Neighbourhood economic deprivation explains racial/ethnic disparities in overweight and obesity among children and adolescents in the USA

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ABSTRACT

Background Low-income and some racial and ethnic subpopulations are more likely to suffer from obesity. Inequities in the physical and social environment may contribute to disparities in paediatric obesity, but there is little empirical evidence to date. This study explored whether neighbourhood-level socioeconomic factors attenuate racial and ethnic disparities in obesity among youth in the USA and whether individual-level socioeconomic status (SES) interacts with neighbourhood deprivation.

Methods This analysis used data from 17 100 youth ages 2–18 years participating in the 2001–2010 National Health and Nutrition Examination Survey linked to census tract-level socioeconomic characteristics. Multilevel logistic regression models were used to examine neighbourhood deprivation in association with odds of obesity (age-specific and sex-specific body mass index percentile ≥95).

Results The unadjusted prevalence of obesity was 15% among non-Hispanic white children and 21% among non-Hispanic black and Mexican-American children. Adjustment for individual-level SES neighbourhood deprivation and the interaction between these two factors resulted in a 74% attenuation of the disparity in obesity between non-Hispanic black and non-Hispanic white children and a 49% attenuation of the disparity between Mexican-American and non-Hispanic white children. There was a significant interaction between individual-level SES and neighbourhood deprivation where higher individual-level income was protective for children living in low-deprivation neighbourhoods, but not for children who lived in high-deprivation areas. Conversely, area deprivation was associated with higher odds of obesity, but only among children who were above the poverty threshold.

Conclusions Future research on disparities in obesity and other health outcomes should examine broader contextual factors and social determinants of inequities.

INTRODUCTION

Approximately, 17% of youth in the USA are obese (body mass index (BMI) percentile ≥95)[1] and subsequently at increased risk of numerous negative health sequelae.[2 3] Racial and ethnic subgroups such as Mexican-American and non-Hispanic black children are disproportionately burdened, with prevalences of obesity in excess of 21–24%.[1] Disparities in weight manifest relatively early in the life course[4–6] and are evident among children as young as 2–5 years of age.[1 7]

Inequities in the physical and social environment may help to explain racial and ethnic and socioeconomic status (SES) disparities in childhood obesity, but the majority of disparities research has not examined the broader context in which people live.[8–11] Failure to account for neighbourhood contextual variables that are correlated with race or ethnicity may lead to biased estimates of individual-level racial and ethnic disparities in health.[8] Some racial and ethnic subpopulations are faced with a disproportionate level of economic hardship and are also more likely to reside in neighbourhoods characterised by social and structural disadvantage.[12–14] There is very little overlap in the distributions of neighbourhood disadvantage comparing white and minority individuals[15]; even the poorest white children live in higher-opportunity neighbourhoods than the majority of black or Latino children.[16] Moreover, previous studies have reported that a large proportion of black and Latino children face the issue of 'double jeopardy' where they grow up in poor families within poor neighbourhoods (17% and 21%, respectively); this is rarely the case for white children (only 1%).[16] Studies have also described cross-level interactions between individual SES and neighbourhood disadvantage in association with health outcomes among adults[17]; however, these issues remain underexplored in relation to child weight outcomes.

Low-income and minority communities often have reduced access to supermarkets or physical activity resources, but a plethora of convenience stores, fast food outlets and other hazards like crime; these factors have been associated with poor dietary intake, lower activity levels and overweight and obesity in prior studies.[18–23] These neighbourhood factors may also contribute to racial and ethnic disparities in weight among children.[11] After accounting for neighbourhood context, a few studies among adults have reported that racial and ethnic disparities are attenuated across a number of health outcomes such as smoking,[14] use of health services,[24 25] hypertension,[26] diabetes[27] and obesity among adults.[28–31] While several studies have reported that neighbourhood factors are associated with obesity among children in the USA,[32–35] few have examined the effect of neighbourhood context on disparities in weight among youth. It is unclear whether the same patterns observed among adult samples may hold for children, who have had less time to accrue exposures to neighbourhood factors. One recent analysis using the National Longitudinal Survey of Youth reported that approximately 44–78% of the racial and ethnic disparities in BMI were explained by household sociodemographic and economic

characteristics and variables related to area-level SES, neighbourhood food availability and physical activity resources.[36] This analysis relied on self-reported height and weight, and county-level data, a large geographic unit that does not characterise an individual's neighbourhood.[37] Another study using the Early Childhood Longitudinal Study-Kindergarten Cohort (from 1998 to 1999) reported that while neighbourhood-level covariates were associated with obesity, these contextual characteristics did not explain racial and ethnic disparities.[38] This study had a number of limitations, including a high degree of missing geographic and individual-level data (18% and 16% of the sample, respectively) and very small cluster sizes (nearly 50% of the neighbourhoods included a single child). Moreover, racial and ethnic disparities were smaller among this sample than has been reported by other nationally representative studies.[1]

The objectives of this study were to examine whether neighbourhood context explains the observed racial and ethnic disparities in obesity among a nationally representative sample of children 2–18 years old and adolescents in the USA from 2001 to 2010 and whether neighbourhood deprivation interacts with individual-level SES such that children experiencing 'double jeopardy' are at heightened risk of obesity.

METHODS

Study population

Data were from 18 639 children, ages 2–18 years who completed the mobile examination component (MEC) of the National Health and Nutrition Examination Survey (NHANES) conducted from 2001 to 2010. NHANES is a cross-sectional survey of the civilian, the non-institutionalised US population conducted continuously in 2-year survey cycles.[39] Of the eligible sample, 1539 were excluded due to missing anthropometry, income, race/ethnicity or other sociodemographic data, leaving a final analytic sample of 17 100 (92%). Unweighted response rates for the total examined sample range from 75% to 80% for the five survey cycles covering 2001–2010.

