Published in final edited form as:

Paediatr Perinat Epidemiol. 2017 January ; 31(1): 37–46. doi:10.1111/ppe.12331.

Living in violent neighbourhoods is associated with gestational weight gain outside the recommended range

Jessica Galin^a, Barbara Abrams^a, Stephanie A. Leonard^{a,*}, Ellicott C. Matthay^{a,*}, Dana E. Goin^a, and Jennifer Ahern^a

^aDivision of Epidemiology, School of Public Health, University of California, Berkeley, Berkeley, CA, USA

Abstract

Background—During pregnancy, most women do not meet gestational weight gain (GWG) guidelines, potentially resulting in adverse maternal and infant health consequences. Social environment determinants of GWG have been identified, but evidence on the relationship between neighbourhood violence and GWG is scant. Our study aims to examine the relationship between neighbourhood violence and GWG outside the recommended range.

Methods—We used statewide vital statistics and health care utilization data from California for 2006–2012 ($n = 2,364,793$) to examine the relationship of neighbourhood violence (quarters of zip-code rates of homicide and assault) in the first 37 weeks of pregnancy with GWG (categorized using the Institute of Medicine's pregnancy weight gain guidelines). We estimated risk ratios (RR) and marginal risk differences, and analyses were stratified by maternal race/ethnicity and prepregnancy body mass index.

Results—Residence in neighbourhoods with the highest quartile of violence was associated with more excessive GWG (adjusted RR 1.04; 95% confidence interval [CI] 1.03, 1.05), compared to the lowest quartile of violence; violence was not associated with inadequate GWG. On the difference scale, this association translates to 2.3% more women gaining weight excessively rather than adequately if all women were exposed to high violence compared to if all women were exposed to low violence. Additionally, associations between neighbourhood violence and excessive GWG were larger in non-white women than in white women.

Conclusions—These findings support the hypothesis that violence can affect weight gain during pregnancy, emphasizing the importance of neighbourhood violence as a public health issue.

Keywords

neighbourhood violence; gestational weight gain; g-computation; pregnancy

Correspondence should be addressed to: Jennifer Ahern, 50 University Hall, University of California, Berkeley, Berkeley, CA 94720, jahern@berkeley.edu.

*These authors contributed equally to this work

Introduction

Maternal weight gain during pregnancy has important implications for the health and well-being of both women and infants. Building on a systematic review of the consequences of gestational weight gain (GWG) by the Agency of Health Research and Quality¹, in 2009 the Institute of Medicine (IOM) reviewed the epidemiology, causes, and consequences of GWG to update guidelines for GWG.² The IOM report concluded that both inadequate and excessive GWG are associated with poor perinatal health outcomes and longer term poor health outcomes such as maternal and child obesity.^{1,2} Recommendations for weight gain during pregnancy were updated and depend on prepregnancy body mass index (BMI).²

Only one in three American women gain weight appropriately during pregnancy based on these IOM guidelines.³ Studies suggest that stressful life events and psychosocial conditions (for example, depression and anxiety) can lead to changes in diet, sleeping patterns, or metabolic rate as well as the uptake of hazardous health habits such as smoking or alcohol which can cause unhealthy weight gain.⁴⁻⁹

Additionally, the IOM Committee recognized that while individual biology and behaviours are important, environmental factors also need consideration, and called for studies that consider “more broadly, the social, cultural and environmental context of GWG”.² (p. 5) Research on the social and environmental determinants of GWG suggest that the neighbourhood environment is associated with both inadequate and excessive GWG.^{10,11} Neighbourhood violence, defined as witnessing or hearing about violence in one’s own community, is a potentially modifiable component of the neighbourhood environment that is associated with higher BMIs in non-pregnant female populations.¹² However, to our knowledge, no studies to date have investigated the role of neighbourhood violence in unhealthy GWG.

This paper fills that research gap by examining the association between neighbourhood violence and GWG. We hypothesize that neighbourhood violence is associated with inadequate and excessive GWG, after accounting for individual characteristics and neighbourhood economic conditions, and that these associations differ by maternal race/ethnicity and prepregnancy BMI.^{2,13}

Methods

Data Sources

We used statewide mortality records from the California Department of Public Health Office of Vital Statistics and hospitalization data from California’s Office of Statewide Health Planning and Development (OSHPD) to characterize violence in ZIP code tabulation areas (ZIP code) from 2006 to 2012. We used OSHPD’s linked birth-hospitalization records from 2007 to 2012 for maternal GWG and covariate assessment. Data from the U.S. Census Bureau and American Community Survey were used for ZIP code-level population estimates and neighbourhood characteristics.

Study Design and Study Population

We used a non-concurrent cohort study design to assess associations between neighbourhood violence and GWG. Our study population of interest was all pregnant women who delivered between 2007 and 2012 in California ($n = 3,213,822$). We included deliveries starting in 2007 because California adopted the revised birth certificate in 2007, which includes maternal height, allowing for calculation of BMI-specific GWG targets. At the time of our analysis, 2012 was the most current year of data available. Eligibility criteria included full-term (37 to 42 completed weeks gestation), singleton pregnancies and residence in urban or suburban ZIP code ($n = 2,753,177$). We restricted to full-term, singleton pregnancies so that IOM recommendations for GWG could be appropriately applied.² We determined full-term pregnancies using the method by Talge et al¹⁴ to select the most plausible gestational age. Rural areas were excluded because estimated neighbourhood violence rates were unreliable due to small populations at the ZIP code level. After excluding women with implausible values (Supplemental Table 1) for prepregnancy weight, delivery weight, or height¹⁵ ($n = 238,718$, 8.7%); or with missing information on key covariates ($n = 149,666$, 5.4%), the final study population included 85.9% ($n = 2,364,793$) of all study-eligible pregnancies (see results for further information on the women excluded due to missing/implausible values).

