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# Neighborhood Typology and Cardiometabolic Pregnancy Outcomes in the Maternal Adiposity Metabolism and Stress (MAMAS) Study

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## Abstract

**Objective:** To assess associations between neighborhood typologies classified across multiple neighborhood domains and cardiometabolic pregnancy outcomes and determine variation in effectiveness of a mindfulness-based stress reduction intervention on outcomes across neighborhood types.

**Methods:** We classified neighborhoods of participants in the Maternal Adiposity Metabolism and Stress (MAMAS) intervention (n=208) across dimensions of socioeconomic, food, safety and service/resource environments using latent class analysis. We estimated associations between neighborhood type and three cardiometabolic pregnancy outcomes— glucose tolerance (GT) during pregnancy, excessive gestational weight gain, and 6-month postpartum weight retention (PPWR)—using marginal regression models. We assessed interaction between neighborhood type and intervention.

**Results:** We identified five neighborhood types differing across socioeconomic, food, and resource environments. Compared to poor, well-resourced neighborhoods, middle income neighborhoods with low resources had higher risk of impaired GT (Relative Risk (RR): 4.1; 95% Confidence Interval (CI): 1.1, 15.5); and wealthy, well-resourced neighborhoods had higher PPWR (Beta: 3.9 kg; 95% CI: 0.3, 7.5). Intervention effectiveness varied across neighborhood

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type with wealthy, well-resourced and poor, moderately-resourced neighborhoods showing improvements in GT scores. PPWR was higher in intervention compared to control groups within wealthy, well-resourced neighborhoods.

**Conclusion:** Consideration of multidimensional neighborhood typologies revealed important nuances in intervention effectiveness on cardiometabolic pregnancy outcomes.

### Keywords

neighborhood quality; cardiovascular risk factors; pregnancy; mindfulness

## Introduction

Neighborhood environment has consistently been associated with women's cardiometabolic health, (1) and women's cardiometabolic risk is significantly impacted by pregnancy. (2) Excessive gestational weight gain (GWG), gestational diabetes mellitus (GDM), and postpartum weight retention (PPWR) impact development of obesity-related diseases, such as type II diabetes and heart disease. (3) Given that 41–51% of women experience excessive GWG, (4) 13–20% of women have PPWR over 5kg (10lbs), (3) and 3–4% of women develop GDM, (5) intervening on these outcomes is critical to improving women's health. Existing interventions mainly target individual level change through diet and physical activity. (6–8) While these interventions have worked within controlled clinical and intervention contexts, they have not been successfully translated into real-world, population level programs. Lack of consideration of the wider context in which women live, especially their neighborhood, may be a main barrier to successfully translating interventions. (9)

Neighborhoods define residential environments that women navigate to achieve healthy pregnancy outcomes. (10) They consist of elements across the physical, social, built and economic environment that jointly impact access to resources and ability to engage in healthy behaviors. However, existing work on neighborhood environments and cardiometabolic pregnancy outcomes largely investigates neighborhood characteristics separately. (11–23) Studies investigating neighborhood socioeconomic deprivation (11–14,23) largely find no association with excessive GWG, (11,12,23) and mixed associations for GDM. (13,14) Studies investigating neighborhood social environment, (15–17,21,22) including presence of social spaces, physical incivilities, ethnic enclaves and community violence, find associations with excessive GWG, (15–17,22) but not GDM. (21) Research examining neighborhood built environment, (14,15,17–21) including access to food stores and physical activity resources, generally find associations with GDM, (14,18,19) although conflicting evidence exists. (20,21) Overall, this literature suggests that while neighborhood characteristics are associated with cardiometabolic pregnancy outcomes, relationships vary across neighborhood characteristics and outcomes investigated.

Existing work provides limited insight into how joint exposures to neighborhood characteristics influence cardiometabolic pregnancy outcomes. (24) Interactions between neighborhood characteristics across domains may reveal types of supportive or adverse neighborhood environments not previously identified by examining neighborhood factors separately. Methodological approaches that classify neighborhoods into types across

multiple domains, such as latent class analysis (LCA), can address this issue. (24,25) However, such approaches have not been applied to understand relationships between neighborhood environment and cardiometabolic pregnancy outcomes.

