Community-level social determinants of health and pregestational and gestational diabetes

Christine Field, MD, MPH; William A. Grobman, MD, MBA; Lynn M. Yee, MD, MPH; Jasmine Johnson, MD; Jiqiang Wu, MSc; Becky McNeil, PhD; Brian Mercer, MD; Hyagriv Simhan, MD; Uma Reddy, MD; Robert M. Silver, MD; Samuel Parry, MD; George Saade, MD; Judith Chung, MD; Ronald Wapner, MD; Courtney D. Lynch, PhD, MPH; Kartik K. Venkatesh, MD, PhD

BACKGROUND: Individual adverse social determinants of health are associated with increased risk of diabetes in pregnancy, but the relative influence of neighborhood or community-level social determinants of health is unknown.

OBJECTIVE: This study aimed to determine whether living in neighborhoods with greater socioeconomic disadvantage, food deserts, or less walkability was associated with having pregestational diabetes and developing gestational diabetes.

STUDY DESIGN: We conducted a secondary analysis of the prospective Nulliparous Pregnancy Outcomes Study: Monitoring Mothers-To-Be. Home addresses in the first trimester were geocoded at the census tract level. The exposures (modeled separately) were the following 3 neighborhood-level measures of adverse social determinants of health: (1) socioeconomic disadvantage, defined by the Area Deprivation Index and measured in tertiles from the lowest tertile (ie, least disadvantage [T1]) to the highest (ie, most disadvantage [T3]); (2) food desert, defined by the United States Department of Agriculture Food Access Research Atlas (yes/no by low income and low access criteria); and (3) less walkability, defined by the Environmental Protection Agency National Walkability Index (most walkable score [15.26–20.0] vs less walkable score [<15.26]). Multinomial logistic regression was used to model the odds of gestational diabetes or pregestational diabetes relative to no diabetes as the reference, adjusted for age at delivery, chronic hypertension, Medicaid insurance status, and low household income (<130% of the US poverty level).

RESULTS: Among the 9155 assessed individuals, the mean Area Deprivation Index score was 39.0 (interquartile range, 19.0–71.0), 37.0% lived in a food desert, and 41.0% lived in a less walkable neighborhood. The frequency of pregestational and gestational diabetes diagnosis was 1.5% and 4.2%, respectively. Individuals living in a community in the highest tertile of socioeconomic disadvantage had increased odds of entering pregnancy with pregestational diabetes compared with those in the lowest tertile (T3 vs T1: 2.6% vs 0.8%; adjusted odds ratio, 2.52; 95% confidence interval, 1.41–4.48). Individuals living in a food desert (4.8% vs 4.0%; adjusted odds ratio, 1.37; 95% confidence interval, 1.06–1.77) and in a less walkable neighborhood (4.4% vs 3.8%; adjusted odds ratio, 1.33; 95% confidence interval, 1.04–1.71) had increased odds of gestational diabetes. There was no significant association between living in a food desert or a less walkable neighborhood and pregestational diabetes, or between socioeconomic disadvantage and gestational diabetes.

CONCLUSION: Nulliparous individuals living in a neighborhood with higher socioeconomic disadvantage were at increased odds of entering pregnancy with pregestational diabetes, and those living in a food desert or a less walkable neighborhood were at increased odds of developing gestational diabetes, after controlling for known covariates.

Key words: Area Deprivation Index, food desert, food insecurity, gestational diabetes, neighborhood disadvantage, pregestational diabetes, pregnancy, social determinants of health, walkability

Introduction

The revalence of pregestational type 1 and 2 diabetes mellitus (DM) and gestational diabetes mellitus (GDM) has nearly doubled in the United States over the past 2 decades.[1–4] In 2021, >2% of pregnant individuals were living with DM, and another 8% developed GDM.[1–3,5] Both DM and GDM are associated with increased risk of adverse pregnancy and postpartum cardiometabolic outcomes for the pregnant individual and child.[6–9] Reducing the risk of DM in pregnancy and associated adverse outcomes requires addressing both medical care and nonmedical social needs.

EDITOR'S CHOICE

Individual adverse social determinants of health (SDOH), which include systemic racism, poverty, housing instability, food and nutrition insecurity, less access to green space, and lack of quality education, health care, transportation, and employment, are associated with higher risk of adverse pregnancy outcomes and DM outside of pregnancy.[10–17] SDOH can also be assessed at the neighborhood or community level, including through the use of measures that assess the structural and social environment, such as socioeconomic disadvantage, food deserts, and walkability.[18–21] Individuals living in neighborhoods with greater socioeconomic disadvantage, food deserts, and less walkability, experience a higher burden of proximal SDOH. These neighborhood-level measures have been associated with inadequate glycemic control among pregnant individuals with DM.[22–24] Elucidating the impact of neighborhood SDOH on the risk of DM and GDM is important to inform and facilitate policy and structural interventions to improve perinatal health.[25,26]

The objective of the current analysis was to determine whether living in a neighborhood that had greater socioeconomic disadvantage, was a food desert, or had less walkability was associated with changes in the rate of

Cite this article as: Field C, Grobman WA, Yee LM, et al. Community-level social determinants of health and pregestational and gestational diabetes. Am J Obstet Gynecol MFM 2024;6:101249.

2589-9333/$36.00

http://dx.doi.org/10.1016/j.ajogmf.2023.101249

AJOG MFM at a Glance

Why was this study conducted?

Pregestational diabetes and gestational diabetes are associated with increased risk of adverse pregnancy outcomes. Such outcomes are also associated with adverse social determinants of health. Whether community- or neighborhood-level measures of adverse social determinants of health are associated with risk of pregestational diabetes and gestational diabetes is uncertain.

Key findings

Nulliparous individuals living in neighborhoods with greater socioeconomic disadvantage were more likely to have pregestational diabetes, after adjustment for known covariates. Those in food deserts or less walkable communities were more likely to develop gestational diabetes, after the same adjustments.

What does this add to what is known?

