SSM - Population Health 2 (2016) 692–699

Contents lists available at ScienceDirect

SSM - Population Health

journal homepage: www.elsevier.com/locate/ssmph

Article

Neighborhood racial composition and poverty in association with pre-pregnancy weight and gestational weight gain

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ARTICLE INFO

Keywords:
Neighborhood
Race
Poverty
Pregnancy
Weight

ABSTRACT

Background: Studies of neighborhood racial composition or neighborhood poverty in association with pregnancy-related weight are limited. Prior studies of neighborhood racial density and poverty has been in association with adverse birth outcomes and suggest that neighborhoods with high rates of poverty and racial composition of black residents are typically segregated and systematically isolated from opportunities and resources. These neighborhood factors may help explain the racial disparities in pre-pregnancy weight and inadequate weight gain. This study examined whether neighborhood racial composition and neighborhood poverty was associated with weight before pregnancy and weight gain during pregnancy and if this association differed by race.

Methods: We used vital birth records of singleton births of 73,061 non-Hispanic black and white women in Allegheny County, PA (2003–2010). Maternal race and ethnicity, pre-pregnancy body-mass-index (BMI), gestational weight gain and other individual-level characteristics were derived from vital birth record data, and measures of neighborhood racial composition (percentage of black residents in the neighborhood) and poverty (percentage of households in the neighborhood below the federal poverty) were derived using US Census data. Multilevel log binomial regression models were performed to estimate neighborhood racial composition and poverty in association with pre-pregnancy weight (i.e., overweight/obese) and gestational weight gain (i.e., inadequate and excessive).

Results: Black women as compared to white women were more likely to be overweight/obese before pregnancy and to have inadequate gestational weight gain (53.6% vs. 38.8%; 22.5% vs. 14.75 respectively). Black women living in predominately black neighborhoods were slightly more likely to be obese prior to pregnancy compared to black women living in predominately white neighborhoods (PR 1.10; 95% CI: 1.03, 1.16). Black and white women living in high poverty areas compared with women living in lower poverty areas were more likely to be obese prior to pregnancy; while only white women living in high poverty areas compared to low poverty areas were more likely gain an inadequate amount of weight during pregnancy.

Conclusions: Neighborhood racial composition and poverty may be important in understanding racial differences in weight among childbearing women.

Introduction

More than half of reproductive age women are overweight prior to pregnancy and almost half exceed the recommended amount of weight gain during pregnancy (Dalenius et al., 2012). Pre-pregnancy weight and gestational weight gain (GWG) are associated with infant and child weight with poor pregnancy weight gain being associated with adverse birth outcomes such as preterm birth (Li et al., 2013; Diesel et al.,

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http://dx.doi.org/10.1016/j.ssmph.2016.09.008
Received 27 April 2016; Received in revised form 25 September 2016; Accepted 27 September 2016

2015); pregnancy complications (Truong et al., 2015); and postpartum weight retention where women who enter pregnancy overweight or obese are more likely to retain the weight after delivery (Haugen et al., 2014; Davis, Stange & Horwitz, 2012). Additionally, there are racial disparities in pregnancy weight gain where non-Hispanic black women are more likely to be obese at the start of pregnancy but to have inadequate weight gain (i.e., not gain enough according to Institute of Medicine guidelines) during pregnancy compared to non-Hispanic white women (Headen et al., 2012). Nevertheless, the reasons for racial disparities in pregnancy-related weight are not well understood (Headen et al., 2012; IOM, 2009; Bodnar et al., 2011).

Previous studies have examined potential factors, including individual income, education, diet, smoking, and body image, that may explain the racial differences in pregnancy-related weight (Headen et al., 2012; Walker et al., 2004). Although individual, proximate risk factors may be important, social ecological models articulate that the multiple levels of influence—individual, family, community, society—can act synergistically to affect health and contribute to racial disparities (Golden & Earp, 2012). Thus, researchers have examined the larger context in relation to health outcomes (Link & Phelan, 1995), including whether the neighborhood environment may be a major determinant of maternal obesity or gestational weight gain (Davis et al., 2012; Headen et al., 2012; Vinikoor-Imler et al., 2011; Laraia et al., 2007; Sellstrom et al., 2009; Mendez et al., 2014). Neighborhood or residential environments may influence pregnancy-related weight in several ways. The neighborhood can include aspects of the social environment, including community relations, cohesion or stability and political power; the service environment, including access to healthcare or resources for healthful eating and physical activity; and the physical environment, including the built environment or environmental exposures, which are theorized to be important for women throughout the life-course (Vinikoor-Imler et al., 2011; Laraia et al., 2007; Laraia et al., 2004; Schempf, Strobino & O'Campo, 2009; Culhane and Elo, 2005).