Measures

Exposure assessment: Neighbourhood Violence—We defined neighbourhood as the mother's ZIP code because it is the smallest geography that OSHPD allows researchers to request. This geographic level is closest to a neighbourhood that we have available, in contrast with larger units such as cities or counties that are commonly used.¹⁶

We characterized neighbourhood violence exposure during the first 37 weeks of pregnancy as the rate of homicides (from mortality records) and assaults resulting in a hospital visit (from hospitalization data) in the ZIP code of maternal residence. We restricted our exposure window to the first 37 weeks of pregnancy to standardize the duration of exposure for all women. We calculated rates by dividing monthly ZIP code-level counts of homicides and assaults (Supplemental Table 2 for exact classifications) by interpolated monthly ZIP code-level population estimates derived from the U.S. Census Bureau and ACS. We then linked eligible pregnancy records using maternal ZIP code of residence to the monthly violence rates and summed all rates during the exposure window of conception through the 37th week of pregnancy, proportionately allocating violence rates for the first and last month of the exposure window (Supplemental Figure 1). We determined the conception date by subtracting the number of weeks' gestation from the delivery date. Lastly, prior to any data exclusions, we categorized violence exposure into quartiles corresponding with low violence (Q1: 0 to 170 per 100,000), low-medium violence (Q2: 171 to 259 per 100,000), medium-high violence (Q3: 260 to 369 per 100,000), high violence (Q4: 370 to 178,124 per 100,000).

Outcome Assessment: Inadequate and Excessive Gestational Weight Gain

We calculated prepregnancy BMI (self-reported weight, kg/self-reported height, m²) and derived GWG as the difference between delivery weight and prepregnancy weight. We then

classified women into four prepregnancy BMI categories (underweight ($<18.5 \text{ kg/m}^2$), normal weight ($18.5\text{--}24.9 \text{ kg/m}^2$), overweight ($25\text{--}29.9 \text{ kg/m}^2$), and obese ($\geq 30 \text{ kg/m}^2$). The IOM defines adequate GWG by prepregnancy BMI group as follows: underweight: 28–40 pounds (12.7–18.1 kg); normal weight: 25–35 pounds (11.3–15.9 kg); overweight: 15–25 pounds (6.8–11.3 kg); and obese: 11–20 pounds (5.0–9.1 kg).² We defined inadequate GWG and excessive GWG as less or more than the IOM recommended range, respectively.

Confounder Assessment: Maternal and Neighbourhood Characteristics

We controlled for maternal characteristics identified a priori from the literature,^{2,10,11,13} including maternal age, parity, race/ethnicity (non-Hispanic white [white]; non-Hispanic black [black]; non-Hispanic Native American [Native American], non-Hispanic Asian/Pacific Islander [Asian/Pacific Islander], non-Hispanic two or more races [multi-race]; and Hispanic), prepregnancy BMI (underweight, normal weight, overweight, obese class I [BMI $30\text{--}34.9 \text{ kg/m}^2$], obese class II [BMI $35\text{--}39.9 \text{ kg/m}^2$], and obese class III [BMI $\geq 40 \text{ kg/m}^2$]), education ($<$ high school, high school or GED, some college, college degree, advanced degree), year of delivery, government insurance as payment source (yes/no [proxy for individual-level poverty]), and immigrant status (yes/no for maternal birth outside the United States). We also controlled for two neighbourhood characteristics: urban/suburban classification and percent of households in the ZIP code below the Federal Poverty Level, defined using the 5-year 2007–11 ACS estimates. Maternal race/ethnicity and pre-pregnancy BMI were considered a priori as a potential effect measure modifiers of the association between neighbourhood violence and GWG.^{2,13}

Statistical Analysis

We compared inadequate and excessive GWG to adequate GWG in separate analyses. To account for the possible correlation between women living in the same ZIP code, we used generalized estimating equation (GEE) in regression models, controlling for confounders, to estimate risk ratios and g-computation to quantify the marginal risk difference for the association of neighbourhood violence with GWG.¹⁷ For marginal risk differences, bias-corrected 95% confidence intervals were calculated by bootstrapping with replacement 599 times.¹⁸ Because the large sample size resulted in highly precise estimates, we considered both precision and the magnitude of the association to determine whether results were meaningful from a clinical perspective.¹⁹

We conducted stratified analysis to determine if relationships differed by either race/ethnicity or prepregnancy BMI. Additionally, to examine the robustness of our results, we conducted an array of sensitivity tests. Broadly, these tests included defining GWG categories using GWG-for-gestational age z-scores and percentiles described by Hutcheon et al²⁰ (Supplemental Table 4 – Supplemental Table 6).

We performed data management in SAS Software, Version 9.3 (Cary, North Carolina, USA) and conducted analyses using STATA 13.1 software (College Station, Texas, USA).

Results

Study Population

Table 1 describes the study population overall and by GWG (inadequate, adequate, excessive). The prevalence of inadequate and excessive GWG were 20.4% and 49.8%, respectively. Compared to the overall population, a higher percentage of women with inadequate weight gain were Hispanic, supported by government insurance, lower education, lower prepregnancy BMI, and immigrant. A higher percentage of women with excessive weight gain were white, obese, and born in the United States. Descriptions of the study population by violence quartiles is available in Supplemental Table 3.

Eligible women excluded from the analysis were similar to women included in the analysis. Excluded women had similar distributions of gestational weight gain categories, violence exposure, maternal education levels, immigrant status, urbanicity, prepregnancy BMI, and race/ethnicity. However, a higher percentage of excluded women paid for delivery with government insurance and gave birth in 2007, the first year California adopted the new version of the birth certificate compared to women included in the analysis (data not shown).

Bivariate estimates indicated that higher quartiles of neighbourhood violence exposure were associated in a dose-response manner with inadequate GWG (Table 2). However, after controlling for confounders, there were no meaningful associations between neighbourhood violence and inadequate GWG.

