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Association between the neighborhood obesogenic environment and colorectal cancer risk in the Multiethnic Cohort

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Abstract

Background—Information on the role of the neighborhood environment and colorectal cancer risk is limited. We investigated the association between a comprehensive suite of possible obesogenic neighborhood attributes (socioeconomic status, population density, restaurant and retail food environments, numbers of recreational facilities and businesses, commute patterns, traffic density, and street connectivity) and colorectal cancer risk in the Multiethnic Cohort Study.

Methods—Among 81,197 eligible participants living in California (35,397 males and 45,800 females), 1,973 incident cases (981 males and 992 females) of invasive colorectal cancer were identified between 1993 and 2010. Separately for males and females, multivariable Cox regression models were used to estimate hazard ratios (HR) and 95% confidence intervals (CI) for colorectal cancer risk overall and by racial/ethnic group (African American, Japanese American, Latino, white).

Results—In males, higher traffic density was associated with an increased risk of colorectal cancer (HR=1.29, 95% CI: 1.03–1.61, p=0.03, for quintile 5 vs. quintile 1; p-trend=0.06). While this association may be due to chance, this pattern was seen (albeit non-statistically significant) in all racial/ethnic groups except whites. There were no other significant associations between other neighborhood obesogenic attributes and colorectal cancer risk.

Conclusion—Findings from our large racial/ethnically diverse cohort suggest neighborhood obesogenic characteristics are not strongly associated with the risk of colorectal cancer.

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Keywords

neighborhood; colorectal cancer; race/ethnicity

1. Introduction

It is estimated that 45% of U.S. colorectal cancer (CRC) cases could be prevented by maintaining a healthy diet, regular physical activity, and healthy weight[1]. Within the Multiethnic Cohort Study (MEC), obesity, smoking, alcohol, and a number of dietary factors have been associated with the risk of CRC[2–4]. In addition, there is evidence that the neighborhood environment can impact diet, obesity, and physical activity, and can influence obesity-related health disparities[5–11]. In the MEC, neighborhood socioeconomic status (nSES) has been associated with obesity in African Americans, Latinos, and whites[8].

While individual-level factors such as obesity and level of physical activity are associated with CRC risk, what is less clear is the effect of the neighborhood environment, and whether its role is independent of these individual-level risk factors. No cohort studies have examined neighborhood-level factors other than socioeconomic status (SES) in relation to CRC risk[12, 13]. In the MEC, we investigated the association between a comprehensive suite of ten *a priori* selected neighborhood obesogenic attributes and risk of CRC, assessing whether associations were independent of individual-level factors and varied by racial/ethnic group.

2. Methods

2.1 Study subjects

The MEC is a large population-based cohort of U.S. adults of five racial/ethnic groups. Methodological details of this study have been described previously[14]. In brief, participants from Hawaii and California completed a baseline questionnaire in 1993–1996 that included information on sociodemographics, height, weight, medical history, family history of cancer, smoking, physical activity, medications, diet, alcohol, and vitamin use.

Of 105,759 African American, Japanese American, Latino, Native Hawaiian, and white MEC participants from California who completed the baseline questionnaire, we excluded participants, hierarchically, who had a history of CRC (n=1,308); were Native Hawaiian (n=171); had no follow-up time (n=8); were an incident, invasive CRC case with a non-adenocarcinoma histology (n=77 carcinoid, n=7 squamous cell, and n=25 other tumors; and n=6 missing); had a residential address that was not geocodable (n=2,155), had missing BMI (n=2,247), or had missing or invalid covariate data (n=18,558)[4]. Thus, 81,197 MEC participants were eligible for analysis.

2.2 Follow-up and case identification

Incident CRC cases were identified through linkage of the cohort to the California Cancer Registry. Deaths were determined through linkages with California death certificate files and the National Death Index.

Follow-up time was calculated as the number of days between the date of completion of the baseline questionnaire and the earliest of: the first diagnosis of invasive CRC (International Classification of Diseases for Oncology-3 [ICD-O-3] site codes C18.0–C18.9, C26.0, C19.9, and C20.9), death, or December 31, 2010. Over a median follow-up time of 16.6 years, 1,973 incident CRC cases were identified.

2.3 Residential neighborhood obesogenic attributes

Baseline residential addresses were geocoded to latitude and longitude coordinates, using parcel data (96%) and street centerline data for those that failed to geocode to a parcel (4%).

Geocodes were linked with the California Neighborhoods Data System, an integrated system of small area-level measures of the social and built environments for California[15]. Census 1990 block group-level data were utilized to ascertain: neighborhood SES (nSES), a validated composite measure[16]; population density (per square mile); commute patterns; and street connectivity[17], which was defined as the ratio of actual number of street segments to the maximum possible number of links between nodes (intersections and cul-de-sacs). These measures were categorized based on the distribution of Los Angeles (LA) County block groups (≥90% of the sample resided in LA County). Business, farmers' market[18], and park data were used to quantify the amenities within a one-mile pedestrian network distance of the participant's residence: the Restaurant Environment Index (REI), defined as the ratio of the number of fast-food restaurants to other restaurants[19]; the Retail Food Environment Index (RFEI), defined as the ratio of the number of convenience stores, liquor stores, and fast-food restaurants to supermarkets and farmers' markets; and total number of recreational facilities, parks, and businesses. Traffic density was based on traffic counts within a 500 meter radius of a participant's residence. These business and traffic-related attributes were categorized according to the study participant distributions (Supplementary Table 1). These ten neighborhood attributes were selected *a priori* for their potential associations with obesity or colorectal cancer risk (all but street connectivity and number of recreational facilities were associated with obesity[8] and all but the number of parks were univariately associated with CRC risk).