Neighborhood and place-based research cite residential racial segregation (henceforth: segregation) as fundamental in understanding differences in neighborhood environments by race and as a key determinant of racial health disparities due to racial differences in exposure to other adverse risks such as neighborhood crime, exposure to toxins, and neighborhood poverty (Williams & Collins, 2001; Ludwig et al., 2011; Masi et al., 2007). Segregated environments influence diet, physical activity, and related behaviors before and during pregnancy (Morland, Wing & Roux, 2002; Bell et al., 2007; Lopez, 2006; Dubowitz et al., 2008), and segregation as a result of institutional and personally-mediated racism may be stressful for women (Mendez, Hogan & Culhane, 2012), leading to inappropriate gestational weight gain and obesity (Davis et al., 2012). On the other hand, in the face of differential exposure to adverse neighborhood conditions by race, it is hypothesized that high racial/ethnic composition or group density, sometimes referred as ethnic enclaves, can confer a protective or health-promoting effect, buffering populations of color from discrimination and other forms of marginalization (Bell et al., 2006). Prior studies of neighborhood racial/ethnic composition or density and pregnancy-related outcomes have found a higher risk of low birth weight and preterm birth with increasing neighborhood density among US-born black infants (Masi et al., 2007; Shaw, Pickett & Wilkinson, 2010) as well as a higher risk of preterm birth among black and white women living in neighborhoods of high black racial composition (Mason et al., 2009). Another study demonstrated similar findings, which was more pronounced among poorer neighborhoods compared to wealthier neighborhoods (Mason et al., 2010).

However, prior studies have not specifically examined neighborhood racial composition or density in association with pregnancy-related weight such as weight prior to pregnancy and gestational weight gain, and the potential intersections with individual race and neighborhood income or poverty. One prior study specifically examined the intersections between residential segregation and an individual's race/ethnicity found that the effects of residential segregation on self-reported health were conditioned upon individual race/ethnicity (Gibbons & Yang, 2014). Another study found that high neighborhood socioeconomic disadvantage was associated with inadequate weight gain (i.e., not enough) and weight loss during pregnancy (Mendez et al., 2014). The present study examines neighborhood racial composition in association with pre-pregnancy BMI (i.e., overweight/obesity) and gestational weight gain (i.e., inadequate and excessive). Additionally, we examine whether neighborhood poverty specifically modifies the association. Given the racial disparities in overweight/obesity prior to pregnancy and inadequate weight gain during pregnancy, we hypothesize that black women living in neighborhoods that are predominately black or white will have the highest risk of inadequate weight gain and pre-pregnancy overweight/obesity compared with all other groups due to the inequitable neighborhood conditions and resultant stressors (Kramer & Hogue, 2009).

Methods

Population and data sources

Individual-level pregnancy data were obtained from birth records of infants born in Allegheny County, Pennsylvania (PA) from 2003–2010. PA adopted the revised U.S. Standard Certificates of Live Birth and Death in 2003, which included the collection of maternal weight and height data (C.D.C., 2003). We studied all women who self-reported their race/ethnicity as non-Hispanic black or non-Hispanic white and who delivered singleton infants with no congenital anomalies from 20 to 42 week gestation (n= n=92,597). We excluded records of births with missing data for pre-pregnancy BMI [includes height and weight] (n=12,080), gestational weight gain (n=5,555), key covariates included in our final models (n=1839), unknown census tracts (n=56), and census tracts with less than 5 births (n=6). The final sample analytic sample included 73,061 births. We addressed the missing outcome data (weight and height) by applying multiple imputation (described below) and comparing results with a complete case analysis (n=73,061).

We linked birth data with 2000 US census data for measures of neighborhood racial composition (i.e., percentage black residents in the census tract) and neighborhood poverty. We examined trend differences in racial composition and neighborhood poverty for US Census data for 2000 and 2010. Since there was not a significant change in neighborhood racial composition (overall mean: 14.0 (SD: 24.0)% black in 2000 and 16.5 (SD: 24.1)% black in 2010) and neighborhood poverty (overall mean: 11.8 (SD: 11.2)% poverty in 2000 and 13.7 (SD: 12.1)% poverty in 2010) during this time period (results not shown), we used 2000 US Census data given that it predates the births included in this study.

Each mother's home address at delivery was recorded in the birth record, geocoded by the Allegheny County Health Department using ArcGIS software version 10.1 (Redlands, California), and assigned a corresponding census tract. The census tract (a proxy of neighborhood) is a geographic unit defined by the U.S. Census, which includes an average of 4000 residents (between 1000 and 8000) (CensusBureau, 2001). Although other administrative units (e.g., block groups) have been used in neighborhood research, census tracts provide a meaningful geographic unit for maternal and child health outcomes and also demonstrate similar findings when comparing census tracts versus block groups as units that serve as a proxy for neighborhood (Messer, Vinikoor-Imler & Laraia, 2012; Mendez, Hogan & Culhane, 2013). There were a total of 416 census tracts in the study area, and our final analytic sample included 413 census tracts since we excluded tracts with less than 5 women per tract. There was a mean of 177 (range: 5 to 694) women per tract.