NHANES uses a complex multistage probability sampling design, with some subgroups oversampled (eg, low-income and non-white persons). NHANES-restricted data files include geographic identifiers which were used to link participating children to census tracts. Census tract-level sociodemographic and economic characteristics were obtained from the US Census 2000 Summary File 3.[40]

Measures

Individual-level characteristics

Standardised weight and height measures collected in the 2001–2010 MEC of NHANES were used to calculate age-specific and sex-specific BMI percentiles for children 2–18 years old, according to the 2000 CDC growth charts.[41 42] Children were classified as obese if they had a sex-specific and age-specific BMI percentile ≥95 and overweight or obese if they had a sex-specific and age-specific BMI percentile ≥85.

Other variables include age, age-squared (to examine non-linear age effects) sex and race/ethnicity (non-Hispanic white, non-Hispanic black, Mexican-American and others). We controlled for individual-level SES by including household income-to-poverty ratio (PIR), caregiver (typically a parent or guardian), education level (less than high school, high school degree, some college or higher) and caregiver marital status (married or cohabitating, single/divorced/widowed). Sample sizes of other racial and ethnic subgroups than non-Hispanic white, non-Hispanic black and Mexican-American are small; thus, results are not presented for participants identifying as other races or ethnicities, though they were included in the analytic sample.

Neighbourhood SES/deprivation

The following socioeconomic variables were obtained from the US 2000 Census Data at the tract level: percentage of adults over 25 years with less than a high school education, percentage of men over 16 years who are unemployed, percentage of families below the Federal Poverty Threshold (FPT), percentage of households receiving public assistance, percentage of female-headed households with children and median household income. Variables were transformed for normality and direction and standardised, so that higher values indicate greater area economic deprivation and modeled continuously. Owing to collinearity of these individual variables, an index of tract-level deprivation was created by taking the mean of these six transformed and standardised variables, consistent with previous studies of health disparities and neighbourhood SES.[37 43 44] Models including the percentage of families below FPT as the sole measure of neighbourhood deprivation were also explored in sensitivity analyses, as previous studies have reported that this single variable is an acceptable proxy for neighbourhood deprivation at the census tract level.[37]

Analyses

Means, proportions and respective SEs were calculated for all individual and neighbourhood characteristics by race/ethnicity, incorporating the study design and unequal selection probabilities. Multilevel logistic regression models (MLM) were used to examine whether neighbourhood-level characteristics were associated with obesity and whether the addition of neighbourhood-level covariates attenuated weight-related disparities by race and ethnicity that remained after individual-level adjustment. Two-level models were specified, where 17 100 children were nested within 2772 census tracts. Continuous covariates were grand-mean centred to aid in interpretation of the coefficients.[45] To examine if there was a synergistic effect of both individual SES and area deprivation, a two-way cross-level interaction of tract deprivation by individual PIR was explored. Stata V.12SE GLLAMM (generalised linear latent and mixed models) commands, robust SEs and MEC sample weights were used to account for the complex sampling design of NHANES.[46 47] Weights were scaled according to methods proposed by Rabe-Hesketh and Skrondal[48]; weighting methods were compared to ensure results were robust to scaling procedure.

The first model adjusted only for race or ethnicity, age, age-squared, survey cycle and sex. Model 2 added caregiver education, PIR and caregiver marital status. Model 3 added the tract-level deprivation index and cross-level interaction term. Fit was assessed by the −2 log likelihood and the Bayesian Information Criterion (BIC), where lower values indicate better fit.[49] Primarily, fit was determined based on the BIC, as it includes a penalty based on the number of predictors in the models so as to avoid overfitting. Posterior probabilities obesity were obtained postestimation and the intraclass correlation coefficient (ICC) was calculated using the latent variable method.[50] The proportion change in variance (PCV) was calculated, which describes the proportion of neighbourhood variation in overweight or obesity that is attributable to the various covariates included in each of the models.[51] A second set of models was run with PIR and tract deprivation dichotomised (PIR≤1 and >1; deprivation ≤0 and deprivation >0) and the interaction between these categorical covariates. Coefficients for race/

ethnicity stratified by the categorical interaction between individual-level poverty and area-level deprivation are presented.

RESULTS

Sociodemographic characteristics and the prevalence of obesity among included children can be seen in table 1. The sample included 17 100 children, with a mean age of 10.1 years (95% CI 10.0 to 10.2); 59.7% identified as non-Hispanic white, 14.3% as non-Hispanic black and 13.0% as Mexican-American. Since the sample sizes of other racial and ethnic subgroups in NHANES are small, they are not reported here. Approximately 31.4% of the sample was overweight or obese and 16.6% of the sample was obese. The prevalence varied by race and ethnicity (see table 1).

