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Short Report

Urban trees and the risk of poor birth outcomes

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ABSTRACT

This paper investigated whether greater tree-canopy cover is associated with reduced risk of poor birth outcomes in Portland, Oregon. Residential addresses were geocoded and linked to classified-aerial imagery to calculate tree-canopy cover in 50, 100, and 200 m buffers around each home in our sample ($n=5696$). Detailed data on maternal characteristics and additional neighborhood variables were obtained from birth certificates and tax records. We found that a 10% increase in tree-canopy cover within 50 m of a house reduced the number of small for gestational age births by 1.42 per 1000 births (95% CI—0.11–2.72). Results suggest that the natural environment may affect pregnancy outcomes and should be evaluated in future research.

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1. Introduction

There is increasing evidence that greenness can improve the health of urban residents. The pioneering work in this field was done by Ulrich (1984), who showed that patients recovering from gall-bladder removal surgery in a room with a view of a natural scene were discharged quicker and required less pain medication than those who recovered in a room with a view of a brick wall. More recently, observational studies have shown that greenness is associated with lower obesity (Bell et al., 2008), perceived general health (Maas et al., 2006), morbidity (Maas et al., 2009b), and mortality (Mitchell and Popham, 2007). The relationship between health and the natural environment has been studied in other fields including evolutionary biology and psychology. Research has concluded that the natural environment, in general (Frumkin, 2001; Wilson, 1984), and trees specifically (Perlman, 1994) can improve human well being.

There has been no research, however, on the effect of greenness on reproductive health. Past research has shown that birth outcomes are related to stress (Miranda et al., 2009), neighborhood-level economic deprivation (Messer et al., 2008; O'Campo et al., 2008), and social capital (Buka et al., 2003). Although these studies did not consider greenness, they suggest potential mechanisms linking greenness and birth outcomes. We address this gap in the literature by quantifying the effect of urban trees on adverse birth outcomes. Specifically, we tested the hypothesis that greater access to urban trees would reduce the incidence of preterm birth (PTB) and small for gestational age (SGA), both of which are major causes of neonatal and infant mortality as well as contributing to health problems in later life (Hack et al., 1995).

We chose to study the effect of trees on birth outcomes, because urban trees are an important element of the natural environment that can be more readily modified than other natural amenities. For example it is easier to plant trees in a neighborhood than increase the size of parks or other open space.

2. Study sample

The study sample consisted of all singleton live births in Portland, Oregon, during 2006 and 2007, where the mother's address was a single-family home ($n=5696$). Of these, 348 births were preterm and 397 were SGA (33 births exhibited both). Our analysis was confined to single-family homes because of practical difficulties measuring trees around multi-family homes. We geocoded houses by matching a mother's address on a birth certificate to an address in the Regional Land Information System (RLIS) database, which contains coordinates for the centroid of each house's lot. The RLIS database is maintained by Metro, which is the metropolitan Portland regional government with responsibility for urban planning and transportation.

3. Measures and method

We used birth certificates to identify PTB, gestational age of less than 37 weeks, and SGA, birth weight below the 10th percentile for

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gestational age and gender. Percentage tree canopy in the 50, 100, and 200 m buffers around the centroid of each mother's house was calculated using classified-aerial imagery (Metro land-cover classification 2007, resolution 1 m). Fig. 1 shows an example of this classified-aerial imagery and the color imagery on which it is based. Both panels show the same houses, although, for privacy reasons, these particular houses were not part of our sample.

Birth certificates provided data on race, age, and education of parents; insurance type (public, private, or none); receipt of prenatal care; and reproductive characteristics of the mother (number, frequency, and outcome of previous pregnancies).

Tax records provided data on the following characteristics of a mother's house: number of bathrooms and bedrooms, type of heating, presence of air conditioning, age of a house, house size, lot size, and 2007 real market value, which we used as a proxy for income (Goodman and Kawai, 1982).

The RLIS database provided data on housing and population density, street connectivity (density of intersections), and distance to closest parks, commercial districts, freeways, and public transit.

The Portland Police Bureau provided data on the number of property and violent crimes that were reported in 2006 and 2007 in the 50, 100, and 200 m buffers around the centroid of a house's lot. Crime was included as a covariate, as it has been shown to increase stress (Koss et al., 1991) and may affect patterns of physical activity (Foster and Giles-Corti, 2008).

