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Protective and Harmful Effects of Neighborhood-Level Deprivation on Individual-Level Health Knowledge, Behavior Changes, and Risk of Coronary Heart Disease

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The authors examined associations between neighborhood-level deprivation and cardiovascular disease-related health knowledge and behavior changes, as well as the estimated 12-year probability of experiencing a coronary heart disease event. Primary analyses included multilevel regression models among 8,197 women and men living in 82 neighborhoods in four northern California cities who were interviewed in one of five surveys conducted between 1979 and 1990. After controlling for age, gender, marital status, race/ethnicity, city, and time, the authors found that adults living in high-deprivation neighborhoods had significantly lower health knowledge and a higher probability of no positive behavior changes than did adults in moderately deprived neighborhoods (i.e., harmful effects). Conversely, those living in low-deprivation neighborhoods had significantly higher health knowledge and lower probabilities of no positive behavior changes and estimated risk of coronary heart disease (i.e., protective effects). The association between high neighborhood deprivation and no positive behavior changes remained statistically significant after additional adjustment for a composite measure of individual-level socioeconomic status. Associations with neighborhood deprivation did not vary by individual-level socioeconomic status. These results suggest that focusing exclusively on changing individuals' behaviors will have a limited effect unless contextual influences at the neighborhood level are also addressed.

adult; California; cardiology; coronary disease; health behavior; health knowledge, attitudes, practice; residence characteristics; social class

Abbreviations: SES, socioeconomic status/position; SHDPP, Stanford Heart Disease Prevention Program.

Studies investigating the independent influence of neighborhood socioeconomic characteristics on individual-level measures of health (''neighborhood effects'') have grown rapidly (1–3). A large proportion have focused on cardiovascular disease-related health behaviors/risk factors (4–8), fatal and nonfatal incidence and prevalence (5, 9–11), or mortality (6, 12, 13). Interpreting their findings in the context of other published work, these authors have often attributed the increased risk associated with living in socioeconomically deprived neighborhood environments to decreased availability of health-promoting goods and services (e.g., healthy affordable food, safe places to exercise, convenient transportation, street lighting, health care) and/or increased exposure to health-damaging residential environments (e.g., crime, noise, delinquency, tobacco and alcohol advertising and availability, high density of fast food restaurants). To a lesser extent, there is recognition that normative values and behaviors, psychological stress, social cohesion among neighbors, and access to information may vary by neighborhood deprivation and influence the health of all residents. In the absence of direct measures of specific neighborhood characteristics, previous literature has relied primarily upon census-derived measures of neighborhood environments, particularly when a large number of neighborhoods are under investigation (such as with population-based survey data), making the time-consuming and expensive task of collecting direct measures unfeasible.

Previous studies have examined neighborhood effects on specific cardiovascular disease-related behaviors and risk factors; however, few studies have examined cardiovascular

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disease-related health knowledge or changes in behaviors related to this disease. Examining only health behaviors may mask important differences among people with a given risk behavior, for instance, among current smokers, those who have reduced the amount they smoke versus those who have not reduced the amount they smoke. We examined the associations between neighborhood-level deprivation and three dependent variables: cardiovascular disease-related health knowledge, no positive cardiovascular disease-related health behavior changes in the past year and, as a measure of morbidity, the estimated 12-year probability of experiencing a coronary heart disease event.

MATERIALS AND METHODS

Data

The analysis was based on individual-level and neighborhood-level data. The Stanford Heart Disease Prevention Program (SHDPP), 1979–1990, contained respondent data from surveys, laboratory measures, and residential addresses. The SHDPP data were linked to census-defined neighborhoods with calculations of the Townsend material deprivation index (14) based on census data. The SHDPP was a 6-year field trial, begun after the baseline survey (1979–1980), and was designed to test whether a comprehensive program of community organization and health education produced favorable changes in cardiovascular disease risk (15). The SHDPP drew participants from two treatment (Monterey, Salinas) and two control (Modesto, San Luis Obispo) cities in northern California, ranging in population size from 35,000 to 145,000 residents (a fifth city, Santa Maria, was followed for morbidity/mortality surveillance only). To assess change in cardiovascular disease risk factors, independent cross-sectional surveys of randomly selected households were conducted. All persons aged 12 through 74 years were eligible to participate and were invited to attend study centers located in each city where they completed surveys, had risk factors assessed by nurses, and underwent laboratory tests. Detailed descriptions of the study design and methodology have been published previously (15–17). All research was approved by the appropriate ethics committee at Stanford University and conforms to the principles of the Declaration of Helsinki.