In both bivariate and multivariate estimates, higher violence was associated with excessive GWG in a dose-response pattern ($aRR_{Q2} = 1.01$, $aRR_{Q3} = 1.02$, $aRR_{Q4} = 1.04$; Table 2). On the difference scale, the association for the highest quartile was 2.3%; this captures the additional percent of women gaining weight excessively rather than adequately if all women were exposed to high violence (61.7%) compared with if all women were exposed to low violence (59.2%). Results from analysis of GWG-for-gestational age z-scores and percentiles show the same patterns as the main analysis (Supplemental Table 4).

In most racial/ethnic groups, neighbourhood violence had dose-response associations with excessive GWG and minimal or null associations inadequate GWG (Table 3). Non-white women had higher risk of excessive gain associated with violence compared to white women. Results from analysis of GWG-for-gestational age percentiles by race show the same patterns as the main analysis (Supplemental Table 5).

Findings for Asian/Pacific Islander women were somewhat different, and indicated a shift in the distribution of GWG associated with violence. Compared to low violence exposure, exposure to greater levels of violence was associated with reduced risk of inadequate GWG ($aRR_{Q2} = 0.98$, $aRR_{Q3} = 0.97$, $aRR_{Q4} = 0.95$) and a greater risk of excessive GWG ($aRR_{Q2} = 1.03$, $aRR_{Q3} = 1.05$, $aRR_{Q4} = 1.05$). On the difference scale, the associations translate to 1.8% fewer Asian/Pacific Islander women in inadequate GWG than adequate GWG and 3.0% more women in excessive GWG than adequate GWG if all Asian/Pacific Islander women were exposed to high violence compared to if all Asian/Pacific Islander women were exposed to low violence.

Results by Prepregnancy BMI

The association between neighbourhood violence and GWG also varied by prepregnancy BMI (Table 4). Higher neighbourhood violence levels were associated with lower risk of inadequate GWG among women with an underweight prepregnancy BMI ($aRR_{Q2} = 0.96$, $aRR_{Q3} = 0.94$, $aRR_{Q4} = 0.94$) and greater risk of inadequate GWG among women with an obese class I BMI ($aRR_{Q2} = 1.03$, $aRR_{Q3} = 1.04$, $aRR_{Q4} = 1.04$). Higher neighbourhood violence was associated with excessive GWG for all pre-pregnancy BMI categories, with the risk attenuating as pre-pregnancy weight increased.

For women with an underweight pre-pregnancy BMI, neighbourhood violence was associated with a shift in weight gain. On the difference scale, the associations translate to 2.6% fewer women in inadequate GWG than in adequate GWG and 3.3% more women in excessive GWG than adequate GWG if all women with an underweight pre-pregnancy BMI were exposed to high violence, compared to if all women with an underweight pre-pregnancy BMI were exposed to low violence.

Results from analyses of GWG-for-gestational age percentiles suggest shifts in weight gain for women with normal weight, and overweight prepregnancy BMIs, in addition to the women with underweight prepregnancy BMIs. Moreover, though higher neighbourhood violence was associated with excessive GWG, the risk did attenuate for obese classes II and III only (Supplemental Table 6).

Comment

Using population wide data on over 2 million pregnancies in California from 2007 to 2012, we found higher exposure to neighbourhood violence increased the risk of excessive GWG. We found stronger associations with violence and GWG for minority women, suggesting that violence may contribute to health disparities. Although we are aware of no other research directly on this topic, these results are consistent with a study that observed that Latinas with higher BMIs post-pregnancy lived in more violent neighbourhoods.²¹ Overall, there was no evidence of an adjusted association with neighbourhood violence and inadequate GWG. However, stratified results suggested differences by maternal race/ethnicity and prepregnancy BMI. For two subgroups (Asian/Pacific Islanders and women with underweight pre-pregnancy BMI), exposure to higher levels of violence was associated with reduced risk of inadequate GWG and an increased risk of excessive GWG, suggesting that, for these subgroups, exposure to higher levels of violence is associated with increased weight gain overall.

Because there is limited research on this topic, we used an exploratory analysis to better understand the relation of our results to past results that looked at neighbourhoods and GWG. Mendez et al¹¹ studied neighbourhood disadvantage in Allegheny County, Pennsylvania and found a link between disadvantage and inadequate GWG, but not excessive GWG. In our study, violence was associated with inadequate and excessive GWG before adjusting for poverty, but only with excessive GWG after adjusting for poverty. Thus, the relationship between neighbourhood violence and inadequate gain in our study was explained by poverty, while the relationship with excessive gain was independent of poverty.

We were not able to directly examine the pathways between neighbourhood violence exposure and GWG, but there are several individual and environmental factors related to obesity that could explain our finding that living in a violent neighbourhood is associated with excessive GWG and would be fruitful for future research. First, violence and fear of violence can result in decreased community investment and limited community cohesion.^{22,23} These barriers can influence individual and environmental barriers to healthy eating and active living, two key drivers of weight gain and obesity.^{22,23} People living in violent communities are less likely to go outside and be physically active; have less access to healthy foods; and are more likely to experience psychological effects such as stress, depression, and anxiety that lead to poor eating habits and physical inactivity.^{22,23}

Second, exposure to neighbourhood violence can trigger biological mechanisms that are linked to weight gain. Chronic stress is associated with an increase in cortisol levels, visceral fat, hyperactivation of the hypothalamic-pituitary-adrenal axis, and the induction of stress and comfort eating of energy dense foods.²³ Additionally, living in violent neighbourhoods may affect sleeping patterns because of psychological stress or outside noises (e.g., sirens, fights). Sleep disturbances can be psychological, emotional, or physical and lead to fewer hours of sleep and more weight gain.²⁴ The amount and quality of sleep can change the balance of physiological weight regulation mechanisms.²⁵

