Supplementary Online Content

Christine PJ, Auchincloss AH, Bertoni AG, et al. Longitudinal associations between neighborhood physical and social environments and incident type 2 diabetes mellitus: the Multi-Ethnic Study of Atherosclerosis (MESA).
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This supplementary material has been provided by the authors to give readers additional information about their work.

eAppendix 1. Further description of the neighborhood GIS, survey, and summary measures

GIS-based measures of access to food stores were created using data obtained from the National Establishment Time Series (NETS) database from Walls and Associates for the years 2000-2012. This data includes time-series data on establishments derived from Dun and Bradstreet (D&B) archival establishment data. Addresses were geocoded using TeleAtlas EZ-Locate web-based geocoding software (TeleAtlas, 2011). We used Standard Industrial Classification (SIC) codes to identify supermarkets and grocery stores (#5411), and fruit and vegetable markets (#5431), which we classified as healthy food stores.[1] Additional supermarket data was obtained from Nielsen/TDLinx to enhance the supermarket list.[2] We identified supermarkets as grocery stores with at least $2 million in annual sales or at least 25 employees. Additionally, we included supermarkets that had a standard chain name based on a list derived from the Nielsen/TDLinx data as described in detail elsewhere.[3] For physical activity resources, 114 SIC codes were selected to represent establishments with indoor conditioning, dance, bowling, golf, team and racquet sports, and water activities derived from lists used in previous studies.[4,5] Simple densities per square mile were created for 1-mile buffers around each address using the point density command in ArcGIS 9.3.

For the survey scales, information on neighborhood level characteristics was ascertained via questionnaire asking participants to rate the area within approximately 1 mile around their home. On the basis of a conceptual model[6] and prior work,[7] four neighborhood dimensions were assessed: walking environment (4 items, “It is pleasant to walk in my neighborhood”, “In my neighborhood it is easy to walk to places”, “I often see other people walking in my neighborhood”, and “I often see other people exercise in my neighborhood”), availability of healthy foods (2 items, “A large selection of fresh fruit and vegetables is available in my neighborhood” and “A large selection of low fat foods is available in my neighborhood”), safety (2 items, “I feel safe walking in my neighborhood day or night” and “Violence is a problem in my neighborhood”), and social cohesion (4 items, “People around here are willing to help their neighbors”, “People in my neighborhood generally get along with each other”, “People in my neighborhood can be trusted”, and “People in my neighborhood share the same values”). Responses for each item ranged from 1 (strongly agree) to 5 (strongly disagree). Questions were reverse coded when needed to indicate a higher score being a more positive or favorable environment. Scales were based on previous work and have acceptable internal consistency (Cronbach alpha 0.64-0.82).[8] Scales based on a 1-mile buffer around the MESA participant’s home address were created by taking the crude mean of the responses for all respondents living within a 1 mile buffer, excluding themselves. Respondents had to have answered all questions within the domain to be included.

To create the summary measures, we standardized the GIS- and survey-based measures by centering each measure at the sample mean and dividing by the standard deviation. We then summed the standardized measures corresponding to each domain (e.g. GIS-based supermarket/fruit and vegetable market availability and survey-based fruit and vegetable availability) to create a summary measure.

eAppendix 2. Individual diet, physical activity, and body mass index (BMI) measurement

Diet was measured using a food frequency questionnaire administered at baseline and at exam 5. To derive an index of "healthy diet", we used the Alternative Healthy Eating Index – 2010 (AHEI-2010), which has been used in a variety of epidemiologic work due to its strong relationship to major chronic diseases.[9,10] The index ranges from 0 to 110, with higher scores indicating better diet quality (high intake of fruits, vegetables, soy, protein, white meat, cereal fiber, polyunsaturated fat and vitamins, and lower intake of alcohol, saturated fat, and red meat). Typical physical activity was measured at exams 1, 2, 3, and 5 using a standardized, semi-quantitative questionnaire adapted from the Cross-Cultural Activity Participation Study.[11] Physical activity was quantified in metabolic equivalent task minutes per week, and included all moderate and vigorous intentional physical activity, including walking for exercise, dance, team sports (e.g. basketball, softball), dual sports (e.g. tennis), individual activities (e.g. golf, yoga), and conditioning activities (e.g. running, swimming, cycling). BMI was calculated at each exam using measured height (m) and weight (kg). As potential mediators, BMI, diet, and physical activity were added to regression models as time-varying covariates, matching each mediator value to the closest preceding exposure measure. The sensitivity of our results to the use of the AHEI-2010 dietary index was tested by running additional models controlling for specific dietary components linked to type 2 diabetes in our cohort and others: percent of calories consumed from trans fats, whole grain consumption (servings per day), and consumption of nuts and seeds (servings per day). These dietary components were added to models individually and then collectively into a single model.