Response rates for the five surveys were 65, 69, 65, 56, and 61 percent, respectively. When eligible subjects refused to participate, a nonrespondent questionnaire was completed that recorded sex, age, language spoken, level of education, body height and weight, and smoking status. Respondents were more likely than nonrespondents to speak English, be more educated, and be overweight (women only), and respondents were less likely to smoke. The magnitude of these differences was modest, suggesting the lack of serious response bias (18, 19). Few significant changes in risk factors between treatment and control cities as a result of the intervention were found; thus, all cities were combined for this analysis (18, 20). The sample for this study included one woman and/or man per household, aged 25–74 years, interviewed during one of the cross-sectional surveys ($n = 8{,}419$). The lower age cutpoint of 25 years was chosen to ensure that most individuals had completed their education. Nearly 80 percent lived in their ‘‘community’’ for 5 years or longer.

A number of factors were considered in defining the neighborhood boundaries. In order to characterize neighborhoods using census data, we chose a priori to rely upon census-defined boundaries, that is, tracts and/or block groups, both of which have been used as proxies for geographically based neighborhoods (4, 9, 11, 21). Because our study was conducted in only four cities, we were able to compare the census-defined boundaries with archival paper neighborhood maps from the time of the surveys to assess whether neighborhood boundaries more closely corresponded to actual neighborhoods (as defined by archival maps) than boundaries defined by the census. A further consideration was determining whether census-defined boundaries in the 1980 US Census were identical to those in the 1990 US Census so that the interpolated neighborhood data for the intercensal surveys (surveys 2–4) corresponded to the same geographic space (details below). Accordingly, site visits were made to each city to meet with key contacts in the city planning departments to obtain neighborhood maps and solicit advice on how each city defined its neighborhoods at the time of the SHDPP. Using the maps and advice, we determined that the neighborhood boundaries corresponded well with single census tracts or block groups for the large majority of neighborhoods. When there was a difference ($n = 12$), we used a combination of tracts or block groups to better represent neighborhood boundaries, based on guidance from the key contacts and/or neighborhood maps in the cities and also by comparing boundaries in 1980 and 1990 using geographic information systems. As a result, a total of 82 neighborhoods across the four cities were defined.

SHDPP respondents were linked to neighborhoods by geocoding their address. Following the methodology of Krieger et al. (22), we tested the accuracy of the geocodes in two ways. Using the government geocoding website (http://www.ffiec.gov/geocode/default.htm) as the ‘‘gold standard,’’ we found that 95–98 percent (depending on the survey year) of a random sample of 173 participant records geocoded to the same 1990 US Census tract geocode as the geocoding service that we used. In addition, we conducted a site visit in two of the cities with census tract maps from the Bureau of the Census to determine the ‘‘real world’’ accuracy of the geocodes (to find out whether the geocode corresponded to the correct census tract in which the address was located) and found high agreement (20 of 21 addresses were located in the same census tract as indicated by the geocoding service). Participants who reported an address that was not within one of the cities ($n = 84$ or 1.0 percent) and participants whose addresses were not able to be geocoded ($n = 138$ or 1.6 percent) were excluded, resulting in a final analytical sample size of 8,197. There were an average of 21 and a median of 17 participants per neighborhood (range: 1–107), calculated separately by survey.

Dependent variables

Cardiovascular disease-related health knowledge was calculated from the number of correct responses to 17 questions related to nutrition, smoking, exercise, cholesterol, and blood pressure. No positive behavior changes were calculated from responses to eight questions regarding whether the participant made any changes in the past year related to dietary habits, smoking, weight, exercise, and stress. Respondents who reported no changes were classified as having no positive behavior changes. The Cornfield risk score (23), a risk factor function based on the Framingham Study (using age, systolic blood pressure, total cholesterol, cigarettes smoked, and relative weight in the equation), was used to calculate the estimated probability of a coronary heart disease event in 12 years.