This prospective study enhances the understanding of the relative influences of multiple community- and neighborhood-level measures of social determinants of health on the risk of living with pregestational diabetes during pregnancy or developing gestational diabetes. These results can inform the development of structural interventions aimed at addressing community-level social determinants of health to decrease the risk of diabetes in pregnancy.

living with DM and acquisition of GDM during pregnancy. We hypothesized that greater exposure to neighborhood-level adverse SDOH across multiple dimensions would increase the risk of DM and the development of GDM.

Materials and Methods

Study setting and participants

This study is a secondary analysis of the Nulliparous Pregnancy Outcomes Study: Monitoring Mothers-to-Be (nuMoM2b) prospective cohort that assessed the contribution of maternal and environmental factors to adverse pregnancy outcomes (ClinicalTrials.gov identifier NCT01322529).[27] Data were prospectively collected between October 2010 and September 2013 at 8 US medical centers. The nuMoM2b study was approved by each site's institutional review board, and participants provided written informed consent.

Nulliparous individuals were enrolled in the study if they fulfilled the following inclusion criteria: no previous delivery at ≥20 weeks' gestation, a viable singleton pregnancy with estimated gestational age from 6 to 13 weeks, and intention to deliver at a participating hospital. Exclusion criteria included those aged <13 years, a history of ≥3 pregnancy losses, donor oocyte pregnancy, planned pregnancy termination, fetal malformations likely to be lethal, fetal aneuploidy, previous enrollment in the study, and an inability to provide informed consent. Individuals were excluded from the current analysis if they did not have a residential address at enrollment that could be geocoded because of a geographic location for which this metric could not be calculated, such as a post office box, a business address, or a coastal or offshore location.

Exposures

The exposures were 3 community-level measures of adverse SDOH modeled separately. The primary participant home address was collected via structured interview at the first visit at 6 to 13 weeks' gestation. Addresses were previously geocoded using ArcGIS (www.arcgis.com; Esri, Redlands, CA), and then linked at the census-tract level to calculate the measures of neighborhood SDOH.

We assessed socioeconomic disadvantage with the 2015 version of the Area Deprivation Index (ADI) available at https://www.neighborhoodatlas.medicine.wisc.edu/, which was developed as a summative measure of several community-level adverse social determinants to study their effect on health outcomes within US neighborhoods. The ADI draws from 17 US census indicators across the 4 domains of income, education, employment, and housing quality.[18,21,28] The measure generates a composite score that is converted to a rank based on a locale's national percentile from 0 to 100. We analyzed the ADI in tertiles, from the lowest ADI (least deprivation, tertile 1 [T1], reference) to the highest (most deprivation, tertile 3 [T3]).[29,30]

Living in a food desert was defined using the Food Access Research Atlas of the United States Department of Agriculture Economic Research Service, which contains a collection of food access indicators by income and measures of supermarket accessibility.[31] Living in a food desert was defined as "yes" or "no" per criteria for both low income and low access to food.[19,32] Communities with low income were defined as those in which at least 20% of the population had a median family income ≤80% of the metropolitan area or state median income. Low community access to food was defined as a number of at least 500 and a proportion of at least 33% of individuals who were located >1 mile (urban) and >10 miles (rural) away from the nearest food store.

Neighborhood walkability was assessed using the US Environmental Protection Agency (EPA) National Walkability Index, which integrates measures of the built environment that reflect the likelihood of people using walking as a mode of transportation. The index comprises the following components: "intersection density" (higher intersection density correlates with more walk trips), "proximity to transit stops" (shorter distance to transit stops correlates with more walk trips), "employment mix" (more diverse employment types [retail, office, industrial] correlate to more walk trips), and "employment and household mix" (more diverse employment types plus many occupied housing units correlate with more walk trips). Scores ranged from 1 to 20, with higher scores representing a higher likelihood of people using walking as a mode of transportation.[20,33] We compared neighborhoods that were the most walkable (score 15.26−20.0) with those that were less walkable (score <15.26) per EPA recommendations.[20]

Outcomes

The primary outcomes were DM and GDM assessed separately in comparison with absence of either diagnosis (reference). DM status inclusive of type 1 and 2 DM was assessed by medical record abstractors at enrollment and at each follow-up visit on the basis of a recorded diagnosis of either type 1 or type 2 DM in the medical record. GDM was defined by one of the following glucose tolerance testing (GTT) criteria: (1) fasting 3-hour 100-g GTT with 2 abnormal values: fasting ≥95 mg/dL, 1-hour ≥180 mg/dL, 2-hour ≥155 mg/dL, 3-hour ≥140 mg/dL; (2) fasting 2-hour 75-g GTT with 1 abnormal value: fasting ≥92 mg/dL, 1-hour ≥180 mg/dL, 2-hour ≥153 mg/dL; and (3) nonfasting 50-g GTT ≥200 mg/dL if no fasting 3-hour or 2-hour GTT was performed. In addition to GTT data, record abstractors documented if a diagnosis of GDM was made during the course of clinical care. If no GTT data were available, the information from record abstraction was used for GDM classification.

Statistical analysis

We compared the frequency of ADI tertiles, community walkability, and living in food deserts by DM and GDM status, respectively. We descriptively compared sociodemographic and clinical characteristics by the 3 exposure measures and by the outcome using chi-square tests for categorical variables and Wilcoxon rank-sum tests for continuous variables. We calculated unadjusted and adjusted odds ratios (aORs) with 95% confidence intervals (CIs). We used multinomial logistic regression given nonbinary outcomes, having neither DM nor GDM (referent), having DM, or having GDM. Models were adjusted for age at enrollment (<25, 25−30, >30−35, and >35 years), chronic hypertension (yes/no), and individual-level SDOH including Medicaid insurance status (yes/no) and household income and size relative to the US poverty level (<130%, 130%−350%, and >350%) based on a directed acyclic graph (Appendix Figure 1). We did not adjust for race and ethnicity given adjustment for multiple and more accurate individual SDOH.