2.4 Statistical analyses

Hazard rate ratios (HR) and 95% confidence intervals (CI) were estimated using multivariable Cox regression models with age as the time metric. Sex and race/ethnicity-specific models were run given the heterogeneity in CRC incidence between these subgroups[4]. Multivariable models were adjusted for the following individual-level CRC risk factors: age, race/ethnicity, body mass index, family history of CRC, history of intestinal polyps, education, cigarette smoking, multivitamin use, nonsteroidal anti-inflammatory medication use, alcohol consumption, vigorous physical activity, history of diabetes, average energy intake, red and processed meat, dietary fiber, calcium, folacin, Vitamin D, and use of hormone therapy (females). These covariates were selected *a priori* as they were associated with CRC risk in the literature or in this cohort[1, 4]. Distributions of these covariates are presented in Supplementary Table 2.

All models were additionally adjusted for clustering by block group, using a sandwich estimator of the covariance structure that accounts for intracluster dependence[20]. As a sensitivity analysis, gamma frailty models were run with block group as a random effect[21]. As the random effect term was not statistically significant and the CIs for the neighborhood attributes did not change, the fixed effect models are presented here. Wald tests for trend across neighborhood characteristic categories (excluding no restaurants for REI, no retail food for RFEI, and missing data categories) were conducted using quantile number as an ordinal variable. Wald Type 3 tests for heterogeneity of the trend parameter across neighborhood characteristic categories by race/ethnicity, BMI, and nSES were computed using cross-product terms. Based on correlation tests of time versus scaled Schoenfeld residuals, no neighborhood or adjustment variables violated the proportional hazards assumption.

The ten neighborhood characteristic variables were first entered separately into models, minimally adjusted for age, race/ethnicity (if applicable), and clustering by block group (Supplementary Tables 3 and 4). Nine of the ten neighborhood variables (all except the number of parks) had at least one category or trend that had a p-value<0.10 in sex and race/ethnicity-specific models. Thus, for the final multivariable models, all the neighborhood attributes except the number of parks were included.

3. Results

This study population (males: 26.0% African American, 14.8% Japanese American, 47.2% Latino, 12.0% white; females: 34.7% African American, 11.8% Japanese American, 36.8% Latino, 16.7% white; Supplementary Table 2) was followed for a median of 16.6 years. The mean age at entry into the cohort was 60 for males and 59 for females. Only 33.2% of males and 30.5% of females lived in high SES neighborhoods (quintiles 4 and 5) (Supplementary Table 1).

The MEC participants in this analysis resided at baseline in 7,348 unique block groups predominantly in LA County. The median number of participants in each block group was five (interquartile range 2 to 13). Of the 7,348 block groups, 19.5% included one participant and 11.6% included two; the largest block group included 432 participants. The neighborhood attributes in these block groups were moderately correlated (Supplementary Table 5; correlations <|0.72|). For example, high SES neighborhoods tended to have a lower population density (r=−0.43) and more commuting (r=0.40).

When each of the neighborhood obesogenic attributes were entered individually into minimally adjusted sex-specific models, only higher traffic density was associated with CRC risk in males (HR=1.24, 95% CI: 1.03–1.51, p=0.025, for quintile 5 vs. quintile 1, p-trend=0.092, Supplementary Tables 3 and 4). In minimally adjusted race/ethnicity-specific models, two trend tests reached statistical significance at the 0.05 level. White males in neighborhoods with more unhealthy retail food options were at increased CRC risk (HR=1.79, 95% CI: 0.95–3.37, p=0.073, for quartile 4 versus quartile 1, p-trend=0.038). In addition, Latino males living in neighborhoods with fewer businesses were at increased CRC risk (HR=1.43, 95% CI: 1.04–1.95, p=0.026, for quintile 1 versus quintile 5, p-trend=0.010).

This association differed by race/ethnicity (p-heterogeneity of the trend=0.023), as white males living in neighborhoods with fewer businesses were at decreased risk (HR=0.53, 95% CI: 0.31–0.91, p=0.022, for quintile 1 versus quintile 5, p-trend=0.054), with no association seen in the other racial/ethnic groups (p-trends >=0.55).

Similar to the minimally adjusted results (Supplementary Tables 3 and 4), when adjusting for individual-level CRC risk factors as well as the other neighborhood attributes, none of the neighborhood obesogenic attributes were associated with CRC risk in males or females (Tables 1 and 2), except for higher traffic density, which was associated with increased risk of CRC in males (HR=1.29, 95% CI: 1.03–1.61, p=0.026, for quintile 5 vs. quintile 1, p-trend=0.056). In males, higher traffic density was associated with non-statistically significant increased risk in quintile 5 for African Americans, Japanese Americans, and Latinos (with hazard ratios above 1.2), while there was no association among whites, with no evidence of heterogeneity in associations by race/ethnicity (p-heterogeneity of the trend=0.78). Similarly, there was no heterogeneity in associations detected by BMI, and only one interaction was seen between nSES and number of recreational facilities in females (p-heterogeneity of the trend =0.011), whereby no versus 3+ recreational facilities was associated with a decreased risk in low nSES areas and an increased risk in high nSES areas (data not shown).

In race/ethnicity-specific analyses in males and females, when adjusting for individual-level CRC risk factors and the other neighborhood attributes, the significant trends seen in the minimally adjusted models (Supplementary Tables 3 and 4) were no longer statistically significant at the p<0.05 level (Tables 1 and 2), and an additional trend test in white females reached statistical significance at this level. Among white females, those living in neighborhoods with more commuting were at decreased risk of CRC (p-trend=0.044), although the number of cases in the reference category was small and the association was not statistically significant for any quintile. Similar to the minimally adjusted results, only the association with total number of businesses in males differed by race/ethnicity in fully adjusted models (p-heterogeneity of the trend=0.048), with a lower number of businesses associated with a non-statistically significant increased risk of CRC in Latino males (HR=1.45, 95% CI: 0.96–2.21, p=0.079, for quintile 1 vs. quintile 5, p-trend=0.069), and a non-statistically significant decreased risk in white males (HR=0.74, 95% CI: 0.33–1.63, p=0.45, for quintile 1 versus quintile 5, p-trend=0.63) and no association seen in the other racial/ethnic groups (p-trends >=0.48).