Independent variables at the individual level

The independent variables at the individual level were age, gender, marital status, race/ethnicity, and a composite measure of socioeconomic status/position (SES). The SES composite measure was calculated as the mean of two categorical variables, each with four levels: annual household income as a percentage of the federal poverty level (0–200, 201–400, 401–600, $\geq$601 percent) and educational attainment ($<$12, 12, 13–15, $\geq$16 years). The Spearman correlation between income and education was 0.33. The city and time of survey were included as control variables.

Independent variable at the neighborhood level

The Townsend material deprivation index was composed of four census variables (proportion of crowded occupied housing units, unemployed persons in the civilian labor force, renter-occupied housing units, and occupied housing units without a vehicle available), calculated for each of the 82 neighborhoods. For survey 1 (1979–1980), 1980 US Census data were used. For survey 5 (1989–1990), 1990 US Census data were used. For surveys 2–4, the four components were estimated through linear interpolation (24). With use of the methodology of Townsend et al. (14), unemployment and crowded housing were first log transformed, each variable was standardized separately by city and survey as a relative measure (i.e., high deprivation in Monterey at survey 1 was considered to be qualitatively different from high deprivation in Modesto at survey 5), and the four variables were then summed with equal weights. Higher numbers indicate higher levels of deprivation (mean: 0; range: -8.4 to 7.9). Because neighborhood effects are thought to be nonlinear, where significant effects are hypothesized to occur beyond a threshold (25), we categorized the deprivation index into three groups: below one standard deviation from the mean (low deprivation), above one standard deviation from the mean (high deprivation), and within one standard deviation of the mean (moderate deprivation), separately by city and survey. This categorization allowed for estimation of both protective and harmful effects in relation to individuals living in neighborhoods falling into the middle group. The number of neighborhoods differed by city, from a low of seven neighborhoods in San Luis Obispo to a high of 33 neighborhoods in Modesto. Of 82 total neighborhoods in the four cities, 12 were classified as low deprivation and 11 were classified as high deprivation. We created the categorization separately for each city for primarily two reasons. First, because on a priori grounds, we believe that people experience deprivation in relation to those around them; thus, we wanted to create neighborhoods with low, moderate, and high deprivation in each city. Second, the cities were and are quite different from each other (refer to table 2 below) in terms of deprivation. Therefore, if neighborhoods were grouped into deprivation categories across all four cities combined, there would be very few (if any) low-deprivation neighborhoods in Modesto or Salinas and very few (if any) high-deprivation neighborhoods in Monterey or San Luis Obispo.

Analysis

For the primary statistical analyses, a series of multilevel logistic or linear regression models with random intercepts were examined for each dependent variable, using the SAS GLIMMIX macro or the MIXED procedure (SAS Institute, Inc., Cary, North Carolina). For each dependent variable, we calculated a model with only neighborhood deprivation to determine the percentage of variation in the neighborhood means explained by neighborhood deprivation. Next, age, city, survey, and the deprivation index were entered into a model (baseline model); then gender, marital status, and race/ethnicity were added (demographic model); finally, the composite SES measure was added (full model). We also tested for random slopes for the composite SES measure and whether cross-level interactions existed between the composite SES measure and the deprivation index. Finally, we repeated the full models for the two control cities, to determine whether the effects were similar in cities that did not experience the SHDPP intervention. Because the percentage of persons reporting no positive behavior changes was high (40–60 percent), the odds ratios should not be interpreted as prevalence ratios, which they will overestimate.

RESULTS

Table 1 presents characteristics of the sample and prevalences of the dependent variables. Over one third of the respondents were aged 50 or more years at the time of the survey, more than half were women, and a large majority were currently married (68 percent). The largest racial/ethnic group was non-Latino Whites (83 percent), followed by Latinos (11 percent). Over 40 percent had incomes that were over 400 percent of the federal poverty level, and nearly 60 percent had at least some college education. Less than one tenth of the respondents lived in neighborhoods classified as high deprivation at baseline. Respondents were approximately evenly distributed by city and survey.