Outcome measures: Pre-pregnancy BMI and gestational weight gain/loss

Pre-pregnancy BMI was calculated as pre-pregnancy weight (kg) divided by height (meters) squared. Similar to other self-reported data, pre-pregnancy weight and height were collected on a form called the "Mother's Worksheet," which is reported by the mother via interview by hospital staff before hospital discharge (C.D.C., 2003). This information can also be ascertained from the mother's prenatal care record or medical record. BMI was categorized as underweight (BMI < 18.5), normal weight (18.5- < 25), overweight (25- < 30), and obese all classes (BMI 30+) based on the World Health Organization (WHO) cut points (WHO, 2006).

Gestational weight gain was calculated as weight at delivery minus pre-pregnancy weight. Weight at delivery is ascertained on the "Facility Worksheet," which is completed by hospital personnel and may be based on self-reported weight or measured weight from labor and delivery records (C.D.C., 2003). Adequacy of gestational weight gain was calculated as the ratio of observed gestational weight gain to expected (recommended) weight gain according to the 2009 Institute of Medicine (IOM) guidelines (IOM, 2009) at the gestational age of delivery, as described previously (Bodnar et al., 2010). Gestational weight gain was categorized as inadequate (less than the lower limit of recommendations), adequate (within recommended range), or excessive (greater than the upper limit of recommendations).

Neighborhood-level exposures

A census-tract level measure of neighborhood racial composition was created. The general population for the study area is predominately black and white so we defined neighborhood racial composition as the percentage of black residents within the census tract was categorized as follows: 0 to less than 33% (low % black/predominately white), 33% to less than 66% (racially mixed), and 66–100% (predominately black) (LaVeist, 2003). We created a variable describing the neighborhood percentage of black residents within the census tract (US Census data) and the individual race of women (vital birth record data). However, with further analysis, there was lack of variability of neighborhood racial composition among non-Hispanic white women so the analysis examining neighborhood racial composition and pregnancy-related weight was conducted among non-Hispanic black women only.

Neighborhood poverty was calculated from US Census data as the percentage of households within the census tract below the federal poverty line. The continuous poverty measure (0–100% poverty) was divided into quartiles based on the entire population of Allegheny County, PA births from 2003–2010 before exclusions were applied and where about 10% of all births occurred in neighborhoods with greater than 25% of households living in poverty. The quartiles were low poverty (0- < 5% of households below the federal poverty line), low-mid poverty (5- < 8%), mid-high (8- < 15%), and high (15–100%).

Individual-level measures

Individual covariates were primarily collected through self-report. Maternal race/ethnicity data included in the birth record was measured based on the minimum categories described by the Office of Management and Budget (http://www.whitehouse.gov/omb/fedreg_1997standards). Our study population included US and foreign-born non-Hispanic black and non-Hispanic white (henceforth called black and white) and not women of mixed race or who did not identify as black or white due to the small number of women from other racial and ethnic categories within the study region. We considered several individual measures as potential confounders in our analyses: maternal education (less than high school, high school graduate, some college, or college graduate), marital status (married or unmarried), maternal age (< 20, 20–29, ≥30), previous live births (0, 1, ≥2), use of the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) during pregnancy (yes or no), and smoking during pregnancy (smoker or nonsmoker).

Missing data and multiple imputation

To address missing data for pre-pregnancy BMI and gestational weight gain, we imputed 10 datasets (multiple imputation relative efficiency= 98%) using Markov Chain Monte Carlo with a Fully Conditional Specification (Rubin, 1987). We imputed pre-pregnancy BMI and gestational weight gain by including maternal race/ethnicity, marital status, maternal education, maternal age, receipt of WIC, insurance status, parity, smoking status during pregnancy, gestational age, year of birth, and census tract in the imputed models. The results from the multiple imputation procedure were obtained by averaging estimates across the 10 imputed datasets. We conducted a sensitivity analysis by comparing the imputed results with the results of the complete dataset. Since the results from the imputed datasets and the complete datasets were similar (data not shown), we present the multivariable results from the imputed datasets.

Statistical analysis

We determined the intraclass correlation (ICC) to assess variability within versus between neighborhoods (census tracts) from an empty model (i.e., model without covariates) (Raundenbush & Bryk, 2002). The ICC for excessive weight gain and inadequate weight gain as outcomes was 0.7% and 2.6% respectively. However, the ICC for pre-pregnancy overweight and obesity was higher at 2.3% and 8.6% respectively. The ICC for pre-pregnancy overweight/obesity indicates that there is significant clustering within neighborhoods for pre-pregnancy weight so this study includes multi-level/hierarchical models for all subsequent analyses.

We wanted to avoid over-adjustment for individual characteristics in regression models. As a result, we selected potential covariates using theory-based causal models, previous studies (Messer et al., 2012), and characteristics that are reliably reported in the birth certificate. Final confounders were based on the change of at least 10% in the adjusted prevalence ratio.

