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Association between Low Urban Neighborhood Greenness and Hypertensive Disorders of Pregnancy

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Abstract

Objective Urban neighborhood greenness is associated with greater cardiovascular health in the general population, and with better pregnancy and neonatal outcomes. Hypertension in pregnancy is a leading cause of maternal mortality and long-term cardiovascular morbidity and mortality in women. We sought to examine the association between greenness and hypertensive disorders of pregnancy.

Study Design This study is a secondary analysis of a prospective cohort study of 1,943 women who received prenatal care from December 2013 to December 2016 at a single, urban, and tertiary academic medical center in Philadelphia, PA. Greenness measure was quantified via residential tree canopy cover within circumferential buffers of 100- and 500-meter radii around participants' homes. Associations between greenness and hypertensive disorders of pregnancy (defined as gestational hypertension or preeclampsia) were estimated by using multilevel logistic regression accounting for maternal sociodemographic information (race-ethnicity, insurance status, and age) medical history (diabetes, body mass index, smoking history, and parity), neighborhood deprivation index, and including 1,225 Philadelphia residents for whom key exposure and outcome data were available.

Results At baseline, the participants' mean (SD) age was 27.5 (5.9) years, (range: 14–44 years). The majority of participants were non-Hispanic Black (857, 70.2%). Participants with less residential tree canopy cover were significantly more likely to have hypertensive disorders of pregnancy. The multivariable-adjusted odds ratio of hypertensive disorders of pregnancy among participants with less than 10% compared with those with greater than 30% tree canopy cover was 2.14 (95% confidence interval [CI]: 1.11–4.15) within 100-meter buffer.

Conclusion In our cohort, greenness was associated with lower hypertensive disorders of pregnancy odds. Our findings add to evidence that greenness may confer health benefits and warrant further investigations in identifying whether there is a causal pathway through which greenness may be protective against hypertensive disorders of pregnancy.

Keywords
- gestational hypertension
- preeclampsia
- tree canopy cover
- greenness
- maternal morbidity
- environmental exposures
- health disparities
- environmental racism
- urban health

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Key Points

- Low residential tree canopy is associated with increased risk of hypertensive disorders of pregnancy
- 100-meter buffers are most sensitive in identifying associations between tree canopy and HDP risk
- The role of greenness against hypertensive disorders of pregnancy should be further studied experimentally

Hypertensive disorders of pregnancy (HDP), which include gestational hypertension and preeclampsia, are a leading cause of maternal morbidity and mortality in the United States (U.S.) and worldwide.[1] Preeclampsia occurs in approximately 3% of pregnancies, and HDP affect 5 to 10% of pregnancies.[2] HDP often lead to and are associated with severe maternal morbidity as defined by the Center for Disease Control and Prevention (unexpected outcomes of labor and delivery that result in significant short- or long-term consequences to a woman's health).[3] HDP are also associated with increased long-term cardiovascular morbidity and mortality for women.[4–7] In addition to overall morbidity, HDP and other cardiovascular complications of pregnancy contribute to a significantly higher proportion of maternal mortality in the United States among non-Hispanic Black women compared with non-Hispanic White women.[8]

The role of neighborhood environments in shaping health generally, and pregnancy outcomes specifically, is well documented. Neighborhood greenness, especially tree canopy cover, is an aspect of the environment which may confer protective health effects. Noise pollution, air quality, and temperature—all of which are influenced by tree canopy—have been associated with increased risk of developing HDP, as well as preterm birth, low birth weight, and stillbirth.[9–12] In the general population, greenness has previously been associated with lower risks of a range of metabolic and cardiovascular diseases including hyperlipidemia, myocardial infarction, ischemic heart disease, heart failure, and chronic hypertension.[13–15] Exposure to greenspace is also thought to impact cardiovascular health through the strengthening of social connections, which is well documented to have a positive impact on health.[16] Furthermore, exposure to greenness is also associated with immediate physiologic cardiovascular benefits including reductions in heart rate and blood pressure.[17–19] Finally, greenspace is theorized to convey immunologic benefits that may also underlie potential cardiovascular benefits of nature.[20]