Furthermore, little existing work investigates whether neighborhood environments modify the effectiveness of interventions to improve cadiometabolic pregnancy outcomes. While interventions themselves vary based on mechanisms that they modify, actions targeted through these interventions are contextualized within neighborhood environments, (9) and benefits of interventions may be constrained by this context. Only two studies to date examine interactions between neighborhood environment and intervention effectiveness on cardiometabolic pregnancy outcomes, one targeting physical activity improvement and the other targeting dietary change. (26,27) The study focusing on physical activity found that perceptions of neighborhood violence modified effectiveness of the intervention among postpartum Latina women. (26) Alternatively, the study implementing a dietary intervention found that neighborhood socioeconomic status (SES) did not modify intervention effectiveness among pregnant women. (27) No studies to date have investigated neighborhood interactions in the context of a mindfulness-based, stress reduction intervention, highlighting the need for more research to understand how neighborhood contexts support or constrain intervention implementation.

Our study extends current research by comprehensively classifying neighborhood environments across multiple neighborhood domains and investigating interactions between neighborhood contexts and intervention effectiveness. Within a cohort of lower income, pregnant women with overweight status/obesity, participating in a mindfulness-based stress reduction intervention, we investigated associations between neighborhood environment and cardiometabolic pregnancy outcomes, including excessive GWG, impaired glucose tolerance (GT) during pregnancy, and PPWR. Using LCA, we comprehensively categorized neighborhoods into types across multiple characteristics and investigated variation in effectiveness of the intervention across neighborhood type. We hypothesized that neighborhoods types with more adverse attributes across dimensions would increase risk of all cardiometabolic pregnancy outcomes. Additionally, our stress reduction intervention would be more effective in neighborhoods types with supportive attributes—wealthier, better access to healthy foods and other resources. Findings from this study will provide insight into how neighborhood environments foster intervention effectiveness in improving cardiometabolic health during pregnancy.

## Methods

### Study Population

Study participants were from the Maternal Adiposity Metabolism and Stress (MAMAS) intervention. Study details are described elsewhere. (28) Briefly, low- and middle-income, women with overweight status or obesity (body mass index (BMI) 25–41kg/m$^2$), 12–23 weeks pregnant with singleton pregnancies, and age 18–45 were recruited from August 2011 to June 2013 to participate in an 8-week mindfulness-based intervention to reduce stress and stress-based eating. (28) Women were recruited directly through targeted outreach and prenatal care providers serving low-income populations in the San Francisco Bay Area.

Women with income above 500% of federal poverty level and medical conditions related to GWG at time of enrollment, such as diabetes or abnormal glucose screening, were excluded. Data on health behaviors, lifestyle, weight, glucose tolerance, and medical outcomes were collected from questionnaires and medical records at baseline and 8–10wks later (post-intervention). At 6 months postpartum, women were re-contacted and reported their weight. We excluded women with missing address information at baseline (n=1). Our analytic sample included 207 women (intervention n=103; control n=104). This project was approved by University of California San Francisco and University of California Berkeley Institutional Review Boards.

**Exposure**

A two-stage approach was used to assess women's neighborhood environment. First, we created a geographically referenced measure of neighborhood type using all neighborhoods in a 9-county (San Francisco, Alameda, Contra Costa, San Mateo, Marin, Santa Clara, Solano, San Joaquin, and Merced counties) study area where women resided. Census tracts, which are sociodemographically homogenous areas containing approximately 4000 individuals per tract, (29) approximated neighborhoods. A total of 1727 census tracts were used to identify neighborhood types.

We measured four domains of neighborhood context informed by existing literature (11–23): socioeconomic, safety, food, and service environment. We used data from the 2008–2012 American Community Survey (ACS), the California Statewide Integrated Traffic Records System (SWITRS), and the Our Space database, a spatial database containing contextual information on social, food, and physical environments across the San Francisco Bay Area. (30) All measures are detailed in Table S1. Socioeconomic deprivation was measured using an 8-item index created from census-based indicators on occupation, employment, poverty, housing, and education. (31) We used traffic safety, measured by density of crashes per census tract obtained from the 2002–2012 SWITRS, to proxy overall neighborhood safety. (32) Neighborhood food environment was measured using kernel density scores of healthy (i.e. supermarkets, grocery stores, and produce stores) and unhealthy (i.e. fast food restaurants, convenience stores, and liquor stores) food retail locations obtained from 2012 InfoUSA Business data. (33) Kernel density distributions of healthy and unhealthy food resources were created using 1-mile buffers around census block centroids. Density scores were averaged by census tract separately for healthy and unhealthy food environment. To measure access to neighborhood services, we used a walkability score. Distances between census tract centroids and key service locations (see Table S1) were measured and aggregated into a weighted score using factor analysis to represent overall access to resources. (34)