Because the relative influence of a community-level metric on DM risk may vary by self-reported race and ethnicity, through which processes consequent to structural racism may operate, we assessed for effect modification in the adjusted model with interaction terms between the exposure (ie, community-level metric) and race and ethnicity. Imputation for missing data was performed using multiple imputation by chained equations (MICE) (n=30 imputations), and estimates were combined using Rubin's rules. All statistical analyses were performed using Stata, version 16.1 (StataCorp LLC, College Station, TX) and R statistical software, version 4.2.0 (R Foundation for Statistical Computing, Vienna, Austria). Statistical significance was defined by $P<.05$.

Results

Among 10,038 enrolled nulliparous pregnant individuals, we excluded those whose address could not be geocoded at enrollment (n=450, 4.4%) and who had unknown DM status (n=433, 4.3%), resulting in a final analytical sample of 9155 (91.2%) individuals (Appendix Figure 2). Those who were excluded were more likely to be younger, experience adverse individual-level SDOH, and have chronic comorbid conditions ($P<.01$ for all) (Appendix Table 1). The frequency of pregestational DM, but not GDM, was lower among those who were included than those who were excluded (1.4% vs 3.5%; overall $P<.05$).

The median age was 28 years (interquartile range [IQR], 23.0−31.0) (Table 1). Over a quarter (27.6%) had Medicaid health insurance, 13.3% self-identified as non-Hispanic Black and 16.5% as Hispanic, 38.2% had some college education or less, and 19.8% had a household income <130% of the US poverty level. Over a fifth (22.0%) lived with obesity, 2.4% had chronic hypertension, and 17.4% smoked.

The median ADI score was 39.0 (IQR, 19.0−71.0), 37.0% of individuals lived in a food desert, and 41.0% lived in a less walkable neighborhood (Table 1). The frequency of DM and GDM diagnosis was 1.5% and 4.2%, respectively. Individuals living in neighborhoods with greater socioeconomic disadvantage, food deserts, and less walkability were more likely to be of younger age, experience individual adverse SDOH, report tobacco use, and live with chronic comorbid conditions ($P<.001$ for all) (Table 1).

Individuals living in neighborhoods in the highest tertile of socioeconomic disadvantage had >2-fold increased odds of living with a DM diagnosis compared with those in the lowest tertile (T3 vs T1: 2.6% vs 0.8%; aOR, 2.52; 95% CI, 1.41−4.48) (Figure 1; Table 2). Neither living in a food desert nor in a less walkable neighborhood was associated with DM.

Individuals who lived in a food desert (4.8% vs 4.0%; aOR, 1.37; 95% CI, 1.06−1.77) or in a less walkable neighborhood (4.4% vs 3.8%; aOR, 1.33; 95% CI, 1.04−1.71) had increased odds of GDM (Figure 2; Table 2). Living in a neighborhood with greater socioeconomic disadvantage was not associated with GDM.

Interaction effects between self-reported race and ethnicity (non-Hispanic White, non-Hispanic Black, Hispanic, and non-Hispanic Asian) and socioeconomic disadvantage (P=.07), living in a food desert (P=.40), and walkability (P=.05) were not statistically significant (P>.05) in the above adjusted models (data not shown).

Comment

Principal findings

In this large prospective cohort of nulliparous individuals, measures of community-level SDOH in early pregnancy were associated with diagnosis of DM and GDM. Specifically, nulliparous individuals living in a neighborhood with greater socioeconomic disadvantage were at increased odds of living with a diagnosis of DM, although food deserts and walkability were not associated with DM. In contrast, those who

TABLE 1

Sociodemographic and clinical characteristics of the study population overall and by area deprivation, food desert, and walkability (N=9155)[a,b]