eAppendix 3. Further description of neighborhood socioeconomic status index

Neighborhood level scales for characteristics of socioeconomic status (SES) were obtained from the U.S. Census 2000 Summary File 1 and Summary File 3, American Community Survey (ACS) 2005-2009, and ACS 2007-2011 estimates at the census tract level. We conducted principal factor analysis with orthogonal rotation of 21 census variables which reflect aspects of race/ethnicity (percent Hispanic, percent non-Hispanic Asian, and percent non-Hispanic black), crowding (percent of households with crowing greater than 1 person per room), foreign born (percent or persons who are foreign born), education (percent of adults age 25 or older with at least a high school education and percent of adults age 25 or older with at least a Bachelor's degree), occupation (percent of persons age 16 and older with executive, managerial, or professional occupation), income and wealth (median value of housing units, percent of housing units without a telephone, percent of housing units without a vehicle, median household income, percent of households with income of at least $50,000, percent of household with interest, dividend, or net rental income, and percent of household receiving public assistance), poverty (percent below poverty level), employment (percent of those age 16 or older who are unemployed and percent of those age 16 and older who are not in the labor force), and housing (percent of occupied housing units, percent of housing units that are owner occupied, and percent of persons living in same house as previous census). Variables that represent a better SES environment were reverse coded. Five factors were kept which reflects 74% of the variance explained. Weighted scales were created by multiplying the factor weights by the standardized variables, and increasing scores represents socioeconomic disadvantage. The first factor, which we used in all analyses, represents education, occupation, housing value, and income, and was highly weighted on % bachelor degree, % managerial occupation, median home value, % HS education, % interest/dividend/rental income, median household income, and % household income >$50,000. The scales are linked to MESA participants by census tract using Census 2000 data for years 2000-2004, ACS 2005-2009 data for years 2005-2007, and ACS 2007-2011 data for years 2008-2012.

eAppendix 4. Description of models using baseline and change since baseline neighborhood measures as the exposures of interest

The parameterization of longitudinal neighborhood exposures as time-varying cumulative averages in the main models of the paper reflects both theory and biological plausibility regarding how neighborhood exposures are likely to influence the risk for type 2 diabetes, a slow, progressive onset chronic disease. Nonetheless, there is interest in evaluating if change in the neighborhood environment is associated with risk for diabetes. We ran additional Cox proportional hazards models parameterizing the neighborhood exposures as two separate regression coefficients: a baseline value, which estimates the association between the baseline level of exposure and the hazard for developing diabetes, and a change since baseline value, which estimates the association between the change in the level of exposure from baseline to the most recent follow-up exam and the hazard for developing diabetes. All models adjusted for the same covariates as the models in the main paper, and the results of these analyses are presented in eTable 7. For simplicity, all hazard ratios and 95% confidence intervals are estimated for a 1-unit change in the exposures.

eReferences:

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eTable 1. Distribution of number of respondents to the survey questionnaires used for creating each individual participant's survey-based exposure measures

	Proportion of index participants with a given number of respondents used to create survey-based exposures (%)											
	1-mile buffer						Census tract buffer					
Number of respondents used to create survey measure[a]	**1**	**2**	**3**	**4**	**≥5**	**Median**	**1**	**2**	**3**	**4**	**≥5**	**Median**
Neighborhood Exposures												
Survey-based healthy food environment	1.6	0.9	1.2	1.2	95.0	78	4.0	5.9	4.1	3.4	82.6	20
Survey-based physical activity environment	1.6	0.9	1.2	1.2	95.0	78	4.0	5.9	4.1	3.4	82.6	20
Survey-based social cohesion	1.4	1.0	1.0	1.4	95.2	76	3.6	5.8	4.1	3.4	83.1	20
Survey-based safety	1.6	0.9	1.2	1.2	95.0	78	4.0	5.9	4.1	3.4	82.6	20