This study was subject to several limitations. Residual confounding is always a concern in epidemiologic studies, although we were able to control many important demographic and socioeconomic covariates. Missing data may also be of concern; there was a large degree of missing data for our analysis sample. However, those removed from our study because of missing data were broadly similar to those retained in our study. Measurement error may be present in our assessment of neighbourhood of residence and the self-reported prepregnancy weight and height. We were unable to assess the validity of self-reported prepregnancy weight and height data which may cause misclassification of prepregnancy BMI and GWG; however, recent studies have found such misclassification does not meaningfully affect estimates for associations with perinatal outcomes.^{26,27,28}

Nonetheless, future studies with measured weights are needed. Additionally, a woman's residence was determined at the time of delivery, and we construct exposure levels based on this residence, despite the possibility that she may have moved during her pregnancy. While there is evidence that residential mobility during pregnancy may cause exposure misclassification, many women move within the same municipality or to similar neighbourhoods, thus any misclassification will likely bias our results toward the null.^{29,30}

Our definition of neighbourhood may not accurately represent a woman's neighbourhood or where violent events occur. Many articles define neighbourhood using census tracts, but ZIP code is the smallest geographic unit available for these births, and is thus the closest to a neighbourhood unit available for these analyses.¹⁶ Moreover, due to the structure of the data, neighbourhood violence is coded to the victim's place of residence, not where the violent event occurred. Women living in neighbourhoods where their neighbours are victims of violence are likely to see violence occur, and to see and hear about the consequences of violence, regardless of the incident location. It is estimated that a large percent of violent

events happen near a victim's home, suggesting that violence rates coded to ZIP codes of residence would be similar to rates based on ZIP codes of violent events.¹⁶ Furthermore, due to personal relationships, a woman could certainly experience stress when violence occurs to someone, whether or not she witnessed the event. However, differential misclassification may remain due to potential clustering of violent events within zip-codes that may be related to neighbourhood conditions such as socio-economics or demographics.

We restricted our sample to term births, and thus associations between violence and GWG for women with preterm births were not captured. However, sensitivity tests with the outcome as GWG-for-gestational age z-scores and percentiles derived for all births with 29 or more weeks' gestation showed similar patterns of association as the IOM categories.

These limitations are balanced by the population wide data that included all eligible California pregnancies (births and foetal deaths) over a 6-year period. The dataset included detailed records that allowed for the assessment of multilevel factors and subgroup analyses for groups most at risk for adverse maternal and infant health outcomes that are often omitted due to inadequate numbers for analysis, such as Native American women and women who are underweight or with severe obesity. Our data also allowed us to characterize violence with a high degree of temporal and geographic precision. In contrast, available crime data have either high geographic or temporal precision, and differences in reporting practices between jurisdictions create concerns about the appearance of differences that may be an artefact of reporting.^{31,32} Our analysis methods established temporality of exposure and outcome. Additionally, we were able to review the robustness of our results using secondary analyses that allowed for the inclusion of premature deliveries.

Inadequate and excessive GWG have negative health effects on mothers and infants, but our understanding of what causes unhealthy GWG is limited. This research supports the hypothesis that aspects of neighbourhood environments such as violence have important implications for weight gain during pregnancy. Our results require confirmation, but suggest that interventions aimed at improving pregnancy health and reducing disparities in maternal and infant health should take into account neighbourhood environments, particularly exposures to violence.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

This project was supported by the National Institute of Health grants #DP2HD080350, #R01HD072008, and #R01MD006104; the Robert Wood Johnson Health and Society Scholars Program; and the University of California, Berkeley Committee on Research.

References

1. Viswanathan, M.; Siega-Riz, AM.; Moos, M., et al. Outcomes of maternal weight gain, evidence report/technology assessment no. 168 (Prepared by RTI International - University of North Carolina Evidence-based Practice Center under Contract No. 290-02-0016). AHRQ Publication No. 08-E009. Rockville, MD: Agency for Healthcare Research and Quality; 2008 May.