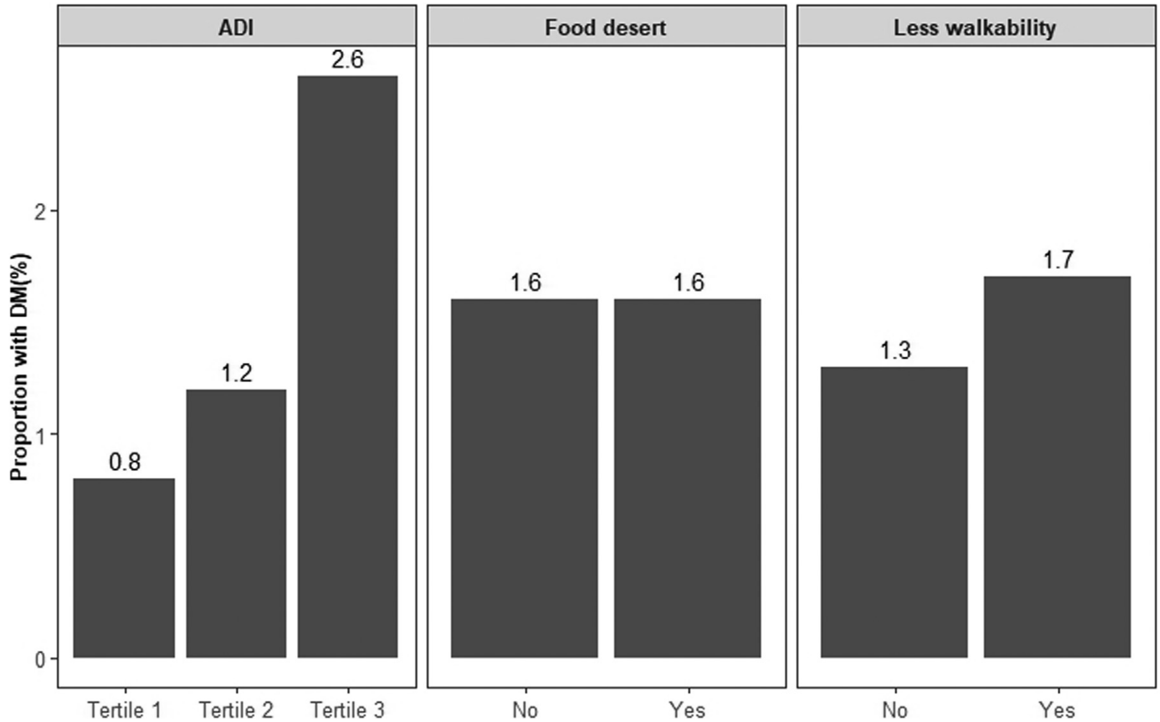
		Area Deprivation Index			Food desert		Less walkability	
Characteristics	Overall	Tertile 1, N=3120	Tertile 2, N=2955	Tertile 3, N=3080	Yes, N=2235	No, N=6920	Yes, N=6069	No, N=3086
Community-level exposure, % (IQR)	39.0 (19.0–71.0)	13.0 (8.0–19.0)	39.0 (32.0–47.0)	86.0 (71.0–95.0)[c]	37.0 (22.0–59.0)	40.0 (17.0–76.0)	41.0 (22.0–73.0)	33.0 (14.0–69.0)[c]
Age, y, median (IQR)	28.0 (23.0–31.0)	30.0 (26.0–33.0)	27.0 (24.0–31.0)	23.0 (20.0–28.0)[c]	26.0 (22.0–30.0)	28.0 (23.0–31.0)[c]	26.0 (22.0–31.0)	29.0 (24.0–32.0)[c]
Medicaid insurance N=9095								
Yes	2509 (27.6)	427 (13.7)	507 (17.2)	1575 (51.8)	536 (24.1)	1973 (28.7)	1853 (30.7)	656 (21.4)
No	6586 (72.4)	2681 (86.3)	2440 (82.8)	1465 (48.2)[c]	1687 (75.9)	4899 (71.3)[c]	4179 (69.3)	2407 (78.6)[c]
Race and ethnicity								
Non-Hispanic White	5601 (61.2)	2216 (71.0)	2166 (73.3)	1219 (39.6)	1642 (73.5)	3959 (57.2)	3654 (60.2)	1947 (63.1)
Non-Hispanic Black	1218 (13.3)	120 (3.8)	192 (6.5)	906 (29.4)	247 (11.1)	971 (14.0)	868 (14.3)	350 (11.3)
Hispanic	1510 (16.5)	440 (14.1)	384 (13.0)	686 (22.3)	194 (8.7)	1316 (19.0)	1046 (17.2)	464 (15.0)
American Indian	7 (0.1)	1 (0.0)	1 (0.0)	5 (0.2)	3 (0.1)	4 (0.1)	3 (0.0)	4 (0.1)
Non-Hispanic Asian	363 (4.0)	212 (6.8)	86 (2.9)	65 (2.1)	48 (2.1)	315 (4.6)	206 (3.4)	157 (5.1)
Native Hawaiian	30 (0.3)	10 (0.3)	11 (0.4)	9 (0.3)	5 (0.2)	25 (0.4)	16 (0.3)	14 (0.5)
No self-reported race or ethnicity	54 (0.6)	18 (0.6)	18 (0.6)	18 (0.6)	8 (0.4)	46 (0.7)	28 (0.5)	26 (0.8)
Multiracial	372 (4.1)	103 (3.3)	97 (3.3)	172 (5.6)	88 (3.9)	284 (4.1)	248 (4.1)	124 (4.0)
Education, N=9148								
High school or less	686 (7.5)	72 (2.3)	127 (4.3)	487 (15.8)	172 (7.7)	514 (7.4)	521 (8.6)	165 (5.3)
Some college	2807 (30.7)	535 (17.2)	860 (29.1)	1412 (45.9)	744 (33.3)	2063 (29.8)	2050 (33.8)	757 (24.5)
College graduate	3510 (38.4)	1319 (42.3)	1320 (44.7)	871 (28.3)	953 (42.6)	2557 (37.0)	2329 (38.4)	1181 (38.3)
Graduate degree	2145 (23.4)	1193 (38.2)	647 (21.9)	305 (9.9)[c]	366 (16.4)	1779 (25.7)[c]	1163 (19.2)	982 (31.8)[c]
Smoking status, N=9149								
Yes	1593 (17.4)	381 (12.2)	447 (15.1)	765 (24.9)	460 (20.6)	1133 (16.4)	1138 (18.8)	455 (14.8)
No	7556 (82.6)	2737 (87.8)	2507 (84.9)	2312 (75.1)[c]	1774 (79.4)	5782 (83.6)[c]	4928 (81.2)	2628 (85.2)[c]
Body mass index, kg/m^2, N=8986								
Underweight	206 (2.3)	72 (2.3)	58 (2.0)	76 (2.5)	44 (2.0)	162 (2.4)	136 (2.3)	70 (2.3)
Normal weight	4579 (51.0)	1846 (60.0)	1467 (50.2)	1266 (42.4)	1050 (47.4)	3529 (52.1)	2872 (48.3)	1707 (56.2)
Overweight	2225 (24.8)	733 (23.8)	740 (25.3)	752 (25.2)	588 (26.5)	1637 (24.2)	1505 (25.3)	720 (23.7)
Obesity	1090 (12.1)	281 (9.1)	370 (12.7)	439 (14.7)	280 (12.6)	810 (12.0)	759 (12.8)	331 (10.9)
Severe obesity	886 (9.9)	146 (4.7)	287 (9.8)	453 (15.2)[c]	254 (11.5)	632 (9.3)[c]	676 (11.4)	210 (6.9)[c]
Household income and size relative to US poverty level, N=7500								
<130%	1486 (19.8)	196 (7.0)	371 (14.5)	919 (42.9)	359 (19.4)	1127 (19.9)	1089 (22.3)	397 (15.1)
130%–350%	2249 (30.0)	548 (19.5)	955 (37.5)	746 (34.8)	658 (35.6)	1591 (28.2)	1547 (31.7)	702 (26.8)
>350%	3765 (50.2)	2062 (73.5)	1224 (48.0)	479 (22.3)[c]	833 (45.0)	2932 (51.9)[c]	2242 (46.0)	1523 (58.1)[c]
Chronic hypertension, N=9063								
Yes	217 (2.4)	50 (1.6)	68 (2.3)	99 (3.3)	58 (2.6)	159 (2.3)	154 (2.6)	63 (2.1)
No	8846 (97.6)	3042 (98.4)	2859 (97.7)	2945 (96.7)[c]	2162 (97.4)	6684 (97.7)	5857 (97.4)	2989 (97.9)
Diabetes in pregnancy								
Pregestational diabetes	137 (1.5)	24 (0.8)	35 (1.2)	78 (2.5)	34 (1.5)	103 (1.5)	98 (1.6)	39 (1.3)
Gestational diabetes	380 (4.2)	134 (4.3)	113 (3.8)	133 (4.3)	105 (4.7)	275 (4.0)	264 (4.3)	116 (3.8)
No diabetes	8638 (94.4)	2962 (94.9)	2807 (95.0)	2869 (93.1)[c]	2096 (93.8)	6542 (94.5)	5707 (94.0)	2931 (95.0)

IQR, interquartile range.

