

Prevalence odds ratios (ORs) and 95 % confidence intervals (CIs) for CagA-specific infection with *H. pylori* were calculated using polytomous logistic regression for the ten neighborhood-level measures of SES, in tertiles based on the distribution in the study population as a whole. The outcomes were categorized as follows: sero-negativity to *H. pylori* and CagA (*H. pylori*−, CagA−), sero-positivity to *H. pylori* but not to CagA (*H. pylori*

+, CagA−), and sero-positivity to both *H. pylori* and CagA (*H. pylori*+, CagA+). Adjusted models included variables representing age (continuous); African ancestry (white and low/medium/high African ancestry); sex; marital status (married/single/other); individual level of education (less than high school/high school or GED/more than high school); antibiotic use in the past year (yes/no); and duration, in years, of residency in the current home as reported during the baseline interview (continuous). Individual level of income was not included as it was not significantly associated with *H. pylori* status, and its inclusion in the models did not change the main results by 10 % or more.

In separate models including each significant neighborhood-level characteristic and in a final model including all significant neighborhood-level characteristics, we examined whether adding these factors attenuated the association between African ancestry and *H. pylori* sero-positivity.

As it has been suggested that population-level characteristics may modify the relationship between individual-level characteristics and the likelihood of disease [20], we investigated whether neighborhood-level educational status acted as an effect modifier on the strong association between individual-level educational status and CagA sero-positivity. To do so, new variables were created to group each participant into one of the six categories, based on individual-level educational achievement (less than high school/high school or more) and neighborhood level of percent adults who had completed high school (in tertiles: <62.7 %/62.7–<75.9 %/≥75.9 %). Prevalence ORs of CagA-specific *H. pylori* positivity for each of the six individual and neighborhood categories (with low individual-level education and low neighborhood-level education as the reference) were calculated using polytomous regression, adjusting for African ancestry, sex, age, and duration of residence in the current home (marital status and antibiotic use were not included in these models to preserve power, as their inclusion did not change the main results by >10 %). The associations between the six combined individual- and neighborhood-education-level categories and *H. pylori* status were also examined in models stratified by race.

Multilevel modeling techniques, such as the use of a random intercept, were not employed in this analysis because there was very little clustering of participants within block groups. The vast majority (88 %, $n = 496$) of the 556 block groups represented by the 665 individuals in this study had only a single participant, with 8 % ($n = 48$) of block groups having two participants, 3 % ($n = 16$) of block groups having three participants, 1 % ($n = 5$) of block groups having four participants, and only one block group having five participants.

Results

Level of African ancestry was significantly associated with individual marital status and education (Table 1). In particular, among African-Americans, the percentage of African ancestry was inversely associated with individual educational attainment. In univariate linear regression models, categories of African ancestry were also significantly associated with lower levels of eight of the ten neighborhood socio-economic characteristics in the realms of income/wealth, education, occupation/employment, and crowding (Table 1).

In crude analyses, three of the ten neighborhood-level socio-economic characteristics (median value of owner-occupied housing units, percent of adults who completed high school, and percent of adults who completed college) were significantly and inversely associated with sero-prevalence of CagA− strains of *H. pylori*, whereas all of the ten neighborhood-level measures except population density were associated with the more virulent CagA+ strains (Table 2). In the final multivariate models, which included adjustment for African ancestry and individual-level socio-economic characteristics, three

neighborhood-level socio-economic characteristics were still significantly associated with *H. pylori*+ CagA+ status: median value of owner-occupied housing units (comparing highest to lowest tertile, prevalence OR: 0.56, 95 % CI: 0.32–0.99); percent of adults who completed high school (comparing highest to lowest tertile, prevalence OR: 0.47, 95 % CI: 0.26, 0.85); and percent employed (comparing middle to lowest tertile, prevalence OR: 0.55, 95 % CI; 0.31, 0.96) (Table 2). In race-stratified analyses, similar results were observed among African-Americans and whites separately.

The univariate association between African ancestry and sero-positivity for the CagA+ strain of *H. pylori* showed a strong (p <0.0001) and monotonic increase in sero-positivity across categories, with those in the highest category (≥95 % African ancestry) having a tenfold increase in risk compared to whites [OR: 10.05, 95 % CI: 5.70, 17.73] (Table 3). Adjustment for neither the individual-level covariates nor the three significant neighborhood-level covariates resulted in much attenuation of these associations, with African-Americans of low, medium, and high African ancestry maintaining two-, seven-, and ninefold increased odds of CagA+ sero-positivity, respectively, compared to whites. Separate models including each of the other seven non-significant neighborhood-level variables similarly found that they do not act as confounders of the relationship between African ancestry and CagA+ sero-positivity (data not shown). In a fully adjusted model including all significant neighborhood-level characteristics (i.e., model 6 from Table 3) restricted to African-Americans, the prevalence OR for CagA+ sero-positivity for those with high vs. low African ancestry was 3.92 (95 % CI; 1.59, 9.70).

