Title

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Publication Date

2018-07-01

DOI

10.1016/j.healthplace.2018.05.007

Peer reviewed

HHS Public Access

Author manuscript

Health Place. Author manuscript; available in PMC 2020 January 14.

Published in final edited form as:

Health Place. 2018 July ; 52: 101–109. doi:10.1016/j.healthplace.2018.05.007.

ASSOCIATIONS BETWEEN CUMULATIVE NEIGHBORHOOD DEPRIVATION, LONG-TERM MOBILITY TRAJECTORIES, AND GESTATIONAL WEIGHT GAIN

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Abstract

Existing research on neighborhood environment and gestational weight gain (GWG) focuses on point-in-time measures of neighborhood context. This precludes understanding how long-term exposure to adverse neighborhood environments influences GWG. We estimated associations between average exposure to and trajectories of long-term neighborhood socioeconomic deprivation and risk of inadequate or excessive GWG. Using data from 5690 full-term, singleton pregnancies in the 1979 National Longitudinal Survey of Youth, we estimated associations between cumulative deprivation and GWG, overall and by race/ethnicity, controlling for individual and residential covariates. A one standard deviation unit (8-point) increase in neighborhood deprivation increased risk of inadequate GWG (Relative Risk (RR): 1.08; 95% Confidence Interval (CI): 1.00–1.16) for all women and excessive GWG (RR: 1.11; 95% CI 1.02–1.21) for white women. Persistent low deprivation (RR: 0.78; 95% CI: 0.64–0.94) and upward mobility (RR: 0.76; 95% CI: 0.61–0.96), compared to persistent high deprivation, reduced risk of inadequate GWG. Persistent low deprivation also reduced risk of excessive GWG (RR: 0.84; 95%

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CI: 0.71–0.98). Long-term neighborhood deprivation contributes to patterns of GWG over women's life course.

Keywords

Pregnancy weight change; neighborhood characteristics; longitudinal study

INTRODUCTION

Weight gained during pregnancy is linked to poor health outcomes in both women and their children.(1,2) Both low and high gestational weight gain (GWG) increase risk of adverse outcomes including low birth weight, preterm birth, maternal postpartum weight retention, and obesity in mother and child.(1–3) Guidelines developed by the Institute of Medicine (IOM) to help women avoid adverse outcomes have proven difficult to achieve.(1) Excessive GWG is more prevalent (41–51%) than adequate GWG (23–34%), and inadequate GWG impacts a substantial minority of women (17–28%).(3) Interventions based on individual-level risk factors for inadequate and excessive GWG have achieved only moderate success.(4) Considering the wider context surrounding pregnant women may bolster the success of such interventions.(4)

Literature consistently links neighborhood context to adverse birth outcomes, such as low birth weight and preterm birth,(5) but few studies have investigated GWG. These studies suggest positive associations between neighborhood factors, such as neighborhood socioeconomic deprivation,(6) social spaces, and neighborhood physical incivilities,(7–9) and GWG. However, these findings rely on point-in-time neighborhood measures, which do not reflect risk accumulation. Neighborhood environments are theorized to impact health through both material deprivation pathways, which deprive women of immediate health resources needed for well-being, and bio-behavioral stress pathways, which dysregulate key biological systems over prolonged periods of wear and tear.(10) Longitudinal assessments of neighborhood environments are needed to improve insight into how neighborhoods influence GWG.

Histories of discrimination and social stratification in the US disproportionately expose racial/ethnic minorities to chronically disadvantaged neighborhoods compared to their white counterparts. (11–13) A well-established body of literature has shown that black and Latino neighborhoods have higher poverty over time, despite trends in declining racial/ethnic inequality in poverty over time, and are still more likely to be geographically segregated from white neighborhoods. (11–13) Furthermore, across these disadvantaged neighborhoods, experiences of socioeconomic disadvantage vary by race/ethnicity.(11) Black neighborhoods are more likely to be characterized by long-term economic disinvestment resulting in a lack of health promoting resources, goods, and services.(12,13) Paired with the consistent trends in racial residential segregation, these patterns give rise to pockets of concentrated poverty.(11–14)

While Latino populations similarly reside in socioeconomically disadvantaged neighborhoods and experience similar levels of racial residential segregation, (13,15) these

neighborhoods are often not characterized by same level of economic disinvestment due to the presence of culturally tailored resources. (15,16) Ethnic enclaves, which often coincide with disadvantaged Latino neighborhoods, also provide social networks and support that buffer negative impacts of these neighborhoods, (15–17) although the extent of this buffering has been shown to vary by immigrant status and ethnic origin. (17) Taken together, evidence suggests that extended residence in black compared to Latino disadvantaged neighborhoods can have different implications for health, resulting in racial/ethnic differences in associations between chronic neighborhood deprivation and GWG.

To build on existing work, we use data from a national cohort of women to examine associations between cumulative neighborhood deprivation and GWG, and determine whether they vary by race/ethnicity. We hypothesize that higher cumulative neighborhood deprivation will increase risk of inadequate and excessive GWG, associations will be stronger among all racial/ethnic minorities, but associations for Black women will be stronger than those for Latina women. Completion of this study can aid in the development of structural interventions to improve weight gain outcomes maternal and child health over the life course.