Older respondents and men appeared to have lower knowledge, higher levels of no behavior changes, and a higher probability of experiencing a coronary heart disease event, compared with younger respondents and women (table 1). Never married respondents had the most favorable health indicators, which probably reflects their younger age. Latinos had the lowest knowledge, a high prevalence of no behavior changes, but the lowest probability of a coronary

TABLE 1. Distributions, means for cardiovascular disease-related health knowledge, prevalences of no positive behavior changes, and means for coronary heart disease event probability among 8,197 persons aged 25–74 years, Stanford Heart Disease Prevention Program, 1979–1990

	Distribution (%)	Cardiovascular disease-related health knowledge (mean*)	No positive behavior changes (%)†,‡	Coronary heart disease event probability (mean)§
Individual-level variables				
Age (years)				
25–49	63	7.7	44	2.2
50–74	37	7.4	54	14.9
Gender				
Women	55	7.8	45	4.4
Men	45	7.4	51	9.8
Marital status				
Never married	11	8.1	40	2.9
Previously married	21	7.2	48	7.3
Married	68	7.6	49	7.4
Race/ethnicity				
Latino	11	5.1	55	4.8
Other race/ethnicity	6	6.4	55	6.1
White	83	8.0	46	7.2
Poverty status (% of federal poverty level)				
0–200	22	6.3	53	6.7
201–400	35	7.5	46	6.3
401–600	23	8.3	45	7.0
≥601	19	8.8	45	7.9
Educational attainment (years)				
<12	16	4.9	62	10.5
12	27	6.8	48	7.4
13–15	42	8.4	45	5.6
≥16	15	9.5	42	6.1
Survey factors				
City				
Modesto, CA	26	6.9	52	7.0
Monterey, CA	27	8.1	43	7.4
Salinas, CA	26	7.1	53	6.5
San Luis Obispo, CA	22	8.4	42	6.7
Survey				
1 (1979–1980)	19	6.5		7.7
2 (1981–1982)	19	7.4	50	7.6
3 (1983–1984)	21	7.3	44	7.1
4 (1985–1986)	20	8.0	45	6.3
5 (1989–1990)	21	8.7	52	6.0
Neighborhood-level variable				
Material deprivation				
High	7	6.2	59	7.2
Moderate	76	7.6	47	6.8
Low	17	8.1	45	7.2

* Mean no. of correct responses to 17 questions; overall mean: 7.6.
† Surveys 2–5: $n = 6,651$.
‡ Overall mean: 48%.
§ Overall mean: 6.9%.

TABLE 2. Selected values of the deprivation index and mean values of its components for neighborhoods, Stanford Heart Disease Prevention Program, 1979–1990

	Townsend deprivation index		
	Low deprivation (>−3.4 to <−2.6)*	Mean† (>−0.8 to <0.8)	High deprivation (>2.8 to <3.2)
Crowded (%)			
Modesto, CA	1.4	6.2	15.3
Monterey, CA	1.2	5.9	17.7
Salinas, CA	5.8	11.8	35.2
San Luis Obispo, CA	2.2	3.6	5.6
Unemployed (%)			
Modesto, CA	8.9	12.2	28.2
Monterey, CA	3.0	6.0	11.1
Salinas, CA	5.8	9.1	16.8
San Luis Obispo, CA	4.8	4.7	5.0
Renters (%)			
Modesto, CA	28.1	43.5	41.1
Monterey, CA	33.7	53.6	67.8
Salinas, CA	40.0	55.5	57.8
San Luis Obispo, CA	32.0	46.8	68.4
No vehicle available (%)			
Modesto, CA	8.1	6.9	11.6
Monterey, CA	8.1	8.6	7.0
Salinas, CA	4.7	6.4	7.1
San Luis Obispo, CA	2.1	5.8	11.9

* The approximate cutpoint for 1 standard deviation below the mean is −3.0; the approximate cutpoint for 1 standard deviation above the mean is 3.0.

† The mean is 0.

heart disease event. Knowledge showed a positive gradient, and no behavior changes showed an inverse gradient with the two SES indicators; in contrast, socioeconomic patterns with the probability of a coronary heart disease event were less consistent. Residents of San Luis Obispo, a city with a large college, generally had the most favorable health indicators. Of particular note is that knowledge increased over time, yet the prevalence of no positive behavior changes remained at about 50 percent throughout the study. The probability of a coronary heart disease event decreased over time, which may reflect broader temporal trends in decreasing coronary heart disease. Finally, respondents living in the most deprived neighborhoods had the lowest knowledge and highest prevalence of no positive behavior changes, but no clear pattern with neighborhood deprivation was found for the probability of a coronary heart disease event.