The distribution of individual-level and neighbourhood-level SES characteristics was not uniform across racial and ethnic subgroups. The mean PIR for non-Hispanic white children was nearly 3 (95% CI 2.8 to 3.1), compared with 1.8 (95% CI 1.7 to 1.9) for non-Hispanic black children and 1.6 (95% CI 1.5 to 1.7) for Mexican-American children. The mean deprivation index (positive values indicate increasing area-level deprivation) for non-Hispanic white children was −0.6 (95% CI −0.6 to −0.5), in contrast to 0.3 for non-Hispanic black children (95% CI 0.3 to 0.4), and 0.1 for Mexican-American children (95% CI 0.4 to 0.2). The distributions of the neighbourhood SES characteristics that constitute the deprivation index are also shown in table 1. To quantify the proportion of children experiencing individual-level poverty and high levels of neighbourhood deprivation (ie, 'double jeopardy'), the tract deprivation index was split at 0 and individual PIR was split at 100% FPT. The distribution by race and ethnicity across these categories can be seen in table 2. Nearly 80% of non-Hispanic white children had incomes above the poverty threshold and lived in tracts lower in deprivation, as compared with only 29% of non-Hispanic black children and 31% of Mexican-American children. At the opposite end of the spectrum, only 6% of non-Hispanic white children experienced double jeopardy, in contrast to nearly 31% of non-Hispanic black children and 26% of Mexican-American children.

Table 3 describes the results of MLM of obesity. Compared to non-Hispanic white children, ORs of obesity were 50% higher for non-Hispanic black children (OR 1.5, 95% CI 1.3 to 1.7) and 60% higher for Mexican-American children (OR 1.6, 95% CI 1.4 to 1.9) in models adjusting only for survey cycle, sex and age. Model 2 adjusted only for individual-level SES (ie, PIR, caregiver marital status and education) and ORs were attenuated by 37% and 28%, respectively. In model 3, adjusted for individual-level SES and tract-level deprivation, ORs were attenuated by 69% and 43%, respectively and the ORs of obesity were no longer significantly higher for non-Hispanic black children compared with non-Hispanic white children (OR 1.1, 95% CI 0.9 to 1.3). In model 4, adjusted for the interaction between individual-level SES and area deprivation was significant; and the ORs of obesity for non-Hispanic black children were attenuated by 74% from the estimate from the first model. The ORs of obesity for Mexican-American children were attenuated by nearly 50%; however, they remained significantly higher than that observed for non-Hispanic white children (OR 1.3, 95% CI 1.1 to 1.5). Of note, the race/ethnicity coefficients are not directly comparable across the models as the estimates from model 1 are interpreted as an overall effect across all levels of deprivation and other covariates, while the estimates from model 4 are interpreted as the effect of race/ethnicity for the average child in the average tract due to the grand-mean centering of covariates.

There was a significant cross-level interaction between tract-level deprivation and individual PIR, suggesting that the effects of PIR are not uniform across the distribution of area deprivation and vice versa. Subsequently, graphical representations of significant interactions can be seen in figure 1. These figures depict the marginal effects of increasing individual PIR across levels of area deprivation (and vice versa), where effects refer to the discrete change in predicted marginal probability of

Table 1 Sociodemographic characteristics of the US children, 2–18 years, 2001–2010 (n=17 100)

	Non-Hispanic white (59.9%) Unweighted n=5198	Non-Hispanic black (14.3%) Unweighted n=4931	Mexican-American (13.0%) Unweighted n=4942	Overall N=17 100
Percentage of Obese	14.8 (13.2 to 16.4)	20.8 (19.5 to 22.1)	21.1 (19.4 to 22.8)	16.6 (15.5 to 17.7)
Age	10.3 (10.1 to 10.5)	10.1 (9.9 to 10.3)	9.5 (9.3 to 9.7)	10.1 (10.0 to 10.2)
Female	48.8 (47.3 to 50.2)	49.8 (48.4 to 51.1)	49.0 (47.4 to 50.5)	49.1 (48.1 to 50.0)
PIR	2.9 (2.8 to 3.1)	1.8 (1.7 to 1.9)	1.6 (1.5 to 1.7)	2.5 (2.4 to 2.6)
Caregiver education				
<High school (HS)	10.8 (8.8 to 12.8)	29.7 (26.8 to 32.5)	51.9 (48.6 to 55.2)	20.6 (19.0 to 22.2)
High school	24.9 (22.6 to 27.2)	25.4 (23.0 to 27.8)	20.5 (18.4 to 22.6)	23.8 (22.2 to 25.3)
Some college+	61.5 (58.3 to 64.7)	42.6 (39.6 to 45.6)	24.9 (21.7 to 28.1)	52.8 (50.7 to 54.9)
Married/cohabitating	78.2 (76.0 to 80.3)	41.0 (38.3 to 43.7)	74.8 (72.7 to 77.0)	71.6 (70.0 to 73.2)
Neighbourhood characteristics				
Deprivation index	−0.6 (−0.6 to −0.5)	0.3 (0.3 to 0.4)	0.1 (0.4 to 0.2)	−0.3 (−0.4 to −0.2)
Percentage of over 25 with <HS education	16.6 (15.3 to 17.9)	26.6 (25.5 to 27.8)	33.1 (30.9 to 35.2)	20.8 (19.8 to 21.9)
Percentage of men over 16 unemployed	4.8 (4.4 to 5.2)	9.1 (8.5 to 9.7)	7.9 (7.2 to 8.6)	6.0 (5.6 to 6.4)
Percentage of below Federal Poverty Threshold	6.8 (6.1 to 7.4)	16.9 (15.7 to 18.0)	15.1 (13.5 to 16.8)	9.9 (9.2 to 10.6)
Median household income	49 195 (46 761 to 51 630)	36 117 (34 419 to 37 816)	39 068 (37 203 to 40 934)	45 520 (43 808 to 47 231)
Percentage of women-headed households with children	5.8 (5.4 to 6.1)	14.5 (13.6 to 15.4)	9.2 (8.8 to 9.7)	7.8 (7.4 to 8.2)
Percentage of households with public assistance	2.7 (2.3 to 3.1)	6.7 (6.0 to 7.3)	5.6 (4.9 to 6.3)	3.9 (3.5 to 4.3)

Values are weighted means/proportions (95% CI).