[a] Chi-square test was used to compare categorical variables and Wilcoxon rank-sum test for continuous variables; $P<.001$ for all assessed characteristics above; [b] The total does not reach the n of 9155 for each variable; [c] P value <.05.

Field. Community-level social determinants of health and diabetes in pregnancy. Am J Obstet Gynecol MFM 2023.

FIGURE 1
DM frequency by measure of community-level SDOH



Displays the frequency living with diabetes in pregnancy by measure of community-level social determinant of health.

ADI, Area Deprivation Index; *DM*, diabetes mellitus.

Field. Community-level social determinants of health and diabetes in pregnancy. Am J Obstet Gynecol MFM 2023.

lived in a food desert or a less walkable neighborhood were at increased odds of being diagnosed with GDM.

Results

These findings demonstrate the associations between 3 community-level constructs of SDOH (including an overall measure of socioeconomic disadvantage [ADI] and measures of food insecurity and walkability) and DM risk in pregnancy. The associations between neighborhood SDOH and DM in pregnancy were similarly observed across racial and ethnic subgroups, suggesting that the impact of these community-level disparities similarly affected these subgroups.[24] Community-level metrics of adverse SDOH have been shown to be associated with increased risk of adverse pregnancy outcomes, including the associations of the Centers for Disease Control and Prevention Social Vulnerability Index with preterm birth, and of ADI with postpartum readmission.[30,34,35] Among individuals with DM, the 3 community-level metrics assessed in the current study have been associated with increased risk of inadequate glycemic control as measured by hemoglobin A1c in early and late pregnancy.[22−24,36] The association between neighborhood walkability and developing GDM has not been consistently observed.[37,38] Studies have demonstrated that living in food deserts is associated with increased GDM risk,[39] and living in a food desert and in neighborhoods with socioeconomic disadvantage is associated with pharmacotherapy to achieve glycemic control with GDM.[40,41] By including 3 community-level metrics of SDOH and assessing the relative relationship with both DM and GDM, the current study provides a comparative understanding of the relative influences of these measures on DM risk in pregnancy.

Clinical implications

The evaluated community-level measures of SDOH are publicly available and can be linked to patient or study participant data through the census tract. The availability of community measures based on geocoded data already in the electronic health record (EHR), provides opportunities for future technologies to incoporate geocoding and calculation of these measures into the EHR to better guide DM prevention and treatment in pregnancy. For example, individuals living in communities with a high ADI, food deserts, or less walkability could undergo additional SDOH screening and referral to community-based resources, such the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) and Medicaid-associated prenatal programs like the Pregnancy Medical Home.[42]

TABLE 2
Frequency of pregestational and gestational diabetes and their association with Area Deprivation Index, food insecurity, and less walkability

		Frequency of diabetes		Unadjusted and adjusted analysis	
Community-level measure	Total N	No, n (%)	Yes, n (%)	Unadjusted odds ratio OR (95% CI)[a]	Adjusted odds ratio aOR (95% CI)[a,b]
Outcome: pregestational diabetes vs no diabetes in pregnancy					
Area Deprivation Index[c]					
Tertile 1	2986	2962 (99.2)	24 (0.8)	1.00	1.00
Tertile 2	2842	2807 (98.8)	35 (1.2)	1.53 (0.91—2.59)	1.36 (0.75—2.44)
Tertile 3	2947	2869 (97.4)	78 (2.6)	3.36 (2.12—5.32)	2.52 (1.41—4.48)
Food desert[d]					
No	6645	6542 (98.4)	103 (1.6)	1.00	1.00
Yes	2130	2096 (98.4)	34 (1.6)	1.03 (0.70—1.52)	0.94 (0.59—1.51)
Less walkability[e]					
No	2970	2931 (98.7)	39 (1.3)	1.00	1.00
Yes	5805	5707 (98.3)	98 (1.7)	1.29 (0.89—1.88)	1.13 (0.73—1.75)
Outcome: gestational diabetes vs no diabetes in pregnancy					
Area Deprivation Index					
Tertile 1	3096	2962 (95.7)	134 (4.3)	1.00	1.00
Tertile 2	2920	2807 (96.1)	113 (3.9)	0.89 (0.69—1.15)	1.05 (0.80—1.39)
Tertile 3	3002	2869 (95.6)	133 (4.4)	1.02 (0.80—1.31)	1.33 (0.97—1.81)
Food desert					
No	6817	6542 (96.0)	275 (4.0)	1.00	1.00
Yes	2201	2096 (95.2)	105 (4.8)	1.19 (0.95—1.50)	1.37 (1.06—1.77)
Less walkability					
No	3047	2931 (96.2)	116 (3.8)	1.00	1.00
Yes	5971	5707 (95.6)	264 (4.4)	1.17 (0.94—1.46)	1.33 (1.04—1.71)

N=9155 (no diabetes: N=8638; pregestational diabetes: N=137; gestational diabetes: N=380).

aOR, adjusted odds ratio; *CI*, confidence interval; *OR*, odds ratio.