When examining the joint effect of individual- and neighborhood-level education, the individual-level index was more strongly associated with sero-positivity for CagA+ *H. pylori* than the neighborhood-level index (Table 4). Furthermore, the neighborhood-level effect seemed evident only among those with at least a high school education, although a significant interaction between individual-level education status and neighborhood-level education status was not found ($P_{interaction}$ = 0.27). When stratified by race, generally similar results to Table 4 were found for both whites and African-Americans (data not shown).

Discussion

We found that individuals living in neighborhoods with higher house values and where proportionately more adults had a high school education and were employed had lower odds of being sero-positive for CagA+ *H. pylori* than those living in neighborhoods with lower levels of these SES measures. These associations with neighborhood-level socio-economic characteristics were observed above and beyond that of the individual's own risk factors for infection with CagA+ *H. pylori* and were present for both whites and African-Americans. Of import is that accounting for these individual- and neighborhood-level measures of SES did not diminish nor explain the strong association between African ancestry and sero-prevalence of CagA+ *H. pylori*, suggesting that it is not mainly through SES that African-Americans are at greater odds of CagA+ *H. pylori* sero-positivity.

Previous studies worldwide have consistently found that individual measures of low SES are associated with greater odds of *H. pylori* infection [5, 21–27], but we are aware of only one study [11] that examined the effect of neighborhood-level socio-economic factors on *H. pylori* sero-prevalence. In this study among Chinese, in which 66 % were sero-positive for *H. pylori*, an increasing risk was observed with decreasing village education level, but no association was found with individual education or income level. The increased odds for those living in a village of medium or low level of education vs. a high education level was similar to ours (OR: 1.7, 95 % CI: 1.4–2.1, and OR: 2.4, 95 % CI: 2.0–2.9, respectively). The authors suggested this association could be due to a shared water source, although no

analyses accounting for the source of drinking water were presented. To our knowledge, no previous studies have evaluated individual- or neighborhood-level measures of SES separately by *H. pylori* type, which is potentially critical given our strong findings regarding the virulent CagA+ strain.

Several previous studies have evaluated the association of neighborhood-level SES with markers of immune response to inflammation, potential indicators of infections, and findings from these studies provide some support to the results obtained in the present study. A study of adults in southwest Pennsylvania found that, independent of individual-level socio-economic risk factors, individuals living in communities of lower SES had higher circulating levels of interleukin-6 and C-reactive protein than individuals in more affluent communities [28]. The authors suggested that the association may be related to differential access to health resources, including exercise and medical facilities, as well as to shared environmental factors that either encourage or discourage health-related behaviors, all of which may relate to inflammation susceptibility. Another US study found significant associations between both low individual- and neighborhood-level measures of SES, and increased levels of fibrinogen and white blood cell count and interestingly found weaker, less consistent results among African-Americans as compared to whites [29]. It had previously been noted however that in that cohort, African-Americans lived in neighborhoods of much lower SES than whites, so that the most advantaged of the African-American neighborhoods were comparable to the least advantaged white neighborhoods [9].

One of the primary strengths of the SCCS is that African-Americans and whites were drawn primarily from the same low-income populations, increasing the power and validity to make comparisons within the same range of socio-economic characteristics. In fact, while the neighborhoods represented by the SCCS are in a relatively narrow, low end of the SES scale, it is a strength of the present study that this hard-to-reach population was able to be studied and attests to the power of the association between neighborhood-level SES and *H. pylori* sero-positivity that significant results were found. However, a weakness of the present study is our limited ability to assess all relevant correlates of neighborhood-level SES. We were only able to use those variables collected and presented by the US Census to describe neighborhood-level SES. Thus, other potential factors related to neighborhood SES that might also explain differing *H. pylori* prevalence—such as sanitation practices, water source, refrigeration, and cooking and eating habits—were not accounted for, although these factors are most likely also associated with individual- and neighborhood-level education and income categories. It has also been suggested that poor oral health is associated with gastric cancer [30] and precancerous lesions [31], although the association with *H. pylori* infection specifically has not been found to be significant above and beyond individual SES parameters [32, 33]. Unfortunately, we did not have sufficient data on oral health to address this question in our population. Another limiting factor is that chronic *H. pylori* infection generally begins in childhood, and the participants in this study were on average around 50 years old, having lived in their current address for approximately 10 years. Thus, we are measuring adult, and not childhood, SES. While studies have generally found positive correlations between childhood and adult SES, it does appear that this association over the lifecourse differs by race, whereby among those living in poor neighborhoods, African-Americans are more likely than whites to have lived there for a longer time span, and among those who leave high-poverty neighborhoods, African-Americans are more likely to reenter them [34]. In the present study, the association with measures of lower levels of neighborhood SES was found not just for African-American individuals compared to whites, but also for individuals of increasing level of African ancestry. Whether the differences in associations of neighborhood SES over the life-course also differ by percent African ancestry among African-Americans is unknown.