Table 2 Distribution of individual-level poverty and tract-level deprivation among children (2–18 years) in NHANES, by race/ethnicity

	Non-Hispanic white (59.9%) Unweighted n=5198	Non-Hispanic black (14.3%) Unweighted n=4931	Mexican-American (13.0%) Unweighted n=4942	Overall N=17 100
Above poverty+lower area deprivation	74.7 (70.5 to 78.8)	29.3 (25.5 to 33.2)	31.4 (27.2 to 35.7)	59.7 (56.5 to 62.9)
Below poverty+lower area deprivation	7.8 (6.6 to 8.9)	8.9 (6.9 to 10.9)	13.7 (11.0 to 16.3)	8.6 (7.7 to 9.5)
Above poverty+higher area deprivation	11.4 (8.6 to 14.3)	31.1 (27.9 to 34.4)	28.7 (24.9 to 32.4)	18.6 (16.3 to 21.0)
Below poverty+higher area deprivation	6.1 (4.0 to 8.2)	30.6 (27.0 to 34.3)	26.3 (23.3 to 29.2)	13.1 (11.5 to 14.6)

Values are percentages within each category (95% CI).
Individual poverty is defined as PIR below 100% of the federal poverty threshold; high-area deprivation is defined as a positive value on the area deprivation index. Column percentages may not sum to exactly 100% due to rounding.
NHANES, National Health and Nutrition Examination Survey.

obesity and not to ORs. There was a positive association between area deprivation and probability of obesity among children above the poverty threshold; the marginal increase in probability of obesity associated with a 1 SD increase in the deprivation index was larger with increasing PIR. For example, area deprivation was not significantly associated with probability of obesity among children below the poverty threshold (figure 1A); but among children with incomes 300% FPT, a 1-SD increase in area deprivation was associated with roughly a 5% higher probability of obesity. Framed a different way, as neighbourhood deprivation increases, the protective effect of individual income for children living in lower-deprivation (ie, high SES) tracts diminishes and then reverses such that a positive association between income and overweight or obesity among children was observed among living in higher-deprivation tracts (figure 1B).

Overall, the PCV indicated that 20.5% of the tract-level variation in odds of obesity was attributable to individual-level characteristics (including race/ethnicity and PIR), tract-level deprivation and the cross-level interaction term included in the model (table 3). Crude and adjusted probabilities of obesity by race/ethnicity obtained from multilevel models stratified by the income-deprivation categories are presented in table 4. Racial and ethnic disparities in obesity are evident for the high-income/low-deprivation group, but disappear for the other income/deprivation categories, with the exception of the below-poverty/low-deprivation group, where there were significantly higher ORs of obesity for Mexican-American children as compared with non-Hispanic white children. The highest prevalences of obesity were observed for the higher deprivation groups.

Similar results were observed for the outcome of overweight or obesity (BMI ≥ 85%). These results can be seen in online supplementary appendix A (supplementary table S1 and figure S1).

Model evaluation and sensitivity analyses

Overall, the best fitting model included the individual sociodemographic and SES characteristics, the tract-level deprivation index and the cross-level interaction of individual PIR with tract-level deprivation. For example, the BICs for the models of obesity decreased from 13 989 for models including only limited demographic characteristics (ie, age, age-squared, sex and survey cycle) to 13 817 for the model that also included individual-level SES, area-deprivation and the interaction between the two. Sensitivity analyses included models with tract-level per cent of families below the poverty threshold (instead of the area deprivation index); results were similar to those presented, but had higher BIC values. Although the between-tract variance was reduced with the addition of tract-level characteristics, the between-tract variance remained

Table 3 Results of multilevel models examining race and ethnicity and ORs of obesity

	Model 1 Race only OR (95% CI)	Model 2 Individual characteristics OR (95% CI)	Model 3 Model 2+tract deprivation OR (95% CI)	Model 4 Model 3+interaction OR (95% CI)
Race or ethnicity				
Non-Hispanic white	Reference	Reference	Reference	Reference
Non-Hispanic black	1.5 (1.3 to 1.7)	1.3 (1.1 to 1.5)	1.1 (0.9 to 1.3)	1.1 (0.9 to 1.3)
Mexican-American	1.6 (1.4 to 1.9)	1.4 (1.2 to 1.6)	1.3 (1.1 to 1.5)	1.3 (1.1 to 1.5)
Change in black–white β from model 1 (%)		−36.5	−68.9	−73.9
Change in MA-white β from model 1 (%)		−28.1	−43.0	−49.0
PIR		1.0 (0.9 to 1.0)	1.0 (0.9 to 1.0)	1.0 (1.0 to 1.0)
Area deprivation			1.2 (1.1 to 1.3)	1.2 (1.1 to 1.3)
Interaction				1.1 (1.1 to 1.1)
ICC	0.09	0.09	0.09	0.08
PCV (%)	10.2	16.1	15.4	20.5
−2LL	13 940.2	13699.8	13676.4	13651.6
BIC	13989.0	13846.0	13832.3	13817.3

Estimates are ORs (95% CI).
Model 1 adjusts for age, age-squared, survey cycle and sex. Models 2–3 add caregiver education, caregiver marital status, and PIR. Model 3 adds the tract deprivation index. Model 4 adds the PIR by deprivation index interaction. Percentage of change in the race/ethnicity coefficients (β) are calculated on the logit scale using model 1 coefficients as the reference.
−2LL, −2 log likelihood; BIC, Bayesian Information Criterion; ICC, intraclass correlation coefficient; PCV, percent change in variance; PIR, poverty-to-income ratio.