[a] Multinomial logistic regression was used; [b] Model adjusted for age, insurance, low household income, and chronic hypertension; [c] The Area Deprivation Index (ADI) is a summative measure of several community-level adverse social determinants that generates a composite score that is converted to a rank from 0 to 100. We analyzed ADI in tertiles, from the lowest ADI (least deprivation, tertile 1 [T1], reference) to the highest (most deprivation, tertile 3 [T3])[29,30]; [d] Food desert was defined by the United States Department of Agriculture Food Access Research Atlas (yes/no per criteria for both low income and low access); [e] Less walkability was defined by the US Environmental Protection Agency National Walkability Index (most walkable [score 15.26—20.0] vs less walkable [score <15.26]).

Field. Community-level social determinants of health and diabetes in pregnancy. Am J Obstet Gynecol MFM 2023.

More broadly, these findings highlight the impact of the broader environment even before pregnancy on the risk of DM and the need for policies to support vulnerable communities (eg, by increasing access to food, green space, economic opportunities, and walkable and safe communities). Findings from this study and others that demonstrate a relationship between community-level measures and adverse health outcomes should encourage health care workers to actively seek out opportunities to collaborate with policymakers and community planners in decisions related to the social and structural environment in their communities.

Research implications

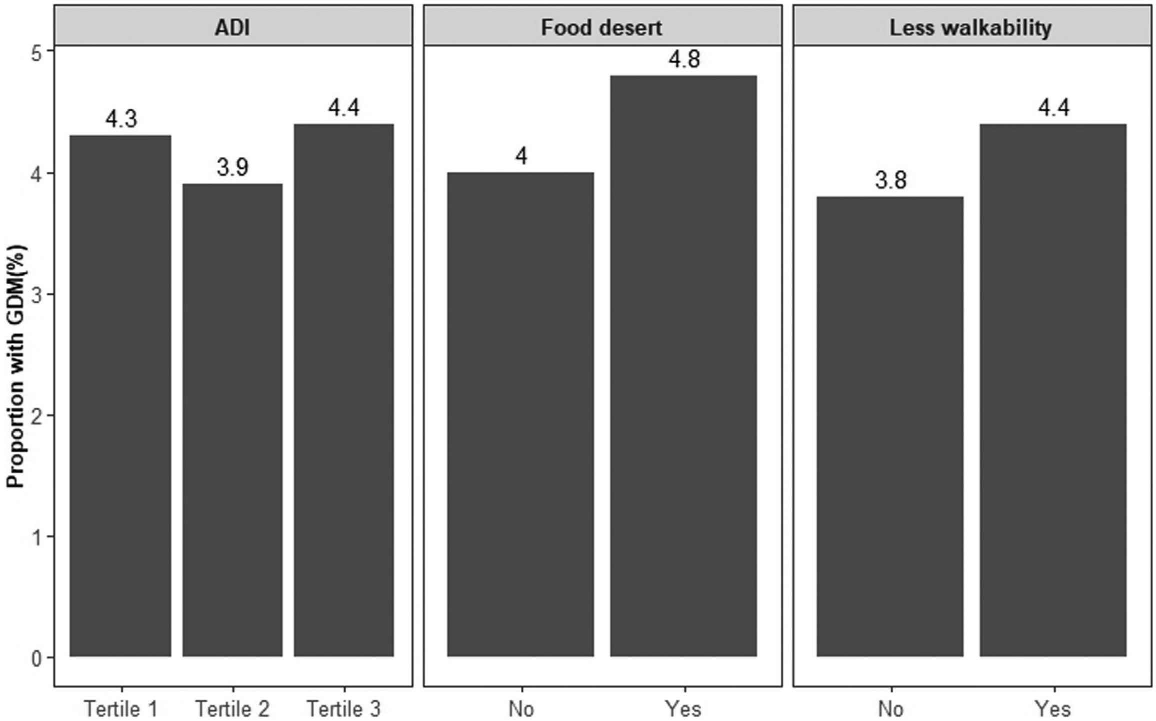
Future research is needed to understand whether community-level interventions aimed to improve the built environment and community-level SDOH can reduce the risk and severity of DM in pregnancy. Such interventions may include policies designed to increase access to housing and transportation, public safety, neighborhood walkability, or the number of stores with healthy foods to address food deserts.

Strengths and limitations

Strengths of the current analysis include the study of multiple measures of community-level SDOH. We also assessed SDOH prospectively with DM risk in a large, diverse cohort of pregnant individuals.

Limitations include that the data are now over 10 years old, but it is unlikely that the demonstrated associations would have changed over time. The exposure was assessed only once in early pregnancy and did not account for changing residential locations, but data suggest that community-level SDOH are relatively stable through a 3-year time frame.[43] This analysis assumes that an individual's place of residence rather than another area such as their place of

FIGURE 2
GDM frequency by ADI, living in a food desert, and less neighborhood walkability



Displays the frequency GDM diagnosis in pregnancy by measure of community-level social determinant of health.

ADI, Area Deprivation Index; *GDM*, gestational diabetes mellitus.

Field. Community-level social determinants of health and diabetes in pregnancy. Am J Obstet Gynecol MFM 2023.

employment is the most influential geographic area. Because of the sample size, we were unable to compare the relative differences in association between community-level SDOH and rates of DM for individuals with type 1 vs type 2 DM. Previous studies have demonstrated that increasing neighborhood-level socioeconomic disadvantage, limited walkability, and food deserts are similarly associated with inadequate glycemic control among pregnant individuals with both type 1 and 2 DM. In this analysis, we did not account for clustering of the error term by neighborhood.[22–24] Clustered standard errors with clusters defined by factors such as geography can be used if there are clusters in the population that may not be apparent in the study sample. Given the observational design of our study, we were able to demonstrate an association between various measures of adverse neighborhood-level SDOH and DM in pregnancy, but not a causal relationship. These results may not be generalizable to all pregnant populations or settings because this study was limited to nulliparous US individuals who were enrolled in a prospective cohort in the first trimester. Pregnant individuals who initiated prenatal care late and who experienced more adverse individual SDOH, such as low educational attainment, lack of health insurance, and poverty, were likely underrepresented in this prospective cohort that enrolled participants in the first trimester. However, a lower proportion of individuals who experienced adverse SDOH is unlikely to affect the observed association between neighborhood SDOH and DM in pregnancy.