[a] Note that each individual's own response was excluded from their survey-based exposure measure in order to minimize self-perception bias. Thus, the number of individuals used to create the survey response does not include the individual's own responses to survey questions.

eTable 2. Hazard ratios associated with a 1-unit increase in cumulative average neighborhood exposures [a]

Neighborhood Exposure	Model 1	Model2: Model 1 + Neighborhood SES
	HR (95% CI)	HR (95% CI)
Health food environment		
GIS-based supermarkets/FV markets	1.00 (0.97, 1.02)	1.01 (0.98, 1.03)
Survey-based	0.76 (0.66, 0.89)	0.81 (0.68, 0.97)
Summary	0.94 (0.89, 0.99)	0.97 (0.91, 1.03)
Physical activity environment		
GIS-based commercial rec establishments	0.98 (0.97, 1.00)	1.00 (0.98, 1.01)
Survey-based	0.53 (0.40, 0.71)	0.55 (0.38, 0.79)
Summary	0.89 (0.83, 0.95)	0.90 (0.83, 0.98)
Social environment		
Survey-based social cohesion	0.96 (0.68, 1.35)	0.99 (0.71, 1.40)
Survey-based safety	0.88 (0.71, 1.08)	0.94 (0.75, 1.16)
Summary	0.98 (0.93, 1.03)	0.99 (0.94, 1.05)

[a] Model 1 is the same as model 1 in the main paper, and controls for baseline age, gender, family history of diabetes, education, household income per capita, race/ethnicity, smoking status, and alcohol consumption.

eTable 3. Sensitivity analyses for adjusted hazard ratios for type 2 diabetes incidence corresponding to an IQR increase in exposure to neighborhood resources[a]

Neighborhood Exposure	Alternative geographic scale[b]	Control for population density[c]	Control for study site	Shared frailty models[d]	1-year lagged exposure[e]
	HR (95% CI)	HR (95% CI)	HR (95% CI)	HR (95% CI)	HR (95% CI)
Healthy food environment					
GIS-based supermarkets/FV markets	1.00 (0.97, 1.04)	0.99 (0.87, 1.14)	0.96 (0.88, 1.06)	1.00 (0.95, 1.05)	0.99 (0.94, 1.04)
Survey-based	0.83 (0.74, 0.94)	0.83 (0.75, 0.92)	0.85 (0.75, 0.97)	0.88 (0.79, 0.97)	
Summary	0.89 (0.79, 1.00)	0.74 (0.63, 0.88)	0.80 (0.67, 0.96)	0.92 (0.82, 1.02)	
Physical activity environment					
GIS-based commercial rec establishments	0.96 (0.92, 1.00)	0.93 (0.89, 0.98)	0.95 (0.91, 1.00)	0.94 (0.90, 0.98)	0.95 (0.92, 0.99)
Survey-based	0.81 (0.72, 0.92)	0.78 (0.70, 0.87)	0.80 (0.71, 0.90)	0.83 (0.75, 0.92)	
Summary	0.87 (0.79, 0.95)	0.74 (0.64, 0.86)	0.78 (0.67, 0.91)	0.85 (0.80, 0.92)	
Social environment					
Survey-based social cohesion	1.03 (0.92, 1.17)	0.96 (0.84, 1.10)	0.92 (0.80, 1.05)	[f]	
Survey-based safety	1.02 (0.96, 1.09)	0.90 (0.78, 1.04)	0.85 (0.73, 0.99)	0.93 (0.81, 1.08)	
Summary	1.05 (0.92, 1.19)	0.93 (0.83, 1.05)	0.89 (0.78, 1.01)	0.94 (0.85, 1.05)	