2. Institute of Medicine. Weight Gain during Pregnancy: Reexamining the Guidelines. National Academies Press; 2009.
3. Deputy NP, Sharma AJ, Kim SY. Gestational weight gain: United States, 2012 and 2013. *Morbidity and Mortality Weekly Report (MMWR)*. 2015; 64(43):1215–1220. [PubMed: 26540367]
4. Zhu P, Huang W, Hao J, Huang K, Jiang X, Tao F. Time-specific effect of prenatal stressful life events on gestational weight gain. *International Journal of Gynecology & Obstetrics*. 2013; 122(3): 207–211. [PubMed: 23820031]
5. Brawarsky P, Stotland N, Jackson R, et al. Pre-pregnancy and pregnancy-related factors and the risk of excessive or inadequate gestational weight gain. *International Journal of Gynecology & Obstetrics*. 2005; 91(2):125–131. [PubMed: 16202415]
6. Picone TA, Allen LH, Schramm MM, Olsen PN. Pregnancy outcome in North American women: Effects of diet, cigarette smoking, and psychological stress on maternal weight gain. *American Journal of Clinical Nutrition*. 1982; 36(6):1205–1213. [PubMed: 7148739]
7. Stein, Z.; Susser, M.; Saenger, G.; Marolla, F. *Famine and human development: The Dutch hunger winter of 1944–1945*. New York: Oxford University Press; 1975.
8. Boy A, Salihu HM. Intimate partner violence and birth outcomes: a systematic review. *International Journal of Fertility and Women's Medicine*. 2004; 49(4):159–164.
9. Moraes CL, Amorim A, Reichenheim ME. Gestational weight gain differentials in the presence of intimate partner violence. *International Journal of Gynecology & Obstetrics*. 2006; 95(3):254–260. [PubMed: 17069816]
10. Laraia B, Messer L, Evenson K, Kaufman JS. Neighborhood factors associated with physical activity and adequacy of weight gain during pregnancy. *Journal of Urban Health*. 2007; 84(6):793–806. [PubMed: 17710552]
11. Mendez DD, Doebler DA, Kim KH, Amutah NN, Fabio A, Bodnar LM. Neighborhood socioeconomic disadvantage and gestational weight gain and loss. *Maternal Child Health J*. 2014; 18(5):1095–1103.
12. Burdette HL, Wadden TA, Whitaker RC. Neighborhood safety, collective efficacy, and obesity in women with young children. *Obesity*. 2006; 14(3):518–525. [PubMed: 16648624]
13. Headen IE, Mujahid MS, Cohen AK, Rehkopf DH, Abrams B. Racial/ethnic disparities in inadequate gestational weight gain differ by pre-pregnancy weight. *Maternal and Child Health Journal*. 2015; 19(8):1672–1686. [PubMed: 25652057]
14. Talge NM, Mudd LM, Sikorskii A, Basso O. United States birth weight reference corrected for implausible gestational age estimates. *Pediatrics*. 2014; 133(5):844–853. [PubMed: 24777216]
15. Martin JA, Hamilton BE, Osterman MJ. *Births in the United States, 2014*. NCHS Data Brief. 2015; 216:1–8.
16. Aizer, A. Neighborhood violence and urban youth; NBER Working Paper No. 13773; <http://www.nber.org/papers/w13773.pdf>
17. Ahern J, Hubbard A, Galea S. Estimating the effects of potential public health interventions on population disease burden: a step-by-step illustration of causal inference methods. *American Journal of Epidemiology*. 2009; 169(9):1140–1147. [PubMed: 19270051]
18. Hall P. On the number of bootstrap simulations required to construct a confidence interval. *The Annals of Statistics*. 1986:1453–1462.
19. Wasserstein RL, Lazar NA. The ASA's statement on p-values: context, process, and purpose. *Am Stat*. 2016 Available online: <http://dx.doi.org/10.1080/00031305.2016.1154108>.
20. Hutcheon JA, Platt RW, Abrams B, Himes KP, Simhan HN, Bodnar LM. A weight-gain-for-gestational-age z-score chart for the assessment of maternal weight gain in pregnancy. *American Journal of Clinical Nutrition*. 2013; 97(5):1062–1067. [PubMed: 23466397]
21. Keller C, Todd M, Ainsworth B, et al. Overweight, obesity, and neighborhood characteristics among postpartum Latinas. *Journal of Obesity*. 2013; 2013
22. Cohen, L.; Davis, R.; Lee, V.; Valdovinos, E. *Addressing the intersection: Preventing violence and promoting healthy eating and active living*. Oakland, CA: Prevention Institute; 2010.
23. Pollack, KM.; Rossen, LM.; Roman, C.; Whitt-Glover, MC.; Leviton, LC. *Obesity Interventions in Underserved Communities: Evidence and Directions*. Baltimore, MD: Johns Hopkins University

- Press; 2014. The importance of public safety in promoting physical activity and curbing obesity within African American communities; p. 162
24. Patel SR, Malhotra A, White DP, Gottlieb DJ, Hu FB. Association between reduced sleep and weight gain in women. *American Journal of Epidemiology*. 2006; 164(10):947–954. doi: kwj280 [pii]. [PubMed: 16914506]
  25. Nedeltcheva AV, Scheer FA. Metabolic effects of sleep disruption, links to obesity and diabetes. *Current Opinion in Endocrinology, Diabetes, and Obesity*. 2014; 21(4):293–298. 10.1097/MED.000000000000082 [doi].
  26. Bodnar LM, Abrams B, Bertolet M, Gernand AD, Parisi SM, Himes KP, et al. Validity of birth certificate-derived maternal weight data. *Paediatric and Perinatal Epidemiology*. 2014; 28(3):203–212. [PubMed: 24673550]
  27. Bodnar LM, Siega-Riz AM, Simhan HN, Diesel JC, Abrams B. The impact of exposure misclassification on associations between prepregnancy BMI and adverse pregnancy outcomes. *Obesity*. 2010; 18(11):2184–2190. [PubMed: 20168307]
  28. Han E, Abrams B, Sridhar S, Xu F, Hedderson M. Validity of self-reported pre-pregnancy weight and body mass index classification in an integrated health care delivery system. *Paediatric and Perinatal Epidemiology*. 2016; 30(4):314–319. [PubMed: 26961120]
  29. Fell DB, Dodds L, King WD. Residential mobility during pregnancy. *Paediatric and Perinatal Epidemiology*. 2004; 18(6):408–414. [PubMed: 15535816]
  30. Pearl, M.; Graham, S.; Sacramento, C.; Ahern, J. Changing residence during pregnancy: Implications for studies of geographically-based exposures. Poster session presented at Understanding the Role of Social Context in Population Health: Novel Foci and Innovative Approaches. 47th Annual Meeting of the Society for Epidemiologic Research; 2014 Jun 24–27; Seattle, WA.
  31. Bailick C. How to make sense of conflicting, confusing and misleading crime statistics. *FiveThirtyEight*. [2016 Jan 8] Retrieved from: <http://fivethirtyeight.com/features/how-to-make-sense-of-conflicting-confusing-and-misleading-crime-statistics/>.
  32. Poston B, Rubin J, Pesce A. LAPD underreported serious assaults, skewing crime stats for 8 years. *Los Angeles Times*. 2015 Oct 15. Retrieved from: <http://www.latimes.com/local/cityhall/la-me-crime-stats-20151015-story.html>.