Neighborhood measures, excluding crash density, were standardized to range from 0–100 and transformed to categorical variables for inclusion in LCA models. Neighborhood socioeconomic deprivation was categorized into quartiles to remain consistent with existing literature. (35) All other measures were categorized into tertiles (low/medium/high). We input categorical measures into LCA models to identify class types. LCA uses an iterative expectation-maximization (EM) algorithm to estimate underlying types, or classes, of

exposure based on observed measures input into the model. (25) The number of classes for a particular model are specified a priori by the investigator, and based on this set number of classes, observations are assigned a probability of class membership for each of the classes specified based on observed data. The optimal number of classes is determined by comparing fit statistics (e.g. Bayesian information criteria (BIC)) from a series of models specifying different class numbers. (25) We fit a set of LCA models with 3–10 classes and selected the best fitting model based on the lowest BIC value. Census tracts were assigned neighborhood class types based on the highest predicted probability of class membership from the best-fitting LCA model.

In the second stage of exposure assessment, we geocoded women's baseline address to identify census tract of residence, and assigned neighborhood class type from the LCA model for that census tract as women's neighborhood environment exposure.

## Outcomes

We assessed three cardometabolic pregnancy outcomes: excessive GWG, GT during pregnancy, and 6-month PPWR. GWG was abstracted from women's prenatal records and calculated as the difference between last measured prenatal (within 30 days of delivery) and pre-pregnancy weight. GWG was coded as missing for weights outside of this window. If pre-pregnancy weight was missing (n=69), then self-reported pre-pregnancy weight was obtained from the eligibility screener. Total GWG was classified as excessive or adequate based on being above or within 2009 Institute of Medicine Guidelines [underweight ($<18.5$kg/m$^2$): 12.5–18kg; normal weight (18.5–24.9 kg/m$^2$): 11.5–16kg; overweight (25.0–29.9 kg/m$^2$): 7–11.5kg; obese ( 30.0kg/m$^2$): 5–9kg)]. (36)

GT was measured using oral glucose tolerance test (OGTT) values, abstracted from prenatal records. A subset (n=144) of women obtained OGTT tests between 24–28 weeks as part of prenatal care. We considered continuous OGTT score and a dichotomous indicator of impaired GT based on blood glucose levels above 130 mg/dL. (37)

We measured PPWR as the difference between weight at 6-month postpartum and pre-pregnancy weight. We considered PPWR continuously and as an indicator for retaining more than 5kg postpartum. (3)

## Covariates

Potential individual-level and neighborhood-level confounders included maternal age (continuous), race/ethnicity (white, black, Latina, and other/multiracial), parity (continuous), marital status (single/married or in a committed relationship), education ( high school graduate/>high school graduate), intervention status (mindfulness training/control), census tract percent minority (continuous), and census tract percent immigrant (continuous).

## Statistical Analysis

Correlations between neighborhood characteristics were calculated using Spearman correlation coefficients. Univariable statistics were calculated for analytic variables using means and standard deviations for continuous variables and frequencies for categorical

variables. We used chi-squared tests and ANOVAs to assess bivariable associations between neighborhood type and analytic variables. To examine associations between neighborhood type and outcomes of interest, we ran multivariable regression models. Separate models were run for excessive GWG, 24wk-OGTTscore, impaired GT (24wk-OGTT 130 mg/dL), total PPWR, and high PPWR (>5kg). We accounted for neighborhood clustering (mean=1.5; range=1–10) using general estimating equation models to obtain population average estimates. Log link functions estimated relative risks (RR) for dichotomous outcomes. Linear link functions estimated difference in means for continuous outcomes. All adjusted models included covariates described above.

We ran interaction models to determine whether associations between intervention and outcomes varied across neighborhood types. We calculated interaction terms as the cross-product between intervention status and neighborhood type. We used Wald tests to assess overall significance of interaction using a threshold of $p < 0.10$. (38) For models with significant interaction, we used the lincom command in Stata to assess neighborhood-specific intervention associations. All analyses were conducted in Stata 14.2 (College Station, TX).

