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Neighborhood-Level Socioeconomic Deprivation Predicts Weight Gain in a Multi-Ethnic Population: Longitudinal Data from the Dallas Heart Study

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Abstract

Objective—To examine relationship between neighborhood-level socioeconomic deprivation and weight change in a multi-ethnic cohort from Dallas County, Texas and whether behavioral/psychosocial factors attenuate the relationship.

Methods—Non-movers (those in the same neighborhood throughout the study period) aged 18–65 (N=939) in Dallas Heart Study (DHS) underwent weight measurements between 2000–2009 (median 7-year follow-up). Geocoded home addresses defined block groups; a neighborhood deprivation index (NDI) was created (higher NDI=greater deprivation). Multi-level modeling determined weight change relative to NDI. Model fit improvement was examined with adding physical activity and neighborhood environment perceptions (higher score=more unfavorable

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Conflict of Interest Statement

The authors declare that there are no conflicts of interest.

perceptions) as covariates. A significant interaction between residence length and NDI was found (p-interaction=0.04); results were stratified by median residence length (11 years).

Results—Adjusting for age, sex, race/ethnicity, smoking, education/income, those who lived in neighborhood>11 years gained 1.0 kilograms (kg) per one-unit increment of NDI (p=0.03), or 6 kg for those in highest NDI tertile compared with those in the lowest tertile. Physical activity improved model fit; NDI remained associated with weight gain after adjustment for physical activity and neighborhood environment perceptions. There was no significant relationship between NDI and weight change for those in their neighborhood≤11 years.

Conclusions—Living in more socioeconomically deprived neighborhoods over a longer time period was associated with weight gain in DHS.

Keywords

neighborhood environment; socioeconomic status; socioeconomic deprivation; obesity

Introduction

The exponential rise in prevalent obesity over three decades and regional variation in obesity prevalence in the United States suggests that environments in which individuals reside likely provide important context for the ability to pursue healthy behaviors and prevent weight gain. (Foundation, 2009) Neighborhood-level socioeconomic environment, as measured by U.S. Census-derived socioeconomic deprivation indices, may influence weight change and increase the likelihood of developing obesity-related cardiovascular risk factors in vulnerable populations. Prior cross-sectional studies support a relationship between neighborhood socioeconomic status (SES), prevalent obesity and cardio-metabolic risk factors. (Black and Macinko, 2010; Corsi et al., 2012; Laraia et al., 2012; Lovasi et al., 2009; Mujahid et al., 2005) However, these results are likely subject to self-selection bias, or a tendency for healthier, more financially secure individuals to live in areas of higher SES. (Leal and Chaix, 2011)

Few longitudinal studies have evaluated the relationship between neighborhood SES and weight gain. (Berry et al., 2010; Coogan et al., 2010; Mujahid et al., 2005; Ruel et al., 2010; Stafford et al., 2010) Results have been mixed, with some showing no significant associations between neighborhood SES and weight trajectory, (Mujahid et al., 2005; Ruel et al., 2010) and others demonstrating that lower neighborhood SES can predict weight gain and incident obesity. (Coogan et al., 2010; Stafford et al., 2010) Lack of access to resources for physical activity and a healthful diet, the influence of neighborhood characteristics on psychosocial stress, and the impact of social norms across neighborhood environments of varying socioeconomic levels are potential mechanisms by which neighborhood-level SES may influence weight change. (Ludwig et al., 2011) However, the relative contributions of access to resources for physical activity and psychosocial factors, particularly in the relationship between neighborhood SES and weight change, has not been fully elucidated in longitudinal studies.

Therefore, we used data from the Dallas Heart Study (DHS), a multi-ethnic, population-based cohort in Dallas County, Texas, to examine the relationship between neighborhood-level SES, as measured by a U.S. Census block group-level neighborhood deprivation index (NDI), and weight change over a median follow-up of seven years among individuals who remained at the same residence over the study period. We also examined mediation of the relationship between neighborhood-level SES and weight change by physical activity and perceptions of neighborhood environment.