METHODS AND MATERIALS

Subjects

We used data from the 1979 National Longitudinal Survey of Youth (NLSY79). Details on the NLSY79 can be found elsewhere. (18) Briefly, the NLSY79 is a nationally-representative cohort of 12686 men and women recruited at age 14–21 and followed longitudinally from 1979–2012. Blacks, Hispanic/Latino/Spanish (referred to as Latino/a going forward), and economically disadvantaged whites were oversampled. Participants were interviewed annually from 1979 to 1994 and biennially from 1994 to 2012. (18)

Starting in 1986, women were asked about pregnancies occurring between interviews, and information about pregnancies occurring before 1986 was retrospectively collected.(18) We restricted our sample to singleton, full term gestations ranging from 37 to 42 weeks, with non-missing information on both exposure and outcome. We restricted our sample to full-term births in order to appropriately apply the IOM GWG guidelines. (1) This resulted in an analytic sample of 5690 pregnancies to 3300 women. The [University] Committee for Protection of Human Subjects approved this study.

Analytic Variables

Exposure: Census tracts approximated neighborhood boundaries. Census tracts are sociodemographically homogeneous areas containing an average of 4000 individuals per tract.(19) Census tract boundaries, obtained through the GeoLytics, Inc Neighborhood Change Database,(20) were standardized to year 2010 for consistency. We measured neighborhood deprivation using socioeconomic data from the 1980, 1990, and 2000 US census as well as the 2006–2010 American Community Survey (5-year estimates). We used geometric interpolation(20) to predict data for inter-censal years. We constructed a deprivation index for each census tract for each year based on an eight-item index (% adults

in management/professional occupations, % unemployed, % crowded households, % families in poverty, % female headed households with dependents, % households on public assistance, % families earning <$30,000, % adults <high school) developed by Messer et al. (2006).(21) We used factor analysis to reduce items into a weighted index score after confirming that all items loaded onto one factor (eigenvalue range: 4.19–5.29). We then transformed this index to range from 0–100, with higher values indicating more deprivation. Deprivation index scores were linked to NLSY79 data using women's census tract at time of interview.

We created two measures of cumulative neighborhood deprivation. First, in order to measure overall accumulation of deprivation, we averaged neighborhood deprivation index scores from 1979 to the closest interview year prior to giving birth for women with at least two index scores over follow-up. This resulted in an up to 2-year lag between measurement of neighborhood deprivation index score and time of birth. Second, in order to measure patterns of deprivation accumulation over time, we created mobility trajectories. Six long-term trajectories were selected "a priori" based on existing literature: persistent low deprivation, persistent moderate deprivation, persistent high deprivation, upward mobility, downward mobility, and mixed-mobility deprivation. We included the persistent low deprivation, persistent high deprivation, upward mobility, and downward mobility trajectories based on prior research linking these trajectories to adverse birth outcomes.(22–25) We additionally included a persistent moderate deprivation trajectory to capture women's lifetime experience of "middle class" status. To create long-term trajectories, we categorized each annual measure of continuous neighborhood deprivation into tertiles and classified women based on amount of time spent in each deprivation category over follow-up. Threshold values for tertiles over time varied based on neighborhood deprivation distribution for each year (Supplementary Table 1). Women were categorized as persistently low deprivation, moderate deprivation, or high deprivation if they stayed in the lowest, middle, or highest tertile of deprivation, respectively, for at least 90% of follow-up. We chose this threshold based on the assumption that brief deviations from a specific deprivation level were not qualitatively different than continuous residence within that deprivation level. Next, women were classified into the upward mobility trajectory if they continuously moved into less deprived neighborhoods over time. This includes women who, at least once over follow-up, moved to a neighborhood categorized in a lower deprivation tertile than the deprivation tertile of the previous year and then continued to reside in neighborhoods within the same or lower deprivation tertile. Similarly, for downward mobility, women were classified into this trajectory if they moved to a neighborhood within a higher deprivation tertile at least once over follow-up and then continued to reside in neighborhoods within the same or higher deprivation tertile for the duration of follow-up. All remaining women were classified within the mixed-mobility group.

Outcome—We calculated GWG as the difference between women's self-reported weight prior to pregnancy and their weight immediately before delivery for each pregnancy. Because length of recall differed for pregnancies occurring before and after 1986, we assessed reliability of prepregnancy weight by comparing it to women's non-pregnant weight at the closest interview prior to pregnancy. Reliability was high across all years and

similar for pregnancies occurring before (r=0.86) and after (r=0.89) 1986. Using 2009 IOM recommendations, we categorized GWG as inadequate, adequate, and excessive. Recommendations varied by prepregnancy body mass index (BMI), with underweight (<18.5kg/m^2), normal weight (18.5–24.9 kg/m^2), overweight (25.0–29.9 kg/m^2), and obese (≥30.0kg/m^2) women recommended to gain 12.5–18kg, 11.5–16kg, 7–11.5kg, 5–9kg, respectively. Women gaining over this amount were classified as excessive gainers and under this amount were classified as inadequate gainers. Height was self-reported in 1981, 1982, 1985, 2006, and 2008; we used the measurement closest to pregnancy to calculate prepregnancy BMI. Height measures were regression-calibrated using National Health and Nutrition Examination Study III data to account for self-reporting bias.(26) Weight measures were not regression-calibrated due to lack of appropriate calibration standards for pregnancy-related weight. (27) Because GWG is dependent on duration of gestation and IOM definitions of GWG adequacies are intended for term births, we restricted our analysis to full term pregnancies.