Table 1

Description of study population

	Gestational Weight Gain Category			
	Total ((n = 2,364,793))	Inadequate ((n = 481,399 20.4%))	Adequate ((n = 706,240 29.9%))	Excessive ((n = 1,177,214 49.8%))
Maternal age (years)mean (SD)	28.3 (6.2)	28.3 (6.4)	28.7 (6.2)	28.0 (6.2)
Parity, median(range)	2.0(0, 29)	2.0(0, 26)	2.0(0, 29)	2.0 (0, 25)
% Households below Federal Poverty Level in ZCTA, median (range)	15.0 (0, 100)	15.8 (0, 100)	14.2 (0, 100)	14.8 (0, 100)
Gestational age at delivery (weeks), mean (SD)	39.1 (1.2)	39.0 (1.2)	39.1 (1.2)	39.2 (1.2)
Neighborhood Violence Quartile (n (%))				
Q1 - Low	575,900 (24.4)	107,893 (22.4)	189,121 (26.8)	278,886 (23.7)
Q2 - Low-Medium	595,200 (25.2)	119,537 (24.8)	178,356 (25.3)	297,327 (25.3)
Q3 - Medium-High	598,544 (25.3)	124,633 (25.9)	172,822 (24.5)	301,089 (25.6)
Q4 - High	595,129 (25.2)	129,247 (26.9)	165,941 (23.5)	299,912 (25.5)
Maternal Race/Ethnicity (n (%))				
White, non-Hispanic	638,440 (27.0)	96,769 (20.1)	184,987 (26.2)	356,684 (30.3)
Black, non-Hispanic	120,652 (5.1)	23,773 (4.9)	28,665 (4.1)	68,214 (5.8)
Native American, non- Hispanic	6,834 (0.3)	1,126 (0.2)	1,543 (0.2)	4,165 (0.4)
Asian/Pacific Islander, non-Hispanic	311,234 (3.2)	73,889 (15.4)	114,718 (16.2)	122,627 (10.4)
Multi-race, non-Hispanic	47,691 (2.0)	7,063 (1.5)	12,507 (1.8)	28,127 (2.4)
Hispanic	1,239,942 (52.4)	278,719 (57.9)	363,820 (51.5)	597,403 (50.8)
Method of Payment for Delivery (n (%))				
Government insurance	1,154,979 (48.8)	262,114 (54.5)	327,806 (46.4)	565,059 (48.0)
Private insurance, self- pay, other	1,209,814 (51.2)	219,225 (45.5)	378,434 (53.6)	612,155 (52.0)
Prepregnancy Body Mass Index (n (%))				
Underweight	95,369 (4.0)	29,241 (6.1)	40,546 (5.7)	25,582 (2.2)
Normal Weight	1,175,739 (49.8)	280,039 (58.2)	413,905 (58.6)	482,795 (41.0)
Overweight	610,603 (25.8)	78,334 (16.3)	152,730 (21.6)	379,539 (32.2)
Obese – Class I	294,254 (12.4)	43,232 (9.0)	58,740 (8.3)	192,282 (16.3)
Obese – Class II	119,395 (5.1)	27,723 (5.8)	25,966 (3.7)	65,706 (5.6)
Obese – Class III	68,433 (2.9)	22,770 (4.7)	14,353 (2.0)	31,310 (2.7)
Urbanicity (n (%))				
Urban	2,219,647 (93.9)	451,372 (93.8)	665,616 (94.3)	1,102,686 (93.7)
Maternal Education (n (%))				
Less than high school diploma	573,032 (24.2)	145,942 (30.3)	169,259 (24.0)	257,831 (21.9)
High school diploma or equivalent	616,644 (26.1)	125,992 (26.2)	169,747 (24.0)	320,905 (27.3)

	Gestational Weight Gain Category			
	Total ((n = 2,364,793))	Inadequate ((n = 481,399 20.4%))	Adequate ((n = 706,240 29.9%))	Excessive ((n = 1,177,214 49.8%))
Some college	432,108 (18.3)	78,512 (16.3)	118,493 (16.8)	235,103 (20.0)
College degree	530,831 (22.5)	93,241 (19.4)	173,105 (24.5)	264,485 (22.5)
Advanced degree	212,178 (9.0)	37,652 (7.8)	75,636 (10.7)	98,890 (8.4)
Mother Born in the United States (n (%))				
United States	1,354,615 (57.3)	231,909 (48.2)	371,117 (52.6)	751,589 (63.8)

Unadjusted and adjusted^a risk ratio and marginal risk differences^b for associations between neighborhood violence and gestational weight gain

Table 2

	Neighborhood Violence Quartile			
	Low (Q1)	Low-Medium (Q2)	Medium-High (Q3)	High (Q4)
Outcome: Inadequate GWG (n = 1,187,577)				
Unadjusted Estimates				
RR (95% CI)	1.00 (Reference)	1.10(1.09, 1.12)	1.15 (1.13, 1.17)	1.21(1.18, 1.23)
Marginal Risk Difference ^c	0.0 (Reference)	3.8%	5.6%	7.5%
Adjusted Estimates				
aRR(95% CI)	1.00 (Reference)	1.01 (1.00, 1.02)	1.01 (0.99, 1.02)	1.00(0.98, 1.02)
Marginal Risk Difference (95% CI) ^d	0.0 (Reference)	0.3% (-0.0%, 0.6%)	0.3% (0.0%, 0.6%)	-0.0% (-0.3%, 0.4%)
Outcome: Excessive GWG (n = 1,883,454)				
Unadjusted Estimates				
RR (95% CI)	1.00 (Reference)	1.05(1.04, 1.06)	1.07(1.06, 1.08)	1.08(1.07, 1.09)
Marginal Risk Difference ^c	0.0 (Reference)	2.9%	3.9%	4.8%
Adjusted Estimates				
aRR(95% CI)	1.00 (Reference)	1.01(1.01, 1.02)	1.02(1.02, 1.03)	1.04(1.03, 1.05)
Marginal Risk Difference (95% CI) ^d	0.0 (Reference)	1.0% (0.8%, 1.2%)	1.5% (1.2%, 1.7%)	2.3% (2.0%, 2.6%)

RR = Risk Ratio. aRR = adjusted Risk Ratio.