3.1. Statistical analyses

We used binary logistic regression to examine whether a tree-canopy cover was independently related to the incidence of SGA or PTB in the study sample. All variables with *p*-values of less than 0.25 in univariate analyses were considered for inclusion in our models. In the case of collinear variables – for example, those describing a mother's education – only the variable from each group with the lowest *p*-value was included. Final model selection was done using an iterative, backward selection of variables with progressively lower *p*-value thresholds of 0.75, 0.5, 0.25, and 0.1. To ensure that all confounders were included, any covariate with significant variation in canopy cover within 50 m of a house that was not selected for retention during the backward selection process was re-introduced to the final model. If any re-introduced variable caused a 10% or greater change in any coefficients of interest, then we retained it in the final model (Rothman et al., 2008). None of the covariates evaluated (including those not shown in Table 1) met this threshold.

To test for spurious correlation, we conducted a Monte Carlo validation test (Good, 2006) using 75% of the sample to estimate the probability of adverse birth outcome in the remaining 25%. We separated the 25% into cases and controls and calculated the mean, predicted probability of an adverse birth outcome in the two groups (if the model had predictive power, then one would expect it to predict an adverse birth outcome more frequently for cases than controls). We retained the difference between the two values and repeated the process 1000 times. We compared the resultant distribution to a control where observations were randomly assigned to the two groups based on the proportion of adverse birth outcomes in the retention sample.

4. Results

Characteristics of women in the study sample are shown in Table 1. Women with greater access to urban trees were more likely to be non-Hispanic white, younger, have fewer previous births, and live in newer, more expensive houses closer to private open space compared to women with less access to urban trees.

A canopy cover within 50 m of a house, and proximity to a private open space, reduced the risk of a baby being born SGA (Table 2) but were not significantly associated with PTB (model not shown). In the SGA model, the effects of parity, education, and race were consistent with past research (Messer et al., 2008; Phung et al., 2003).

Based on the results of our Monte Carlo validation test, the model performed significantly better than random chance ($p<0.0001$; Fig. 2). The predictive power of the model was also compared to a restricted model without variables describing the canopy cover or distance to a private open space. The full model performed better than the restricted model ($p<0.0001$), supporting the contribution of these variables to the predictive power of the model.

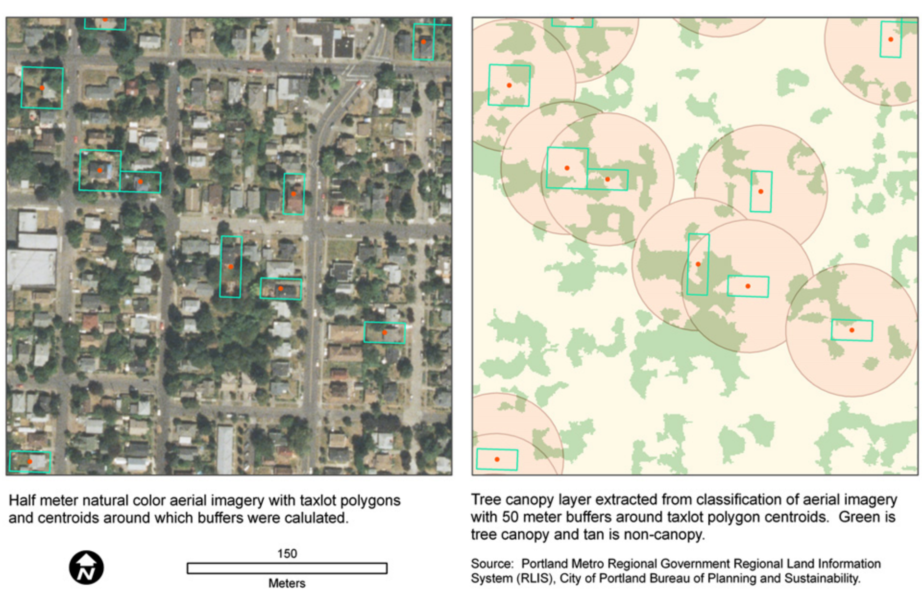

Fig. 1. Left—half meter natural color aerial imagery with taxlot polygons and centroids around which buffers were calculated. Right—tree canopy layer extracted from classification of aerial imagery with 50 m buffers around taxlot polygon centroids. Green represents tree canopy and tan non-canopy.