Conclusions

Living in a neighborhood with greater socioeconomic disadvantage increased the odds of living with DM. Living in a food desert or a less walkable community increased the odds of developing GDM. These findings underscore the importance of community-level SDOH as potentially modifiable risk factors for DM in pregnancy. ■

Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.ajogmf.2023.101249.

References

1. Gregory EC, Ely DM. Trends and characteristics in gestational diabetes: United States, 2016-2020. Natl Vital Stat Rep 2022;71:1–15.

2. Shah NS, Wang MC, Freaney PM, et al. Trends in gestational diabetes at first live birth by race and ethnicity in the US, 2011-2019. JAMA 2021;326:660–9.

3. Feig DS, Hwee J, Shah BR, Booth GL, Bierman AS, Lipscombe LL. Trends in incidence of diabetes in pregnancy and serious perinatal outcomes: a large, population-based study in

Ontario, Canada, 1996-2010. Diabetes Care 2014;37:1590–6.
4. Venkatesh KK, Harrington K, Cameron NA, et al. Trends in gestational diabetes mellitus among nulliparous pregnant individuals with singleton live births in the United States between 2011 to 2019: an age-period-cohort analysis. Am J Obstet Gynecol MFM 2023;5:100785.
5. Britton LE, Hussey JM, Crandell JL, Berry DC, Brooks JL, Bryant AG. Racial/ethnic disparities in diabetes diagnosis and glycemic control among women of reproductive age. J Womens Health (Larchmt) 2018;27:1271–7.
6. Peterson C, Grosse SD, Li R, et al. Preventable health and cost burden of adverse birth outcomes associated with pregestational diabetes in the United States. Am J Obstet Gynecol 2015;212:74.e1–9.
7. HAPO Study Cooperative Research Group-Metzger BE, Lowe LP, et al. Hyperglycemia and adverse pregnancy outcomes. N Engl J Med 2008;358:1991–2002.
8. Vounzoulaki E, Khunti K, Abner SC, Tan BK, Davies MJ, Gillies CL. Progression to type 2 diabetes in women with a known history of gestational diabetes: systematic review and meta-analysis. BMJ 2020;369:m1361.
9. Agha MM, Glazier RH, Moineddin R, Booth G. Congenital abnormalities in newborns of women with pregestational diabetes: a time-trend analysis, 1994 to 2009. Birth Defects Res A Clin Mol Teratol 2016;106:831–9.
10. Hill-Briggs F, Adler NE, Berkowitz SA, et al. Social determinants of health and diabetes: A scientific review. Diabetes Care 2020;44:258–79.
11. Dagher RK, Linares DE. A critical review on the complex interplay between social determinants of health and maternal and infant mortality. Children (Basel) 2022;9:394.
12. Christine PJ, Auchincloss AH, Bertoni AG, et al. Longitudinal associations between neighborhood physical and social environments and incident type 2 diabetes mellitus: the multi-ethnic study of atherosclerosis (MESA). JAMA Intern Med 2015;175:1311–20.
13. Chandrabose M, den Braver NR, Owen N, Sugiyama T, Hadgraft N. Built environments and cardiovascular health: REVIEW AND IMPLICATIONS. J Cardiopulm Rehabil Prev 2022;42:416–22.
14. Frank LD, Adhikari B, White KR, et al. Chronic disease and where you live: built and natural environment relationships with physical activity, obesity, and diabetes. Environ Int 2022;158:106959.
15. Howell NA, Booth GL. The weight of place: built environment correlates of obesity and diabetes. Endocr Rev 2022;43:966–83.
16. Durfey SNM, Kind AJH, Buckingham WR, DuGoff EH, Trivedi AN. Neighborhood disadvantage and chronic disease management. Health Serv Res 2019;54(Suppl1):206–16.
17. Sheets L, Petroski GF, Jaddoo J, et al. The effect of neighborhood disadvantage on diabetes prevalence. AMIA Annu Symp Proc 2018;2017:1547–53.
18. Kind AJH, Buckingham WR. Making neighborhood-disadvantage metrics accessible – the neighborhood atlas. N Engl J Med 2018;378:2456–8.
19. United States Department of Agriculture. Introduction to the food access research atlas. Available at: https://gisportal.ers.usda.gov/portal/apps/experiencebuilder/experience/?id=a53ebd7396cd4ac3a3ed09137676fd40&page=page_0. Accessed June 8, 2022.
20. National walkability index user guide and methodology. United States Environmental Protection Agency. 2021. Available at: https://www.epa.gov/smartgrowth/national-walkability-index-user-guide-and-methodology#:~:text=The%20National%20Walkability%20Index%20(2021,to%20rank%20the%20block%20groups. Accessed November 30, 2022.
21. Kind AJ, Jencks S, Brock J, et al. Neighborhood socioeconomic disadvantage and 30-day rehospitalization: a retrospective cohort study. Ann Intern Med 2014;161:765–74.
22. Venkatesh K, Joseph JJ, Clark A, et al. Association of community-level food insecurity and glycemic control among pregnant individuals with pregestational diabetes. Prim Care Diabetes 2023;17:73–8.
23. Venkatesh KK, Germann K, Joseph J, et al. Association between social vulnerability and achieving glycemic control among pregnant individuals with pregestational diabetes. Obstet Gynecol 2022;139:1051–60.
24. Field C, Lynch CD, Fareed N, et al. Association of community walkability and glycemic control among pregnant individuals with pregestational diabetes mellitus. Am J Obstet Gynecol MFM 2023;5:100898.
25. Castrucci B, Auerbach J. Meeting individual social needs falls short of addressing social determinants of health.HealthAffairs 2019. Available at: https://www.healthaffairs.org/content/forefront/meeting-individual-social-needs-falls-short-addressing-social-determinants-health. Accessed November 30, 2022.
26. Gurewich D, Garg A, Kressin NR. Addressing social determinants of health within healthcare delivery systems: a framework to ground and inform health outcomes. J Gen Intern Med 2020;35:1571–5.
27. Haas DM, Parker CB, Wing DA, et al. A description of the methods of the Nulliparous Pregnancy Outcomes Study: monitoring mothers-to-be (nuMoM2b). Am J Obstet Gynecol 2015;212:539.e1–539.e24.
28. Singh GK. Area deprivation and widening inequalities in US mortality, 1969-1998. Am J Public Health 2003;93:1137–43.
29. Kiefer MK, Mehl R, Rood KM, et al. Association between social vulnerability and COVID-19 vaccination hesitancy and vaccination in pregnant and postpartum individuals. Vaccine 2022;40:6344–51.
30. Meiman J, Grobman WA, Haas DM, et al. Association of neighborhood socioeconomic disadvantage and postpartum readmission. Obstet Gynecol 2023;141:967–70.
31. Rhone A, Ver Ploeg M, Dicken C, Williams R, Breneman V. Low-income and low-supermarket-access census tracts 2010–2015. Economic Research Service, U.S. Department of Agriculture. 2017. Available at: https://www.ers.usda.gov/publications/pub-details/?pubid=82100. Accessed November 30, 2022.
32. Economic Research Service (ERS), United States Department of Agriculture (USDA). Food access research atlas. Available at: https://www.ers.usda.gov/data-products/food-access-research-atlas/. Accessed June 8, 2022.
33. United States Environmental Protection Agency. Smart location mapping: interactive maps and data for measuring location efficiency and the built environment. Available at: https://www.epa.gov/smartgrowth/smart-location-mapping. Accessed November 30, 2022.
34. Givens M, Teal EN, Patel V, Manuck TA. Preterm birth among pregnant women living in areas with high social vulnerability. Am J Obstet Gynecol MFM 2021;3:100414.
35. Salazar EG, Montoya-Williams D, Passarella M, et al. County-level maternal vulnerability and preterm birth in the US. JAMA Netw Open 2023;6:e2315306.
36. Zahedi-Spung L, Polnaszek B, Duckham H, et al. The impact of neighborhood deprivation on glycemic control for patients with type 2 diabetes during pregnancy. J Womens Health (Larchmt) 2022;31:1156–64.
37. Kew S, Ye C, Mehmood S, et al. Neighborhood walkability and risk of gestational diabetes. BMJ Open Diabetes Res Care 2020;8:e000938.
38. Rundle AG, Kinsey EW, Widen EM, et al. Neighbourhood walkability is associated with risk of gestational diabetes: a cross-sectional study in New York City. Paediatr Perinat Epidemiol 2023;37:212–7.
39. Kahr MK, Suter MA, Ballas J, et al. Geospatial analysis of food environment demonstrates associations with gestational diabetes. Am J Obstet Gynecol 2016;214:110.e1–9.
40. Fonge YN, Jain VD, Harrison C, Brooks M, Sciscione AC. Examining the relationship between food environment and gestational diabetes. Am J Obstet Gynecol MFM 2020;2:100204.
41. Pham A, Wiese AD, Spieker AJ, et al. Social vulnerability and initiation of pharmacotherapy for gestational diabetes mellitus in a Medicaid population. Womens Health Issues 2023;33:273–9.
42. Mallampati D, Jackson C, Menard MK. The association between care management and neonatal outcomes: the role of a Medicaid-managed pregnancy medical home in North Carolina. Am J Obstet Gynecol 2022;226:848.e1–9.
43. Knighton AJ. Is a Patient's current address of record a reasonable measure of neighborhood deprivation exposure? A case for the use