Differential exposure to environmental factors by race[21] may contribute to observed racial disparities in pregnancy outcomes,[22,23] but whether greater neighborhood greenness may attenuate disparities in HDP is unknown. Our study, therefore, had two objectives. First, we sought to quantify associations between greenness and odds of HDP in a cohort of pregnant women living in Philadelphia. Second, we sought to evaluate if the relationship between greenness and HDP differed between non-Hispanic Black and non-Hispanic White women. Greenness, if associated with lower HDP odds, may represent an attractive place-based intervention for policymakers seeking to address maternal morbidity and mortality in the United States.

Materials and Methods

Study Cohort

We performed a retrospective study from a prospective cohort of women who were recruited during the course of prenatal care in a tertiary hospital in Philadelphia, PA. The parent study, Motherhood & Microbiome (M&M),[24,25] enrolled 2,000 pregnant participants from 2013 to 2017. This analysis includes just the women who lived in Philadelphia with the fine-scale greenspace layer. There were three study visits during pregnancy which were at 16 to 20 weeks; 20 to 24 weeks; and 24 to 28 weeks of gestation. Cervicovaginal swabs were obtained at each visit since the primary goal of the study was to understand associations between the microbial/immune state and spontaneous preterm birth. There were multiple psychosocial questionnaires administered including instruments for perceived stress, anxiety, and depression. There were no additional study visits. However, permission to obtain clinical data and demographic data throughout pregnancy was included as part of the consent process. Women were excluded from the cohort study if they met any of the following criteria: (1) major fetal anomaly, (2) HIV positive status, (3) history of organ transplant, and (4) chronic steroid use (>20 mg per day for more than 30 days at the time of first study visit).

For our analysis, inclusion criteria were the following: a geocodable home address within Philadelphia and gestational age at delivery 20 weeks or greater. Women with spontaneous preterm birth were excluded from the primary analysis, as this is a competing outcome, which may occur before women develop either gestational hypertension or preeclampsia. Women with a history of chronic hypertension were also excluded, as they cannot be diagnosed with gestational hypertension (►Fig. 1). Participants missing exposure or outcome data were excluded from the analysis. The University of Pennsylvania institutional review board approved this study (ID 818914). We followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guideline.[26]

Exposure Assessment

Neighborhood greenness was measured by tree canopy cover. Data were acquired from the Philadelphia's Parks and Recreation open access database on tree canopy. Tree canopy data are a collection of tree canopy outlines generated by Intergraph Government Solutions for trees greater than 6' diameter from 2015 LiDAR data capture.[27] While the exposure was independently assessed over halfway through our study period, evidence shows neighborhood characteristics such as tree canopy cover change relatively slowly,[28] and the Philadelphia Tree Canopy assessment shows minimal changes in the areas most inhabited by our sample population between 2008 and 2018.[29]

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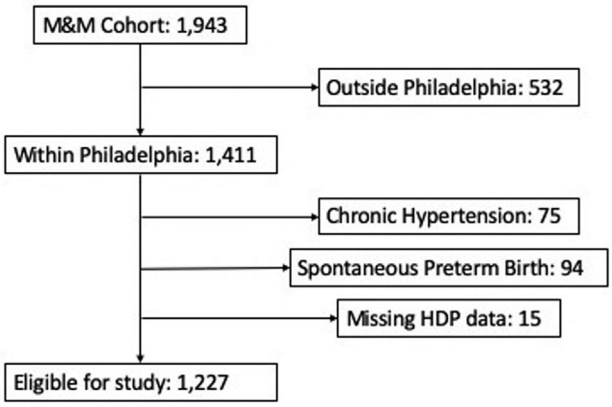

Fig. 1 Flow chart of motherhood and microbiome cohort participants eligible for analysis.