We conducted a sensitivity analysis using 1990 IOM GWG recommendations(28) since births in our sample occurred before the 2009 IOM recommendations. Findings were similar, so we only report results using 2009 IOM GWG recommendations.

Covariates—We included a number of covariates considered to be potential confounders based on previous literature. (1,29,30) These covariates included race/ethnicity, foreign-born, marital status, maternal age, parity, child's birth year, education, home ownership, employment, and equivalized income. (31) We additionally controlled for covariates related to geographical location, residential selection, and mobility(32) These covariates were measured as region of residence, rural residence at time of birth, moving in birth year, length of residence, and number of moves. All covariates except for race/ethnicity and foreign-born status were measured at the interview period prior to the index pregnancy. Categorization of all variables can be found in Table 1.

Statistical Analysis

Survey weighted means, standard deviations, and frequencies were calculated for analytic variables. Bivariable associations between covariates by both outcome and exposure were assessed using Chi squared tests or ANOVAs. Regression models were fit to estimate crude and adjusted associations between cumulative neighborhood deprivation and inadequate (compared to adequate) GWG, and excessive (compared to adequate) GWG. Inadequate and excessive GWG outcomes were modeled separately in order to support the estimation of relative risks (RR), using generalized linear models with log link functions, rather than odds ratios (OR), which would be estimated from multinomial logistic regression models. Because our outcomes are common (inadequate GWG: 23%; excessive GWG: 43%), the OR does not approximate the RR. Cumulative deprivation was transformed to increase by standard deviation units (SD=8.0). Continuous covariates were median-centered. Survey weights were used to account for the sampling design and reweighted the population to be representative of the national population of women in 1979. Clustering by census tract was small (<2 women per tract), so we only used robust standard errors to account for multiple pregnancies for participants. We assessed effect measure modification of associations

between cumulative neighborhood deprivation and GWG by race/ethnicity using interaction terms based on the cross-product between cumulative neighborhood deprivation and race/ethnicity. We used Wald tests to assess overall significance of effect measure modification using a $p \leq 0.10$ threshold. Race/ethnicity stratified models were presented instead of main association models if effect measure modification was significant.

The prevalence of missing data for covariates ranged from 0 to 31% (Supplementary Table 2). To address potential bias, we used regression-based multiple imputation using chained equations. Across 10 data sets, covariate values were imputed using regression models that included all covariates, exposure and outcome measures to predict missing values. Multiple imputation techniques were then used to analyze data across the 10 imputed data sets.(33) All analyses were conducted in Stata 12.0 (College Station, TX).

RESULTS

In our weighted sample, mean age at time of birth was 27.3 years (SD=4.9), 80.0% of women were white, 13.2% were Black, 5.7% were Latina, and 68.4% were married (Table 1). Mean cumulative neighborhood deprivation was 18.0 (SD=8.0). Forty three percent gained excessively and 23% gained inadequately. Most covariates varied across GWG adequacy categories, excluding foreign-born, region of residence, and maternal age (Table 1). Adequate gainers were more likely to be white (83.0%), married (80.0%), college graduates (27.5%), homeowners (51.0%) and high income (40.3%).

Cumulative neighborhood deprivation varied across most covariates (Table 2). Women who gained inadequately (19.4; SD=8.9) or excessively (18.1; SD=7.9) had higher mean cumulative deprivation scores. Black (28.7; SD=13.4) and Latina (26.3; SD=14.4) women had significantly higher cumulative deprivation scores compared to white women (15.6; SD=4.7). Trajectories of neighborhood deprivation varied across covariates as well (Table 2). White women were more likely to persistently reside in low deprivation (96.3%) or moderate deprivation (84.6%) neighborhoods. Among those persistently residing in high deprivation neighborhoods, women were more likely to be Black (58.0%) or Latina (21.7%). Women experiencing either upward or downward neighborhood mobility were more likely to be white (75.6% and 82.8%, respectively, compared to 13.9%/10.7% and 8.9%/5.8% for Black and Latina women).

Average Cumulative Neighborhood Deprivation

A one-standard deviation unit increase (i.e. 8 point) in average cumulative neighborhood deprivation was associated with an 8% (95% Confidence Interval (CI) 1.00, 1.16) increase in risk of inadequate GWG compared to adequate GWG after adjusting for covariates, with no evidence of effect measure modification by race/ethnicity (Wald p=0.21). (Table 3) Average cumulative neighborhood deprivation was also associated with excessive GWG, increasing risk by about 6% (95% CI 1.00, 1.12) after adjusting for covariates. This association was modified by race/ethnicity (Wald p=0.08), and higher cumulative neighborhood deprivation was only associated with increased excessive GWG for white women (RR: 1.11; 95% CI 1.02, 1.21).

Long-term Mobility Trajectories

Adjusted associations between individual trajectory types and inadequate GWG found that persistent low deprivation (RR 0.78; 95% CI 0.64, 0.94) and upward mobility (RR 0.76; 95% CI 0.61, 0.96) were associated with decreased risk of inadequate GWG (Table 4) compared to persistent high deprivation. For excessive GWG, only persistent low deprivation decreased the adjusted risk of excessive GWG (RR 0.84; 95% CI: 0.71, 0.98). Associations for long-term mobility trajectories and both inadequate (Wald p=0.15) and excessive GWG (Wald p=0.19) did not vary by race/ethnicity.