Table 2 presents the values of the deprivation index components for low, average, and high neighborhood deprivation for each city. Each component generally increased with increasing neighborhood deprivation within each city, with the percentages of crowded housing and unemployed increasing the most.

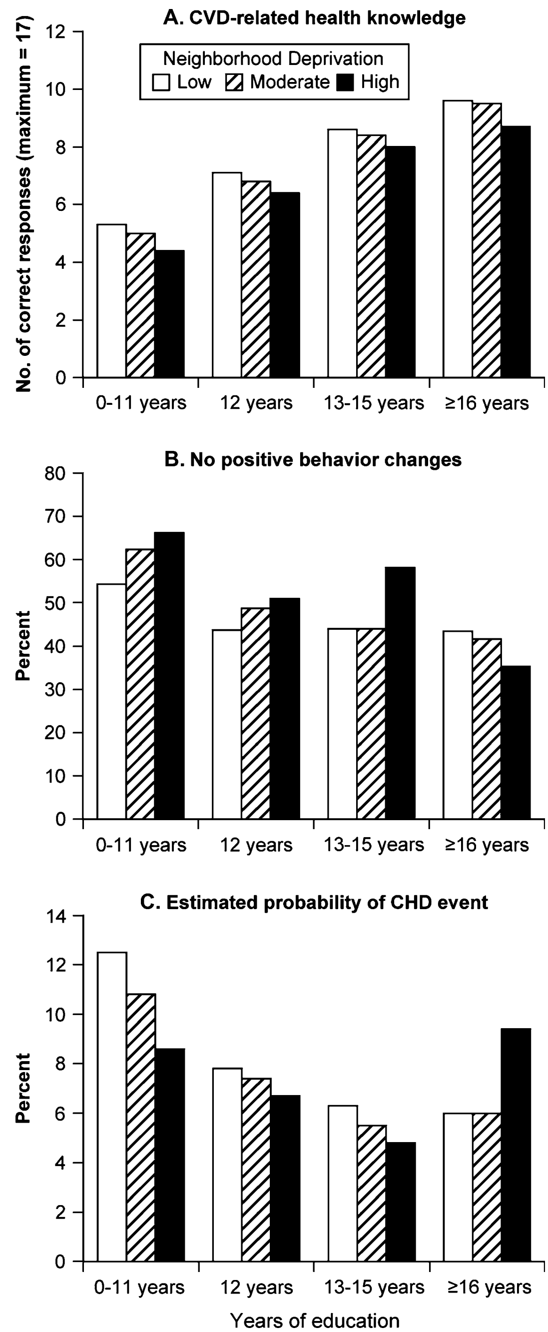

FIGURE 1. Prevalences of each dependent variable by neighborhood deprivation and individual-level educational attainment, Stanford Heart Disease Prevention Program, 1979–1990. A, cardiovascular disease (CVD)-related health knowledge (n = 8,197); B, no positive behavior changes (n = 6,651); C, 12-year estimated probability of a coronary heart disease (CHD) event (n = 8,197). All participants were aged 25–74 years.

Figure 1 presents the prevalences of each dependent variable according to neighborhood deprivation and individual-level educational attainment. Within each level of educational attainment, health knowledge appeared to

TABLE 3. Mean differences in cardiovascular disease-related health knowledge and 95% confidence intervals among 8,197 persons aged 25–74 years, Stanford Heart Disease Prevention Program, 1979–1990