## Results

### Identifying Neighborhood Type

Correlations between neighborhood characteristics ranged from $r = 0.19$–$0.82$ (data not shown) Healthy food environment, unhealthy food environment, service environment, and traffic safety were highly correlated ($r = 0.73$–$0.82$). Neighborhood socioeconomic deprivation was less correlated with other neighborhood characteristics ($r = 0.19$–$0.44$). Results from LCA models indicated a 5-class solution (BIC=796.4), and model statistics indicated that groups were distinct from each other (Entropy=0.75). Distributions of neighborhood factors across neighborhood type are described in Table 1. Differing patterns across the socioeconomic, food, and service environment largely differentiated neighborhood types. We described the five neighborhood types based on the attributes that predominantly characterized neighborhoods within a type: type 1—wealthy, excellent food and service access; type 2—wealthy, low food and service access; type 3—middle income, low food, moderate service access; type 4—high poverty, excellent food and service resource access; type 5—high poverty, moderate food and service access. Detailed descriptions and examples of each neighborhood type are displayed in Supplementary Materials Table S2. Concentrations of minority and immigrant populations also varied across neighborhood types (Table 2). The middle income, low food and moderate service access (mean: 80%; SD: 13%) and high poverty, high food and service access (mean: 69%; SD: 20%) neighborhoods had the highest percent of non-white residents. Immigrant residence was highest in the high poverty, moderate food and service access neighborhood (mean: 39%; SD: 12%).

### Distribution of study sample across neighborhood type

Most participants lived in the two neighborhoods with the highest poverty levels, with 43.0% of women in the high poverty, excellent food and service access and 28.5% of women in the

high poverty, moderate food and service access neighborhood (Table 2). White women were more likely to live in wealthier neighborhoods and black women were more likely to live in poorer neighborhood types. Latina women were least likely to live in the wealthy, low food and service access neighborhoods. Parity, marital status, age, and education did not vary significantly across neighborhood type. Intervention status did not vary across neighborhood type.

**Associations between neighborhood and cardiometabolic outcomes**

Small sample size in the wealthy, low food and service resource neighborhood type (n=13) decreased model stability, and was excluded from final analytic models. The high poverty, excellent food and service access neighborhood type was our referent group. Most women lived in this type of neighborhood and it is representative of the typical urban, densely populated neighborhood type (see Table S2) in which low-income women reside. Table 3 shows associations between neighborhood type and cardiometabolic pregnancy outcomes. Compared to women in poor, excellent food and service access neighborhoods, women in middle income, low food and moderate service access neighborhoods had increased risk of impaired GT (RR: 4.1; 95% CI: 1.1, 15.5), and women in wealthy, high food and service access neighborhoods retained more weight postpartum (β: 3.9kg; 95% CI: 0.3, 7.5). Neighborhood type was not associated with excessive GWG.

Neighborhood type modified associations between our intervention and three outcomes: 24wk-OGTT score (Wald p-value= 0.002), PPWR (Wald p-value=0.02), and high PPWR (Wald p-value=0.05). Table 4 shows variation in associations between intervention and outcomes across neighborhood types; neighborhood specific mean values and risks for outcomes in the intervention and control groups are also available in supplementary materials (Table S3). Women in the intervention, compared to control, had significantly lower 24wk-OGTT scores in the wealthy, high food and service access (β: −21.0 mg/dL; 95% CI: −36.8, −5.1) and the poor, moderate food and service access neighborhoods (β: −36.4 mg/dL; 95% CI: −55.4, −17.3). For PPWR, differences between intervention and control were significant in wealthier neighborhoods, but in opposite directions. Within wealthy, high food and service access neighborhoods, women in the intervention retained more weight (β: 5.9kg, 95% CI: 0.6, 11.2) and had higher risk of high PPWR (RR: 2.8; 95% CI: 1.0, 7.6) than control group women. Conversely, within middle income, low food and moderate service access neighborhoods, women in the intervention retained significantly less (β: −8.5kg, 95% CI: −16.3, −0.7) than their control group counterparts. They also had lower risk of high PPWR (RR: 0.4; 95% CI: 0.1, 1.0), although this association was marginally significant.