[a] All models control for baseline age, gender, family history of diabetes, education, household income per capita, race/ethnicity, smoking status, and alcohol consumption.
[b] For GIS-based measures, simple 3-mile buffers were used. For survey-based measures, including social cohesion and safety, and summary measures, census tracts were used. Alternative geographic scale measures were created in the same manner as those described in the methods section.
[c] Population density, measured as persons per square mile within a 1-mile buffer of the participant's address, was calculated based on block-level census population. Each block was weighted by the percent of the block area that falls within the participant buffer. The total population within that block was then multiplied by this weight and the weighted populations were summed together for the total population within the buffer. The total population was divided by total buffer area in square miles. For dates prior to January 2006, population counts originated from the 2000 Census (Census, 2000). For dates on and after January 2006, population counts originated from the 2010 Census.
[d] Shared frailty models are the random effects analogue of the Cox models presented in the main analyses. Rather than using robust standard errors to account for geographic clustering of the outcome, the shared frailty models use a random intercept for each census tract to account for geographic clustering of incident cases within census tracts. The advantage to including the random intercept for census tract is that it may help to control for residual confounding at the neighborhood level due to unmeasured or mismeasured factors (e.g. confounding not accounted for by covariates in our model, such as socioeconomic index).[12] The disadvantage is that such models assume homogeneity of unobserved factors within census tracts, which may be incorrect, especially in larger census tracts. All shared frailty models assumed a lognormal frailty distribution.
[e] 1-year lagged exposures were only available for GIS-based measures, since these exposures were collected annually. Survey-based measures were not collected annually, and hence comparable exposure measures could not be created.
[f] Shared frailty models for social cohesion failed to converge (a recognized problem with such models[13])

eTable 4. Baseline values and mean 10-year changes for neighborhood healthy food, physical activity, and social environment measures

Neighborhood Summary and Component Measures	Baseline values, median (IQR)	Mean 10-year changes (95% CI)
Healthy food environment summary score	-0.31 (2.14)	0.83 (0.83, 0.84)
GIS-based density of favorable food stores	0.96 (2.23)	-0.20 (-0.21, -0.19)
Survey-based healthy food availability	3.49 (0.65)	0.48 (0.48, 0.48)
Physical activity environment summary score	-0.48 (1.17)	0.54 (0.53, 0.54)
GIS-based density of physical activity resources	1.91 (2.87)	2.01 (1.98, 2.03)
Survey-based walking environment	3.86 (0.35)	0.09 (0.09, 0.09)
Social environment summary score	-0.03 (2.09)	0.26 (0.25, 0.27)
Survey-based social cohesion	3.54 (0.33)	0.07 (0.07, 0.08)
Survey-based safety	3.68 (0.68)	0.01 (0.01, 0.01)

eTable 5. Hazard ratios associated with an IQR increase in cumulative mean neighborhood exposures, comparing models with and without BMI, diet, and physical activity

Neighborhood Exposures	Model 1: All individual-level covariates[a]	Model 2: Model 1 + BMI[b]	Model 3: Model 2 + diet and physical activity[c]
	HR (95% CI)	HR (95% CI)	HR (95% CI)
Healthy Food Environment			
GIS-based supermarkets/FV markets	0.99 (0.94, 1.04)	1.00 (0.95, 1.05)	1.00 (0.95, 1.05)
Survey-based	0.84 (0.76, 0.93)	0.87 (0.78, 0.96)	0.85 (0.77, 0.95)
Summary	0.88 (0.79, 0.98)	0.91 (0.82, 1.02)	0.89 (0.79, 1.01)
Physical Activity Environment			
GIS-based commercial rec establishments	0.96 (0.92, 0.99)	0.97 (0.93, 1.01)	0.97 (0.92, 1.00)
Survey-based	0.79 (0.71, 0.88)	0.81 (0.73, 0.91)	0.80 (0.70, 0.88)
Summary	0.79 (0.69, 0.90)	0.82 (0.71, 0.93)	0.80 (0.68, 0.91)
Social Environment			
Survey-based social cohesion	0.97 (0.77, 1.23)	0.96 (0.75, 1.22)	0.98 (0.75, 1.29)
Survey-based safety	0.96 (0.90, 1.03)	0.96 (0.89, 1.02)	0.96 (0.89, 1.04)
Summary	0.96 (0.86, 1.07)	0.96 (0.85, 1.09)	0.96 (0.85, 1.09)