To address the possibility of chance due to the number of hypotheses tested (9 neighborhood variables × 2 sexes × 5 racial/ethnic groups including overall), we applied a conservative Bonferroni significance threshold of $p<5.5 \times 10^{-4}$ (alpha=0.05/90). No associations reached this conservative significance threshold.

4. Discussion

Our study found a modest association between higher traffic density and increased CRC risk among MEC males overall, residing predominately in LA County, with a similar pattern of association among African Americans, Japanese Americans, and Latinos. Higher traffic density may be an indicator of a less walkable environment[22] and have a negative impact on physical activity[23], which is an established health behavior associated with obesity and CRC risk[1, 24]. In our cohort, traffic density was weakly negatively correlated with moderate (males: r=−0.02, p<0.0001; females: r=−0.04, p<0.0001) but not vigorous physical activity. No other associations between the neighborhood obesogenic environment and CRC risk were observed.

Neighborhood-level SES and CRC risk has been examined previously in two prospective studies[12, 13]. The National Institutes of Health-AARP Diet and Health Study (NIH-AARP) assessed in men and women combined baseline education and a measure of baseline census-tract level neighborhood socioeconomic deprivation[12]. Lower levels of education and living in a more deprived neighborhood were independently associated with higher CRC risk, even after adjustment for individual-level behavioral factors. However, the association with neighborhood deprivation was limited to rectal cancer risk. The Nurses' Health Study (NHS) examined in women baseline education and a measure of baseline census-tract level nSES[13]. Lower nSES was associated with increased rectal cancer risk for all women and increased colon cancer risk for higher-educated women, adjusted for neighborhood factors, demographics, education, and family history. A path analysis found this association to be mediated by individual-level behavioral factors, including BMI. These results are not consistent with our finding of no association between baseline block group-level nSES and CRC risk in models adjusted for other neighborhood attributes, with and without adjustment for individual-level behavioral factors. In addition, we found no association between nSES and either risk of colon or rectal cancer (data not shown). These differing results could be due to substantial differences in study populations and/or study designs. The NIH-AARP Study and NHS were both national samples in which over 90% were white and 29.7% and 23.7%, respectively, were in the quintile representing those in the least deprived or highest SES neighborhood. In contrast, our study includes predominantly African Americans and Latinos in LA County[14], and only 14.7% were white and 13.0% were in the highest nSES quintile. In addition, our study may support the hypothesis that the effect of SES differs by race/ethnicity, as certain racial/ethnic groups at the same level of SES may not share the same benefits as non-Hispanic whites[25, 26]. Moreover, the NIH-AARP Study and NHS used a larger geographical area of census tract that typically contain 1,200 to 8,000 people to characterize nSES, whereas we used census block groups, which typically contain 600 to 3,000 people. Census block groups are more homogenous than census tracts and better represent where individuals likely engage in healthy behaviors, access services, and receive health care; and have been shown to be useful for defining neighborhoods for health studies[27]. Also, the NIH-AARP study used education and a measure of neighborhood deprivation, which included different components than were used to define nSES in our study, so results may not be directly comparable.

Although we did not observe associations between obesogenic neighborhood attributes and CRC risk after applying the conservative Bonferroni correction, the neighborhood environment has been shown to impact obesity, levels of physical activity, and diet[5–11], as well as cancer incidence and mortality[28]. In the MEC, after adjustment for individual- and neighborhood-level factors, obesity (versus normal weight) was associated with lower nSES in African American, Latino, and white men (odds ratio (OR)=1.48, 95% CI: 1.07–2.06 for nSES quintile 1 vs. quintile 5 for African Americans), whereas both overweight and obese were associated with lower nSES in African American, Latina, and white women (OR=1.31, 95% CI; 1.08–1.59 and OR=2.07, 95% CI: 1.62–2.65 for African Americans, respectively)[8]. A review paper identified six studies most of which found differences in cancer incidence by nSES and ethnic enclave[28], including one which found lower incidence of CRC with higher nSES in whites[29]. In addition, individual-level behavioral factors, such as obesity and physical activity, may be on the causal pathway between the neighborhood environment and cancer risk. In fact, we observed some notable (albeit modest) neighborhood associations in the minimally adjusted models stratified by sex and race/ethnicity, which were no longer statistically significant (at the $p<0.05$ level) after adjusting for the individual-level factors. We did not evaluate a mediation effect, as we saw no associations between neighborhood attributes and CRC risk by sex, except for traffic density in males, and were limited by the small number of cases in the strata by sex and race/ethnicity. In addition, there was adequate variation in neighborhood attributes between block groups of MEC participants. For example, the mean value of nSES was −0.09 and the standard deviation (Std) was 1.05. Neighborhood SES quintile 1 values ranged from −3.31 to −1.11 and block groups in nSES quintile 1 had a mean percent of households below the poverty line of 32%. In comparison, nSES quintile 5 values ranged from 0.88 to 2.88 and block groups in nSES quintile 5 had a mean percent of households below the poverty line of 4%. For population density, the mean value was 4.53 and the Std was 3.14, with quintile 1 ranging from 0 to 1.98 and quintile 5 ranging from 6.39 to 47.25.