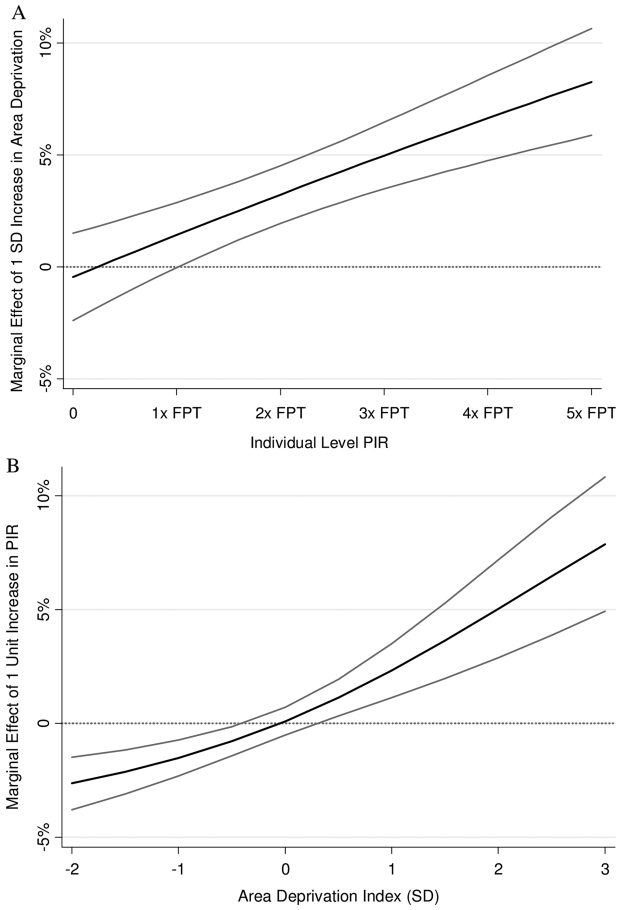

Figure 1 Interaction between individual-level poverty and tract-level deprivation in models of obesity. Marginal effects are the average marginal increase in probability of obesity associated with a one-unit increase in poverty-to-income ratio or area deprivation. Note: Marginal effects were obtained using the margins, dydx command in Stata following svy logistic regression procedures which produces the discrete change in probability of the outcome with respect to the interaction terms.

significant. Analyses using different weight scaling procedures were largely consistent with reported results, however, the estimated between-tract variation was larger and the BIC values were larger than for the models reported. The results using the second weighting method can be seen in online supplementary appendix B (supplementary tables S2 and S3).

DISCUSSION

In this multilevel analysis using a nationally representative sample of youth in the USA, estimates of disparities in obesity were significantly attenuated, by 74% for non-Hispanic black children and by 49% for Mexican-American children, after controlling for various individual-level and area-level SES characteristics and the interaction between individual-level SES and area deprivation. This study is one of the first examinations of associations between neighbourhood deprivation and racial and ethnic disparities in childhood obesity; findings are consistent with previous studies examining community-level determinants of disparities among adults.[28 52 53] Results are also consistent with a prior study of weight-related disparities among children that relied on self-report BMI and county-level SES data.[36] One recent study reported that racial/ethnic disparities were not attenuated after accounting for neighbourhood characteristics.[38]

Table 4 Crude and adjusted prevalence (95% CI) of obesity by race/ethnicity, individual poverty and area deprivation

	Prevalence (95% CI)	OR
Crude prevalence		
Non-Hispanic white	14.8 (13.2 to 16.4)	Reference
Non-Hispanic black	20.8 (19.5 to 22.1)	1.5 (1.3–1.7)*
Mexican-American	21.1 (19.4 to 22.8)	1.6 (1.4–1.9)*
Above poverty+lower area deprivation		
Non-Hispanic white	13.2 (11.7 to 14.8)	Reference
Non-Hispanic black	19.5 (17.3 to 21.8)	1.6 (1.4–1.9)*
Mexican-American	16.5 (14.0 to 19.1)	1.3 (1.0–1.7)*
Below poverty+lower area deprivation		
Non-Hispanic white	16.0 (12.3 to 19.7)	Reference
Non-Hispanic black	17.0 (11.0 to 23.0)	1.1 (0.6–1.8)
Mexican-American	22.4 (18.2 to 26.7)	1.5 (1.0–2.3)*
Above poverty+higher area deprivation		
Non-Hispanic white	22.3 (18.4 to 26.2)	Reference
Non-Hispanic black	20.4 (18.1 to 22.8)	0.9 (0.7–1.2)
Mexican-American	22.0 (19.5 to 24.5)	1.0 (0.7–1.3)
Below poverty+higher area deprivation		
Non-Hispanic white	21.4 (16.7 to 26.2)	Reference
Non-Hispanic black	20.9 (18.1 to 23.7)	1.0 (0.7–1.4)
Mexican-American	23.2 (20.2 to 26.3)	1.1 (0.8–1.5)

ORs (OR; 95% CI) for racial/ethnic disparities are also shown; non-Hispanic white children are the reference group.
*Indicates p<0.05. Individual poverty is defined as poverty-to-income ratio below 100% of the federal poverty threshold; tract deprivation is defined as a positive value on the area deprivation index.