## Discussion

This study assessed associations between multidimensional neighborhood types and three cardiometabolic pregnancy outcomes: excessive GWG, GT during gestation, and 6-month PPWR. We further assessed whether neighborhood type modified associations between a stress reduction intervention and these outcomes. Classification of neighborhoods across multiple domains identified five neighborhood types varying in patterns of socioeconomic

deprivation, food access, and service resources. Neighborhood type was associated with differences in risk of impaired GT during gestation and differences in PPWR, but not excessive GWG. Neighborhood type modified effectiveness of a stress reduction intervention on these outcomes. The intervention improved GT scores in the best resourced and the least resourced neighborhoods, and significantly changed PPWR in wealthier neighborhoods, although associations were not always in the expected direction.

Findings from studies investigating neighborhood context and similar cardiometabolic pregnancy outcomes are equivocal. Two studies investigating GWG found that neighborhood physical incivility, which includes measures of litter, graffiti, and vacant spaces, increased risk of excessive GWG in a birth record cohort of women in North Carolina. (17,39) Findings from the Pregnancy, Infection, and Nutrition study also linked social spaces, which includes measures of parks, sidewalks, and presence of people, with excessive GWG. (16) A study in a national, longitudinal cohort of women followed over 30 years also found that long-term neighborhood socioeconomic deprivation increased risk of excessive GWG, but only among white women. (23) In contrast, a study using Pennsylvania birth records found no association between neighborhood SES and excessive GWG. (11) Similar to this study, we found no association between neighborhood type and excessive GWG. Literature has more consistently linked neighborhood environment with inadequate GWG, (11,16,17,39) which we were underpowered to investigate, but future studies should study this association further.

Research exploring neighborhoods and GT during pregnancy or GDM is sparse, and findings are inconsistent. Two studies conducted in New York City found no association between neighborhood food environment (20) or ethnic enclaves (21) and GDM. However, studies in Texas and California supported associations between food environment and risk of GDM. (18,19) Similarly, our study finds that women in middle-income neighborhoods that lack food but have moderate service access had higher risk of impaired GT during pregnancy compared to women in poor neighborhoods with ample food and service resources.

We did not identify any studies investigating neighborhoods and PPWR. However, because our study found that PPWR was higher in wealthy neighborhoods with high food and service access, more research is needed in this area.

This study is one of the first to investigate variation of intervention success across neighborhood type for cardiometabolic pregnancy outcomes; two prior studies exist, but they focus on interventions targeting different mechanisms than our own. One study found that perceived neighborhood violence modified effectiveness of a social support based diet and exercise intervention among postpartum Latina women. (26) Women with high perceptions of neighborhood violence had larger gains in walking activity. (26) Another study found that neighborhood SES did not modify effectiveness of a dietary intervention on excessive GWG. (27) Our findings corroborate those from Keller et al., (26) suggesting that neighborhood type impacts intervention effectiveness. Our intervention improved GT scores in the most supportive and the least supportive neighborhood environments. These findings may partially be explained by increased presence of social services, such as home-visiting programs, in low-income, resource poor neighborhoods. (40) These social services provide

women with additional support needed to allow them to take better advantage of our mindfulness-based stress reduction intervention and achieve outcomes similar to women in wealthier neighborhoods. We additionally, and unexpectedly, found that in wealthy, high food and service resource neighborhoods, women in the intervention retained more weight than control group women. This finding mirrors evidence from literature on all-cause mortality which finds similar trends of higher rates of mortality among low income women residing in higher income neighborhoods, (41) and may be attributable to barriers that lower income women living in wealthy neighborhoods face in accessing resources, such as poor public transportation accessibility and spatial separation from support systems. (40) These barriers may hinder lower-income women's integration into the social fabric of wealthier neighborhoods and limit access to available opportunities. (40) Participation in a mindfulness based intervention, designed to increase awareness and acceptance of current situations may increase women's awareness of these barriers, (42) resulting in unintended consequences when combined with other stresses arising postpartum. More research is needed to elucidate mechanisms underlying women's increased PPWR in some neighborhoods despite stress-reduction interventions.

Compared to main findings from the MAMAS study, accounting for neighborhood type revealed important nuances in intervention effectiveness on cardiometabolic pregnancy outcomes. (28; data available upon request) Main findings identified associations between intervention participation and improved GT outcomes. Our current analysis reveals that these impacts are greater for women residing in the most supportive or least supportive neighborhood environments. Furthermore, in our main findings, the intervention did not improve PPWR. The current study suggests that heterogeneity in associations across neighborhood type explains this lack of association. Overall, our findings imply that addressing neighborhood environment is integral to successful, large-scale implementation of such an intervention.