Strengths of our study included a large, racial/ethnically diverse prospective cohort; linkage to a cancer registry for virtually complete outcome ascertainment; the availability of detailed individual-level data; and the availability of comprehensive and geographically extensive, small area-level data on SES and built environments[15]. Limitations included multiple comparisons and a small number of cases in some race/ethnicity-specific analyses; thus, in these stratified analyses we focused on the trend across levels of the neighborhood attributes. In addition, a large number of participants were excluded due to missing covariate information. When models were rerun including participants with missing covariate data by including categories for missing data, results were similar (data not shown), although the association with traffic density in males was attenuated somewhat and no longer statistically significant at $p<0.05$ (HR=1.20, 95% CI: 0.98–1.48, p=0.076, for quintile 5 vs. quintile 1, p-trend=0.14) and the p-trend for unhealthy retail food in white males was statistically significant at $p<0.05$ (HR=2.11, 95% CI: 1.12–3.97, p=0.021, for quintile 4 vs. quintile 1, p-trend=0.041). A potential limitation is that we did not adjust for CRC screening, which can be lower in low SES groups[30]. However, results were similar when adjusting for CRC screening in the subcohort (75%) with information on screening (data not shown). Also, neighborhood boundaries, which were based on pre-defined census block groups, may not represent perceived neighborhood environments. However, it is plausible that perceived neighborhoods correlate well with census block groups and the use of pre-defined census areas is an efficient and cost-effective way to examine a large number of neighborhood attributes[31, 32]. Another limitation was the use of residential neighborhoods, as individuals may spend a substantial amount of time outside of their residence each day[28]. In addition, residential neighborhood was assessed at baseline, which reflected only one point in time and may not capture the critical exposure window for CRC development. When we repeated the analysis using a time-dependent approach based on the residential history for the entire study period, we found no associations with CRC risk in females and no meaningful associations in males, including no significant association with traffic density and an attenuation of the positive association (HR=1.05, 95% CI: 0.86–1.29 for quintile 5 vs. quintile 1). Future studies should include assessments of the work environment, account for changes in the neighborhood environment and changes in residence, and evaluate the neighborhood environment across the lifecourse[28].

In conclusion, neighborhood obesogenic characteristics were not strongly associated with risk of CRC in the large racial/ethnically diverse MEC cohort. However, increased risk associated with traffic density warrants further follow-up.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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Table 1

Associations between colorectal cancer risk and body mass index and the neighborhood obesogenic environment in males, Multiethnic Cohort, 1993 – 2010

Males	Overall N=35,397				African Americans N=9,190			Japanese Americans N=5,222			Latinos N=16,724			Whites N=4,261		
	No.	**HR[a]**	**95% CI**	**p-int[b]**	**No.**	**HR[c]**	**95% CI**	**No.**	**HR[c]**	**95% CI**	**No.**	**HR[c]**	**95% CI**	**No.**	**HR[c]**	**95% CI**
Body mass index (kg/m2)																
<18.5	8	1.73	(0.86–3.49)		5	**3.25**[d]	**(1.24–8.54)**	2	1.14	(0.28–4.66)	1	0.88	(0.13–6.04)	0		
18.5–24.9	315	1.00			76	1.00		102	1.00		108	1.00		29	1.00	
25.0–29.9	472	1.01	(0.87–1.17)		124	0.95	(0.71–1.27)	72	0.97	(0.70–1.34)	218	0.94	(0.74–1.19)	58	1.57	(0.98–2.51)
≥30.0	186	1.18	(0.98–1.43)		80	**1.42**[e]	**(1.03–1.96)**	11	1.21	(0.65–2.26)	80	0.97	(0.73–1.31)	15	1.21	(0.62–2.37)
Neighborhood socioeconomic status[e]				0.52												
Q5 high	126	1.00			20	1.00		43	1.00		36	1.00		27	1.00	
Q4	209	1.21	(0.96–1.53)		53	1.45	(0.84–2.51)	62	1.19	(0.75–1.88)	66	1.17	(0.79–1.75)	28	1.14	(0.63–2.07)
Q3	219	1.21	(0.95–1.56)		47	1.11	(0.62–1.96)	42	1.09	(0.68–1.76)	108	1.42	(0.95–2.12)	22	0.96	(0.50–1.85)
Q2	230	1.09	(0.83–1.44)		79	1.12	(0.62–2.03)	28	1.42	(0.78–2.59)	109	1.12	(0.73–1.74)	14	0.83	(0.35–1.98)
Q1 low	196	1.06	(0.77–1.45)		86	1.07	(0.56–2.02)	12	1.36	(0.57–3.26)	87	1.07	(0.64–1.78)	11	1.33	(0.48–3.72)
p-trend[f]		0.95				0.52			0.38			0.94			0.95	
Population density[e]				0.67												
Q5 high	171	1.00			62	1.00		23	1.00		73	1.00		13	1.00	
Q4	225	1.02	(0.82–1.28)		82	0.89	(0.62–1.28)	29	0.80	(0.40–1.58)	95	1.17	(0.82–1.68)	19	1.20	(0.56–2.56)
Q3	229	0.99	(0.78–1.27)		61	0.81	(0.53–1.22)	50	0.85	(0.42–1.73)	96	1.10	(0.74–1.62)	22	1.04	(0.44–2.43)
Q2	189	1.05	(0.81–1.37)		38	0.81	(0.50–1.33)	50	0.92	(0.46–1.85)	84	1.28	(0.85–1.93)	17	0.75	(0.31–1.84)
Q1 low	167	0.97	(0.72–1.31)		42	0.88	(0.51–1.51)	35	0.72	(0.32–1.62)	59	1.05	(0.66–1.70)	31	1.29	(0.55–3.02)
p-trend[f]		0.96				0.53			0.69			0.72			0.87	
Restaurant environment index[g]				0.65												
0[h]	176	1.00			35	1.00		35	1.00		85	1.00		21	1.00	
Q1 low	198	0.97	(0.76–1.23)		42	1.23	(0.71–2.14)	45	0.79	(0.44–1.43)	86	0.95	(0.67–1.34)	25	1.27	(0.57–2.81)
Q2	190	0.95	(0.75–1.20)		51	1.08	(0.65–1.80)	41	0.94	(0.55–1.61)	75	0.86	(0.61–1.22)	23	1.21	(0.57–2.57)