DISCUSSION

We investigated associations between long-term neighborhood deprivation and GWG adequacy in a national cohort of women over their reproductive life course and determined whether these associations varied across racial/ethnic groups. We found that higher average cumulative deprivation was associated with increased risk of inadequate GWG and that this association did not vary by race/ethnicity. However, for excessive GWG, only white women had higher risk of excessive GWG associated with higher cumulative deprivation. These findings extend previous work relying on point-in-time measures to assess neighborhood environment and emphasize the importance of considering long-term neighborhood environment going forward.

To our knowledge, this is the first study to investigate associations between cumulative neighborhood deprivation and GWG. An existing body of literature has investigated associations between cumulative neighborhood environment and birth outcomes, and our findings are consistent with this literature. Studies reported that long-term neighborhood deprivation increased the risk of both low birth weight(22,23,34) and preterm birth.(24,25) An existing body of literature has also examined neighborhood environments and GWG using point-in-time neighborhood measures. Using a deprivation index similar to ours, Mendez and colleagues found that neighborhood socioeconomic deprivation at the time of delivery is associated with inadequate GWG and weight loss during pregnancy.(6) Additionally, studies investigating specific neighborhood attributes, such as physical incivilities (i.e. litter, graffiti, vacant spaces) and social spaces (i.e. parks, sidewalks, presence of people), have found that fewer social spaces and more physical disorder are associated with inadequate GWG.(7–9) Our results are consistent with this literature.

Associations between cumulative neighborhood deprivation and inadequate GWG may be driven by stress-based mechanisms. Psychosocial stress is associated with lower GWG,(35) and interpersonal violence during pregnancy, as a specific violence-based stressor, increases risk of inadequate GWG.(36) However, not all forms of violence have been linked to inadequate GWG. Community violence has been associated with an increased risk of excessive GWG.(37) Nonetheless, studies on community crime have found associations with low birth weight(38) and preterm birth,(39) all of which are associated with inadequate GWG. Thus, while stress, including violence-based stress, may underlie associations between cumulative neighborhood deprivation and inadequate GWG, more work is needed to clarify these findings. Long-term exposure to socioeconomically deprived neighborhoods places women at disproportionately higher risk of experiencing both interpersonal and

community violence due to the presence of social disorder within these neighborhoods.(10) Social norms in deprived neighborhoods could also contribute to associations between cumulative neighborhood deprivation and inadequate GWG.(40) In particular, higher prevalence of smoking and drug use(40) may increase women's likelihood of engaging in these behaviors when they become pregnant, especially if exposure to these norms is prolonged.

In contrast to our findings for inadequate weight gain, we found that cumulative neighborhood deprivation only increases risk of excessive GWG for white women. Previous studies using point-in-time neighborhood measures have reported inconsistent associations between neighborhood environment and excessive GWG.(7–9) One study conducted in the Pregnancy, Infection, and Nutrition (PIN) cohort in North Carolina found that fewer neighborhood social spaces increased risk of excessive GWG.(7) However, this finding was not supported by two other studies conducted in a birth record cohort from the same geographic location. This work documented that neighborhood physical disorder was associated with increased risk of excessive GWG, but only in white women.(8,9) Their findings are consistent with ours, but further work is needed to understand why associations between neighborhood characteristics and excessive GWG vary by race/ethnicity.

One potential explanation for racial/ethnic differences in associations between neighborhood environment and excessive GWG may lie in racial/ethnic differences in neighborhood composition. Due to social processes that lead to race-based spatial stratification of residential environments in the US, neighborhoods that Black and Latina women move through over time differ from their white counterparts.(41) For example, the wealthier neighborhoods that Black women live in may still lack key resources and health facilitators that are present in white neighborhoods of equivalent economic status.(41) Alternatively, for Latina women, lower income neighborhoods may be ethnic enclaves bolstered by more culturally tailored services, resources, and social support than white or Black neighborhoods of similar socioeconomic status.(42,43) In both cases, many factors influencing access to residential environments, such as race-based discrimination and institutionalized racism,(11) impact racial/ethnic minorities across the socioeconomic spectrum,(11) thus, reducing the benefit of upward mobility to less deprived neighborhoods.

To our knowledge, our study is also the first to investigate neighborhood deprivation trajectories and GWG. Other studies, however, have investigated neighborhood deprivation trajectories and birth outcomes.(24,25) A set of studies conducted in a trans-generationally linked birth cohort in Chicago found that lifetime (stable) deprivation increases risk of low birth weight, and that mobility trajectories (i.e. upward mobility and downward mobility) increase risk of preterm birth.(24,25) We found that persistent low deprivation, as opposed to high deprivation, protected women from excessive and inadequate GWG, and that upward mobility was associated with decreased risk of inadequate GWG across all racial/ethnic groups.

Interestingly, we did not find that persistent residence in moderate deprivation neighborhoods protected women from either inadequate or excessive GWG. This suggests that rather than a gradient of association existing as women move up the socioeconomic

ladder, a more substantial level of socioeconomic gain is related to improvements in healthy GWG. The particular benefits of neighborhood affluence, which represents concentrated wealth and resources above and beyond the individual level, have been highlighted in literature looking at other health outcomes.(32) Studies have found that neighborhood affluence is associated with lower systolic blood pressure, higher self-rated health, and higher cognitive function in children.(32) More work is needed to understand how specific dimensions of affluent neighborhood environments, such as concentration of resources or presence of strong social cohesion and psychological support,(32) can be integrated into structural interventions to improve neighborhood environments across the socioeconomic gradient.