Methods

DALLAS HEART STUDY

The DHS cohort is a multiethnic, probability-based sample of Dallas County residents aged 18 to 65 at study entry with data collection from 2000–2002 and follow-up data collection from 2007–2009. Non-Hispanic blacks were intentionally over-sampled to compose half of the study population, and detailed data collection methods were reported previously. (Victor et al., 2004) At study entry, 3072 participants completed a detailed survey, objectively-measured anthropometry, and laboratory testing. Participants underwent follow-up testing during a single visit to the University of Texas (UT) Southwestern Medical Center between September 2007 and December 2009. The DHS protocol was approved by the UT Southwestern Medical Center's Institutional Review Board; all study participants provided written informed consent at study entry and follow-up. A protocol for DHS neighborhood environment data analyses (13-H-N041) was approved by the Institutional Review Board of the National Heart, Lung, and Blood Institute of the National Institutes of Health.

Medical histories and demographic data, including age, sex, race/ethnicity, household income, and achieved education, were obtained by self-report. Participants also reported length of neighborhood residence, and were asked to respond to questions about perceptions of their neighborhood environment abstracted from the Project on Human Development in Chicago Neighborhoods. (Sampson et al., 1997) To evaluate neighborhood environment perceptions, we computed a neighborhood perception score as previously described, (Powell-Wiley et al., 2013) with a higher overall score representative of more unfavorable perceptions of neighborhood environment. The three neighborhood factors assessed in the overall neighborhood perception score were 1) perceived neighborhood violence, 2) perceived physical environment, and 3) perceived social cohesion. The score for perceived physical environment was also evaluated separately given its relationship with prevalent obesity in DHS. (Powell-Wiley et al., 2013) A higher perceived physical environment score was representative of more unfavorable perceptions of neighborhood aesthetics (i.e. trash/litter presence, excessive noise, heavy traffic) and available resources, including food stores, recreation areas, and walkability. Physical activity at both DHS time-points was determined using a validated conversion scale for activity intensity, which was used to convert self-reported leisure-time physical activity dose into metabolic equivalents (METs)-minute per week. (Diez Roux et al., 2007; LaMonte et al., 2001; Mathieu et al., 2012; Services, 1999) Measured weight and height were used to calculate body mass index (BMI) in kilograms per meter-squared. Waist (WC) and hip circumference (HC) were measured as previously described. (Powell-Wiley et al., 2012)

GEOCODING

Self-reported residential address data were geocoded with ArcGIS 10 software (ESRI, Redlands CA). Automatic matching was initially used with match parameters of a spelling sensitivity=80%, minimum candidate score=30%, and minimum match score=85%. Interactive matching, where address matches were reviewed and corrected as needed, was used for <10% of participants and for those addresses that did not have an automatic match. Participants whose address had a match score of <85% in either automatic or interactive matching were excluded from our study analysis (N=1 in study entry; N=66 in follow-up). Each DHS participant's address was linked with corresponding 2000 U.S. Census block group data according to U.S. Census TIGER/Line files.

NEIGHBORHOOD DEPRIVATION INDEX

A block group-level NDI was developed for Dallas County using 21 variables from the 2000 U.S. Census, as described previously. (Lian et al., 2011; Messer et al., 2006) Neighborhood variables incorporated into the NDI were in six domains (education, employment/ occupation, housing conditions, income/poverty, racial composition, and residential stability).(Diez-Roux et al., 2001; Krieger et al., 2003; Messer et al., 2006; Singh, 2003) Principal-components factor analysis with varimax rotation was used to select key block group-level variables. (Lian et al., 2011) Six variables were selected to compute the NDI score (% unemployment, % female-headed households, % households on public assistance, % households with a car, % the population below the federal poverty line, and % non-Hispanic blacks) after being standardized and weighted by their factor loading coefficients. Cronbach's alpha coefficient (0.86 for the block group variables) suggested that Census variables used in this study were internally consistent. NDI score was analyzed as a continuous variable and categorized into tertiles of low, medium, or high neighborhood-level socioeconomic deprivation. NDI values were standardized to the mean NDI for Dallas County block groups; therefore, one unit change in baseline NDI for the study represented one standard deviation increase in NDI and an average neighborhood would be represented by an NDI=0.

STUDY POPULATION

Non-movers were identified based on having the same geocoded address at study entry and follow-up. We focused on non-movers because they were presumed to have exposure to a consistent neighborhood socioeconomic level over the study period. Of the 2,485 follow-up participants, we excluded those who moved between entry and follow-up (N=1430), those with missing or inadequate address data (N=4), those missing height and/or weight data (N=9), participants with a history of cancer (N=75), a history of bariatric surgery (N=20), and who were pregnant at entry or follow-up (N=8), leaving a final sample of 939 DHS participants for the analyses.