Our use of neighborhood types that classify neighborhoods across multiple domains builds on existing literature. Complexity in methods used to assess neighborhood environments is increasing, but continues to disaggregate multidimensional neighborhood data to assess neighborhood characteristics separately. For example, studies using administrative or survey data (e.g. 12,22) and research using observation-based audit assessments (e.g. 16,19) capture multiple aspects of physical, social, and built environments. However, across these studies, findings are reported separately for neighborhood dimensions. Research is beginning to use aggregate indexes of neighborhood characteristics, such as the Child Opportunity Index (COI), (43) to retain complexity of neighborhood environments. However, this work remains largely descriptive, excluding investigation of associations with health outcomes. Our approach using LCA extends index-based work, and highlights the importance of capturing neighborhood complexity to design appropriate context-specific interventions.

Our study has some limitations. First, LCA is a probabilistic classification approach. By assigning neighborhood types using these probabilities, we deterministically set neighborhood type. This may introduce misclassification bias that can attenuate associations of interest. (44,25) Emerging approaches to address this issue do not yet exist for multilevel or interaction analyses. (44,25) Second, LCA depends on measured indicators to identify

class types. (24) Our findings may be biased by exclusion of neighborhood characteristics important for distinguishing underlying types. While we include many neighborhood factors that influence our main outcomes, future work should include more neighborhood characteristics, especially measures of neighborhood crime, violence, and social environment, which we lacked data on, to determine whether identification of neighborhood types is improved.

Third, small sample size may limit our ability to detect some associations, especially in interaction models. Relatedly, we acknowledge the exploratory nature of our interaction analysis given the intervention study was not explicitly designed to detect variations in effect across neighborhoods. However, given that we do detect interactions for outcomes, future work should replicate this study in larger populations within intervention contexts that are explicitly designed to detect variation in effect across neighborhood types. Fourth, our findings may be subject to bias commonly present in neighborhood association studies arising from two problems related to the geographic operationalization of neighborhoods boundaries: the modifiable areal unit problem (MAUP) and the uncertain geographic context problem (UGCoP). (45) While prior research on the MAUP in studies of neighborhoods and pregnancy outcomes suggests that associations are stable across different levels of geographic aggregation, (39) more work is needed to understand this problem in the context of LCA. With regards to the UGCoP, future research on activity spaces of pregnant women is needed to understand relevant spatial scales at which neighborhood factors are most relevant for cardiometabolic pregnancy outcomes. Lastly, our focus on high-risk, lower income women may limit generalizability of findings. However, this population disproportionately bears the burden of the health risks we are investigating, so findings are appropriate for understanding joint impacts of neighborhood environments and individual interventions for women most in need.

A major strength of our study is that it is one of the first to assess interactions between neighborhood, a stress reduction intervention, and cardiometabolic pregnancy outcomes. To our knowledge, we also are the first to incorporate a classification approach that captures the complexity of how attributes across different domains create neighborhood types. This is an important expansion of literature investigating single neighborhood dimensions because it allows us to more efficiently investigate joint exposure across multiple dimensions and patterns of neighborhood risk. Our observation of variation in intervention effectiveness across neighborhood types, despite our small sample, indicates the importance of pursing this line of research in larger samples.

## Conclusion

There is an increasing need for translational work that transforms existing interventions for cardiometabolic pregnancy outcomes into sustainable programs. Our findings that success of a mindfulness-based, stress reduction intervention varied across neighborhood types suggest that considering individual and neighborhood contexts is integral to effective interventions. Continued work to develop multilevel interventions that address the diverse contexts that women navigate during pregnancy is critical to improving long-term health of women and their children.

## Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

## Acknowledgments

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**Study Importance—What is known?**

- Existing research links individual neighborhood factors to cardiometabolic pregnancy outcomes, but excludes investigation of multi-domain neighborhood types.

- Little research has examined how neighborhood environments might interact with individual interventions to impact cardiometabolic pregnancy outcomes.