Males	Overall N=35,397				African Americans N=9,190			Japanese Americans N=5,222			Latinos N=16,724			Whites N=4,261		
	No.	HR[a]	95% CI	p-int[b]	No.	HR[c]	95% CI	No.	HR[c]	95% CI	No.	HR[c]	95% CI	No.	HR[c]	95% CI
Q3	184	0.92	(0.73–1.17)		55	0.88	(0.53–1.48)	30	1.06	(0.60–1.90)	79	0.87	(0.62–1.23)	20	1.21	(0.54–2.72)
Q4 & <1	170	0.96	(0.76–1.23)		79	1.12	(0.68–1.83)	23	1.25	(0.71–2.23)	59	0.85	(0.58–1.24)	9	0.80	(0.31–2.04)
Q4 & ≥1	19	0.85	(0.54–1.33)		9	1.32	(0.62–2.81)	1	0.31	(0.04–2.25)	9	1.02	(0.52–1.97)	0		
No restaurants	44	1.22	(0.79–1.87)		14	0.59	(0.21–1.70)	12	**2.58**[d]	**(1.13–5.89)**	14	1.54	(0.86–2.77)	4	0.63	(0.24–1.69)
p-trend[f]			0.55				0.80			0.44			0.29			0.41
Retail food environment index[i]				0.27												
0[j]	33	0.92	(0.62–1.38)		8	1.96	(0.80–4.81)	8	0.90	(0.40–2.04)	12	0.65	(0.35–1.20)	5	1.42	(0.52–3.90)
Q1 low	206	1.00			48	1.00		36	1.00		109	1.00		13	1.00	
Q2	226	1.15	(0.95–1.39)		74	1.24	(0.85–1.80)	31	0.84	(0.50–1.40)	99	1.19	(0.89–1.59)	22	1.58	(0.77–3.21)
Q3	208	1.04	(0.85–1.28)		53	0.84	(0.56–1.27)	47	1.06	(0.63–1.76)	83	1.02	(0.75–1.39)	25	1.89	(0.87–4.12)
Q4 high	273	1.11	(0.91–1.36)		86	1.15	(0.77–1.73)	57	0.97	(0.59–1.59)	97	0.95	(0.69–1.30)	33	**2.14**[d]	**(1.00–4.57)**
No retail food	35	1.08	(0.69–1.68)		16	**2.68**[d]	**(1.02–7.03)**	8	0.83	(0.30–2.33)	7	0.73	(0.31–1.71)	4	1.00	(0.31–3.22)
p-trend[f]			0.32				0.77			0.81			0.94			0.056
Number of recreational facilities[k]				0.50												
3+	302	1.00			69	1.00		82	1.00		113	1.00		38	1.00	
2	189	1.10	(0.91–1.34)		68	1.28	(0.91–1.80)	25	0.85	(0.53–1.38)	83	1.14	(0.84–1.54)	13	0.89	(0.45–1.79)
1	242	1.15	(0.95–1.39)		62	1.15	(0.77–1.70)	47	1.29	(0.84–1.99)	107	1.02	(0.76–1.39)	26	1.70	(0.94–3.08)
0	248	1.04	(0.85–1.29)		86	1.06	(0.72–1.57)	33	0.99	(0.58–1.70)	104	0.98	(0.70–1.36)	25	1.37	(0.75–2.49)
p-trend[f]			0.45				0.95			0.74			0.42			0.75
Commute by car/motorcycle[e]				0.72												
Q1 low	177	1.00			65	1.00		20	1.00		77	1.00		15	1.00	
Q2	162	0.83	(0.67–1.05)		66	1.23	(0.86–1.78)	24	0.96	(0.49–1.88)	60	**0.65**[d]	**(0.45–0.94)**	12	0.57	(0.26–1.25)
Q3	202	0.97	(0.77–1.22)		52	1.21	(0.83–1.78)	41	1.15	(0.57–2.31)	86	0.77	(0.54–1.12)	23	1.12	(0.50–2.50)
Q4	217	0.84	(0.65–1.08)		51	1.16	(0.75–1.80)	44	0.91	(0.44–1.89)	92	**0.66**[d]	**(0.44–1.00)**	30	0.85	(0.37–1.95)
Q5 high	222	0.85	(0.66–1.11)		51	1.22	(0.75–1.97)	58	1.20	(0.60–2.41)	91	0.66	(0.43–1.01)	22	0.60	(0.26–1.38)
p-trend[f]			0.35				0.59			0.58			0.17			0.39

Males	Overall N=35,397				African Americans N=9,190			Japanese Americans N=5,222			Latinos N=16,724			Whites N=4,261		
	No.	HR[a]	95% CI	p-int[b]	No.	HR[c]	95% CI	No.	HR[c]	95% CI	No.	HR[c]	95% CI	No.	HR[c]	95% CI
Total number of businesses[l]				**0.048**												
Q5 high	206	1.00			46	1.00		64	1.00		66	1.00		30	1.00	
Q4	202	1.12	(0.91–1.38)		69	1.17	(0.77–1.77)	48	1.19	(0.77–1.85)	69	1.16	(0.80–1.68)	16	0.87	(0.44–1.71)
Q3	172	1.02	(0.81–1.28)		54	0.79	(0.49–1.28)	23	0.92	(0.53–1.60)	72	1.21	(0.83–1.75)	23	1.34	(0.67–2.67)
Q2	195	1.13	(0.89–1.43)		56	1.03	(0.64–1.64)	22	0.91	(0.49–1.67)	100	1.34	(0.91–1.95)	17	0.98	(0.48–2.00)
Q1 low	206	1.15	(0.89–1.49)		60	0.91	(0.53–1.56)	30	1.17	(0.62–2.20)	100	1.45	(0.96–2.21)	16	0.74	(0.33–1.63)
p-trend[f]			0.37				0.48			0.96			0.07			0.63
Traffic density[m]				0.78												
Q1 low	199	1.00			53	1.00		38	1.00		85	1.00		23	1.00	
Q2	205	1.15	(0.92–1.43)		55	1.06	(0.66–1.71)	41	1.46	(0.88–2.40)	89	1.08	(0.78–1.49)	20	1.10	(0.56–2.18)
Q3	174	1.02	(0.81–1.29)		57	0.98	(0.61–1.57)	27	1.14	(0.64–2.02)	75	1.01	(0.72–1.42)	15	0.81	(0.39–1.69)
Q4	182	1.10	(0.87–1.39)		64	1.08	(0.67–1.74)	42	1.38	(0.83–2.28)	54	0.92	(0.63–1.34)	22	0.95	(0.45–1.98)
Q5 high	221	**1.29**[d]	**(1.03–1.61)**		56	1.22	(0.76–1.96)	39	1.47	(0.84–2.57)	104	1.23	(0.89–1.70)	22	0.95	(0.47–1.91)
p-trend[f]			0.056				0.40			0.30			0.34			0.77
Street connectivity[e, n]				0.31												
Q5 high	152	1.00			66	1.00		27	1.00		46	1.00		13	1.00	
Q4	178	1.17	(0.93–1.45)		79	**1.42**[d]	**(1.01–1.99)**	24	0.91	(0.52–1.60)	59	1.01	(0.68–1.49)	16	1.32	(0.63–2.75)
Q3	193	1.18	(0.94–1.49)		54	1.26	(0.86–1.85)	36	0.99	(0.55–1.79)	82	1.23	(0.84–1.82)	21	1.41	(0.70–2.83)
Q2	193	0.93	(0.74–1.18)		34	0.73	(0.46–1.15)	46	0.82	(0.45–1.47)	93	1.07	(0.74–1.56)	20	0.98	(0.47–2.05)
Q1 low	265	1.10	(0.86–1.41)		52	1.23	(0.77–1.95)	54	0.83	(0.45–1.55)	127	1.19	(0.81–1.76)	32	1.10	(0.52–2.30)
p-trend[f]			0.89				0.80			0.49			0.37			0.86