We fit a series of multilevel log binomial (i.e., inadequate weight gain and excessive weight gain each versus adequate weight gain; obese and overweight each versus normal weight) regression models to calculate prevalence ratios. Our multilevel models included 2 levels: level-1 the individual-level variables and level-2 the neighborhood (i.e., census tract) level. Individuals were nested within census tracts. We fit unadjusted models that included either neighborhood racial composition alone or neighborhood poverty alone, then assessed neighborhood racial composition adjusted for neighborhood poverty and then finally fit a series of models adjusted for individual-level covariates. We assessed effect measure modification on the multiplicative scale (i.e., statistical interaction) between neighborhood racial composition and neighborhood poverty and between maternal race/ethnicity and neighborhood poverty. Our final models adjusted for maternal education, marital status, and pre-pregnancy BMI for gestational weight gain outcomes and use of WIC for pre-pregnancy BMI outcomes. All analyses were conducted using SAS software version 9.3 (Cary, NC). The University of Pittsburgh Institutional Review Board approved this study.

Results

Descriptive and bivariate results

The women with complete data compared with women missing data were more likely to be white (80% vs. 71%) or married (64% vs. 46%), and live in neighborhoods (i.e., census tracts) with 0–33% black

Table 1
Population individual and neighborhood characteristics for all women and by maternal race, Allegheny County, PA, 2003–2010.

	All (n=73,061)	Black (n=14,292; 19.6%)	White (n=58,769; 80.4%)
	Total N (%)	Total N (%)	Total N (%)
Married (yes)	46491 (63.6)	2557 (17.9)	43934 (74.8)
Maternal Education			
No Diploma	6073 (8.3)	2886 (20.2)	3187 (5.4)
HS/GED	15241 (20.9)	5033 (35.2)	10208 (17.4)
Some College	20621 (28.2)	4658 (32.6)	15963 (27.2)
College Grad and Beyond	31126 (42.6)	1715 (12.0)	29411 (50.0)
Used WIC (yes)	22263 (30.5)	9438 (66.0)	12825 (21.8)
Insurance Status			
Private Insurance	40380 (55.3)	3529 (24.7)	36851 (62.7)
Medicaid	15746 (21.5)	7024 (49.2)	8722 (14.8)
Self-Pay	390 (0.5)	90 (0.6)	300 (0.5)
Other	487 (0.7)	353 (0.6)	134 (27.5)
Missing	16058 (22.0)	3515 (21.9)	12543 (21.3)
Number of previous live births			
Zero	37294 (51.1)	6767 (47.4)	30527 (51.9)
One	30420 (41.6)	5699 (39.9)	24721 (42.1)
Two or more	5347 (7.3)	1826 (12.8)	3521 (6.0)
Cigarettes Use During Pregnancy (yes)	12976 (17.8)	3211 (22.5)	9765 (16.6)
Maternal Age			
< 20	5545 (7.6)	3016 (21.1)	2529 (4.3)
20–29	33243 (45.5)	8166 (57.1)	25077 (42.7)
30+	34273 (46.9)	3110 (21.8)	31163 (53.0)
Neighborhood Characteristics			
Neighborhood Racial Composition			
Non-Black (0- < 33% black)	63574 (87.0)	6723 (47.0)	56851 (96.7)
Mixed (33–66% black)	3993 (5.5)	2705 (19.0)	1288 (2.2)
Black (> 66–100% black)	5494 (7.5)	4864 (34.0)	630 (1.1)
Neighborhood Poverty			
Low (0- < 5%)	21252 (29.1)	538 (3.8)	20714 (35.3)
Low-Mid (5- < 8%)	16770 (23.0)	1229 (8.6)	15541 (26.4)
Mid-High (8- < 15%)	19080 (26.1)	3616 (25.3)	15464 (26.3)
High (15–100%)	15959 (21.8)	8909 (62.3)	7050 (12.0)

residents (87% vs. 81%). Almost 20% of the women included in the study identified as black, and most women in the study were married, college-educated, nulliparous, nonsmokers, lived in low-poverty neighborhoods and those with less than 33% black residents (Table 1). When we examined individual and neighborhood characteristics by race, black women were more likely to be unmarried, have a high school education, use WIC, have Medicaid-funded deliveries, live in predominately black or mixed neighborhoods, and live in high poverty neighborhoods compared with white women.

Approximately, 23% of women were overweight and 19% were obese before pregnancy and 59% of women gained an excessive amount of weight during pregnancy. Black women compared with white women were more likely to be overweight or obese pre-pregnancy and to have inadequate pregnancy weight gain (Table 2).

Table 3 displays the prevalence of pre-pregnancy BMI and gestational weight gain by maternal and neighborhood characteristics. Women who were married, nulliparous, age 20 years and older, had a college degree or greater, did not use WIC services, were nonsmokers during pregnancy, lived in neighborhoods with at least 33% black residents, lived in low poverty neighborhoods, and were white women in non-black/predominately white neighborhoods were most likely to be normal weight. Women who were underweight, unmarried, with no high school diploma, used WIC, had 2 or more previous live births, used cigarettes, were younger than 20, lived in predominantly black neighborhoods, high poverty neighborhoods, and were black women living in black neighborhoods were more likely to have inadequate pregnancy weight gain.