**Study Importance—What does this study add?**

- We use a novel application of latent classification techniques to identify multi-domain neighborhood types

- We investigate whether effects of a mindfulness-based stress-reduction intervention vary by neighborhood types identified

**Table 1.**

Descriptive Statistics for Neighborhood Characteristics by Neighborhood Type for all Census Tracts in Study Area (n=1727)

| | Overall | Type 1: (n=233) | Type 2 (n=460) | Type 3 (n=401) | Type 4 (n=345) | Type 5 (n=288) |
|---|---|---|---|---|---|---|
| | Mean (SD) | Mean (SD) | Mean (SD) | Mean (SD) | Mean (SD) | Mean (SD) |
| Unhealthy Food Environment (Range: 0–100) | 8.0 (10.6) | 7.7 (3.7) | 0.8 (0.8) | 4.4 (2.1) | 20.5 (17.1) | 9.8 (3.5) |
| Healthy Food Environment (Range: 0–100) | 12.3 (15.2) | 19.1 (8.4) | 1.6 (2.2) | 6.4 (4.2) | 32.1 (20.7) | 8.0 (4.3) |
| Service Environment (Range: 0–100) | 49.6 (20.5) | 63.0 (10.7) | 24.9 (12.8) | 45.7 (9.4) | 72.7 (11.9) | 55.1 (8.9) |
| Traffic Safety (Range: 0–2641) | 133 (210) | 117 (94) | 16 (18) | 56 (34) | 375 (350) | 149 (87) |
| Neighborhood Deprivation (%) | | | | | | |
| Quartile 1 | 25% | 27.8% | 45.0% | 32.1% | 7.4% | 2.3% |
| Quartile 2 | 25% | 50.0% | 25.1% | 27.5% | 16.2% | 11.1% |
| Quartile 3 | 25% | 22.2% | 18.8% | 27.5% | 34.1% | 22.2% |
| Quartile 4 | 25% | 0.0% | 11.1% | 12.9% | 42.3% | 64.4% |

**Table 2.**

Descriptive Statistics for Neighborhood Type in Analytic Sample (n=141 Census Tracts) and for the Maternal Adiposity Metabolism and Stress Analytic Cohort (n=207)

| | Overall | Type 1: Wealthy Well Resourced | Type 2: Wealthy Low Resourced | Type 3: Middle Income Low Resourced | Type 4: Poor, Well Resourced | Type 5: Poor, Moderately Resourced | p-value |
|---|---|---|---|---|---|---|---|
| **Neighborhood Characteristics** | | | | | | | |
| Number of Tracts | 141 | 19 | 13 | 10 | 65 | 34 | |
| % Non-White (mean, SD) | 69% (19%) | 57% (16%) | 63% (21%) | 80% (13%) | 71% (12%) | 69% (20%) | <0.001 |
| % Immigrant (mean, SD) | 36% (13%) | 33% (11%) | 28% (9%) | 35% (13%) | 30% (14%) | 39% (12%) | 0.01 |
| **Individual Cohort Characteristics** | | | | | | | |
| Number of women | 207 | 25 | 13 | 21 | 89 | 59 | |
| Intervention (%) | | | | | | | 0.70 |
| Control | 50.2 | 56.0 | 53.9 | 47.6 | 55.9 | 44.9 | |
| Mindfulness | 49.8 | 44.0 | 46.2 | 52.4 | 44.1 | 55.1 | |
| Race (%) | | | | | | | 0.05 |
| White | 13.6 | 25.0 | 30.8 | 4.8 | 10.2 | 12.4 | |
| Black | 38.8 | 29.2 | 46.2 | 61.9 | 47.5 | 29.2 | |
| Latina | 30.1 | 33.3 | 7.7 | 14.3 | 27.1 | 38.2 | |
| Other/Multi | 17.5 | 12.5 | 15.4 | 19.1 | 15.3 | 20.2 | |
| Parity (mean, SD) | 0.9 (1.2) | 0.9 (1.2) | 0.6 (1.0) | 1.0 (1.3) | 1.1 (1.3) | 0.9 (1.1) | 0.60 |
| Married (mean, SD) | 67.5 | 76.0 | 69.2 | 66.7 | 65.5 | 66.3 | 0.91 |
| Age (mean, SD) | 27.9 (5.9) | 29.3 (6.67) | 28.8 (5.7) | 28.0 (5.8) | 26.3 (5.1) | 28.4 (6.1) | 0.14 |
| > High School Education (%) | 66.7 | 72.0 | 76.9 | 64.4 | 71.4 | 64.0 | 0.82 |
| **Outcomes** | | | | | | | |
| GWG (%) | | | | | | | 0.36 |
| Inadequate | 15.3 | 14.3 | 0.0 | 11.1 | 9.6 | 22.2 | |
| Adequate | 15.9 | 14.3 | 9.1 | 22.2 | 21.2 | 12.4 | |
| Excessive | 68.9 | 71.4 | 90.9 | 66.7 | 69.2 | 65.4 | |
| 24–28wk OGTT (mg/dL) | 106.1 (26.0) | 107.3 (22.1) | 100.3 (17.5) | 106.4 (32.4) | 108.7 (22.5) | 105.8 (25.3) | 0.96 |
| Impaired Glucose Tolerance (>130 mg/dL; %) | 14.3 | 11.1 | 0.0 | 19.4 | 20.0 | 12.9 | 0.57 |
| 6-month PPWR (mean, SD) | 5.0 (8.6) | 8.3 (9.0) | 4.2 (7.4) | 7.1 (7.9) | 4.8 (8.7) | 3.8 (8.8) | 0.35 |
| High PPWR (%) (<5kg; 5lbs) | 46.2 | 52.9 | 33.3 | 61.5 | 44.6 | 43.8 | 0.68 |