[a] Adjusted for clustering effect of block group, age, race/ethnicity, body mass index, family history of colorectal cancer, history of intestinal polyps, education, pack-years of smoking, multivitamin use, nonsteroidal anti-inflammatory medication use, alcohol consumption, vigorous physical activity, history of diabetes, calories, red meat, dietary fiber, calcium, folacin, vitamin D, and all of the neighborhood variables presented in the table; age was the time metric.

[b] Heterogeneity of the trend across race/ethnicity, excluding missing values, no restaurants for restaurant environment index, and no retail food for retail food environment.

[c] Adjusted for clustering effect of block group, age, body mass index, family history of colorectal cancer, history of intestinal polyps, education, pack-years of smoking, multivitamin use, nonsteroidal anti-inflammatory medication use, alcohol consumption, vigorous physical activity, history of diabetes, calories, red meat, dietary fiber, calcium, folacin, vitamin D, and all of the neighborhood variables presented in the table; age wast the time metric.

[d] p-value 0.01–<0.05

[e] Census 1990 block-group level measures; quintiles based on Los Angeles County distribution.

[f] p-trend analysis excluding missing values, no restaurants, and no retail food.

[g] Residential buffer measure within a 1600 meter network distance; ratio of the average number of fast food restaurants to other restaurants; quartiles based on sample distribution.

[h] No fast food restaurants, but other restaurants.

[i] Residential buffer measure within a 1600 meter network distance; ratio of the average number of convenience stores, liquor stores, and fast food restaurants to supermarkets and farmers' markets; quartiles based on sample distribution.

[j] No convenience stores, liquor stores, or fast food restaurants, but supermarkets or farmers' markets

[k] Within a 1600 meter network distance.

[l] Annual average number of businesses that were active during a 3-year window within a 1600 meter network distance; quintiles based on sample distribution.l

[m] Traffic density within a 500 meter network distance; vehicle kilometers traveled (VKmT); quintiles based on sample distribution.

[n] Ratio of actual number of street segments to maximum possible number of intersections.

Abbreviations: No., number of cases of invasive colorectal cancer; HR, hazard rate ratio; CI, confidence interval

Table 2

Associations between colorectal cancer risk and body mass index and the neighborhood obesogenic environment in females, Multiethnic Cohort, 1993 – 2010

Females	Overall N=45,800				African Americans N=15,903			Japanese Americans N=5,415			Latinas N=16,836			Whites N=7,646		
	No.	HR[a]	95% CI	p-int[b]	No.	HR[c]	95% CI	No.	HR[c]	95% CI	No.	HR[c]	95% CI	No.	HR[c]	95% CI
Body mass index (kg/m2)																
<18.5	30	**1.71**[d]	**(1.17–2.50)**		8	1.95	(0.92–4.12)	15	**1.87**[e]	**(1.07–3.27)**	3	1.63	(0.53–5.03)	4	1.52	(0.55–4.22)
18.5–24.9	326	1.00			97	1.00		91	1.00		73	1.00		65	1.00	
25.0–29.9	332	1.06	(0.91–1.25)		157	1.03	(0.80–1.34)	25	0.97	(0.60–1.57)	97	1.06	(0.79–1.43)	53	1.12	(0.77–1.63)
≥30.0	304	**1.30**[d]	**(1.09–1.55)**		162	1.13	(0.87–1.47)	10	1.83	(0.92–3.62)	89	**1.41**[e]	**(1.01–1.97)**	43	1.45	(0.96–2.19)
Neighborhood socioeconomic status[f]				0.57												
Q5 high	111	1.00			22	1.00		34	1.00		21	1.00		34	1.00	
Q4	197	1.14	(0.90–1.43)		67	1.13	(0.72–1.77)	45	1.14	(0.67–1.94)	29	0.69	(0.39–1.23)	56	1.50	(0.96–2.33)
Q3	216	1.12	(0.88–1.43)		74	1.07	(0.67–1.69)	41	1.07	(0.63–1.81)	61	0.94	(0.56–1.59)	40	1.23	(0.75–2.02)
Q2	258	1.12	(0.87–1.46)		129	1.19	(0.75–1.89)	13	0.62	(0.29–1.36)	89	0.98	(0.57–1.68)	27	1.22	(0.64–2.32)
Q1 low	210	1.06	(0.78–1.43)		132	1.14	(0.70–1.84)	8	1.07	(0.38–2.98)	62	0.83	(0.43–1.57)	8	0.90	(0.34–2.40)
p-trend[g]			0.81				0.67			0.55			0.88			0.92
Population density[f]				0.68												
Q5 high	187	1.00			89	1.00		13	1.00		68	1.00		17	1.00	
Q4	244	0.97	(0.78–1.20)		135	1.15	(0.86–1.55)	26	1.08	(0.50–2.35)	62	0.71	(0.48–1.05)	21	0.69	(0.33–1.43)
Q3	238	0.97	(0.77–1.24)		97	1.12	(0.77–1.62)	41	1.38	(0.61–3.11)	53	**0.60**[e]	**(0.38–0.94)**	47	1.04	(0.53–2.06)
Q2	178	1.00	(0.77–1.30)		53	1.02	(0.66–1.56)	32	1.19	(0.49–2.91)	45	0.73	(0.46–1.17)	48	1.06	(0.53–2.10)
Q1 low	145	0.91	(0.68–1.21)		50	1.04	(0.63–1.73)	29	1.46	(0.58–3.68)	34	0.74	(0.45–1.21)	32	0.60	(0.28–1.28)
p-trend[g]			0.70				0.96			0.46			0.37			0.46
Restaurant environment index[h]				0.07												
0[i]	163	1.00			47	1.00		25	1.00		45	1.00		46	1.00	
Q1 low	194	0.98	(0.77–1.24)		73	1.17	(0.77–1.78)	45	1.66	(0.87–3.16)	48	0.79	(0.50–1.24)	28	0.70	(0.39–1.26)