^aMultivariable estimates adjusted for maternal age, maternal race/ethnicity, delivery payment method, prepregnancy BMI, urbanicity, maternal education, maternal birthplace, parity, calendar year, and neighborhood percent poverty, clustered by ZIP code.

^bMarginal Risk Difference is the difference in expected values (predicted from the model) between all records being exposed to the violence category and all records being exposed to low violence.

^cBias-corrected bootstrapped 95% CI calculated for adjusted marginal risk differences using 599 bootstraps¹⁸.

^dBootstrapped 95% CI cannot be calculated for unadjusted models.

Adjusted^a risk ratios and marginal risk differences^b for associations between neighborhood violence and gestational weight gain, stratified by race/ethnicity

Table 3

	Neighborhood Violence Quartile			
	Low (Q1)	Low-Medium (Q2)	Medium-High (Q3)	High (Q4)
Outcome: Inadequate Gestational Weight Gain				
White, non-Hispanic (n = 281,756)				
aRR (95% CI)	reference	1.00 (0.98, 1.02)	1.02 (1.00, 1.04)	1.00 (0.97, 1.02)
Marginal Risk Difference (95% CI)	reference	0.1% (−0.4%, 0.6%)	0.6% (0.1%, 1.2%)	0.1% (−0.7%, 0.6%)
Black, non-Hispanic (n = 52,438)				
aRR (95% CI)	reference	1.00 (0.96, 1.04)	1.00 (0.96, 1.04)	0.99 (0.95, 1.04)
Marginal Risk Difference (95% CI)	reference	0.2% (−2.0%, 1.8%)	−0.1% (−2.2%, 1.7%)	0.4% (−2.7%, 1.4%)
Native American, non-Hispanic (n = 2,669)				
aRR (95% CI)	reference	0.99 (0.84, 1.16)	0.99 (0.84, 1.16)	1.02 (0.86, 1.20)
Marginal Risk Difference (95% CI)	reference	−0.5% (−6.8%, 6.5%)	−0.6% (−7.1%, 6.3%)	0.6% (−6.7%, 7.6%)
Asian/Pacific Islander, non-Hispanic (n = 188,607)				
aRR (95% CI)	reference	0.98 (0.96, 1.00)	0.97 (0.94, 0.99)	0.95 (0.92, 0.99)
Marginal Risk Difference (95% CI)	reference	−0.7% (−1.3%, −1.3%)	−1.3% (−2.1%, −0.6%)	−1.8% (−2.6%, −1.0%)
Multi-race, non-Hispanic (n = 19,570)				
aRR (95% CI)	reference	1.07 (1.01, 1.13)	1.05 (0.99, 1.12)	1.09 (1.02, 1.17)
Marginal Risk Difference (95% CI)	reference	2.3% (0.1%, 4.2%)	1.8% (−0.4%, 3.9%)	3.1% (0.2%, 5.4%)
Hispanic (n = 642,539)				
aRR (95% CI)	reference	1.01 (1.00, 1.03)	1.01 (0.99, 1.03)	1.01 (0.98, 1.03)
Marginal Risk Difference (95% CI)	reference	0.6% (0.1%, 1.0%)	0.5% (0.0%, 0.9%)	0.3% (−0.2%, 0.8%)
Outcome: Excessive Gestational Weight Gain				
White, non-Hispanic (n = 541,671)				
aRR (95% CI)	reference	1.00 (1.00, 1.01)	1.01 (1.00, 1.02)	1.01 (1.00, 1.02)
Marginal Risk Difference (95% CI)	reference	0.3% (0.0%, 0.6%)	0.6% (0.2%, 1.0%)	0.7% (0.2%, 1.1%)
Black, non-Hispanic (n = 96,879)				

Neighborhood Violence Quartile				
	Low (Q1)	Low-Medium (Q2)	Medium-High (Q3)	High (Q4)
aRR (95% CI)	reference	1.00 (0.98, 1.02)	1.02 (1.00, 1.04)	1.03 (1.01, 1.05)
Marginal Risk Difference (95% CI)	reference	0.0% (−1.2%, 1.2%)	1.2% (0.1%, 2.5%)	1.8% (0.5%, 3.0%)
Native American, non-Hispanic (n = 5,708)				
aRR (95% CI)	reference	1.04 (0.98, 1.11)	1.03 (0.97, 1.10)	1.05 (0.98, 1.12)
Marginal Risk Difference (95% CI)	reference	3.2% (−0.9%, 7.1%)	2.1% (−2.0%, 6.3%)	3.2% (−0.9%, 7.9%)
Asian/Pacific Islander, non-Hispanic (n = 237,345)				
aRR (95% CI)	reference	1.03 (1.02, 1.05)	1.05 (1.03, 1.06)	1.05 (1.03, 1.07)
Marginal Risk Difference (95% CI)	reference	1.5% (1.0%, 2.0%)	2.3% (1.6%, 2.9%)	2.5% (1.7%, 3.3%)
Two or More Races, non-Hispanic (n = 40,628)				
aRR (95% CI)	reference	1.02 (1.00, 1.04)	1.02 (1.00, 1.05)	1.04 (1.02, 1.07)
Marginal Risk Difference (95% CI)	reference	1.5% (0.3%, 2.7%)	1.7% (0.2%, 3.0%)	3.0% (1.4%, 4.5%)
Hispanic (n = 961,223)				
aRR (95% CI)	reference	1.02 (1.01, 1.02)	1.02 (1.01, 1.03)	1.04 (1.03, 1.05)
Marginal Risk Difference (95% CI)	reference	1.0% (0.6%, 1.3%)	1.3% (0.9%, 1.6%)	2.5% (2.0%, 2.8%)

aRR = adjusted Risk Ratio.