This study had several limitations. First, we could not rule out the impact of self-selection into neighborhood environments.(44) If unmeasured neighborhood selection factors are also linked to GWG, then unmeasured confounding could bias observed associations. While we have controlled for an extensive set of maternal socioeconomic and demographic characteristics identified as key predictors of neighborhood selection, (32,44) we were not able to control for selection factors at the neighborhood level, such as built environment and transit characteristics. (45) Thus, our estimates may be biased to the extent that these factors are also related to GWG. Second, we used census tracts to approximate neighborhood boundaries, which may bias our associations if smaller or larger scales of geography are more relevant for this outcome.(44) However, a study that assessed neighborhood deprivation at various spatial levels, including census block and tract, found that differences in size of geography did not bias associations between neighborhood deprivation and pregnancy related outcomes, including maternal weight gain.(9)

Third, we used an administrative index of general socioeconomic deprivation. While this is a relevant proxy for adverse social and economic exposures that cluster within poor neighborhoods,(44) it does not allow investigation of specific neighborhood characteristics in relation to GWG. For example, determining the relative contributions of depleted service environments versus chronic violence exposure would strengthen our understanding of mechanisms underlying cumulative neighborhood deprivation and GWG. Future studies should prioritize this avenue of investigation.

Finally, our study relied on self-reported data to ascertain our outcome, GWG. Reporting bias in self-reported GWG can moderately misclassify women, and tends to overestimate the prevalence of excessive GWG. However, this misclassification does not substantially bias associations between GWG and birth outcomes.(27) More work is needed to ascertain bias when GWG is the outcome, so we cannot rule out the impact of such reporting error on our findings. However, the development of appropriate bias correction techniques for self-reported pregnancy-related weight measures(27) can aid in addressing this limitation going forward.

These limitations are balanced by a number of strengths. This is one of the first studies to use a national sample of women with a 30-year follow-up, providing multiple repeated observations of women's residential location. Existing studies investigating cumulative deprivation and pregnancy outcomes have relied on access to birth records to create these

measures,(23,34) which limits information on neighborhood environments to that which is available at the time that births are recorded. Prior studies also were limited to specific geographic locations (Chicago, IL(23) or Atlanta, GA(34)). Our sample is racially/ethnically diverse. We are among the first to examine associations of cumulative neighborhood deprivation and GWG among Latina women, although future work should continue to explore ethnic sub-groups within this population. Finally, we were able to control for a wide range of socioeconomic indicators over time. Socioeconomic status is a multidimensional construct that includes multiple domains.(40) Exclusion of any of these domains may result in incomplete measurement of socioeconomic status, and residual confounding in associations of interest. This is particularly of concern in neighborhood studies as the resulting bias from excluded individual SES measures may be picked up in the neighborhood-level point estimate of interest.(44)

CONCLUSION

Our findings have important implications for understanding how the impact of neighborhood environment varies across individual characteristics and life stages, which can inform the development of better interventions. In particular, during the critical period of pregnancy, chronic neighborhood deprivation more consistently contributes to gaining too little rather than too much weight. Furthermore, our findings illustrate the important contribution of trajectories of lifetime deprivation. Thus, going forward, continued inclusion of women's chronic exposure to neighborhood factors is needed to better comprehend the neighborhood context shaping weight gain during pregnancy. Understanding the dynamic roles of neighborhood deprivation across extended time frames will be key to creating successful interventions to improve GWG and the health trajectories of mothers and children.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgements:

Views expressed in this manuscript are not necessarily those of the Bureau of Labor Statistics or the National Institute of Minority Health and Health Disparities. This work was supported by the National Institute of Minority Health and Health Disparities [R01MD006104] and by the Health Resources and Services Administration [T76MC00002].

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Highlights

- Chronic neighborhood deprivation is associated with gestational weight gain (GWG)
- Chronic neighborhood deprivation increases risk of inadequate GWG
- Stable low deprivation and upward mobility trajectories lower risk of inadequate GWG
- Results for excessive GWG were limited to white women and implied an increased risk
- Understanding chronic neighborhood deprivation can help address adverse GWG outcomes

Table 1.

Survey Weighted Descriptive Statistics for Analytic Sample by Gestational Weight Gain (GWG) Adequacy, 1979 National Longitudinal Survey of Youth (1979–2012)