Table 2
Prevalence of Pre-Pregnancy Weight and Gestational Weight Gain for all women and by maternal race, Allegheny County, PA, 2003–2010.

	All (n=73,061)	Black (n=14,292; 19.6%)	White (n=58,769; 80.4%)
	Total N (%)		
Pre-Pregnancy Weight			
Underweight	2914 (4.0)	523 (3.6)	2391 (4.1)
Normal weight	39667 (54.3)	6115 (42.8)	33552 (57.1)
Overweight	16659 (22.8)	3782 (26.5)	12877 (21.9)
Obese	13821 (18.9)	3872 (27.1)	9949 (16.9)
Gestational Weight Gain			
Adequate weight gain	18345 (25.1)	3030 (21.2)	15315 (26.1)
Inadequate weight gain	11833 (16.2)	3210 (22.5)	8623 (14.7)
Excessive weight gain	42883 (58.7)	8052 (56.3)	34831 (59.3)

Neighborhood racial composition and poverty, pre-pregnancy BMI and gestational weight gain

We examined the relationship between neighborhood racial composition and pregnancy-related weight (Table 4). Due to the limited variability in neighborhood racial composition among white women, we present the adjusted results among black women only. We found that among black women, residence in predominately black (> 66%) and mixed (33–66% black) neighborhoods was associated with a 10% and 7% increase respectively in the prevalence of pre-pregnancy obesity compared with neighborhoods of low black racial composition (< 33%) after adjusting for WIC used [PR= 1.10 95% confidence interval (CI) 1.03, 1.16; PR=1.07 95% CI 0.99, 1.15]. Neighborhood poverty did not confound or further modify these effects (results not shown). There was no significant association between neighborhood racial composition and gestational weight gain among black women. Although less than 1% of white women lived in predominately black neighborhoods and less than 2% of white women lived in mixed neighborhoods, these women were more likely to be obese before pregnancy and to have inadequate weight gain during pregnancy compared with white women living in low % black/predominately white neighborhoods (results not shown).

We found that individual race/ethnicity modified the effect of neighborhood poverty on gestational weight gain and pre-pregnancy BMI (Table 5). Among white women, high neighborhood poverty was associated with a 10% increase in prevalence of inadequate weight gain, and mid-high neighborhood poverty was associated with an 4% increase in prevalence of inadequate weight gain [PR= 1.10, 95% CI 1.04, 1.16 and PR= 1.04, 95% CI 1.2, 1.08, respectively] compared with low neighborhood poverty after adjustment. There was no association between neighborhood-level poverty and gestational weight gain among black women. After adjustment, we also found that mid-low neighborhood poverty was associated with a 23% increase in the prevalence of pre-pregnancy obesity; mid-high was associated with a 20% increase; and high was associated with a 31% increase in

Table 3
Prevalence and Frequency of Pre-Pregnancy Weight and Gestational Weight Gain by maternal and neighborhood characteristics.