STATISTICAL ANALYSIS

The Jonckheere–Terpstra test was used to compare continuous and categorical variables across deprivation tertiles. (Mielke and Berry, 2000) The Jonckheere-Terpstra test is a nonparametric test for ordered differences in which the exposure is an ordinal variable; the test is not restrictive to looking at linear trends across categories. Multilevel linear regression modeling with random effects was used to determine longitudinal weight change associated with a one-unit increase in NDI, with models adjusted for age, sex, race/ethnicity, education, income, and smoking status. NDI measured at baseline was used in the analyses. A binary variable indicating the study round in which the weight observation was recorded ("survey year") was included in the multi-level models independently and interacted with NDI. The model's dependent variable was weight. The beta coefficient for the interaction term for NDI as a continuous variable and survey year was used to determine temporal trends in weight associated with NDI, or weight change over the study time period per one unit increase in baseline NDI. The beta coefficient for NDI in the model was used to determine the difference in baseline weight per one unit increase in baseline NDI.

Effect modification by length of residence was evaluated using an interaction term for NDI and time in neighborhood as continuous variables in the overall regression model. When effect modification by residence length was identified, sensitivity analyses were conducted stratifying results by mean residence length and quartiles of residence length instead of median length of residence. These analyses were done to test the sensitivity of the results to different parameterizations of the length of residence variable. Random effects in the linear models were used to account for clustering effects due to repeated measures at the individual-level and clustering effects of living within the same block group. Akaike information criterion (AIC) for unadjusted and adjusted models including physical activity, overall neighborhood environment perceptions, and neighborhood physical environment perceptions were compared to evaluate goodness of fit with addition of these covariates, with an AIC decrease representing better model fit. Two-sided p-values ≤0.05 were considered statistically significant. All analyses were performed using SAS, version 9.2 (SAS Institute, Cary NC).

Results

Table 1 displays unadjusted baseline characteristics for non-movers in the DHS population across NDI tertiles. The study population was comprised of 51% non-Hispanic blacks, 34% non-Hispanic whites, and 14% Hispanics. The NDI distribution was from −1.1 (minimum) to 5.8 (maximum). Those living in higher NDI neighborhoods were more likely to be Hispanic or black, had lower achieved education and less income, had greater BMI and waist circumference, were more likely to be current smokers, and less likely to report adequate physical activity than those in lower NDI neighborhoods (p-trend <0.05 for all). In addition, residing in a more socioeconomically deprived neighborhood corresponded to having more unfavorable perceptions of the overall neighborhood environment (p-trend<0.0001) and the neighborhood physical environment (p-trend<0.0001).

In longitudinal analyses modeling the association between neighborhood deprivation and weight change, a statistical interaction between NDI and time in neighborhood was found to be statistically significant (p-interaction=0.04). Therefore, all results were stratified by median length of neighborhood residence for the population (11 years), as shown in Table 2. There was a non-significant decrease in weight for those who had lived in their neighborhood for ≤11 years [unadjusted weight change (95% CI)= −0.5 kg (−1.1, 0.1); adjusted weight change (95% CI)= −0.4 kg (−1.0, 0.3)].

In contrast, neighborhood socioeconomic deprivation was associated with weight gain for those who lived in their neighborhoods over the median residence length (Table 2). At baseline, each unit increase in deprivation was associated with 2.6 kg higher weight (95% CI = 0.8, 4.4). Additionally, each one-unit increment of NDI was associated with an approximate 1-kg increase in weight change (95% CI = 0.2, 1.6) over the seven-year follow-up period for those who had lived in their neighborhood over 11 years. This relationship remained after adjustment for confounders. For those living in neighborhoods with socioeconomic deprivation indices in the highest tertile, this translated into approximately 6 kg greater weight gain over the seven-year follow-up period as compared to those in the average neighborhood.