Our finding that an increasing percentage of African ancestry is associated with increased odds of infection with CagA+ *H. pylori*, independent of significant individual- and neighborhood-level measures of SES, suggests the possibility that the biology of the bacteria and/or the host is responsible for the association. In fact, conservation of *H. pylori* genotype by race in the United States has been found before, and findings indicate that transmission occurs primarily through the family; thus, genotypes of the bacteria could be conserved through multiple human generations [35, 36]. In addition, the host genetics in families will be more similar. It is possible, then, that individuals of greater percentage of African ancestry have also had greater conservation of their *H. pylori* genotype. Others have suggested that African-American race is associated with higher *H. pylori* sero-prevalence above and beyond socioeconomic risk factors due to a shorter "generational distance" than whites from being very economically disadvantaged [37]. This association may also apply to increasing percentage of African ancestry. Finally, in terms of host factors, African-Americans, particularly those of greater African ancestry, may be more susceptible to initial and/or chronic *H. pylori* infection. Additionally, increasing African ancestry in our study was strongly associated not only with the prevalence (yes/no) of sero-positivity but also with antibody titer level among those sero-positive for CagA+ *H. pylori* (data not shown), potentially indicating a greater inflammatory response.

Conclusions

Beyond individual-level socio-economic factors, neighborhood levels of education, employment, and house values are associated with infection with CagA+ *H. pylori*, highlighting high-risk areas for targeted prevention and screening efforts. Furthermore, the strong relationship between African-American race, particularly individuals of a high level of African ancestry, and CagA+ *H. pylori* sero-prevalence is not diminished nor explained by individual- or neighborhood-level socio-economic characteristics, suggesting the possibility of a biological basis—of the bacteria and/or the host—for the association between African ancestry and *H. pylori* infection.

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Table 1

Demographic and lifestyle characteristics, by race/ancestry status, of a sample of 665 participants in the Southern Community Cohort Study recruited from 12 southeastern states between 2002 and 2004

	White *n* = 329	African-American		
		Level of African ancestry:		
		Low (50–84.9 %) *n* = 54	Med. (85–94.9 %) *n* = 94	High (≥95 %) *n* = 188
Individual-level measures				
Age (years, mean) *	53.4	48.9	52.2	52.1
Women (%)	52.9	42.6	48.9	56.9
Marital status (%) **				
Married	47.4	24.1	16.0	30.3
Separated/divorced	33.1	48.2	40.4	35.6
Widowed	9.4	1.9	12.8	11.7
Single/never married	10.0	25.9	30.9	22.3
Education (%) **				
Less than high school	26.1	11.1	37.2	39.9
High school or GED	41.0	40.7	38.3	42.6
More than high school	32.8	48.2	24.5	17.6
Currently working (%)	33.0	55.6	35.9	41.6
Household income ($, %)				
<15,000	61.2	45.3	68.8	61.5
≥15,000–<25,000	18.9	32.1	19.4	23.1
≥25,000	20.2	22.6	11.8	13.4
Household size (%)				
1–2	65.7	61.1	56.4	59.6
3–4	25.2	25.9	29.8	29.3
5+	9.1	13.0	13.8	11.2
Antibiotic prescription in the past year (%) *	54.7	38.9	47.9	41.5
Years in current home (mean) *	7.9	8.0	11.8	10.1
Neighborhood-level measures (mean)				
Income/wealth				
Median household income ($) **	33,817	31,479	25,634	25,308
Percent poverty **	18.3	24.4	30.8	31.9
Median value of owner-occupied housing units($) *	80,217	72,087	78,930	63,572
Percent of housing units that are owner-occupied **	67.3	56.0	51.9	54.3
Education (individuals ≥25 years old)				
Percent completed high school **	72.4	70.7	66.5	64.9
Percent completed college	15.0	16.2	15.2	12.9
Occupation/Employment (individuals ≥16 years old)				
Percent employed *	58.4	59.8	56.1	54.5