	Pre-Pregnancy BMI				Gestational Weight Gain(GWG)		
	Underweight	Normal Weight	Overweight	Obese	Adequate	Inadequate	Excessive
Pre-Pregnancy BMI (N %)							
Underweight	–	–	–	–	1198 (41.1)	695 (23.9)	1021 (35.0)
Normal weight	–	–	–	–	12408 (31.3)	6425 (16.2)	20834 (52.5)
Overweight	–	–	–	–	2718 (16.3)	1662 (10.0)	12279 (73.7)
Obese	–	–	–	–	2021 (14.6)	3051 (22.1)	8749 (63.3)
Married (N %)							
Yes	1439 (3.1)	26428 (55.8)	10506 (22.6)	8118 (17.5)	12444 (26.8)	6644 (14.3)	27403 (58.9)
No	1475 (5.5)	13239 (49.8)	6153 (23.2)	5703 (21.5)	5901 (22.2)	5189 (19.5)	15480 (58.3)
Maternal Education (N %)							
No Diploma	451 (7.4)	3239 (53.3)	1302 (21.4)	1081 (17.8)	1359 (22.4)	1449 (23.9)	3265 (53.8)
HS/GED	771 (5.1)	7300 (47.9)	3627 (23.8)	3543 (23.25)	3468 (22.8)	2947 (19.3)	8826 (57.9)
Some College	756 (3.7)	9857 (47.8)	5034 (24.4)	4974 (24.1)	4750 (23.0)	3397 (16.5)	12474 (60.5)
College Grad and Beyond	936 (3.0)	19271 (61.9)	6696 (21.5)	4223 (13.6)	8768 (28.2)	4040 (13.0)	18318 (59.8)
Used WIC (N %)							
Yes	1144 (5.1)	10402 (46.7)	5274 (23.7)	5443 (24.5)	4851 (21.8)	4366 (19.6)	13046 (58.6)
No	1770 (3.5)	29265 (57.6)	11385 (22.4)	8378 (16.5)	13494 (26.6)	7467 (14.7)	29837 (58.7)
Insurance Status (N %)							
Private Insurance	1283 (3.2)	22717 (56.3)	9248 (22.9)	7132 (17.7)	10612 (26.3)	5892 (14.6)	23876 (59.1)
Medicaid	862 (5.5)	7518 (47.8)	3691 (23.4)	3675 (23.3)	3490 (22.2)	3220 (20.4)	9036 (57.4)
Self-Pay	26 (6.7)	228 (58.5)	75 (19.2)	61 (15.6)	120 (30.8)	84 (21.5)	186 (47.7)
Other	18 (3.7)	228 (46.8)	116 (23.8)	125 (25.7)	115 (23.6)	112 (23.0)	260 (53.4)
Missing	725 (4.5)	8976 (55.9)	3529 (22.0)	2828 (17.6)	4008 (25.0)	2525 (15.7)	9525 (59.3)
Number of previous live births (N %)							
Zero	1612 (4.3)	21083 (56.5)	8206 (22.0)	6393 (17.1)	8900 (23.9)	5384 (14.4)	23010 (61.7)
One	1133 (3.7)	16053 (52.8)	7206 (23.7)	6028 (19.8)	8040 (26.4)	5294 (17.4)	17086 (56.2)
Two or more	169 (3.2)	2531 (47.3)	1247 (23.3)	1400 (26.2)	1405 (26.3)	1155 (21.6)	2787 (52.12)
Cigarettes Use During Pregnancy (N %)							
Yes	882 (6.8)	6367 (49.1)	3018 (23.3)	2709 (20.9)	2968 (22.9)	2702 (20.8)	7306 (56.3)
No	2032 (3.4)	33300 (55.4)	13641 (22.7)	11112 (18.5)	15377 (25.6)	9131 (15.2)	35577 (59.2)
Maternal Age (N %)							
< 20	410 (7.4)	3322 (59.9)	1139 (20.5)	674 (4.9)	1287 (23.2)	1165 (21.0)	3093 (55.8)
20–29	1564 (4.7)	17351 (52.2)	7632 (23.0)	6696 (20.1)	7875 (23.7)	5546 (16.7)	19822 (59.6)
30+	940 (2.7)	18994 (55.4)	7888 (23.0)	6451 (18.8)	9183 (26.8)	5122 (14.9)	19968 (58.3)
Neighborhood Characteristics							
Neighborhood Racial Composition (N %)							
Non-Black (i.e., 0- < 33% black)	2520 (4.0)	35522 (55.9)	14258 (22.4)	11274 (17.7)	16303 (25.6)	9749 (15.3)	37522 (59.0)
Mixed (i.e., 33–66% black)	174 (4.4)	1800 (45.1)	982 (24.6)	1037 (26.0)	889 (22.3)	828 (20.7)	2276 (59.0)
Black (i.e., > 66–100% black)	220 (4.0)	2345 (42.7)	1419 (25.8)	1510 (27.5)	1153 (21.0)	1256 (22.9)	3085 (56.1)
Neighborhood Poverty (N %)							
Low (i.e., 0- < 5%)	778 (3.7)	13081 (61.5)	4522 (21.3)	2871 (13.5)	5893 (27.7)	2873 (13.5)	12486 (58.8)
Low-Mid (i.e., 5- < 8%)	582 (3.5)	9481 (56.5)	3765 (22.4)	2942(17.5)	4281 (25.5)	2486 (14.8)	10003 (59.7)
Mid-High (i.e., 8- < 15%)	835 (4.4)	9701 (50.8)	4544 (23.8)	4000 (21.0)	4568 (23.9)	3146 (16.5)	11366 (59.6)
High (i.e., 15–100%)	719 (4.5)	7404 (46.4)	3828 (24.0)	4008 (25.1)	3603 (22.6)	3328 (20.9)	9028 (56.6)

prevalence compared with low neighborhood poverty among black women [PR= 1.23, 95% CI 1.02, 1.48; PR= 1.20, 95% CI 1.01, 1.42; and high PR= 1.31, 95% CI 1.12, 1.55 respectively]. Among white women, low-mid [PR= 1.23, 95% CI 1.11, 1.37], mid-high [PR= 1.46, 95% CI 1.32, 1.61, and high [PR= 1.45, 95% CI 1.30, 1.62] neighborhood poverty was also associated with a higher prevalence of pre-pregnancy obesity compared to low neighborhood poverty.