[a] Model 1 is the same as model 1 in the main paper, and controls for baseline age, gender, family history of diabetes, education, household income per capita, race/ethnicity, smoking status, and alcohol consumption.
[b] Model 2 controls for all covariates in model 1, and adds time-varying BMI as a potential mediator.
[c] Model 3 controls for all covariates in model 2, and adds diet (measured as the AHEI 2010 dietary index) and physical activity (total intentional physical activity measured in MET-mins/wk) as potential mediators. For additional details regarding the measurement of diet and physical activity, see eText 2.Results when including specific dietary features (% of calories from tans fat, whole grain consumption [servings/day], and nuts/seed consumption [servings/day]) were nearly identical to the results presented in the table.

eTable 6. Hazard ratios associated with an IQR increase in cumulative mean neighborhood exposures, using interval-censored survival models[a]

Neighborhood Exposures[b]	Model 1: All individual-level covariates[c]	Model 2: Model 1 + Neighborhood SES
	HR (95% CI)	HR (95% CI)
Healthy Food Environment		
GIS-based supermarkets/FV markets	0.99 (0.94, 1.04)	1.04 (0.98, 1.10)
Survey-based	0.65 (0.58, 0.72)	0.67 (0.59, 0.74)
Summary	0.72 (0.63, 0.82)	0.78 (0.67, 0.89)
Physical Activity Environment		
GIS-based commercial rec establishments	0.92 (0.88, 0.97)	0.96 (0.91, 1.01)
Survey-based	0.73 (0.66, 0.81)	0.77 (0.67, 0.87)
Summary	0.80 (0.74, 0.87)	0.83 (0.74, 0.91)
Social Environment		
Survey-based social cohesion	0.94 (0.84, 1.04)	0.94 (0.85, 1.04)
Survey-based safety	0.93 (0.80, 1.06)	0.97 (0.84, 1.10)
Summary	0.94 (0.84, 1.03)	0.96 (0.86, 1.05)

[a] All analyses use accelerated failure time models with a Weibull distribution to account for interval censoring of diabetes events. Standard errors and confidence intervals were calculated using the delta method.
[b] All exposure measures correspond to the most recent cumulative average exposure at the time of interval censoring, or at the end of follow-up for those remaining free of diabetes.
[c] Model 1 controls for baseline age, gender, family history of diabetes, education, and race/ethnicity, and most recently reported household income per capita, smoking status, and alcohol consumption.

eTable 7. Hazard ratios associated with IQR increase in cumulative mean neighborhood exposures, with additional adjustment for diabetes risk factors at baseline

Neighborhood Exposures	Model 1: All individual-level covariates[a]	Model 2: Model 1 + baseline BMI	Model 2: Model 1 + baseline hypertension[b]	Model 4: Model 1 + baseline high cholesterol[c]	Model 5: Model 1 + baseline BMI, hypertension, and high cholesterol
	HR (95% CI)	HR (95% CI)	HR (95% CI)	HR (95% CI)	HR (95% CI)
Healthy Food Environment					
GIS-based supermarkets/ FV markets	0.99 (0.94, 1.04)	1.00 (0.95, 1.05)	0.99 (0.94, 1.04)	0.99 (0.95, 1.05)	1.00 (0.95, 1.05)
Survey-based	0.84 (0.76, 0.93)	0.86 (0.78, 0.96)	0.85 (0.77, 0.94)	0.84 (0.76, 0.92)	0.86 (0.78, 0.95)
Summary	0.88 (0.79, 0.98)	0.91 (0.81, 1.02)	0.89 (0.79, 0.99)	0.88 (0.79, 0.99)	0.91 (0.81, 1.02)
Physical Activity Environment					
GIS-based commercial rec establishments	0.96 (0.92, 0.99)	0.96 (0.92, 1.01)	0.96 (0.93, 1.00)	0.96 (0.92, 0.99)	0.96 (0.92, 1.01)
Survey-based	0.79 (0.71, 0.88)	0.81 (0.72, 0.90)	0.81 (0.72, 0.90)	0.79 (0.72, 0.88)	0.82 (0.73, 0.91)
Summary	0.79 (0.69, 0.90)	0.88 (0.81, 0.96)	0.88 (0.81, 0.95)	0.87 (0.80, 0.94)	0.89 (0.82, 0.96)
Social Environment					
Survey-based social cohesion	0.97 (0.77, 1.23)	0.99 (0.88, 1.11)	0.98 (0.88, 1.09)	0.99 (0.88, 1.10)	0.98 (0.88, 1.10)
Survey-based safety	0.96 (0.90, 1.03)	0.92 (0.79, 1.06)	0.91 (0.79, 1.05)	0.93 (0.81, 1.07)	0.92 (0.80, 1.06)
Summary	0.96 (0.86, 1.07)	0.96 (0.86, 1.07)	0.95 (0.86, 1.06)	0.96 (0.86, 1.07)	0.96 (0.86, 1.07)