	Cardiovascular disease-related health knowledge					
	Baseline model		Demographic model		Full model	
	Mean difference	95% confidence interval	Mean difference	95% confidence interval	Mean difference	95% confidence interval
Age (per year)	−0.009***	−0.014, −0.004	−0.015***	−0.020, −0.010	−0.006*	−0.011, −0.001
Gender						
Women			0.512***	0.376, 0.648	0.795***	0.665, 0.925
Men			1.000		1.000	
Marital status						
Never married			0.021	−0.211, 0.253	0.099	−0.121, 0.319
Previously married			−0.523***	−0.696, −0.350	−0.250**	−0.414, −0.086
Married			1.000		1.000	
Race/ethnicity						
Latino			−2.686***	−2.927, −2.445	−1.791***	−2.023, −1.559
Other race/ethnicity			−1.492***	−1.782, −1.202	−1.333***	−1.607, −1.059
White			1.000		1.000	
Composite socioeconomic status (per unit increase, range: 1–4)					1.357***	1.269, 1.445
City						
Modesto, CA	−1.692***	−2.069, −1.315	−1.434***	−1.761, −1.107	−0.799***	−1.074, −0.524
Monterey, CA	0.590**	0.191, 0.989	−0.467**	−0.810, −0.124	−0.267	−0.556, 0.022
Salinas, CA	−1.445***	−1.836, −1.054	−0.816***	−1.156, −0.476	−0.364*	−0.649, −0.079
San Luis Obispo, CA	1.000		1.000		1.000	
Survey (per unit increase, range: 1–5)	0.211***	0.175, 0.247	0.224***	0.193, 0.255	0.179***	0.152, 0.206
Material deprivation						
High	−1.119***	−1.517, −0.721	−0.588**	−0.949, −0.227	−0.166	−0.471, 0.139
Moderate	1.000		1.000		1.000	
Low	0.791***	0.489, 1.093	0.620***	0.354, 0.886	0.202	−0.033, 0.437

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

decrease with increasing neighborhood deprivation. No positive behavior changes appeared to increase with increasing neighborhood deprivation, except among respondents with a college degree, whose rates appeared to decrease with increasing neighborhood deprivation. In contrast, for the probability of a coronary heart disease event, rates appeared to decrease or remain steady with increasing neighborhood deprivation for all groups except respondents with a college degree, whose rates appeared to increase with increasing neighborhood deprivation. Similar, but less consistent, patterns were found when these prevalences were examined by individual-level poverty status.

Table 3 presents estimates for health knowledge in a series of multilevel models. The baseline model indicates that respondents living in neighborhoods characterized by high deprivation had lower health knowledge (−1.12), and respondents living in neighborhoods characterized by low deprivation had higher health knowledge (0.79), compared with respondents living in neighborhoods in moderately deprived neighborhoods. The estimates were attenuated but still significant in the demographic model; however, in the full model, the estimates were reduced to nonsignificance. We included a random effect for the individual-level SES composite in the full model because it was statistically significant, indicating that the effect of individual-level SES (i.e., the slope) varied by neighborhood. In the model with a random intercept and no individual-level covariates, 13 percent of the variation in neighborhood mean knowledge (1.715) was explained by neighborhood deprivation (1.715 − 1.500/1.715; results not shown).

Odds ratios for no positive behavior changes are shown in table 4. In the baseline and demographic models, living in neighborhoods with high deprivation was associated with increased odds of no positive behavior changes, and living in neighborhoods with low deprivation was associated with decreased odds of no positive behaviors changes, compared with living in moderately deprived neighborhoods. In contrast to the results for health knowledge, in the full model for no behavior changes, the increased odds associated with high deprivation remained significant. Fourteen percent of

TABLE 4. Odds ratios and 95% confidence intervals for no positive behavior changes among 6,651 persons aged 25–74 years, Stanford Heart Disease Prevention Program, 1979–1990

	No positive behavior changes (surveys 2–4)					
	Baseline model		Demographic model		Full model	
	Mean difference	95% confidence interval	Mean difference	95% confidence interval	Mean difference	95% confidence interval
Age (per year)	1.19***	1.18, 1.19	1.19***	1.18, 1.19	1.18***	1.17, 1.18
Gender						
Women			0.78***	0.70, 0.86	0.75***	0.68, 0.83
Men			1.00		1.00	
Marital status						
Never married			0.89	0.76, 1.05	0.88	0.74, 1.04
Previously married			0.98	0.87, 1.11	0.94	0.83, 1.07
Married			1.00		1.00	
Race/ethnicity						
Latino			1.22*	1.03, 1.44	1.07	0.90, 1.28
Other race/ethnicity			1.37**	1.11, 1.70	1.34**	1.08, 1.65
White			1.00		1.00	
Composite socioeconomic status (per unit increase, range: 1–4)					0.83***	0.78, 0.89
City						
Modesto, CA	1.55***	1.30, 1.85	1.53***	1.28, 1.82	1.41***	1.19, 1.68
Monterey, CA	1.12	0.93, 1.33	1.12	0.93, 1.33	1.09	0.92, 1.30
Salinas, CA	1.62***	1.36, 1.93	1.53***	1.28, 1.84	1.45***	1.22, 1.74
San Luis Obispo, CA	1.00		1.00		1.00	
Survey (per unit increase, range: 1–5)	1.02*	1.00, 1.04	1.02*	1.00, 1.04	1.03**	1.01, 1.05
Material deprivation						
High	1.36**	1.10, 1.68	1.33**	1.07, 1.64	1.25*	1.01, 1.54
Moderate	1.00		1.00		1.00	
Low	0.82**	0.70, 0.95	0.82**	0.70, 0.95	0.87	0.75, 1.01