	White *n* = 329	African-American		
		Level of African ancestry:		
		Low (50–84.9 %) *n* = 54	Med. (85–94.9 %) *n* = 94	High (≥95 %) *n* = 188
Percent employed in executive, managerial or professional occupations	24.7	22.6	22.8	22.1
Crowding				
Population density (all ages within block group) **	870	1,552	1,318	1,285
Mean number of occupants per room **	0.42	0.46	0.46	0.47

* $p < 0.05$ comparing individuals across the four race/African ancestry categories

** $p < 0.0001$ comparing individuals across the four race/African ancestry categories

Table 2

Prevalence odds ratios (OR) for antibodies to *H. pylori* and CagA in relation to neighborhood-level characteristics among a sample of 665 participants in the Southern Community Cohort Study recruited from 12 southeastern states between 2002 and 2004

Neighborhood-level measures	*H. pylori* +, CagA−				*H. pylori* +, CagA+			
	Crude OR	95 % CI	Adjusted OR[a]	95 % CI	Crude OR	95 % CI	Adjusted OR[a]	95 % CI
Income/wealth								
Median household income								
<$23,567	1.00	Ref	1.00	Ref	1.00	Ref	1.00	Ref
$23,567–<$33,500	0.73	0.42, 1.28	0.82	0.45, 1.48	0.45	0.27, 0.73	0.79	0.45, 1.39
≥$33,500	1.04	0.60, 1.79	1.41	0.78, 2.53	0.35	0.21, 0.58	0.79	0.44, 1.40
Percent poverty								
<14.0 %	1.00	Ref	1.00	Ref	1.00	Ref	1.00	Ref
14.0–<29.1 %	1.19	0.73, 1.93	1.08	0.65, 1.79	1.62	1.01, 2.60	1.07	0.63, 1.82
≥29.1 %	1.47	0.85, 2.55	1.17	0.64, 2.13	3.87	2.33, 6.44	1.59	0.89, 2.86
Median value of owner-occupied housing units								
<$52,000	1.00	Ref	1.00	Ref	1.00	Ref	1.00	Ref
$52,000–<$76,000	0.62	0.36, 1.08	0.70	0.39, 1.25	0.53	0.32, 0.88	0.73	0.41, 1.29
≥$76,000	0.55	0.32, 0.95	0.73	0.41, 1.28	0.35	0.21, 0.58	0.56	0.32, 0.99
Percent of housing units that are owner-occupied								
<50.3 %	1.00	Ref	1.00	Ref	1.00	Ref	1.00	Ref
50.3–<77.9 %	1.27	0.74, 2.19	1.36	0.76, 2.42	0.72	0.44, 1.19	1.01	0.57, 1.77
≥77.9 %	0.93	0.55, 1.57	1.05	0.59, 1.87	0.46	0.29, 0.75	0.91	0.51, 1.60
Education								
Percent adults ≥25 years completed high school								
<62.7 %	1.00	Ref	1.00	Ref	1.00	Ref	1.00	Ref
62.7–<75.9 %	0.49	0.27, 0.87	0.52	0.28, 0.95	0.41	0.24, 0.70	0.72	0.40, 1.30
≥75.9 %	0.40	0.23, 0.69	0.51	0.28, 0.91	0.25	0.15, 0.42	0.47	0.26, 0.85
Percent adults ≥25 years completed college								
<7.2 %	1.00	Ref	1.00	Ref	1.00	Ref	1.00	Ref
7.2–<15.5 %	0.42	0.24, 0.72	0.45	0.26, 0.80	0.54	0.33, 0.90	0.69	0.39, 1.21
≥15.5 %	0.45	0.26, 0.77	0.58	0.33, 1.01	0.51	0.31, 0.84	0.63	0.36, 1.11
Occupation/employment								