For each participant's home address, we used ArcGis Pro 10.0 (Esri, Redlands, CA) to create buffers at 100- and 500-meter radii (►**Fig. 2A**, which approximately encompass respectively one, and four city blocks. Buffer radii were selected based upon prior studies reporting health benefits associated with greenness.[30,31] This setting of buffer size is typically based on the assumption that this range represents the neighborhood environment where people spend their time sitting, walking, or interacting with neighbors. Buffers were then spatially joined to the tree canopy dataset. We then calculated the amount of tree canopy within each buffer as a percentage of total land area. For analysis, participants were classified into four groups based on examples from prior similar studies (tree canopy cover 0–10, 10–20, 20–30, and >30%).►**Fig. 2B** for tree canopy covers distribution in Philadelphia.

Outcome

HDP was defined as either gestational hypertension or preeclampsia. Cases of HDP were confirmed with manual review of electronic medical records during the primary study. Gestational hypertension and preeclampsia diagnoses were given by patients' clinical providers, following the American College of Obstetricians and Gynecologists' guidelines.[30,32]

Covariates

Individual-level covariates included self-identified race/ethnicity, health insurance status, age at delivery, parity, diabetes history, smoking history, and pre-pregnancy body mass index (BMI) as a continuous variable. These variables were selected because they are associated with or known risk factors for HDP. To account for neighborhood-level socioeconomic status, we used census tract-level neighborhood deprivation data from the Nationwide Community Deprivation Index.[33] The index from 0 to 1 (national average = 0.4) with lower numbers reflecting higher neighborhood socioeconomic status. Variables included in the index are poverty rate, median household income, education, rates of health insurance cover, the fraction of households receiving public assistance, and fraction of houses that are vacant. We also accounted for seasonality, since some health benefits of trees such as shade and decreased temperature are only present during leaf-growing time periods. We defined leaf-growing season as March 21st to September 21st given that deciduous trees begin to lose their leaves in the fall and then regrow them in the spring. We then determined if each participant's last menstrual period (LMP) took place in or out of leaf-growing season based on estimated LMP, given existing evidence suggesting that environmental exposures surrounding placentation contribute to risk of preeclampsia.[11,34]

Statistical Analysis

We used descriptive statistics to compare women with and without HDP. We used multilevel logistic regressions accounting for clustering of participants within census tracts to examine the association between neighborhood greenness and the odds developing HDP. The main model assessed HDP in relation to each greenness buffer at the individual level, adjusting for race/ethnicity, age, parity and history of pregestational or gestational diabetes, insurance status, smoking history, pre-pregnancy BMI and seasonality (leaf-growing vs. non-leaf-growing season) of LMP at the individual level, and neighborhood deprivation index at the census tract level. We chose the neighborhood deprivation index at the census tract level because recent evidence showed that in the United States, overall 70.4% of total geographic variations in life expectancy is attributable to census-tract level differences.[35] In other words, adjusting for census tract-level socioeconomic variables allows us to address spatial correlation and significantly accounts for social determinants of health that may otherwise be responsible for observed disparities, including in our cohort.

Fig. 2 (**A**) Example of Philadelphia home with 50-, 100-, and 500-meter buffers. (**B**) Tree canopy distribution in Philadelphia, PA by neighborhood.

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Given the history of residential racial segregation in U.S. cities and its impact on the built environment greenness distributions vary by race/ethnicity, we conducted subgroup analyses of non-Hispanic black and non-Hispanic white participants to assess whether associations of greenness, and HDP were similar across racial groups.[36] We did not conduct the subgroup analysis for Hispanic participants and those in the other category because of the small sample sizes. Finally, to address potential selection bias because we excluded women with chronic hypertension and women with spontaneous preterm birth from the primary analysis, we performed a sensitivity analysis using a multinomial, multilevel logistic regression model of associations of tree canopy cover with four possible outcomes: (1) term delivery without HDP; (2) preeclampsia (regardless of delivery timing, and including participants with a history of chronic hypertension); (3) gestational hypertension (regardless of delivery timing); and (4) spontaneous preterm birth without HDP. Statistical analyses were performed by using STATA (Version 16, StataCorp, College Station, TX). Statistical tests were two-tailed and $p < 0.05$ was considered statistically significant.