of point in time measures of residence in clinical care. Health Equity 2018;2:62–9.

Author and article information

From the Department of Obstetrics and Gynecology, The Ohio State University, Columbus, OH (Drs Field and Grobman, Mr Wu, and Drs Lynch and Venkatesh); Department of Obstetrics and Gynecology, Northwestern University, Chicago, IL (Dr Yee); Department of Obstetrics and Gynecology, Indiana University, Indianapolis, IN (Dr Johnson); RTI International, Durham, NC (Dr McNeil); Department of Obstetrics and Gynecology, Case Western Reserve University, Cleveland, OH (Dr Mercer); Department of Obstetrics and Gynecology, and Reproductive Sciences, University of Pittsburgh, Pittsburgh, PA (Dr Simhan); Department of Obstetrics and Gynecology, Columbia University, New York, NY (Drs Reddy and Wapner); Department of Obstetrics and Gynecology, University of Utah, Salt Lake City, UT (Dr Silver); Department of Obstetrics and Gynecology, University of Pennsylvania, Philadelphia, PA (Dr Parry); Department of Obstetrics and Gynecology, University of Texas Medical Branch, Galveston, TX (Dr Saade); Department of Obstetrics and Gynecology, University of California, Irvine School of Medicine, Irvine, CA (Dr Chung).

Received July 5, 2023; revised Oct. 20, 2023; accepted Dec. 4, 2023.

The authors report no conflict of interest.

Support for the Nulliparous Pregnancy Outcomes Study: Monitoring Mothers-to-Be (nuMoM2b) study was provided by grant funding from the Eunice Kennedy Shriver National Institute of Child Health and Human Development (RTI International grant U10 HD063036; Case Western Reserve University grant U10 HD063072; Columbia University grant U10 HD063047; Indiana University grant U10 HD063037; University of Pittsburgh grant U10HD063041; Northwestern University grant U10 HD063020; University of California, Irvine grant U10 HD063046; University of Pennsylvania grant U10 HD063048; and University of Utah grant U10 HD063053). In addition, support was provided by the respective clinical and translational science institutes of Indiana University (grant UL1TR001108) and University of California, Irvine (grant UL1TR000153). K.K.V. was supported by the Care Innovation and Community Improvement Program at The Ohio State University.

This study was presented as a poster and ePoster theater presentation at the 83rd Scientific Sessions of the American Diabetes Associationon, San Diego, CA, June 23−26, 2023.

Corresponding author: Christine Field, MD, MPH. christine.field@osumc.edu