^aAdjusted for maternal age, delivery payment method, pre-pregnancy BMI, urbanicity, maternal education, maternal birthplace, parity, calendar year, and neighborhood percent poverty, clustered by ZIP code.

^bMarginal Risk Difference is the difference in expected values (predicted from the model) between all records being exposed to the violence category and all records being exposed to low violence. Bias-corrected bootstrapped 95% CI calculated for marginal risk differences using 599 bootstraps¹⁸.

Adjusted^a risk ratios and marginal risk differences^b for associations between neighborhood violence and gestational weight gain, stratified by prepregnancy body mass index

Table 4

	Neighborhood Violence Quartile			
	Low (Q1)	Low-Medium (Q2)	Medium-High (Q3)	High (Q4)
Outcome: Inadequate Gestational Weight Gain				
Underweight (n = 69,787)				
aRR (95% CI)	reference	0.96 (0.94, 0.99)	0.94 (0.91, 0.97)	0.94 (0.91, 0.98)
Marginal Risk Difference (95% CI)	reference	-1.5% (-2.8%, -0.4%)	-2.5% (-3.6%, -0.6%)	-2.5% (-3.9%, -1.1%)
Normal Weight (n = 693,944)				
aRR (95% CI)	reference	1.00 (0.99, 1.02)	1.00 (0.98, 1.01)	0.99 (0.97, 1.01)
Marginal Risk Difference (95% CI)	reference	0.1% (-0.2%, 0.5%)	-0.1% (-0.4%, 0.3%)	-0.4% (-0.9%, -0.0%)
Overweight (n = 231,064)				
aRR (95% CI)	reference	0.99 (0.96, 1.02)	1.01 (0.98, 1.04)	0.99 (0.95, 1.03)
Marginal Risk Difference (95% CI)	reference	-0.2% (-0.9%, 0.4%)	1.9% (-0.4%, 0.9%)	-0.3% (-1.0%, 0.5%)
Obese - Class I (n = 101,972)				
aRR (95% CI)	reference	1.03 (1.00, 1.06)	1.04 (1.01, 1.08)	1.04 (1.00, 1.09)
Marginal Risk Difference (95% CI)	reference	-0.2% (-0.9%, 0.4%)	1.9% (-0.4%, 0.9%)	-0.3% (-1.0%, 0.5%)
Obese - Class II (n = 53,689)				
aRR (95% CI)	reference	1.01 (0.98, 1.04)	1.01 (0.98, 1.05)	1.02 (0.98, 1.05)
Marginal Risk Difference (95% CI)	reference	0.6% (-0.9%, 2.0%)	0.7% (-0.8%, 2.2%)	0.8% (-0.8%, 2.4%)
Obese - Class III (n = 37,123)				
aRR (95% CI)	reference	0.99 (0.96, 1.03)	1.00 (0.97, 1.03)	1.00 (0.96, 1.03)
Marginal Risk Difference (95% CI)	reference	-0.3% (-2.3%, 1.5%)	-0.1% (-1.8%, 1.7%)	-0.2% (-2.5%, 1.8%)
Outcome: Excessive Gestational Weight Gain				
Underweight (n = 66,128)				
aRR (95% CI)	reference	1.06 (1.03, 1.09)	1.08 (1.04, 1.11)	1.09 (1.05, 1.13)
Marginal Risk Difference (95% CI)	reference	2.1% (1.0%, 3.1%)	2.8% (1.5%, 3.9%)	3.3% (2.0%, 4.6%)
Normal Weight (n = 896,700)				

Neighborhood Violence Quartile				
	Low (Q1)	Low-Medium (Q2)	Medium-High (Q3)	High (Q4)
aRR (95% CI)	reference	1.02 (1.01, 1.03)	1.03 (1.02, 1.04)	1.05 (1.04, 1.07)
Marginal Risk Difference (95% CI)	reference	1.0% (0.8%, 1.3%)	1.6% (1.2%, 1.8%)	2.8% (2.4%, 3.2%)
Overweight (n = 532,269)				
aRR (95% CI)	reference	1.01 (1.00, 1.01)	1.01 (1.02, 1.04)	1.03 (1.02, 1.04)
Marginal Risk Difference (95% CI)	reference	0.4% (0.0%, 0.8%)	0.8% (0.4%, 1.1%)	1.6% (1.1%, 2.0%)
Obese - Class I (n = 251,022)				
aRR (95% CI)	reference	1.02 (1.01, 1.02)	1.02 (1.01, 1.03)	1.02 (1.01, 1.04)
Marginal Risk Difference (95% CI)	reference	1.1% (0.6%, 1.7%)	1.4% (0.9%, 1.9%)	1.8% (1.1%, 2.4%)
Obese - Class II (n = 91,672)				
aRR (95% CI)	reference	1.00 (0.99, 1.01)	1.00 (0.99, 1.02)	1.01 (0.99, 1.03)
Marginal Risk Difference (95% CI)	reference	0.1% (-1.0%, 1.0%)	0.2% (-0.9%, 1.2%)	0.8% (-0.3%, 1.9%)
Obese - Class III (n = 45,663)				
aRR (95% CI)	reference	0.98 (0.96, 1.00)	0.99 (0.97, 1.01)	1.00 (0.97, 1.03)
Marginal Risk Difference (95% CI)	reference	-1.3% (-2.8%, 0.1%)	-0.6% (-2.1%, 0.9%)	-0.1% (-1.6%, 1.5%)
aRR = adjusted Risk Ratio				

^a Adjusted for maternal age, maternal race/ethnicity, delivery payment method, urbanicity, maternal education, maternal birthplace, parity, calendar year, and neighborhood percent poverty, clustered by ZIP code.

^b Marginal Risk Difference is the difference in expected values (predicted from the model) between all records being exposed to the violence category and all records being exposed to low violence. Bias-corrected bootstrapped 95% CI calculated for marginal risk differences using 599 bootstraps¹⁸.