	Un-weighted N (n= 5690)	Total Sample (%; mean (SD))	Inadequate (n=1,401; 23%)	Adequate (n=1,841; 34%)	Excessive (n=2,448; 43%)	p-value
Cumulative Neighborhood Deprivation	5690	18.0 (8.0)	19.4 (8.9)	17.0 (7.4)	18.1 (7.9)	<0.0001
Mobility						<0.0001
Trajectories						
Persistent Low Deprivation	1,000	26.1%	22.7%	31.5%	23.6%	
Persistent Moderate Deprivation	743	13.9%	15.1%	12.2%	14.6%	
Persistent High Deprivation	1,030	8.9%	12.5%	6.7%	8.6%	
Upward Mobility	554	8.7%	7.0%	8.8%	9.6%	
Downward Mobility	599	11.6%	11.5%	10.4%	12.4%	
Mixed-mobility	1,764	30.9%	31.2%	30.4%	31.2%	
Race						<0.0001
White *	3272	80.6%	74.6%	84.2%	80.9%	
Black	1374	13.1%	17.7%	9.8%	13.3%	
Hispanic	1044	6.3%	7.7%	6.0%	5.8%	
Foreign born						0.69
No	5213	95.1%	95%	95%	95%	
Yes	477	4.9%	5%	5%	5%	
Marital Status						<0.001
No	2,240	31.6%	34.4%	27.1%	33.7%	
Yes	3,259	68.4%	65.6%	73.0%	66.3%	
Employment						<0.001
Unemployed	2,049	31.3%	37.8%	31.4%	27.7%	
Part-time	1,524	28.1%	26.1%	29.4%	28.3%	
Full time	1,972	40.6%	36.2%	39.2%	44.0%	
Region of Residence						0.82
Northeast	1,035	20.4%	20.2%	19.6%	21.2%	
North Central	1,303	29.0%	28.0%	30.3%	28.6%	
South	1,826	30.9%	32.8%	30.4%	30.2%	
West	1,306	19.7%	19.1%	19.7%	20.0%	
Home Ownership						<0.001
No	3,398	53.4%	56.0%	49.0%	55.4%	
Yes	1,876	46.6%	44.0%	51.0%	44.6%	
Child’s Birth Year	5,690	1988 (5.0)	1988 (5.3)	1989 (4.8)	1989 (5.0)	0.01
Education						<0.0001
<12y	1,238	15.5%	20.0%	12.8%	15.1%	
12–15y	3,368	63.2%	62.4%	59.7%	66.5%	
>=16y	885	21.3%	17.6%	27.5%	18.4%	

	Un-weighted N (n= 5690)	Total Sample (%; mean (SD))	Inadequate (n=1,401; 23%)	Adequate (n=1,841; 34%)	Excessive (n=2,448; 43%)	p-value
Equivalized Income (mean, SD)	4,959	9.9 (1.1)	9.7 (1.20	10.0 (1.0)	9.9 (1.1)	<0.001
Quartile 1	1,137	15.7%	18.8%	13.3%	16.1%	0.01
Quartile 2	1,197	18.7%	20.3%	16.5%	19.6%	
Quartile 3	1,273	29.1%	28.6%	30.0%	28.7%	
Quartile 4	1,352	36.5%	32.4%	40.3%	35.7%	
Maternal Age (mean, SD)	5,690	27.4 (4.9)	27.1 (5.3)	27.5 (4.6)	27.4 (4.8)	0.17
<20	388	4.9%	5.8%	4.6%	4.6%	0.13
20–24	1,720	26.4%	29.1%	24.9%	26.1%	
25–29	1,991	36.0%	34.0%	38.2%	35.3%	
30–34	1,137	23.6%	20.4%	23.9%	25.1%	
35–39	409	8.3%	9.7%	7.6%	8.2%	
>=40	45	0.9%	1.0%	0.9%	0.8%	
Parity (mean, SD)	5,690	1.0 (1.0)	1.1 (1.2)	1.0 (1.0)	0.9 (1.0)	<0.0001
0	2,194	40.6%	32.8%	40.0%	45.4%	<0.0001
1	1,973	35.2%	39.0%	35.2%	33.0%	
2	983	16.3%	17.8%	17.4%	14.6%	
3	350	5.6%	6.7%	5.3%	5.2%	
≥4	190	2.4%	3.8%	2.1%	1.9%	
Moved in birth Year						0.33
No	2,739	71.0%	70.6%	72.7%	69.6%	
Yes	1,197	29.0%	29.5%	27.3%	30.4%	Yes
Length of Residence	5,224	1.5 (2.2)	1.6 (2.4)	1.6 (2.1)	1.5 (2.2)	0.28
Long term resident (>=5 years						0.82
No	4,748	90.0%	89.5%	89.9%	90.3%	
Yes	476	10.0%	10.5%	10.1%	9.7%	
Cumulative times moved	5,690	1.7 (1.6)	1.6 (1.6)	1.7 (1.6)	1.7 (1.6)	0.04
Frequent mover (>=5 times)						0.26
No	5,336	93.1%	94.4%	93.0%	92.5%	
Yes	354	6.9%	5.6%	7.0%	7.6%	
Rural						0.08
No	4,618	85.2%	82.7%	85.4%	86.3%	
Yes	688	14.9%	17.4%	14.6%	13.7%	

* The “white” ethnicity group is referred to as such because this group is majority white (88%). However, this group does included all other non-Black, non-Latino women in our sample, such as those classified as Indian and Native American, other, and Asian.

Table 2.

Survey Weighted Mean Cumulative Neighborhood Deprivation by Study Covariates and Variation Across Mobility Trajectories for Analytic Sample, 1979 National Longitudinal Survey of Youth (1979–2012)