Results

A total of 1,225 women were included in the final analysis (►Fig. 1). ►Supplementary Table S1 (available in the online version) compares included and excluded participants. A total of 281 participants had HDP (22.9%): 253 participants had gestational hypertension, of which 48 progressed to preeclampsia. Twenty-eight participants developed preeclampsia without prior diagnosis of gestational hypertension. Characteristics according to HDP status are presented in ►Table 1. Women with HDP were more likely to be non-Hispanic black, older, nulliparous, and have a higher BMI. Mean (standard deviation) tree canopy cover within 100-meter radius buffers was 16.6% (9.3%) and within 500-meter radius buffers was 17.1% (7.4%). Participants who developed HDP had lower exposure to tree canopy cover (►Table 2).

At the 100-meter buffer level in unadjusted analysis, participants with less than 10% tree canopy cover had increased odds of having HDP compared with those with greater than 30% tree canopy cover (odds ratio [OR]: 2.08, 95% confidence interval [CI]: 1.12–3.86). The association persisted after adjusting for individual- and neighborhood-level covariates including race/ethnicity, age, health insurance status, parity, history of diabetes, pregnancy BMI, LMP seasonality, and neighborhood deprivation index by census tract. Participants with less than 10% tree canopy cover had more than twice the odds of HDP compared with those with greater than 30% (adjusted odds ratio [aOR]: 2.14, 95% CI: 1.11–4.15). We conducted the same analysis using tree canopy cover as a continuous variable, and the unadjusted analysis showed that for each standard deviation increase in tree canopy cover within 100-meter buffers, there was a 13% (95% CI: 1–25%, $p = 0.047$) decrease in HDP odds. The results were similar in the adjusted multilevel logistic model, showing a 14% (95% CI: 1–26%, $p = 0.05$) decrease of HDP odds per standard deviation increase in tree canopy cover. The 500m sensitivity analysis showed similar results (►Supplementary Table S2 [available in the online version]). Notably, for each standard deviation in tree canopy cover increase, there was a 19% (95% CI 5–31%, $p = 0.01$) decrease in HDP odds.

In this cohort, non-Hispanic Black women were more likely than non-Hispanic White women to be younger, obese, have Medicaid insurance or no insurance, and to have HDP

Table 1 Study participant characteristics among women with and without hypertensive disorders of pregnancy, and motherhood and microbiome cohort ($n = 11,225$, two excluded due to missing data)

	No HDP ($n = 944$)	HDP ($n = 281$)
Race/ethnicity (%)		
Non-Hispanic white	198 (21.0)	37 (13.2)
Non-Hispanic black	638 (67.5)	219 (78.0)
Hispanic	46 (4.9)	12 (4.3)
Other	62 (6.6)	13 (4.5)
Age (%)		
< 20	78 (8.3)	32 (11.4)
20–34	734 (77.7)	205 (72.95)
35+	132 (14)	44 (15.66)
Heath insurance (%)		
Employer-based	379 (40.1)	105 (37.37)
Medicaid/uninsured	565 (59.9)	176 (62.63)
Education (%)		
< High school	86 (9.1)	37 (13.2)
High school/some college	479 (50.7)	157 (55.9)
Graduated college	151 (16.0)	46 (16.4)
Graduate/professional	161 (17.1)	30 (10.9)
Other	67 (7.10)	11 (3.9)
Prenatal BMI (SD)	27.57 (6.89)	31.03 (8.6)
Smoking during pregnancy (%)	77 (8.1)	17 (6.0)
Parity (%)		
Multiparous	539 (57.1)	127 (45.2)
Nulliparous	405 (42.9)	154 (54.8)
Diabetes (%)		
No diabetes	901 (95.4)	244 (86.8)
Gestational diabetes	31 (3.3)	27 (9.6)
Pregestational diabetes	12 (1.27)	9 (3.20)
LMP seasonality (%)		
Non-leaf-growing season	500 (53.0)	161 (57.3)
Leaf-growing season	444 (47.0)	120 (42.7)
Neighborhood deprivation index (SD)	0.5 (0.11)	0.53 (0.12)

Abbreviations: BMI, body mass index; HDP, hypertensive disorders of pregnancy; LMP, last menstrual period; SD, standard deviation.
Note: Data presented as *n* (%) unless otherwise specified. Two participants excluded due to missing body mass index and deprivation index data.