However, results of this analysis are not directly comparable as that study relied on data on very young children (5–6 years) in 1998–1999 and included a number of intervening individual-level characteristics, potentially contributing to over-adjustment and biased estimations of neighbourhood-level effects.[54]

There was a significant interaction between neighbourhood deprivation and individual-level SES whereby neighbourhood deprivation was significantly associated with higher ORs of obesity among children above the poverty threshold. The effect of greater area-level deprivation was stronger for higher income children, as compared to lower income children, which is contrary to the notion that children experiencing 'double jeopardy' are at increased risk due to the potentially synergistic effects of individual or neighbourhood poverty in isolation.

While individual-level income was protective against obesity among children living in lower deprivation neighbourhoods, it was positively associated with greater ORs of obesity among children living in higher-deprivation tracts. This interaction could help to explain some of the complex SES gradients in risk of obesity by race and ethnicity that have been reported in previous studies[5 9 55] where there are 'diminishing returns' of the effect of increasing individual SES on health outcomes for racial and ethnic subpopulations as compared to non-Hispanic white individuals.[56] For example, previous studies have found that the inverse association between income and obesity is stronger for white children than for black children and that for some subgroups income is positively associated with obesity.[5 9 55] These studies have not examined neighbourhood deprivation or SES in the context of these patterns. Results of this study suggest that the 'diminishing returns' of increasing income seen among certain racial and ethnic subpopulations may be related to the higher levels of neighbourhood deprivation experienced by these groups in comparison to non-Hispanic white individuals.

In the context of higher levels of neighbourhood deprivation, greater individual-level income was associated with increased risk of obesity among children in this sample. Given that the majority of black or Latino children live in more disadvantaged communities than even the poorest white children,[16] the deleterious effects of living in higher deprivation neighbourhoods are more relevant for these racial and ethnic subgroups as compared with non-Hispanic white children, regardless of individual-level income.

Research that relies solely on individual-level measures of SES may mask racial and ethnic differences in environments.[57 58] Low-income and minority communities often have reduced access to supermarkets or physical activity resources, but a plethora of convenience stores, fast food outlets and other hazards like crime; these factors have been associated with poor dietary intake, lower activity levels and overweight and obesity in prior studies.[18–23] These community characteristics could help explain the interaction between individual SES and area deprivation, as it is possible that these neighbourhood factors are more influential for higher income children than those in poverty. For example, higher income children may not face the same financial barriers to purchasing convenience or fast food as children in poverty. The potential mediating pathways through which the built and social environments influence weight-related disparities remain unclear, as most studies of disparities in child obesity have focused on individual/family characteristics such as parent education/SES, sedentary behaviours (eg, TV watching), dietary behaviours (eg, snacking, fast food, sugar-sweetened beverage consumption), physical activity and breastfeeding.[59 60]

This study has a few limitations, the first of which is the preclusion of causal inferences due to the reliance on cross-sectional, observational data. Second, SES at both the tract and individual level were assessed at one point in time using a limited number of variables, which do not capture chronic, multidimensional and potentially time-varying exposures[61]; there may have been change in neighbourhood SES over time, resulting in misclassification of exposure based on data from the 2000 US Census. In dichotomising area deprivation, a cut-point of 0 was chosen to ensure adequate sample sizes by race and ethnicity within the groups. However, this cut-point was arbitrary, as values above or below 0 do not necessarily correspond to high or low deprivation, respectively. A related limitation is the broad categorisation of race and ethnicity, which does not encapsulate the diversity within and across various racial and ethnic subpopulations. Third, quality data on potentially mediating community-level characteristics such as availability of food or physical activity resources in the community do not exist on a national scale in the USA, precluding the examination of pathways by which neighbourhood SES may influence weight outcomes. Dietary intake or physical activity were not examined, as the inclusion of these intervening variables leads to over-adjustment, biasing estimates of neighbourhood-outcome associations.[54] More research is needed to explore the pathways by which deprivation is associated with differential opportunities and exposures to risks in the environment, which then may deter or promote health behaviours to ultimately influence health outcomes and related disparities.

Despite the above limitations, this study has several strengths. This is one of the first studies to examine the context of racial and ethnic disparities in childhood obesity using a nationally representative sample of US children with measured height and weight data. The inclusion of individual-level SES, area-level deprivation and the interaction between these two factors resulted in substantially attenuated estimates of disparities in obesity by race and ethnicity. Disparities between non-Hispanic black and non-Hispanic white children were attenuated by 74% and disparities between Mexican-American and non-Hispanic white children were attenuated by 49%. Future research on disparities in obesity and other health outcomes should examine broader contextual factors and social determinants of inequities.

What is already known on this subject

- Previous research has shown that racial/ethnic disparities in health outcomes among adults are attenuated after controlling for neighbourhood context. Few studies have examined racial/ethnic disparities in childhood obesity in the context of neighbourhood and individual-level socioeconomic factors.

What this study adds

- Racial/ethnic disparities in obesity among the US youth are attenuated after controlling for area deprivation and there was a significant interaction between area deprivation and individual-level income. Income was protective against obesity for children living in low-deprivation areas, but positively associated with obesity for children in high-deprivation areas.

Competing interests None.