Females	Overall N=45,800				African Americans N=15,903			Japanese Americans N=5,415			Latinas N=16,836			Whites N=7,646		
	No.	HR[a]	95% CI	p-int[b]	No.	HR[c]	95% CI	No.	HR[c]	95% CI	No.	HR[c]	95% CI	No.	HR[c]	95% CI
Q2	213	1.08	(0.85–1.35)		78	0.99	(0.66–1.47)	40	**2.02**[e]	**(1.10–3.70)**	55	0.96	(0.63–1.48)	40	1.07	(0.64–1.81)
Q3	191	0.97	(0.76–1.23)		86	0.92	(0.61–1.38)	18	1.48	(0.75–2.95)	62	1.06	(0.69–1.63)	25	0.76	(0.42–1.37)
Q4 & <1	178	0.93	(0.72–1.19)		115	1.01	(0.67–1.52)	9	1.18	(0.51–2.68)	39	0.99	(0.62–1.59)	15	0.54	(0.27–1.07)
Q4 & ≥1	27	1.29	(0.84–1.99)		12	1.16	(0.58–2.32)	1	0.67	(0.09–5.23)	11	**2.21**[e]	**(1.11–4.40)**	3	0.63	(0.20–2.02)
No restaurants	26	0.71	(0.45–1.13)		13	0.74	(0.40–1.37)	3	0.37	(0.10–1.38)	2	0.74	(0.17–3.26)	8	0.75	(0.34–1.62)
p-trend[g]			0.94				0.78			0.79			0.15			0.14
Retail food environment index[j]				0.49												
0[j]	26	0.93	(0.62–1.37)		9	1.45	(0.70–2.99)	6	1.67	(0.71–3.94)	3	0.38	(0.12–1.19)	8	1.04	(0.44–2.48)
Q1 low	226	1.00			90	1.00		31	1.00		75	1.00		30	1.00	
Q2	218	0.87	(0.71–1.05)		100	0.88	(0.65–1.18)	22	0.56	(0.30–1.03)	67	1.01	(0.70–1.45)	29	1.03	(0.61–1.76)
Q3	222	0.85	(0.70–1.03)		92	0.76	(0.56–1.04)	38	0.81	(0.47–1.39)	57	0.95	(0.65–1.37)	35	1.09	(0.66–1.81)
Q4 high	274	0.90	(0.74–1.10)		121	0.89	(0.66–1.20)	38	0.73	(0.41–1.30)	60	0.85	(0.56–1.28)	55	1.34	(0.79–2.27)
No retail food	26	1.00	(0.62–1.64)		12	1.16	(0.51–2.63)	6	2.22	(0.66–7.40)	0			8	1.08	(0.35–3.35)
p-trend[g]			0.41				0.27			0.32			0.76			0.25
Number of recreational facilities[l]				0.33												
3+	323	1.00			117	1.00		70	1.00		83	1.00		53	1.00	
2	183	0.97	(0.80–1.18)		88	0.98	(0.72–1.33)	18	0.82	(0.48–1.40)	53	0.94	(0.64–1.37)	24	1.10	(0.66–1.83)
1	245	1.02	(0.85–1.24)		106	0.98	(0.73–1.32)	34	1.38	(0.84–2.28)	70	0.85	(0.59–1.22)	35	1.20	(0.74–1.95)
0	241	0.92	(0.75–1.12)		113	0.82	(0.60–1.12)	19	0.86	(0.44–1.69)	56	0.73	(0.50–1.07)	53	**1.64**[e]	**(1.02–2.65)**
p-trend[g]			0.82				0.93			0.22			0.23			0.19
Commute by car/motorcycle[f]				0.62												
Q1 low	176	1.00			110	1.00		12	1.00		42	1.00		12	1.00	
Q2	192	1.09	(0.88–1.36)		92	1.00	(0.74–1.34)	26	1.31	(0.61–2.79)	49	1.29	(0.80–2.06)	25	1.12	(0.54–2.32)
Q3	203	1.21	(0.96–1.53)		68	1.00	(0.72–1.41)	27	0.99	(0.45–2.19)	64	**1.68**[e]	**(1.06–2.65)**	44	1.22	(0.61–2.44)
Q4	207	1.07	(0.84–1.36)		80	1.16	(0.84–1.60)	42	1.01	(0.45–2.23)	48	1.28	(0.75–2.19)	37	0.65	(0.31–1.36)
Q5 high	214	1.17	(0.90–1.50)		74	1.28	(0.90–1.82)	34	0.84	(0.38–1.87)	59	**1.71**[e]	**(1.00–2.92)**	47	0.73	(0.34–1.55)