Neighborhood-level measures	*H. pylori* +, CagA−				*H. pylori* +, CagA+			
	Crude OR	**95 % CI**	**Adjusted OR[a]**	**95 % CI**	**Crude OR**	**95 % CI**	**Adjusted OR[a]**	**95 % CI**
Percent employed								
<53.0 %	1.00	Ref	1.00	Ref	1.00	Ref	1.00	Ref
53.0–<62.6 %	0.77	0.45, 1.34	0.73	0.42, 1.29	0.51	0.31, 0.85	0.55	0.31, 0.96
≥ 62.6 %	0.64	0.37, 1.09	0.75	0.43, 1.32	0.35	0.21, 0.57	0.59	0.34, 1.03
Percent employed in executive, managerial, or professional occupations								
<17.2 %	1.00	Ref	1.00	Ref	1.00	Ref	1.00	Ref
17.2–<26.7 %	0.60	0.36, 1.02	0.71	0.41, 1.23	0.58	0.35, 0.94	0.89	0.51, 1.55
≥26.7 %	0.61	0.36, 1.03	0.80	0.45, 1.40	0.64	0.39, 1.04	0.95	0.54, 1.66
Crowding								
Population density								
<306	1.00	Ref	1.00	Ref	1.00	Ref	1.00	Ref
306–<1,370	0.90	0.54, 1.49	0.80	0.47, 1.38	1.29	0.80, 2.10	0.88	0.51, 1.54
≥1,370	0.67	0.40, 1.13	0.58	0.33, 1.03	1.41	0.87, 2.26	0.81	0.46, 1.42
Mean number of occupants per room								
<0.408	1.00	Ref	1.00	Ref	1.00	Ref	1.00	Ref
0.408–<0.466	0.84	0.51, 1.39	0.78	0.47, 1.31	1.23	0.77, 1.95	1.13	0.67, 1.91
≥0.466	1.48	0.87, 2.54	1.24	0.70, 2.18	2.43	1.47, 4.03	1.47	0.83, 2.60

[a]Adjusted for individual-level measures of African ancestry, sex, marital status, and education, as well as participant age, whether antibiotics were used in the past year, and duration of residency in the current home as reported during the baseline interview. All ORs relative to persons negative for *H. pylori*

Table 3

Prevalence odds ratios (OR) for antibodies to CagA+ *H. pylori* in relation to race/ancestry, among a sample of 665 participants in the Southern Community Cohort Study recruited from 12 southeastern states between 2002 and 2004

	White		African-American					
			Level of African ancestry					
			Low (50–84.9 %)		Medium (85–94.9 %)		High (≥95 %)	
	OR	95 % CI	OR	95 % CI	OR	95 % CI	OR	95 % CI
Model 1: crude relationship	1.00	Reference	1.95	0.96, 3.97	8.03	3.88, 16.58	10.05	5.70, 17.73
Model 2: adjusted for individual-level factors[a] only	1.00	Reference	2.38	1.13, 5.00	7.95	3.69, 17.11	10.01	5.47, 18.34
Model 3: adjusted for individual-level factors[a] plus neighborhood-level value of owner-occupied housing units	1.00	Reference	2.27	1.07, 4.78	7.58	3.51, 16.37	9.52	5.18, 17.48
Model 4: adjusted for individual-level factors[a] plus neighborhood-level education	1.00	Reference	2.32	1.10, 4.90	7.43	3.43, 16.11	9.02	4.87, 16.70
Model 5: adjusted for individual-level factors[a] plus neighborhood-level employment	1.00	Reference	2.35	1.11, 4.95	7.61	3.53, 16.40	9.56	5.18, 17.65
Model 6: adjusted for individual-level factors[a] plus the neighborhood-level factors included in models 3–5 above	1.00	Reference	2.28	1.08, 4.83	7.38	3.40, 16.03	9.29	4.99, 17.29

[a]Individual-level factors adjusted for included sex, marital status, and education, as well as participant age, whether antibiotics were used in the past year, and duration of residency in the current home as reported during the baseline interview

Table 4

Prevalence odds ratios (OR) for antibodies to CagA+ *H. pylori* in relation to joint individual- and neighborhood-level education, among a sample of 665 participants in the Southern Community Cohort Study recruited from 12 southeastern states between 2002 and 2004

Neighborhood education level	Individual education level			
	Less than high school		High school/GED or more	
	OR[a]	95 % CI	OR[a]	95 % CI
Percent adults ≥25 years completed high school				
<62.7 %	1.00	Reference	0.37	0.14, 0.97
62.7–<75.9 %	0.83	0.27, 2.61	0.25	0.10, 0.63
≥75.9 %	1.08	0.24, 4.84	0.16	0.07, 0.40

[a]Adjusted for African ancestry and sex, as well as participant age and duration of residency in the current home as reported during the baseline interview