DHS participants who had lived in the most socioeconomically deprived neighborhoods for more than 11 years remained at risk for weight gain after accounting for reported physical activity, overall perceptions of neighborhood environment, and perceptions of neighborhood physical environment (Table 2). Addition of physical activity to the adjusted models improved goodness-of-fit based on decreasing AIC but did not substantially change the effect estimate [adjusted weight change=1.0 kg (95% CI=0.1, 1.8)]. However, addition of perceptions of overall neighborhood environment or neighborhood physical environment did not improve the models and there was minimal change in the effect estimates [weight change adjusted for perceptions of overall environment=0.9 kg (95% CI=0.7, 1.7); weight change adjusted for perceptions of physical environment=0.9 kg (95% CI=0.1, 1.7)]. Additionally, neighborhood-level socioeconomic deprivation was not associated with weight change among those who lived in their neighborhoods ≤11 years when adjusting for physical activity or perceptions of neighborhood environment. In sensitivity analyses using mean and quartiles of residence length, neighborhood socioeconomic deprivation remained associated with weight gain for those living in their neighborhood above the mean residence length or in the highest quartile of residence length (data not shown).

Discussion

In cross-sectional analyses at baseline, DHS participants living in neighborhoods of high socioeconomic deprivation were more likely to be obese. In longitudinal analyses, the association between weight change and neighborhood-level deprivation was modified by length of residence in one’s neighborhood. For DHS participants that had lived in their neighborhood for the longest time period, greater neighborhood-level socioeconomic deprivation was independently associated with greater weight gain over the seven-year follow-up period. Notably, physical activity did not appear to mediate the relationship between neighborhood-level SES and weight change, and the effect estimates for weight change were not attenuated by adding perceptions about one’s neighborhood environment to the models.

This is one of the first studies to demonstrate the influence of length of residence in the relationship between neighborhood socioeconomic environment and weight change. Our findings suggest cumulative exposure to neighborhoods of greater socioeconomic deprivation may increase an individual's risk of weight gain, and potentially, its adverse cardio-metabolic consequences. From a physiologic standpoint, longer exposure to neighborhood disadvantage may lead to greater likelihood of disruption of the hypothalamic-pituitary-adrenal (HPA) axis or sympathetic nervous system, resulting in abnormally elevated levels of glucocorticoids or catecholamines and subsequent weight gain. (Farag et al., 2008; Miller et al., 2009; Siervo et al., 2009) Prior data demonstrate that neighborhood disadvantage is associated with abnormal cortisol levels or inflammatory markers, but these studies have not examined whether these relationships differ by length of neighborhood residence. (Do et al., 2011; Dulin-Keita et al., 2012; Nazmi et al., 2010) Moreover, recent studies evaluating neighborhood-level SES and weight change did not account for length of residence in the analyses. (Coogan et al., 2010; Stafford et al., 2010; Stoddard et al., 2013) Length of residence was not found to be an effect modifier in the relationship between neighborhood deprivation and deterioration of perceived health (Ellaway et al., 2012) or poor health behaviors, including physical inactivity. (Halonen et al., 2012) However, these studies did not look specifically at weight change as an outcome. Body weight may also be particularly affected by cumulative exposure to a neighborhood environment given the relationship between exposure to social networks over time and obesity. (Christakis and Fowler, 2007)

Second, physical activity did not appear to mediate the association between neighborhood-level SES and weight change, given that the effect estimate did not change with the addition of physical activity to the models despite the improved goodness of fit. More recent studies are beginning to explore physical activity as a mediating factor in the relationship between neighborhood environment and weight, with inconsistent results. (Cummins and Fagg, 2012; Navalpotro et al., 2012) Third, perceptions about the overall neighborhood environment or the physical environment of the neighborhood did not appear to be explanatory factors in the causal pathway between neighborhood-level socioeconomic deprivation and weight change in the DHS cohort. Berry et al. demonstrated that low neighborhood-level SES was associated with increasing BMI in a Canadian population. In this Canadian cohort, unfavorable perceptions of traffic were independently associated with increasing BMI. Nonetheless, it was not clear from this study how the relationship between neighborhood-SES and increasing BMI over time was attenuated by perceptions about traffic. (Berry et al., 2010) In prior work from DHS, we found that unfavorable perceptions of heavy traffic in one's neighborhood were also associated with 20–40% greater likelihood of prevalent obesity. (Powell-Wiley et al., 2013) However, these perceptions may not play a predominant role in explaining weight change in the DHS cohort. Other behavioral or psychosocial factors related to neighborhood environment must be examined to determine how they relate to the development of obesity for this population, particularly those that may be relevant to long-term residents of a neighborhood, including dietary intake due to limitations of the food environment (Powell et al., 2007) or other measures of psychosocial stress. (Burdette and Hill, 2008; Cunningham et al., 2013; Fowler-Brown et al., 2009)