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REFERENCES

1 Ogden CL, Carroll MD, Kit BK, *et al*. Prevalence of obesity and trends in body mass index among US children and adolescents, 1999–2010. *JAMA* 2012;307:483–90.
2 Daniels SR, Arnett DK, Eckel RH, *et al*. Overweight in children and adolescents: pathophysiology, consequences, prevention, and treatment. *Circulation* 2005;111:1999–2012.
3 Lobstein T, Baur L, Uauy R, *et al*. Obesity in children and young people: a crisis in public health. *Obes Rev* 2004;5(Suppl 1):4–104.
4 Beydoun MA, Wang Y. Socio-demographic disparities in distribution shifts over time in various adiposity measures among American children and adolescents: What changes in prevalence rates could not reveal. *Int J Pediatr Obes* 2010;6:21–35.
5 Scharoun-Lee M, Kaufman JS, Popkin BM, *et al*. Obesity, race/ethnicity and life course socioeconomic status across the transition from adolescence to adulthood. *J Epidemiol Community Health* 2009;63:133–9.
6 Singh GK, Siahpush M, Kogan MD. Rising social inequalities in US childhood obesity, 2003–2007. *Ann Epidemiol* 2010;20:40–52.
7 Anderson SE, Whitaker RC. Prevalence of obesity among US preschool children in different racial and ethnic groups. *Arch Pediatr Adolesc Med* 2009;163:344–8.
8 Do DP, Finch BK, Basurto-Davila R, *et al*. Does place explain racial health disparities? Quantifying the contribution of residential context to the Black/white health gap in the United States. *Soc Sci Med* 2008;67:1258–68.
9 Wang Y. Disparities in pediatric obesity in the United States. *Adv Nutr* 2011;2:23–31.
10 White K, Borrell LN. Racial/ethnic residential segregation: framing the context of health risk and health disparities. *Health Place* 2011;17:438–48.
11 Yancey AK, Kumanyika SK. Bridging the gap: understanding the structure of social inequities in childhood obesity. *Am J Prev Med* 2007;33:S172–4.
12 LaVeist TA. Disentangling race and socioeconomic status: a key to understanding health inequalities. *J Urban Health* 2005;82:26–34.
13 Laveist TA. Minority populations and health: an introduction to health disparities in the United States. San Francisco, CA: Jossey-Bass, 2005.