	Average Cumulative Deprivation		Mobility Trajectory							
	Mean (SD) (n=5690)	p-value	Total Sample (n=5690)	Persistent Affluence (n=1000)	Persistent Middle Class (n=743)	Persistent Deprivation (n=1030)	Upward Mobility (n=554)	Downward Mobility (n=599)	Mixed-Mobility (n=1764)	p-value
GWG		<0.0001								<0.0001
Inadequate	19.4 (8.9)		23.0%	20.0%	25.0%	32.5%	18.5%	23.0%	23.2%	
Adequate	17.0 (7.4)		34.3%	41.4%	30.1%	26.0%	34.3%	31.1%	33.7%	
Excessive	18.1 (7.9)		42.7%	38.6%	44.9%	41.4%	47.1%	45.9%	43.1%	
Race		<0.0001								<0.0001
White *	15.6 (4.7)		80.6%	97.4%	85.2%	20.4%	77.2%	83.6%	81.4%	
Black	28.7 (13.4)		13.1%	1.3%	10.8%	58.0%	13.9%	10.7%	11.9%	
Hispanic	26.3 (14.4)		6.3%	1.3%	4.0%	21.7%	8.9%	5.8%	6.7%	
Foreign born		<0.0001								<0.01
No	17.8 (7.8)		95.1%	97.4%	94.3%	90.0%	92.8%	96.2%	95.1%	
Yes	21.9(11.4)		4.9%	2.6%	5.7%	10.0%	7.3%	3.8%	4.9%	
Marital Status		<0.0001								<0.0001
No	21.8 (10.9)		13.6%	21.1%	31.9%	65.9%	31.7%	34.8%	29.3%	
Yes	16.3 (6.0)		68.4%	78.9%	68.1%	34.1%	68.3%	65.2%	70.7%	
Employment		<0.0001								<0.0001
Unemployed	20.4 (10.0)		31.3%	27.4%	33.0%	51.8%	31.5%	31.3%	27.9%	
Part-time	17.9 (7.6)		28.1%	27.6%	26.8%	24.5%	28.0%	35.6%	27.5%	
Full time	16.3 (6.2)		40.6%	45.1%	40.2%	23.7%	40.5%	33.1%	44.6%	
Region of Residence		0.10								<0.0001
Northeast	18.1 (8.5)		20.4%	22.5%	14.3%	22.4%	23.3%	16.3%	21.6%	
North Central	17.0 (7.3)		29.0%	28.7%	29.6%	23.0%	27.2%	24.7%	24.4%	
South	19.0 (8.1)		30.9%	24.1%	40.3%	38.7%	29.6%	33.7%	29.5%	
West	17.9 (7.5)		19.7%	14.7%	15.8%	15.8%	19.9%	25.4%	24.5%	
Home Ownership		<0.0001								<0.0001
No	20.2 (9.6)		53.4%	40.2%	53.3%	85.2%	57.1%	59.0%	52.9%	
Yes	15.1 (5.0)		46.6%	59.8%	46.8%	14.8%	43.0%	41.0%	47.1%	

	Average Cumulative Deprivation		Mobility Trajectory							
	Mean (SD) (n=5690)	p-value	Total Sample (n=5690)	Persistent Affluence (n=1000)	Persistent Middle Class (n=743)	Persistent Deprivation (n=1030)	Upward Mobility (n=554)	Downward Mobility (n=599)	Mixed-Mobility (n=1764)	p-value
		<0.0001								<0.0001
Education										
<12y	23.6 (11.0)		15.5%	7.8%	19.4%	37.7%	17.3%	18.3%	12.2%	
12–15y	18.2 (7.5)		63.2%	63.0%	72.4%	57.1%	66.4%	65.7%	59.3%	
>=16y	13.5 (4.7)		21.3%	29.2%	8.3%	5.2%	16.3%	16.0%	28.6%	
Equivalized Income		<0.0001								<0.0001
Quartile 1	23.0 (10.9)		15.7%	6.2%	18.9%	38.2%	19.5%	23.1%	13.0%	
Quartile 2	21.3 (9.8)		18.7%	11.6%	22.0%	34.5%	19.1%	19.4%	18.9%	
Quartile 3	16.9 (5.8)		29.1%	32.2%	36.9%	17.1%	25.5%	29.8%	26.9%	
Quartile 4	14.2 (4.6)		36.5%	50.0%	22.2%	10.1%	35.9%	27.6%	41.2%	
Maternal Age		<0.0001								<0.0001
<20	23.5 (10.9)		4.9%	3.6%	8.9%	13.2%	4.9%	6.7%	01.0%	
20–24	21.1 (8.9)		26.4%	21.2%	41.0%	40.5%	34.5%	33.3%	14.6%	
25–29	17.6 (7.3)		36.0%	37.3%	29.5%	28.6%	37.8%	37.8%	38.8%	
30–34	15.6 (6.5)		23.6%	27.2%	15.0%	12.3%	16.8%	16.7%	32.2%	
35–39	14.5 (6.2)		8.3%	8.4%	5.0%	5.2%	5.7%	5.5%	12.4%	
>=40	13.1 (7.2)		0.9%	1.6%	0.6%	0.2%	0.3%	0.0%	1.1%	
Parity		<0.0001								<0.0001
0	17.3 (7.4)		40.6%	46.6%	41.9%	36.2%	40.1%	41.5%	36.1%	
1	17.9 (7.7)		35.2%	34.0%	35.4%	32.5%	36.7%	37.1%	35.6%	
2	18.7 (8.5)		16.3%	13.8%	17.7%	18.7%	15.9%	14.8%	17.6%	
3	19.9 (9.4)		5.6%	4.1%	4.4%	7.1%	4.9%	4.7%	7.4%	
≥4	22.4 (12.8)		2.4%	1.5%	0.6%	5.5%	2.6%	1.9%	3.3%	
Moved in birth Year		0.03								<0.0001
No	17.5 (8.0)		71.0%	81.6%	82.5%	77.7%	63.9%	69.6%	58.4%	
Yes	18.1 (7.5)		29.0%	18.4%	17.5%	22.3%	36.1%	30.4%	41.6%	
Long term resident (>=5 years)		0.01								<0.0001
No	18.2 (8.0)		90.0%	86.4%	88.0%	88.1%	92.2%	90.3%	93.6%	
Yes	16.9 (8.0)		10.0%	13.6%	12.0%	11.9%	7.8%	9.7%	6.4%	
Frequent Mover (>=5 times)		<0.0001								<0.0001