Discussion

In this study, we found that black women living in predominately black or racially mixed neighborhoods were more likely to be obese pre- pregnancy compared with black women living in non-black/predominately white neighborhoods; and that neighborhood racial composition was not associated with gestational weight gain among black women. Our hypothesis was that black women living in the most segregated areas will present with the greatest risk of inadequate weight gain was not supported by our findings; however, our other hypothesis that segregation would be associated with pre-pregnancy obesity was supported. We expected neighborhood racial composition to be associated with inadequate gestational weight gain due to previous studies of other pregnancy outcomes that have found that high racial/ethnic neighborhood composition or density to be associated with preterm birth and low birth weight among US-born black women (Masi et al., 2007; Mason et al., 2009). However, neighborhood racial composition, a proxy for segregation, may have more of an influence on early health factors prior to pregnancy (e.g., pre-pregnancy BMI) rather than weight gain during the short window of

Table 4
Adjusted prevalence Ratio (95% CI) for the association between neighborhood racial composition and pregnancy-related weight among black women, Allegheny County, PA, 2003–2010.

	Gestational Weight Gain[a, b]		Pre-Pregnancy Body Mass Index[c, d]	
	Inadequate (N=8577)	Excessive (N=15,482)	Overweight (N=13,468)	Obese (N=13,525)
	Adjusted PR (95% CI)			
Neighborhood Racial Composition				
Non-Black (0- < 33% black) (ref)	1.0	1.0	1.0	1.0
Mixed (33–66% black)	0.99 (0.93, 1.06)	0.99 (0.94, 1.04)	1.03 (0.96, 1.10)	1.07 (0.99, 1.15)
Black (> 66–100% black)	1.03 (0.98, 1.08)	1.00 (0.96, 1.04)	1.04 (0.99, 1.10)	1.10 (1.03, 1.16)

[a] Compared with adequate weight gain.
[b] Adjusted for maternal education, marital status, and pre-pregnancy BMI.
[c] Compared with normal weight prior to pregnancy.
[d] Adjusted for WIC use.

Table 5
Adjusted prevalence ratio (95% CI) of the association between neighborhood poverty and pregnancy-related weight by race, Allegheny County, PA, 2003–2010.

	Inadequate[a, b]		Obese[c, d]	
	Black (N=8598)	White (N=29,483)	Black (N=8011)	White (N=39,646)
	Adjusted PR (95% CI)			
Neighborhood Poverty				
Low (0- < 5%)	1.0	1.0	1.0	1.0
Low-Mid (5- < 8%)	1.07 (0.92, 1.23)	1.03 (0.99, 1.07)	1.23 (1.02, 1.48)	1.23 (1.11, 1.37)
Mid-High (8- < 15%)	1.01 (0.88, 1.16)	1.04 (1.0, 1.08)	1.20 (1.01, 1.42)	1.46 (1.32, 1.61)
High (15–100%)	1.02 (0.89, 1.16)	1.10 (1.04, 1.16)	1.31 (1.12, 1.55)	1.45 (1.30, 1.62)

[a] Compared to adequate weight gain.
[b] Adjusted for maternal education, marital status, and pre-pregnancy BMI.
[c] Compared to normal weight prior to pregnancy.
[d] Adjusted for WIC use.

pregnancy. Additionally, the stressful environments hypothesized as a result of isolated, segregated neighborhoods (Williams & Collins, 2001), may be more likely to send women on a trajectory of unhealthy weight patterns even prior to pregnancy that may exude different effects on weight during the course of pregnancy.

We also found that neighborhood poverty was not associated with inadequate gestational weight gain for black women but was moderately associated for white women; while neighborhood poverty was more strongly associated with pre-pregnancy obesity for white women than black women. In a previous study with a similar population, neighborhood socioeconomic disadvantage was associated inadequate weight gain among both black and white women (Mendez et al., 2014). There is an extensive body of literature that shows residents of socioeconomically disadvantaged neighborhoods, and neighborhoods with high social disorder are more likely to be obese, compared to residents of more advantaged neighborhoods (Chang, Hillier & Mehta, 2009; Glass, Rasmussen & Schwartz, 2006; Inagami et al., 2006). Although there are limited prior studies investigating neighborhood income or poverty in association with pregnancy-related weight, a European study found that pre-pregnancy obesity was associated with residence in a poor area (Sellstrom et al., 2009), and US-based studies found that residence in metropolitan areas were associated with pre-pregnancy obesity (Janevic et al., 2010; Lee et al., 2005). Finally, we hypothesized that there would be an association between neighborhood racial composition and pregnancy-related weight outcomes that would differ with varying levels of neighborhood poverty; however, there was no effect measure modification among black women and the lack of variability in neighborhood racial composition limited this analysis among white women.

The association between neighborhood poverty, neighborhood racial composition and pregnancy-related weight may be related to obesogenic neighborhoods plagued with unhealthy food environments, built environments that discourage physical activity, high crime, and widespread psychosocial stressors (Culhane & Elo, 2005; Chang et al., 2009; Chang, 2006; Cummins & Macintyre, 2006; Papas et al., 2007). The factors that women may face in their neighborhood environments may be stressful, leading to adverse pregnancy outcomes (Culhane & Elo, 2005; Mendez et al., 2012). The intersections between neighborhood racial composition and poverty are important to note, particularly since other studies demonstrate that low income white populations are more likely to be more integrated with higher income white populations than low income black populations are to integrated with higher income black populations (Williams & Collins, 2001). In other words, socioeconomic segregation is more prevalent among black compared to whites, influencing black populations' access to resources, goods, and opportunities essential for optimal health (Williams & Collins, 2001). In our study, our sample lacked black women living in predominantly black, low poverty neighborhoods. It would be worthwhile to determine the prevalence of inadequate weight gain among this group in other geographic regions in the US.