* $p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

the variation in neighborhood mean behavior changes (0.494) was explained by neighborhood deprivation (0.494 – 0.424/0.494; results not shown).

Table 5 presents a similar set of multilevel linear models for the 12-year probability of experiencing a coronary heart disease event. Living in a neighborhood with high deprivation was not significant in any model. However, respondents living in neighborhoods with low deprivation had significantly lower probabilities in the baseline and demographic models, but not in the full model. None of the between-neighborhood variance (1.655) in the probability of experiencing a coronary heart disease event was accounted for by neighborhood deprivation.

No evidence was found for random individual SES composite effects for no positive behavior changes, the probability of a coronary heart disease event, or cross-level interactions between neighborhood deprivation and individual-level SES for the three dependent variables. Similar patterns were observed in the full models restricted to the control cities, except that respondents living in a neighborhood with low deprivation had significantly higher health knowledge compared with those living in moderately deprived neighborhoods.

DISCUSSION

We found evidence of both protective (higher health knowledge and lower probabilities of no positive behavior changes and estimated risk of coronary heart disease) and harmful (lower health knowledge, higher probability of no positive behavior changes) associations with neighborhood deprivation. However, the association between high neighborhood deprivation and no positive behavior changes was the only remaining statistically significant neighborhood deprivation association after additional adjustment for individual-level SES. Individual-level SES, as well as other demographic factors, could be on the pathway between neighborhood deprivation and the dependent variables (i.e., neighborhoods may partially determine one's attainment of

TABLE 5. Mean differences in the 12-year probability of a coronary heart disease event and 95% confidence intervals among 8,197 persons aged 25–74 years, Stanford Heart Disease Prevention Program, 1979–1990

	Coronary heart disease event probability					
	Baseline model		Demographic model		Full model	
	Mean difference	95% confidence interval	Mean difference	95% confidence interval	Mean difference	95% confidence interval
Age (per year)	0.494***	0.483, 0.506	0.508***	0.497, 0.519	0.503***	0.492, 0.514
Gender						
Women			−5.830***	−6.132, −5.528	−6.001***	−6.305, −5.698
Men			1.00		1.00	
Marital status						
Never married			1.039***	0.529, 1.549	1.002***	0.494, 1.509
Previously married			−0.195	−0.576, 0.187	−0.368	−0.749, 0.013
Married			1.00		1.00	
Race/ethnicity						
Latino			0.082	−0.427, 0.592	−0.576*	−1.105, −0.046
Other race/ethnicity			−0.472	−1.105, 0.161	−0.615	−1.246, 0.116
White			1.00		1.00	
Composite socioeconomic status (per unit increase, range: 1–4)					−0.836***	−1.029, −0.644
City						
Modesto, CA	0.257	−0.233, 0.746	0.503*	0.019, 0.986	0.173	−0.309, 0.656
Monterey/Salinas, CA	0.577**	0.150, 1.004	0.787***	0.356, 1.218	0.648**	0.222, 1.073
San Luis Obispo, CA	1.00		1.00		1.00	
Survey (per unit increase, range: 1–5)	−0.149***	−0.201, −0.097	−0.157***	−0.207, −0.106	−0.132***	−0.182, −0.082
Material deprivation						
High	−0.082	−0.742, 0.577	0.086	−0.550, 0.722	0.187	−0.820, 0.447
Moderate	1.00		1.00		1.00	
Low	−0.571*	−1.021, −0.121	−0.605**	−1.037, −0.173	−0.345	−0.777, 0.086

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

SES through educational and employment opportunities). Thus, the full models may be overcontrolling for mediating effects. Consequently, the ''true'' neighborhood deprivation effect may perhaps best be considered as lying somewhere between the baseline model and the full model associations.