14 Laveist TA, Thorpe RJ Jr, Mance GA, *et al*. Overcoming confounding of race with socio-economic status and segregation to explore race disparities in smoking. *Addiction* 2007;102(Suppl 2):65–70.
15 Osypuk TL, Galea S, McArdle N, *et al*. Quantifying separate and unequal: racial-ethnic distributions of neighborhood poverty in metropolitan America. *Urban Aff Rev* 2009;45:25–65.
16 Acevedo-Garcia D, Osypuk TL, McArdle N, *et al*. Toward a policy-relevant analysis of geographic and racial/ethnic disparities in child health. *Health Aff (Millwood)* 2008;27:321–33.
17 Finch BK, Phuong Do D, Heron M, *et al*. Neighborhood effects on health: concentrated advantage and disadvantage. *Health Place* 2010;16:1058–60.
18 Gordon-Larsen P, Nelson MC, Page P, *et al*. Inequality in the built environment underlies key health disparities in physical activity and obesity. *Pediatrics* 2006;117:417–24.
19 Larson NI, Story MT, Nelson MC. Neighborhood environments: disparities in access to healthy foods in the U.S. *Am J Prev Med* 2009;36:74–81.
20 Lovasi GS, Hutson MA, Guerra M, *et al*. Built environments and obesity in disadvantaged populations. *Epidemiol Rev* 2009;31:7–20.
21 Papas MA, Alberg AJ, Ewing R, *et al*. The built environment and obesity. *Epidemiol Rev* 2007;29:129–43.
22 Sallis JF, Glanz K. The role of built environments in physical activity, eating, and obesity in childhood. *Future Child* 2006;16:89–108.
23 Slater SJ, Ewing R, Powell LM, *et al*. The association between community physical activity settings and youth physical activity, obesity, and body mass index. *J Adolescent Health* 2010;47:496–503.
24 Gaskin DJ, Dinwiddie GY, Chan KS, *et al*. Residential segregation and disparities in health care services utilization. *Med Care Res Rev* 2011;69:158–75.
25 Gaskin DJ, Price A, Brandon DT, *et al*. Segregation and disparities in health services use. *Med Care Res Rev* 2009;66:578–89.
26 Thorpe RJ Jr, Brandon DT, LaVeist TA. Social context as an explanation for race disparities in hypertension: findings from the Exploring Health Disparities in Integrated Communities (EHDIC) Study. *Soc Sci Med* 2008;67:1604–11.
27 LaVeist TA, Thorpe RJ Jr, Galarraga JE, *et al*. Environmental and socio-economic factors as contributors to racial disparities in diabetes prevalence. *J Gen Intern Med* 2009;24:1144–8.
28 Bleich SN, Thorpe RJ Jr, Sharif-Harris H, *et al*. Social context explains race disparities in obesity among women. *J Epidemiol Community Health* 2010;64:465–9.
29 Do DP, Dubowitz T, Bird CE, *et al*. Neighborhood context and ethnicity differences in body mass index: a multilevel analysis using the NHANES III survey (1988–1994). *Econ Hum Biol* 2007;5:179–203.
30 Robert SA, Reither EN. A multilevel analysis of race, community disadvantage, and body mass index among adults in the US. *Soc Sci Med* 2004;59:2421–34.
31 Ruel E, Reither EN, Robert SA, *et al*. Neighborhood effects on BMI trends: examining BMI trajectories for Black and White women. *Health Place* 2010;16:191–8.
32 Grow HM, Cook AJ, Arterburn DE, *et al*. Child obesity associated with social disadvantage of children's neighborhoods. *Soc Sci Med* 2010;71:584–91.
33 Lumeng JC, Appugliese D, Cabral HJ, *et al*. Neighborhood safety and overweight status in children. *Arch Pediatr Adolesc Med* 2006;160:25–31.
34 Nelson MC, Gordon-Larsen P, Song Y, *et al*. Built and social environments associations with adolescent overweight and activity. *Am J Prev Med* 2006;31:109–17.
35 Singh GK, Siahpush M, Kogan MD. Neighborhood socioeconomic conditions, built environments, and childhood obesity. *Health Aff (Millwood)* 2010;29:503–12.
36 Powell LM, Wada R, Krauss RC, *et al*. Ethnic disparities in adolescent body mass index in the United States: the role of parental socioeconomic status and economic contextual factors. *Soc Sci Med* 2012;75:469–76.
37 Krieger N, Chen JT, Waterman PD, *et al*. Geocoding and monitoring of US socioeconomic inequalities in mortality and cancer incidence: does the choice of area-based measure and geographic level matter? The Public Health Disparities Geocoding Project. *Am J Epidemiol* 2002;156:471–82.
38 Kimbro RT, Denney JT. Neighborhood context and racial/ethnic differences in young children's obesity: structural barriers to interventions. *Soc Sci Med* 2012;95:97–105.
39 National Center for Health Statistics. National Health and Nutrition Examination Survey: Questionnaires, datasets, and related documentation. http://www.cdc.gov/nchs/nhanes/nhanes_questionnaires.htm
40 U.S. Department of Commerce Bureau of the Census. *Census of population and housing, 2000: summary file 3*. Washington, DC: U.S. Department of Commerce, Bureau of the Census, 2002.
41 Kuczmarski RJ, Ogden CL, Grummer-Strawn LM, *et al*. CDC growth charts: United States. *Adv Data* 2000;314:1–27.
42 Kuczmarski RJ, Ogden CL, Guo SS, *et al*. 2000 CDC growth charts for the United States: methods and development. *Vital Health Stat* 2002;11:1–190.
43 Escarce J, Lurie N, Jewell A. RAND Center for Population Health and Health Disparities (CPHHD) data core series: segregation indices, 1990–2000. Ann Arbor, MI: Inter-university Consortium for Political and Social Research, 2011.
44 Messer LC, Laraia BA, Kaufman JS, *et al*. The development of a standardized neighborhood deprivation index. *J Urban Health* 2006;83:1041–62.
45 Kreft IGG, Deleeuw J, Aiken LS. The effect of different forms of centering in hierarchical linear-models. *Multivar Behav Res* 1995;30:1–21.
46 Rabe-Hesketh S, Skrondal A, Pickles A. GLLAMM manual. UC Berkeley division of biostatistics working paper series. Berkeley, CA, USA, 2004.
47 StataCorp. Stata Statistical Software. College Station, TX: StataCorp LP, 2011.
48 Rabe-Hesketh S, Skrondal A. Multilevel modelling of complex survey data. *Journal of the Royal Statistical Society: Series A* 2006;169:805–27.
49 Andel J, Perez MG, Negrao AI. Estimating the dimension of a linear-model. *Kybernetika* 1981;17:514–25.
50 Merlo J, Chaix B, Ohlsson H, *et al*. A brief conceptual tutorial of multilevel analysis in social epidemiology: using measures of clustering in multilevel logistic regression to investigate contextual phenomena. *J Epidemiol Community Health* 2006;60:290–7.
51 Merlo J, Chaix B, Yang M, *et al*. A brief conceptual tutorial of multilevel analysis in social epidemiology: linking the statistical concept of clustering to the idea of contextual phenomenon. *J Epidemiol Community Health* 2005;59:443–9.
52 Chang VW. Racial residential segregation and weight status among US adults. *Soc Sci Med* 2006;63:1289–303.
53 Corral I, Landrine H, Hao Y, *et al*. Residential segregation, health behavior and overweight/obesity among a national sample of African American adults. *J Health Psychol* 2012;17:371–8.
54 Schisterman EF, Cole SR, Platt RW. Overadjustment bias and unnecessary adjustment in epidemiologic studies. *Epidemiology* 2009;20:488–95.
55 Wang Y, Zhang Q. Are American children and adolescents of low socioeconomic status at increased risk of obesity? Changes in the association between overweight and family income between 1971 and 2002. *Am J Clin Nutr* 2006;84:707–16.
56 Farmer MM, Ferraro KF. Are racial disparities in health conditional on socioeconomic status? *Soc Sci Med* 2005;60:191–204.
57 Acevedo-Garcia D, Osypuk TL. Invited commentary: residential segregation and health—the complexity of modeling separate social contexts. *Am J Epidemiol* 2008;168:1255–8.
58 Zhang Q, Wang Y. Socioeconomic inequality of obesity in the United States: do gender, age, and ethnicity matter? *Soc Sci Med* 2004;58:1171–80.
59 Singh GK, Kogan MD, Van Dyck PC, *et al*. Racial/ethnic, socioeconomic, and behavioral determinants of childhood and adolescent obesity in the United States: analyzing independent and joint associations. *Ann Epidemiol* 2008;18:682–95.
60 Taveras EM, Gillman MW, Kleinman K, *et al*. Racial/ethnic differences in early-life risk factors for childhood obesity. *Pediatrics* 2010;125:686–95.
61 Do DP. The dynamics of income and neighborhood context for population health: do long-term measures of socioeconomic status explain more of the black/white health disparity than single-point-in-time measures? *Soc Sci Med* 2009;68:1368–75.