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Table 2 Associations between tree canopy cover and hypertensive disorders of pregnancy ($n = 1,225$)

		No HDP *n* (%)	HDP *n* (%)	OR (95% CI) *n* = 1,225	*p*-Value	Adjusted[a] OR (95% CI) *n* = 1,225	*p*-Value
Buffer size	Tree canopy cover						
100 m	>30%	98 (10.4)	14 (4.0)	1 (ref)		1 (ref)	
	20–30%	189 (20.0)	57 (20.3)	2.11 (1.12–3.98)	0.047	2.00 (1.02–3.93)	0.05
	10–20%	421 (44.6)	140 (49.8)	2.33 (1.29–4.21)	0.057	1.98 (1.05–3.73)	0.04
	<10%	236 (25.0)	70 (24.9)	2.08 (1.12–3.86)	0.023	2.14 (1.11–4.16)	0.02

Abbreviations: CI, confidence interval; HDP, hypertensive disorders of pregnancy; OR, odds ratio; SD, standard deviation.
[a]Adjusted for age, prenatal body-mass index, smoking history, parity, history of diabetes, health insurance, last menstrual period seasonality, and deprivation index by census tract).

Table 3 Association between tree canopy cover and hypertensive disorder of pregnancy among non-Hispanic black participants ($n = 857$)

Buffer size	Tree canopy cover	No HDP *n* (%)	HDP *n* (%)	OR (95% CI)	*p*-Value	Adjusted[a] OR (95% CI)	*p*-Value
100 m	>30%	49 (7.7)	6 (2.7)	1 (ref)		1 (ref)	
	20–30%	142 (22.3)	49 (22.4)	2.82 (1.14–6.99)	0.025	3.23 (1.23–8.50)	0.017
	10–20%	314 (49.2)	118 (53.9)	3.07 (1.28–7.35)	0.012	3.13 (1.23–7.95)	0.016
	<10%	133 (20.8)	46 (21.00)	2.82 (1.14–7.03)	0.026	3.29 (1.24–8.70)	0.017

Abbreviations: CI, confidence interval; HDP, hypertensive disorders of pregnancy; OR, odds ratio.
[a]Adjusted for prenatal body mass index, parity, history of diabetes, age, insurance, seasonality of last menstrual period, and deprivation index by census tract.

(►**Supplementary Table S3** [available in the online version]). Non-Hispanic black participants were also disproportionately exposed to low levels of tree canopy cover. In the subgroup analyses analysis at the 100-meter buffer level, non-Hispanic black women exposed to <10% tree canopy cover had higher adjusted odds of HDP compared with non-Hispanic black women with >30% (OR: 3.29, 95% CI: 1.24–8.70; ►**Table 3**). Results were even more pronounced at the 500-meter level (►**Supplementary Table S2** [available in the online version]). Among non-Hispanic white participants, we did not detect significant associations between tree canopy cover and HDP (►**Supplementary Table S4** [available in the online version]).

Because we were concerned that the exclusion of women with spontaneous preterm birth and chronic hypertension could cause selection bias, we performed a sensitivity analysis which included these women. We performed a multinomial multilevel logistic regression model in which women could have one of four outcomes: term delivery without HDP (base outcome), gestational hypertension (regardless of delivery timing), preeclampsia (regardless of delivery timing, and including participants with chronic hypertension), or preterm birth without HDP. In this breakdown, lesser tree canopy cover was associated with significantly increased odds of gestational hypertension only. At 100 meters, participants with less than 10% tree canopy cover had nearly three times the odds of developing gestational hypertension compared with those with greater than 30% (aOR: 2.56, 95% CI: 1.18–5.55; ►**Supplementary Table S5** [available in the online version]). There were no significant associations of tree canopy cover with preterm birth without HDP or with preeclampsia.