Females	Overall N=45,800				African Americans N=15,903			Japanese Americans N=5,415			Latinas N=16,836			Whites N=7,646		
	No.	HR[a]	95% CI	p-int[b]	No.	HR[c]	95% CI	No.	HR[c]	95% CI	No.	HR[c]	95% CI	No.	HR[c]	95% CI
p-trend[g]			0.42				0.12			0.20			0.12			**0.044**
Total number of businesses[m]				0.65												
Q5 high	213	1.00			76	1.00		60	1.00		43	1.00		34	1.00	
Q4	205	0.94	(0.76–1.17)		84	0.81	(0.57–1.17)	32	0.88	(0.54–1.46)	61	1.41	(0.93–2.15)	28	1.09	(0.63–1.87)
Q3	205	0.94	(0.75–1.17)		105	0.92	(0.65–1.32)	19	0.98	(0.52–1.85)	45	1.02	(0.65–1.60)	36	1.14	(0.64–2.04)
Q2	191	0.94	(0.74–1.19)		79	0.91	(0.63–1.34)	14	0.71	(0.35–1.43)	63	1.22	(0.78–1.92)	35	1.12	(0.64–1.98)
Q1 low	178	0.85	(0.65–1.13)		80	0.85	(0.54–1.34)	16	0.69	(0.32–1.51)	50	1.18	(0.71–1.96)	32	0.95	(0.45–2.00)
p-trend[g]			0.35				0.81			0.32			0.87			0.94
Traffic density[n]				0.78												
Q1 low	205	1.00			77	1.00		34	1.00		60	1.00		34	1.00	
Q2	211	0.97	(0.78–1.19)		87	0.94	(0.68–1.32)	26	0.77	(0.44–1.33)	56	0.81	(0.55–1.20)	42	**1.70**[e]	**(1.04–2.77)**
Q3	188	0.83	(0.67–1.02)		73	**0.69**[e]	**(0.48–0.99)**	28	0.87	(0.51–1.48)	44	**0.65**[e]	**(0.44–0.98)**	43	**1.66**[e]	**(1.03–2.68)**
Q4	196	0.81	(0.65–1.01)		102	0.84	(0.60–1.19)	26	0.62	(0.34–1.11)	43	0.76	(0.50–1.16)	25	1.10	(0.59–2.03)
Q5 high	192	0.90	(0.72–1.12)		85	1.02	(0.71–1.46)	27	0.78	(0.44–1.40)	59	0.89	(0.60–1.32)	21	0.89	(0.49–1.62)
p-trend[g]			0.16				0.94			0.31			0.62			0.36
Street connectivity[f, o]				0.32												
Q5 high	194	1.00			116	1.00		18	1.00		39	1.00		21	1.00	
Q4	189	1.06	(0.86–1.30)		103	1.09	(0.84–1.42)	21	1.36	(0.70–2.64)	46	1.06	(0.67–1.68)	19	0.85	(0.46–1.58)
Q3	163	0.94	(0.76–1.17)		68	0.98	(0.73–1.31)	26	1.16	(0.63–2.11)	47	0.85	(0.55–1.30)	22	0.81	(0.41–1.60)
Q2	219	1.07	(0.87–1.31)		72	1.10	(0.81–1.51)	38	1.01	(0.57–1.80)	62	0.94	(0.63–1.40)	47	1.13	(0.64–1.98)
Q1 low	227	1.03	(0.82–1.30)		65	1.20	(0.83–1.75)	38	0.98	(0.51–1.88)	68	0.85	(0.55–1.31)	56	1.21	(0.69–2.14)
p-trend[g]			0.78				0.45			0.58			0.38			0.24

[a]Adjusted for clustering effect of block group, age, race/ethnicity, body mass index, family history of colorectal cancer, history of intestinal polyps, education, pack-years of smoking, multivitamin use, nonsteroidal anti-inflammatory medication use, use of hormone therapy, alcohol consumption, vigorous physical activity, history of diabetes, calories, red meat, dietary fiber, calcium, folacin, vitamin D, and all of the neighborhood variables presented in the table; age was the time metric.

[b]Heterogeneity of the trend across race/ethnicity, excluding missing values, no restaurants for restaurant environment index, and no retail food for retail food environment.

[c] Adjusted for clustering effect of block group, age, body mass index, family history of colorectal cancer, history of intestinal polyps, education, pack-years of smoking, multivitamin use, nonsteroidal anti-inflammatory medication use, use of hormone therapy, alcohol consumption, vigorous physical activity, history of diabetes, calories, red meat, dietary fiber, calcium, folacin, vitamin D, and all of the neighborhood variables presented in the table; age was the time metric.

[d] p-value 0.001–<0.01

[e] p-value 0.01–<0.05

[f] Census 1990 block-group level measures; quintiles based on Los Angeles County distribution.

[g] p-trend analysis excluding missing values, no restaurants, and no retail food.

[h] Residential buffer measure within a 1600 meter network distance; ratio of the average number of fast food restaurants to other restaurants; quartiles based on sample distribution.

[i] No fast food restaurants, but other restaurants.

[j] Residential buffer measure within a 1600 meter network distance; ratio of the average number of convenience stores, liquor stores, and fast food restaurants to supermarkets and farmers' markets; quartiles based on sample distribution.

[k] No convenience stores, liquor stores, or fast food restaurants, but supermarkets or farmers' markets.

[l] Within a 1600 meter network distance.

[m] Annual average number of businesses that were active during a 3-year window within a 1600 meter network distance; quintiles based on sample distribution.

[n] Traffic density within a 500 meter network distance; vehicle kilometers traveled (VKmT); quintiles based on sample distribution.

[o] Ratio of actual number of street segments to maximum possible number of intersections.

Abbreviations: No., number of cases of invasive colorectal cancer; HR, hazard rate ratio; CI, confidence interval