Strengths of this study include the multi-ethnic, urban nature of the cohort, the availability of longitudinal data for the analyses, allowing us to look at changes in weight rather than looking at strictly cross-sectional relationships, and objective measurements of height and weight for study participants as opposed to use of self-reported values. (Berry et al., 2010; Burdette and Needham, 2012; Coogan et al., 2010) However, limitations of this study must be acknowledged. The choice of neighborhoods in which DHS participants lived is likely subject to residential selection bias due to non-random factors, including education, income, race/ethnicity and other socio-demographic factors that influence location of residence. (Zick et al., 2013) Residential selection factors like income and education are particularly important because these factors may differentially influence weight change in higher versus lower NDI neighborhoods, leading to bias in our results. Our study examined only non-movers, which may not be representative of the full study population, potentially leading to selection bias. However, we assume that neighborhood effects are similar among movers and non-movers if they have lived in a neighborhood for the same time period, which likely limits this bias. Additionally, longitudinal NDI data was not evaluated in this study, limiting the ability to assess causality between change in neighborhood environment and weight change. The DHS represents an urban and geographically localized population, limiting the generalizability of the data to other locations and variability of neighborhood environments as compared to studies of cohorts representative of the U.S. population. (Ewing et al., 2006) In addition, survey data on physical activity and perceptions of neighborhood environment are subject to measurement error, although both measurements are based on validated survey instruments. Finally, the lack of dietary intake data from the DHS participants does not allow evaluation of this factor as a covariate in models.

Thus, the relationship between neighborhood-level deprivation and weight gain seen among DHS participants living in their neighborhoods the longest period of time is hypothesis-generating and suggests cumulative exposure to the neighborhood environment may influence cardio-metabolic risk for this population. This relationship between neighborhood SES and weight did not appear to be explained by unfavorable perceptions of the neighborhood environment. More work is needed to elucidate psychosocial factors that may affect the causal pathway between neighborhood environment and weight change. While economic policy changes are necessary to improve neighborhood-level deprivation, this study provides evidence to support development of community-level interventions in Dallas County combatting weight gain for individuals with long-term exposure to socioeconomically deprived neighborhoods.

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Highlights

- We examine a relationship between neighborhood socioeconomic status & weight change.
- Those living in a poorer neighborhood are more likely to be obese at baseline.
- Living in a poorer neighborhood for a longer period of time can lead to weight gain.

Table 1

Baseline Characteristics for Non-Movers in Dallas Heart Study Population (Dallas County, Texas 2000–2009) Stratified by Categories of Neighborhood Deprivation (N=939)

	Low Deprivation[a]	Medium Deprivation[b]	High Deprivation[c]	P Trend
Sample Size (N)	389	312	238	
Range of Deprivation Index	−1.15 to −0.03	−0.03 to 1.15	1.18 to 6.33	
Mean Age, mean (SD)[d], years	45.9 (9.4)	46.2 (10)	47.6 (10.3)	0.04
Female Sex, N (%)	203 (52%)	175 (56%)	139 (58%)	0.1
Race/Ethnicity				
Non-Hispanic Black, N (%)	48 (12%)	210 (67%)	220 (92%)	<0.0001
Non-Hispanic White, N (%)	277 (71%)	38 (12%)	2 (1%)	<0.0001
Hispanic, N (%)	64 (16%)	64 (21%)	16 (7%)	0.005
Education				
Less than High School, N (%)	40 (10%)	58 (19%)	46 (19%)	0.001
High School, N (%)	80 (21%)	103 (33%)	105 (44%)	<0.0001
Some College, N (%)	116 (30%)	85 (27%)	62 (26%)	0.3
College Grad or higher, N (%)	152 (39%)	66 (21%)	25 (11%)	<0.0001
Annual Income				
<$16,000, N (%)	15 (4%)	35 (14%)	62 (33%)	<0.0001
$16,000 – $29,999, N (%)	44 (13%)	51 (21%)	55 (29%)	<0.0001
$ 30,000 – $49,999, N (%)	83 (24%)	82 (34%)	54 (29%)	0.1
$ 50,000 or higher, N (%)	199 (58%)	74 (31%)	16 (9%)	<0.0001
Anthropometric Measures				
BMI[e], mean (SD)[d], kg/m^2	28.2 (5.8)	29.7 (6.4)	31.3 (7.7)	<0.0001
Waist-Hip Ratio, mean (SD)[d]	0.9 (0.2)	0.9 (0.1)	0.9 (0.1)	0.04
Waist Circumference, mean (SD)[d], cm	97 (15.3)	100.1 (15.7)	102.7 (16.7)	<0.0001
Health Behaviors				
Physical Activity ≥150 met/min-wk, N (%)	210 (60%)	140 (47%)	97 (44%)	<0.0001
Current Smoker, N (%)	69 (18%)	65 (21%)	75 (32%)	<0.0001
Perceptions of Neighborhood Environment				
Overall Perception of Neighborhood [f], mean (SD)	24.4 (7.2)	26.9 (10.1)	31.4 (12)	<0.0001
Perception of Neighborhood Physical environment[g], mean (SD)	10.6 (4.5)	12.3 (6.3)	14.6 (6.9)	<0.0001