Discussion

Principal Findings and Results

This study demonstrates that lower levels of neighborhood tree canopy cover were associated with higher odds of HDP after adjusting for individual sociodemographic variables, medical covariates previously associated with HDP, and neighborhood-level deprivation, a holistic indicator of overall socioeconomic status. Noting significant racial disparities in HDP, our results suggest that less greenness is particularly strongly associated with higher odds of HDP among non-Hispanic black women. We did not detect a significant association among non-Hispanic white participants; however due to small sample size and wide confidence intervals, we cannot rule out an association. In our sensitivity analysis, while there was an association between tree canopy cover and gestational hypertension odds, this association was not significant for preeclampsia, which may be due to the smaller sample size of participants who developed preeclampsia.

This study adds to evidence demonstrating the importance of neighborhood environment in adverse pregnancy outcomes. Greenness has been associated with improved neonatal outcomes, including lower risk of preterm birth and low birth weight.[37] A single study evaluating greenness found associations with neonatal outcomes but found no association between greenness and preeclampsia; however, it did not investigate gestational hypertension.[38] In terms of cardiovascular health, a 2019 community-based study showed that increases in neighborhood greenness were associated with lower blood pressure and hypertension prevalence, and the associations were stronger among women than men.[15]

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Clinical Implications

There are several mechanisms that may explain the association between higher tree canopy cover and lower odds of HDP, including improved air quality, reduced urban heat island effect, and lower stress.[16,20] For instance, trees remove fine particles from the atmosphere and consequently improve air quality,[39] while air pollution from road traffic is associated with increased risk of preeclampsia.[10,40] A previous study found lower levels of personal exposure to air pollution among pregnant women residing in greener areas, which based on normalized difference vegetation index within 100-meter buffers.[41] Trees also provide shade and reduce ambient temperature,[42] and higher ambient temperatures and humidity surrounding conception are also associated with preeclampsia.[11] Additionally, proximity to green spaces is associated with lower noise annoyance.[43] One study showed that prevalence of preeclampsia was higher among pregnant patients exposed to greater levels of noise pollution, especially early onset and severe preeclampsia.[9] Furthermore, the increased amount of shade from tree canopy cover may increase levels of physical activity and a perceived sense of community cohesion associated with lower odds of cardiovascular disease in the general population.[44–46] Recent experimental evidence demonstrated that exposure to greenness led to a positive physiological response and increased community cohesion in a Philadelphia neighborhood walking trial, and being in view of greened vacant neighborhood lots decreased participants' heartrate significantly more than did being in view of non-greened vacant lots or not in view of any vacant lots.[19] Other covariates associated with increased risk of HDP, such as pre-pregnancy BMI, are also affected by environmental exposures including tree canopy cover. Studies have found associations between residential tree canopy cover and physical activity, as well as obesity. In other words, pre-pregnancy BMI may mediate the effect of tree canopy cover on HDP risk.[47]

The cumulative experience of stress from a variety of sources—including environmental, discrimination, and poverty—may make the presence of green space, a known buffer to stress, particularly important in black neighborhoods.[48] These results are also in line with prior research demonstrating the importance of sociodemographic context in evaluating risk factors for pregnancy outcomes. For example, a recent study of green spaces, health inequality, and pregnancy outcomes in Spain found that the beneficial effects of green spaces are only among pregnant participants of lower socioeconomic position.[49]