[a] Model 1 controls for baseline age, gender, family history of diabetes, education, household income per capita, race/ethnicity, smoking status, and alcohol consumption.
[b] Baseline hypertension was defined as systolic blood pressure ≥140, or diastolic blood pressure ≥90, or taking antihypertensive medications.
[c] Baseline high cholesterol was defined as LDL cholesterol ≥ 160 or taking cholesterol-lowering medications.

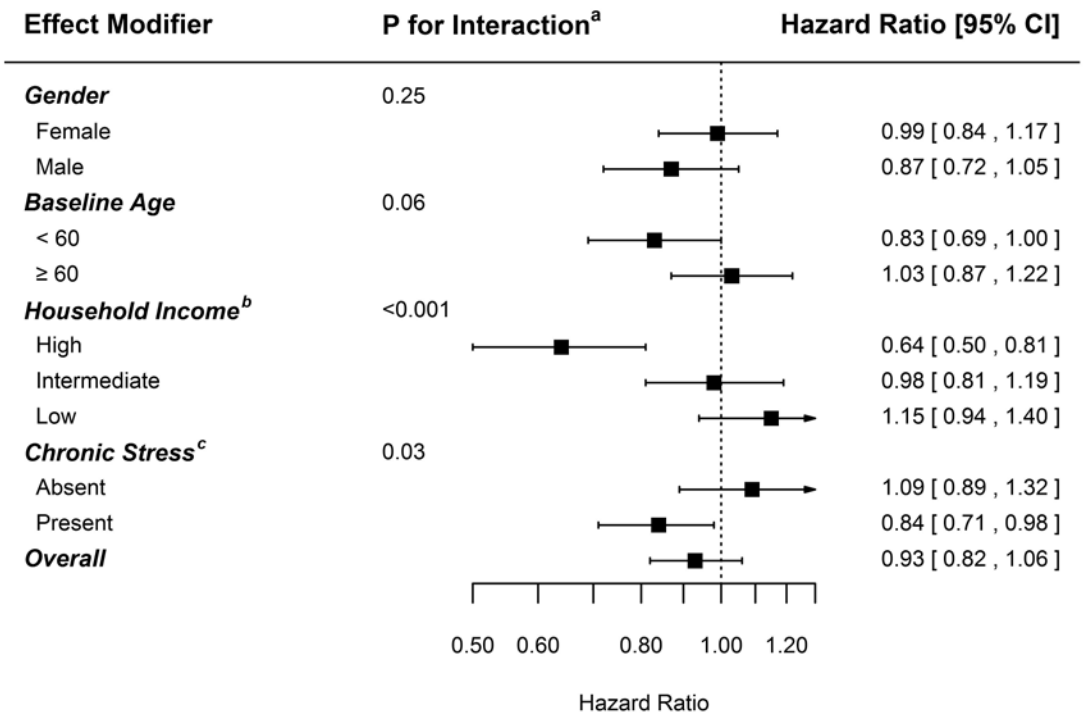
eTable 8. Adjusted hazard ratios for type 2 diabetes incidence corresponding to 1-unit increases in baseline and change from baseline exposure measures