[a]Low deprivation represents high neighborhood socioeconomic status

[b]Medium deprivation represents medium neighborhood socioeconomic status

[c]High deprivation represents low neighborhood socioeconomic status

[d]SD – standard deviation

[e]BMI – body mass index

[f]Total perception of neighborhood environment scores were derived from sub-scores for perceived neighborhood violence, perceived neighborhood physical environment, and perceived social cohesion. A higher total score is representative of more unfavorable perceptions of overall neighborhood environment.

[g]A higher perception of neighborhood physical environment score is representative of more unfavorable perceptions of the neighborhood physical environment.

Table 2

Effect Estimates for Multilevel Models of Neighborhood Deprivation and Weight Change for Non-Movers in Dallas Heart Study Population (Dallas County, Texas, 2000–2009), Stratified by Median Length of Residence in Neighborhood (N=939)

	Less than or Equal to 11 years in Neighborhood (N=476)		Greater than 11 years in Neighborhood (N=462)	
	Unadjusted[a]	**Adjusted for Covariates**[a,b]	**Unadjusted**[a]	**Adjusted for Covariates**[a,b]
	Estimate (95% CI[c]**)**	**Estimates (95% CI**[c]**)**	**Estimates (95% CI**[c]**)**	**Estimates (95% CI**[c]**)**
Weight Measures				
Baseline Weight[d]	1.8 (0.2, 3.4)	1.8 (−0.3, 4.0)	2.6 (0.8, 4.4)	4.2 (1.4, 7.1)
Change in Weight[e]	−0.5 (−1.1, 0.1)	−0.4 (−1.0, 0.3)	1.0 (0.2, 1.6)	1.0 (0.1, 1.7)
Change in Weight Adjusted for[f]:				
Physical Activity[g]		−0.3 (−1.0, 0.3)		1.0 (0.1, 1.8)
Perceptions of Overall Neighborhood Environment[h]		−0.3 (−1.0, 0.3)		0.9 (0.7, 1.7)
Perceptions of Physical Environment[i]		−0.4 (−1.0, 0.2)		0.9 (0.1, 1.7)

[a]Multilevel models include terms accounting for clustering effects for repeated observations at individual level and clustering effects due to those living within the same block group

[b]Models adjusted for **age** (continuous), **age**^{2} (continuous), **male sex** (female sex as referent group), **white race** (non-white race as referent group), **education** (college graduate or higher as referent group), **annual income** (<$16,000 as referent group), **current smoker** (non-smoker as referent group)

[c]CI – confidence interval

[d]Effect estimate derived from beta coefficient for deprivation index term in the multilevel model. This effect estimate represents difference in baseline weight in kilograms for every one unit increase in baseline neighborhood deprivation index (NDI). NDI is standardized to the mean NDI value for Dallas County so that one unit increase in baseline NDI represents one standard deviation increase in baseline NDI.

[e]Effect estimate derived from beta coefficient for unit of deprivation*survey year interaction term in the multilevel model. This effect estimate represents weight change in kilograms for every one unit increase in baseline neighborhood deprivation index. Survey year represents time period in study (survey year=0 for study entry and survey year=1 for follow-up).

[f]Effect estimate for the additional change of weight models derived from beta coefficient for unit of deprivation*survey year interaction term in model adjusted for age, age2, male sex, white race, education, annual income, current smoker and additional covariates (physical activity, perceptions of overall neighborhood environment or perceptions of physical environment)

[g]Physical activity added to model as a continuous variable

[h]Perceptions of overall neighborhood environment added to model as a continuous variable based on derived score

[i]Perceptions of physical environment added to model as a continuous variable based on derived score