The larger effect size of the impact of greenness on HDP among Black women may be due to environmental racism. Environmental racism is a concept from the environmental justice movement that illustrates the fact that black, indigenous and other people of color are more likely to live near polluters and more likely to be exposed to a higher magnitude of pollution compared with white people, as a result of state-sanctioned policies.[50,51] For example, historical government-sanctioned housing segregation on the basis of race (redlining) and subsequent decades of White flight and neighborhood disinvestment[52] are linked to present day differences in neighborhood social and physical environment, including crime, air quality, and temperature. Studies have identified racial disparities in distribution of green spaces, with census tracts with a higher proportion of racial and ethnic minorities having less greenness, as well as losing more greenness overtime compared the those with a higher proportion of white residents.[28] This was true in our study sample with disproportionate exposure to low tree canopy cover among black women. Other environmental factors associated with greenness follow a similar pattern. A recent study on intraurban heat showed that nationally, formerly redlined neighborhoods are on average 2.6°C warmer than nonredlined neighborhoods, and the difference can be as high as 7°C.[53] Similarly, disparities in neighborhood air quality fall along racial lines and redlining status.[21,54] The protective effect of trees may thus be most tangible among women facing a disproportionately high level of toxic environmental exposures.

In addition to its association with maternal mortality, HDP is associated with long-term cardiovascular morbidity in women,[7,55,56] as well as elevated blood pressures in their children.[57] If validated as a potential intervention, increased exposure and access to greenness may serve as a tool to address racial disparities in maternal morbidity and mortality, as well as disparities in postpartum and long-term complications, and chronic illness associated with HDP.[58] This hypothesis is supported by a recent study of tree canopy cover in Philadelphia, which showed that achieving city-wide tree canopy cover of at least 30% by 2025 could prevent 403 premature deaths annually, 244 of which in areas of lower socioeconomic status.[59] For these reasons, our findings support the idea that neighborhood greening may be a nonpharmacological strategy for policymakers and health systems to reduce maternal morbidity and mortality associated with HDP, as well as to address racial disparities in pregnancy outcomes.

Research Implications

The association between low tree canopy cover and odds of developing HDP during pregnancy found in our study is nonexperimental, and does not address whether the identified association infers causality, and if so, by which pathway this might occur. This therefore warrants further studies evaluating the interaction between greenness and other environmental exposures such as air and noise pollution, ambient temperatures, and HDP risk, as well as the impact of environmental changes on HDP incidence. Furthermore, additional research on associations between greenness and HDP in suburban settings is warranted.

Strengths and Limitations

Strengths of our study include prospective enrollment before the outcome of HDP was assessed. We had a large sample of non-Hispanic Black women who are particularly at-risk for HDP. However, this study is based out of a single-center, tertiary care center in an urban setting; participants

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included in this analysis (Philadelphians) were more likely to be non-Hispanic black, more likely to have Medicaid insurance or be uninsured than those who resided outside of Philadelphia and thus not included (►**Supplementary Table S1** [available in the online version]). Notably, the HDP incidence was 23%, which is greater than the incidence of HDP in the general population. Therefore, our findings may not be generalizable to other settings or populations. Tree canopy cover is a static measure that does not necessarily reflect participants' engagement and activity related to green spaces such as frequency or time spent outdoors, and there may be unmeasured confounders we were not able to adjust for. Our study is observational; therefore, the associations identified cannot be determined to be causal. Lastly, we did not account for spatial autocorrelation between potentially overlapping buffers. However, we accounted for autocorrelation at the census tract level by adjusting for the census-tract neighborhood deprivation index.

Conclusion

In our cohort, low-level tree canopy cover was independently associated with elevated odds of HDP, especially among non-Hispanic black participants. Prior studies of neighborhood greenness in pregnancy are limited by not assessing gestational hypertension, whereas ours addresses this gap. Our findings warrant further investigations to examine the interactions between greenness, environmental factors such as air quality, noise pollution and temperature, and their impact on the incidence of HDP in pregnancy. Additionally, this contributes to a framework for policymakers for planning and designing urban environments that incorporate place-based initiatives such as tree-planting and upkeep to address health inequities, especially in more socioeconomically deprived neighborhoods.

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Conflict of Interest

None declared.

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