	Average Cumulative Deprivation		Mobility Trajectory							
	Mean (SD) (n=5690)	**p-value**	**Total Sample (n=5690)**	**Persistent Affluence (n=1000)**	**Persistent Middle Class (n=743)**	**Persistent Deprivation (n=1030)**	**Upward Mobility (n=554)**	**Downward Mobility (n=599)**	**Mixed-Mobility (n=1764)**	**p-value**
No	18.2 (8.2)		93.1%	96.6%	97.9%	98.9%	96.6%	97.9%	83.5%	
Yes	15.5 (5.5)		6.9%	3.5%	2.1%	1.1%	3.4%	2.1%	16.5%	
Rural		0.63								<0.0001
No	18.0 (8.4)		85.2 %	88.6%	73.0%	89.6%	85.5%	84.1%	86.7%	
Yes	17.7 (5.7)		14.9%	11.4%	27.0%	10.4%	14.5%	15.9%	13.3%	

*The “white” ethnicity group is referred to as such because this group is majority white (88%). However, this group does included all other non-Black, non-Latino women in our sample, such as those classified as Indian and Native American, other, and Asian.

Table 3.

Main Associations Between Cumulative Neighborhood Exposure and Gestational Weight Gain (GWG), Overall and Stratified by Race/Ethnicity For Significant Interaction, 1979 National Longitudinal Survey of Youth (1979–2012) *

	Crude		Adjusted†		Wald test for Interaction§
	RR	**95% CI**	**RR**	**95% CI**	**P-value**
Inadequate GWG (n=3242)	**1.19**	**(1.13,1.26)**	**1.08**	**(1.00,1.16)**	0.21
Excessive GWG (n=4289) **	--	--	--	--	**0.08**
White	**1.11**	**(1.03,1.20)**	**1.11**	**(1.02,1.21)**	
Black	1.01	(0.95,1.07)	1.00	(0.94, 1.07)	
Latina	0.98	(0.88,1.10)	0.98	(0.88,1.09)	

* Results in table reflect results from separate models for inadequate compared to adequate GWG and excessive compared to adequate GWG. Sample sizes for each model are reported with their respective outcomes.

† Models adjusted for rural/urban, kid's birth year, marital status, employment, education, race/ethnicity, equivalized income, mother's age at birth, parity, region, immigrant status, home ownership, moving in the birth year, cumulative times moved over follow up, length of residence in current census tract.

§ Overall tests for significant interaction between race/ethnicity and gestational weight gain were conducted using Wald tests; interaction was considered significant if $p<0.10$.

** Race stratified models are presented due to the detection of significant interaction by race/ethnicity of the cumulative neighborhood deprivation and excessive GWG relationship. The "white" ethnicity group is referred to as such because this group is majority white (88%). However, this group does included all other non-Black, non-Latino women in our sample, such as those classified as Indian and Native American, other, and Asian.

Table 4.

Associations Between Long-term Mobility Trajectories and Gestational Weight Gain (GWG), 1979 National Longitudinal Survey of Youth (1979–2012)*

	Inadequate GWG (n=3242)				Excessive GWG (n=4289)			
	Crude		Adjusted†		Crude		Adjusted†	
	RR	95% CI	RR	95% CI	RR	95% CI	RR	95% CI
Persistent Low Deprivation	**0.59**	**(0.49, 0.70)**	**0.78**	**(0.64, 0.94)**	**0.79**	**(0.69, 0.90)**	**0.84**	**(0.71, 0.98)**
Persistent Moderate Deprivation	**0.82**	**(0.70, 0.96)**	0.97	(0.81, 1.15)	0.98	(0.87, 1.09)	1.01	(0.87, 1.16)
Persistent High Deprivation	ref.	ref.	ref.	ref.	ref.	ref.	ref.	ref.
Upward Residential Mobility	**0.63**	**(0.50, 0.79)**	**0.76**	**(0.63, 0.96)**	0.94	(0.82,1.08)	0.99	(0.85, 1.15)
Downward Residential Mobility	**0.76**	**(0.64,0.92)**	0.93	(0.76, 1,15)	0.97	(0.85,1.11)	1.02	(0.87, 1.19)
Mixed-mobility	**0.73**	**(0.65, 0.83)**	0.96	(0.83, 1.11)	0.91	(0.82, 1.02)	0.93	(0.81, 1.07)
Wald Test Mobility Trajectories Overall	**<0.0001**		0.07		**0.01**		**0.04**	

*Results in table reflect results from separate models for inadequate compared to adequate GWG and excessive compared to adequate GWG. Sample sizes for each model are reported with their respective outcomes.

†Models adjusted for rural/urban, kid's birth year, marital status, employment, education, race/ethnicity, equivalized income, mother's age at birth, parity, region, immigrant status, home ownership, moving in the birth year, cumulative times moved over follow up, length of residence in current census tract.