**Table 3.**

Associations Between Neighborhood Type and Weight-Related Pregnancy Outcomes in the Maternal Adiposity Metabolism and Stress Study[*]

| | Type 1: Wealthy High Resource Access | Type 3: Middle Income Low Resource | Type 4: Poor, High Resource Access | Type 5: Poor, Moderate Resource Access |
|---|---|---|---|---|
| Excessive GWG (RR, 95% CI) | 0.9 (0.7, 1.2) | 1.0 (0.6, 1.4) | ref. | 1.0 (0.7, 1.3) |
| 24–28wk OGTT (mg/dL; β, 95% CI) | 2.3 (−9.0, 13.6) | 12.0 (−3.5, 27.5) | ref. | 1.9 (−11.8, 15.5) |
| Impaired Glucose Tolerance (RR, 95% CI) | 1.3 (0.3, 6.5) | **4.1 (1.1, 15.5)** | ref. | 2.5 (0.9, 6.9) |
| 6-month PPWR (kg; β, 95% CI) | **3.9 (0.3, 7.5)** | 3.4 (−2.4, 9.2) | ref. | 1.5 (−2.2, 5.1) |
| High PPWR at 6-month (RR, 95% CI) | 1.3 (0.8, 2.2) | 1.1 (0.6, 2.0) | ref. | 0.9 (0.6, 1.5) |

GWG=gestational weight gain; RR=relative risk; 95% CI= 95% Confidence Interval; OGTT=oral glucose tolerance test; PPWR=postpartum weight retention. Significant associations at the $p < 0.05$ level are indicated in bold.

[*] Models adjusted for maternal age, race/ethnicity, parity, marital status, education, intervention status, census tract percent minority, and census tract percent immigrant

**Table 4.**

Association between Intervention, Glucose Tolerance, and 6-month PPWR by Neighborhood Type in the Maternal Adiposity and Metabolism Study[*]

| | Type 1: Wealthy, High Resource Access | Type 3: Middle Income, Low Resource | Type 4: Poor, High Resource Access | Type 5: Poor, Moderate Resource Access |
|---|---|---|---|---|
| 24–28wk OGTT (mg/dL; β, 95% CI) | **−21.0 (−36.8, −5.1)** | 12.5 (−6.3, 31.4) | −6.4 (−18.9, 6.2) | **−36.3 (−55.4, −17.3)** |
| 6-month PPWR (kg; β, 95% CI) | **5.9 (0.6, 11.2)** | **−8.5 (−16.3, −0.7)** | −2.7 (−7.2, 1.8) | −1.6 (−6.5, 3.4) |
| High 6-month PPWR (RR, 95% CI) | **2.8 (1.0, 7.6)** | 0.4 (0.1, 1.0) | 0.9 (0.5, 1.7) | 0.9 (0.5, 1.6) |

OGTT=oral glucose tolerance test; PPWR=postpartum weight retention; RR=relative risk; 95% CI=95% Confidence Interval. Significant associations at the $p<0.05$ level are indicated in bold.

[*] Models shown represent the difference in outcome for the intervention group compared to the control group (referent) within each neighborhood type. Models shown are only for outcomes for which interaction was deemed significant.