Strengths of the study include the careful assessment of geographic neighborhood boundaries, validation of geocodes, and low proportions of missing data. Given that census boundaries may not conform to neighborhood boundaries, we consulted with city planners and archival neighborhood maps to create more meaningful neighborhood boundaries than simply relying upon census tracts or block groups. In addition, given the variability in the accuracy of geocodes (22), our study was strengthened by validating the accuracy of the geocodes, both by comparing a sample of addresses with a gold standard and by conducting site visits. The survey data and addresses available for geocoding were virtually complete.

The study also has limitations. Factors associated with self-selection into certain neighborhoods could account for the results, leading to erroneous conclusions of neighborhood effects. Neighborhoods are based on geographically defined census tract boundaries, and considerable debate exists as to whether these boundaries represent neighborhoods as defined by the residents living within them. Moreover, geographic boundaries may not be the most appropriate way to define neighborhoods; for example, others have suggested that neighborhood definitions should be based on patterns of social interaction (26, 27). In addition, we were not able to examine the historical context of neighborhoods, how they were changing, or how long people have been exposed to their neighborhood environments (we only know how long they lived in their ''community'' which may not represent the same area) (27). Finally, the study design is cross-sectional; thus, no causal inferences should be made.

Neighborhood environments could plausibly influence behavior changes in a variety of ways, including social cohesion (i.e., sense of trust and solidarity among neighbors), access to information, exposure to positive or negative health or media messages, and availability, quality, and cost of goods, services, and resources. Trust and solidarity among neighbors may be more difficult to achieve in neighborhoods that are deprived, because residents may be more likely to experience social isolation and other stressors associated with resource deprivation (28). Low levels of social cohesion as well as social isolation and stressors could account for a lower probability of making positive behavior changes by influencing normative behaviors, social support, and/or psychological factors. In addition, access to accurate health information (e.g., in health care settings, stores, and media) may be lower in more deprived neighborhoods compared with less deprived neighborhoods. However, even when health information is readily available, individuals living in deprived neighborhoods may be more likely to be exposed to negative health messages that counteract health information, such as tobacco advertising or promotion of high-fat foods. In neighborhoods with low deprivation, the opposite influences would apply (i.e., high levels of social cohesion, combined with high access to accurate information and low exposure to negative health messages and media advertising). The availability, quality, and cost of goods, services, and resources may vary according to neighborhood deprivation and thus may enhance or provide barriers to positive health behavior change for all residents. For example, previous studies have found that local resources that can enhance healthy behaviors, such as facilities for physical activity and the availability of healthy foods, are more prevalent in neighborhoods with low deprivation compared with neighborhoods with high deprivation. In turn, these have been found to be associated with positive dietary habits, body weight, and physical activity (29–35). This is not likely to be the case in the current study, however. Participants living in more deprived neighborhoods had a greater number of banks, schools, gyms and parks, pharmacies, and grocery stores near their homes (counts within 0.5 mile (0.81 km) of their homes) compared with participants in less deprived neighborhoods (data not shown). Although the physical presence of local resources does not guarantee equal access and people may utilize resources outside their neighborhoods (e.g., close to where they work), the evidence suggests that neighborhood-level availability of goods and services is unlikely to explain the deprivation associations with behavior changes. Rather, other mechanisms may be more relevant, such as normative behaviors and values, levels of social cohesion, access to information, psychosocial factors such as social isolation and stressors due to fear or economic deprivation, and/or exposure to negative health messages.

In conclusion, these results provide important evidence of neighborhood deprivation influences on adults' behavior changes. Although the independent effect sizes for neighborhood factors were generally modest, the public health significance is large because of the number of persons at risk, as well as the serious nature of the potential consequences. These results suggest that an exclusive focus on increasing individuals' knowledge will have a limited effect on changing their behaviors unless contextual influences at the neighborhood level are also addressed. To increase our understanding of neighborhood contextual effects, further studies are needed to elucidate the mechanisms through which neighborhood-level deprivation influences behaviors. The mechanisms are likely to be complex and overlapping and to vary by time and place. Further investigations, such as theoretically based qualitative research on the factors represented by neighborhood deprivation that may influence behavior change (as well as the mechanisms involved), are needed to provide information upon which to base public health interventions and policy change.

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