Approaches vary in terms of addressing residential segregation or neighborhood income or economic factors as a means to improve health. One well-known national program implemented by the US Department of Housing and Urban Development (HUD), Moving to Opportunity (MTO), families are given the opportunity to move from high poverty to low poverty neighborhoods via housing vouchers. An analysis of health outcomes among the MTO families found that moving to a residence in low poverty neighborhoods compared to controls was associated with modest reductions in extreme obesity (Ludwig et al., 2011). Another study found that residential segregation was associated with an increase in obesity among black women and went further to suggest that policies and interventions should consider how the mechanisms in which upstream factors such as neighborhood segregation and poverty may influence weight (Bower et al., 2015). Although the present study is focused on pregnancy, neighborhood poverty was associated with pre-pregnancy obesity among our study's population, having implications for how exposure to these neighborhood contexts, particularly segregation and poverty may influence weight prior to and during pregnancy and avenues for improving health.

There are a few limitations to this study. Since this is a cross-sectional study of birth records in Pennsylvania, we could not capture residence or neighborhood characteristics over time or throughout life. However, prior studies indicate that although some women may change residences during pregnancy, resulting in potential misclassification, women are likely to remain in similar types of neighborhoods when they move (Miller, Siffel & Correa, 2010; Fell, Dodds & King, 2004; Briem, 2011; Saadeh et al., 2013). Most studies, including the present study, examining neighborhood contexts and weight or obesity are

observational, limiting our full understanding of whether neighborhood-level interventions may change weight outcomes among the general population and specifically among pregnant women. One well-known study, Moving to Opportunity (MTO), which randomly assigned women with children to move to a lower poverty neighborhood through the Department of Housing and Human Development (HUD) voucher program, was associated with a modest reduction in the prevalence of extreme obesity (Ludwig et al., 2011). Structural confounding as a result of social stratification and 'selection' into certain neighborhoods, particularly racially segregated neighborhoods is an important consideration for this study (Acevedo-Garcia & Osypuk, 2008; Oakes, 2006; Messer, Oakes & Mason, 2010). As a result, our study specifically explored geographic separation for both black and whites and how this may influence the risk of pre-pregnancy overweight and poor weight gain. Although 19% of records were missing data on key outcome variables, the similarity between the multiple imputation results and the complete case analysis suggests that data may be missing at random. Misclassification of pre-pregnancy weight, height, and weight at delivery can be common particularly among the extremes of weight gain (Bodnar et al., 2014), however, our sample only had a total of 130 women with extreme weight gain values. Additionally, we did not have adequate sample size to examine other racial/ethnic groups other than non-Hispanic black and non-Hispanic white women. Although we used the census tract as a proxy for the neighborhood, prior studies assessing the relationships between neighborhood factors and pregnancy outcomes across different neighborhood units finds that tracts and block groups present similar conclusions (Vinikoor-Imler et al., 2011; Messer et al., 2012).

Despite these limitations, there are several strengths of this study. Our use of a large, diverse population-based cohort of births in an urban US county provided us with an adequate sample size to study associations with pregnancy-related weight outcomes. This study also included many neighborhoods (i.e., census tracts) in an urbanized area. This has allowed for a study of pregnancy-related weight and the association with neighborhood that has been overlooked in prior research.

The results of this study, taken together with previous studies of pregnancy-related weight specifically and weight among women in general, demonstrate the complex relationships with neighborhood environments. Key neighborhood factors in this study were differentially associated with pregnancy-related weight outcomes by race, and the associations varied for pre-pregnancy weight versus gestational weight gain. Given the complex social, political, and economic forces related to neighborhood segregation and poverty, future research studies and initiatives should consider how institutional policies and practices reinforce neighborhood racial composition and neighborhood poverty that may play an important role in pregnancy-related weight as well as how segregation and poverty may be associated with health promoting or damaging environments. Finally, the public health sector may be in a unique position to provide support to childbearing women by buffering the detrimental effects of adverse neighborhood environments through individual and community interventions before and during pregnancy.

Funding sources

This research was made possible by funding from the Aetna Foundation (PI: Mendez) (# 11-02359), the National Institute of Health, NICHD (R21 HD065807, PI: LM Bodnar), and the Thrasher Research Fund (# 9181).The funding sources had no involvement in the study design, data collection, analysis, interpretation of results, or writing of this manuscript.

Competing interests

The authors have no conflicts of interest.

Acknowledgements

We would like to acknowledge the Pennsylvania and Allegheny County Health Departments for their assistance with accessing key geodata for the vital birth records.

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