	Model 1: All individual-level covariates[a]		Model 2: Model 1 + Neighborhood SES	
Neighborhood Exposure	**Baseline exposure**	**Change from baseline exposure**	**Baseline exposure**	**Change from baseline exposure**
	HR (95% CI)	**HR (95% CI)**	**HR (95% CI)**	**HR (95% CI)**
Health food environment				
GIS-based supermarkets/ FV markets	0.99 (0.97, 1.02)	1.03 (0.95, 1.10)	1.01 (0.98, 1.03)	1.04 (0.96, 1.12)
Survey-based	0.78 (0.67, 0.90)	0.94 (0.74, 1.19)	0.83 (0.69, 0.99)	0.96 (0.76, 1.22)
Summary	0.94 (0.89, 1.00)	1.00 (0.88, 1.14)	0.97 (0.91, 1.03)	1.01 (0.89, 1.15)
Physical activity environment				
GIS-based commercial rec establishments	0.98 (0.97, 1.00)	1.01 (0.99, 1.03)	0.96 (0.94, 0.99)	1.02 (0.97, 1.06)
Survey-based	0.55 (0.41, 0.73)	0.64 (0.41, 0.99)	0.54 (0.41, 0.73)	0.64 (0.41, 0.99)
Summary	0.89 (0.84, 0.95)	0.92 (0.81, 1.04)	0.90 (0.82, 0.98)	0.92 (0.81, 1.05)
Social environment				
Survey-based social cohesion	0.96 (0.67, 1.37)	0.76 (0.46, 1.26)	0.99 (0.70, 1.41)	0.79 (0.48, 1.29)
Survey-based safety	0.89 (0.72, 1.10)	0.79 (0.55, 1.14)	0.95 (0.76, 1.20)	0.80 (0.56, 1.14)
Summary	0.98 (0.93, 1.04)	0.94 (0.86, 1.04)	0.99 (0.94, 1.05)	0.95 (0.87, 1.04)

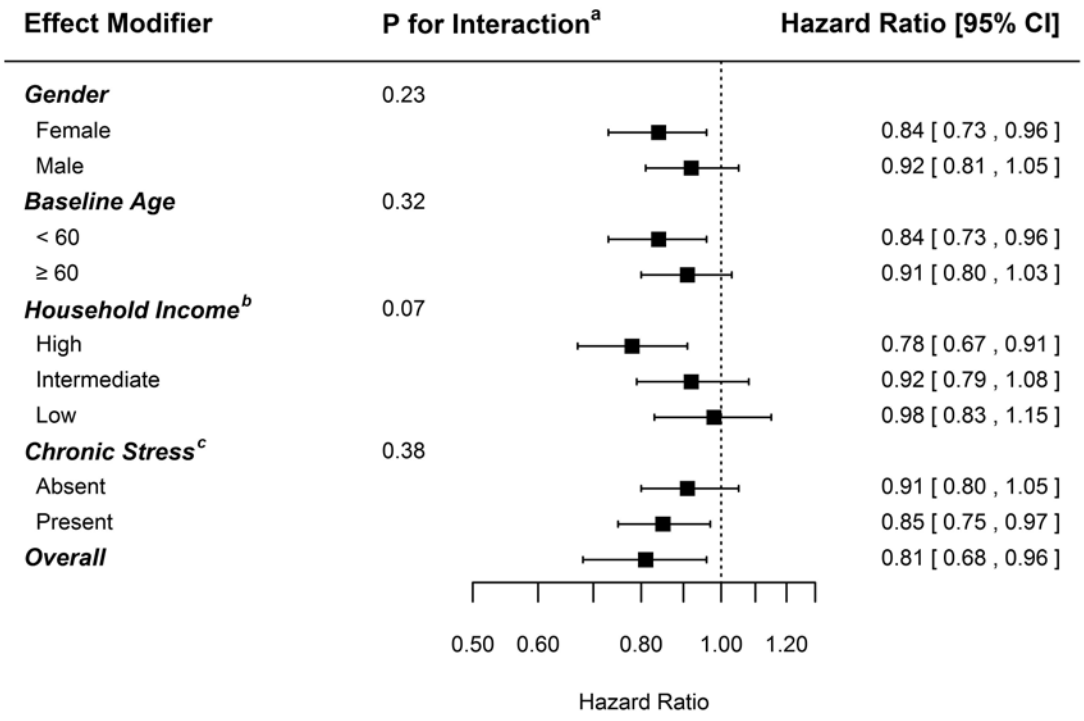
[a] Model 1 controls for baseline age, gender, family history of diabetes, education, household income per capita, race/ethnicity, smoking status, and alcohol consumption. Exposures are all parameterized for a 1-unit increase.

eFigure. Effect modification of adjusted hazard ratios for type 2 diabetes incidence for an IQR increase in cumulative neighborhood exposure by sex, baseline age, household income, and chronic stress status for summary a) healthy food, b) physical activity, and c) social environments

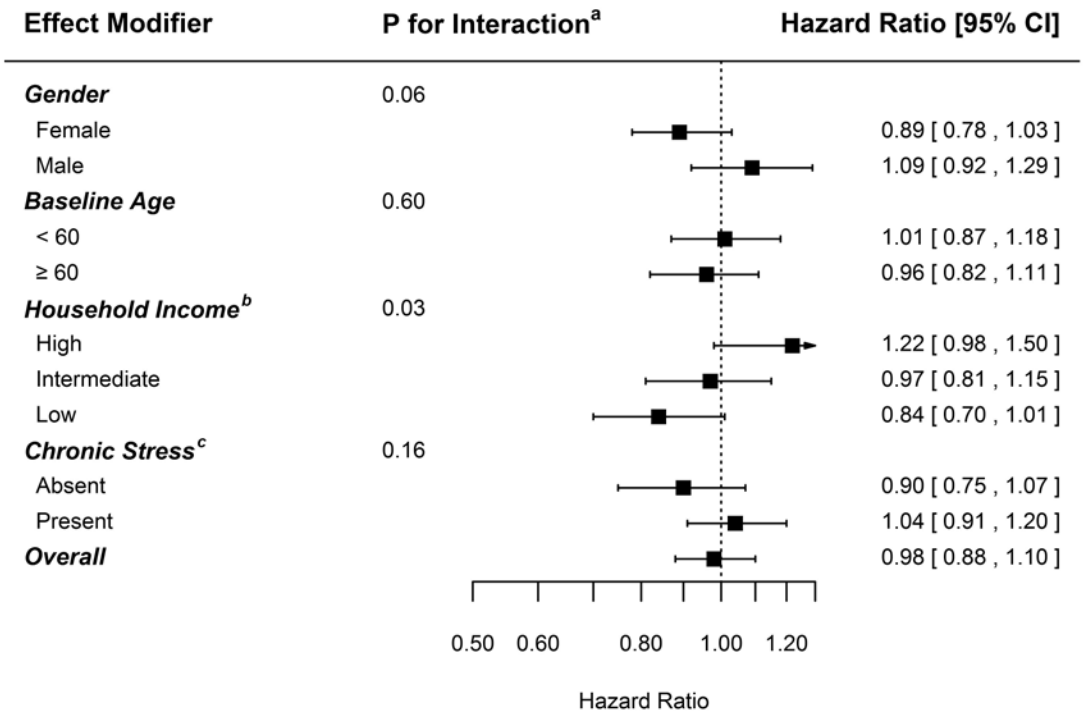
a)



b)



c)



[a] P-values for interaction come from a model adjusting for baseline age, gender, family history of diabetes, household per capita income, education, smoking status, alcohol consumption, and neighborhood SES index, and including an interaction term between the neighborhood exposure and effect modifier of interest. P-values are from Wald Chi-square tests for departures from multiplicative joint effects.

[b] Household income per capita is divided into tertiles.

[c] Chronic stress corresponds to self-reported problems due to money, job status, health concerns, or relationships that have lasted for greater than 6 months. Respondents answering yes to any chronic problems in the domains specified were classified as “present”.