Table 1
Selected individual and neighborhood characteristics overall and by tree canopy within 50 m.

Variable	Overall	Tree canopy within 50 m below median	Tree canopy within 50 m above median
2007 real market value ($)	268 000	260 000*	276 000*
Mother did not graduate high school (%)	9.7	10.0	9.4
Mother non-Hispanic white (%)	71.1	73.3*	69.0*
Mother's age (years)	30.3	30.1*	30.6*
Married (%)	78.1	77.1	79.0
Total births	1.80	1.76*	1.83*
Gestational age (weeks)	39.0	39.0	39.1
Birth weight (g)	3425	3407	3443
Delivery cost paid by private insurance (%)	74.2	73.6	74.8
House age (years)	66.3	64.9*	67.7*
Distance to nearest private open space (m)	3008	2948*	3070*
Distance to nearest public transit stop (m)	679	682	676
Violent crimes within 200 m (2006 and 2007)	1.59	1.60	1.59

* Overall p-value <0.05 comparing characteristics by level of tree canopy within 50 m of mother's residence.

Table 2
Multiple logistic regression of small for gestational age births (Portland, Oregon, 2006 and 2007, $n=5295$).

Variable	Odds ratio	95% CI	*p*-value	Marginal effect per 1000 births
Total births	0.8466	0.7611–0.9418	0.0022	−10.3
Mother has no college education	1.4424	1.1267–1.8465	0.0037	25.3
Mother non-Hispanic white	0.6941	0.5580–0.8633	0.0010	−24.4
Percent canopy cover within 50 m	0.9902	0.9811–0.9993	0.0343	−1.42*
Distance to private open space (m)	1.0001	1.0000–1.0001	0.0178	−1.85**
McFadden *R*-squared	0.01853			

* For a 10% increase in canopy cover.
** For a 500 m reduction in distance (private open space consists of cemeteries, golf courses, private-school grounds, and community gardens).

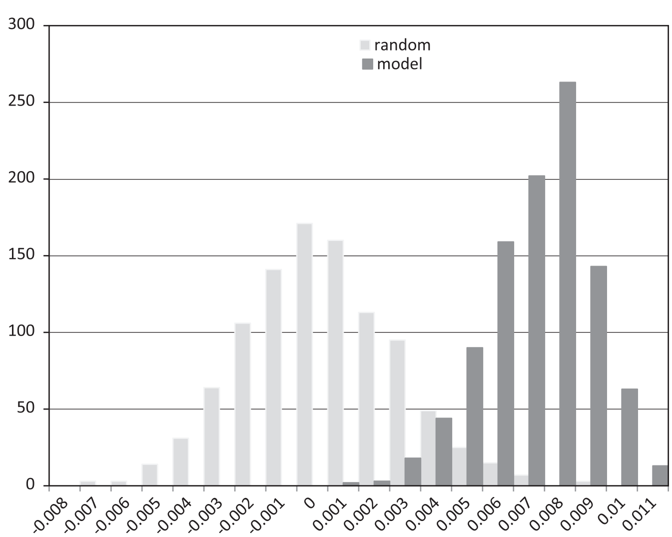

Fig. 2. Monte Carlo validation results. x-axis shows difference in mean probability of an SGA birth (predicted using 75% of sample) between observations where an SGA birth occurred and those that were normal weight.

5. Discussion

Greater tree-canopy cover within 50 m of a house, and proximity to a private open space, were associated with a reduced risk of SGA. Results do not provide direct insight into how urban trees may improve birth outcomes. However, stress reduction is a plausible biological mechanism linking trees to SGA, as previous research has shown that maternal stress can increase the probability of underweight birth (Miranda et al., 2009), and exposure to natural environments can reduce stress (Ulrich et al., 1991). In addition, green space may act as a buffer against the negative health impact of stressful life events (van den Berg et al., 2010). Improved social contacts are another possible psychosocial mechanism, as perceived levels of neighborhood social support are positively associated with infant birth weight (Buka et al., 2003) and the availability of large green spaces is associated with perceived social support (Maas et al., 2009a). Neighborhood greenness is also associated with greater levels of physical activity (Townshend and Lake, 2009), and greater levels of physical activity during pregnancy may protect against SGA births (Gollenberg et al., in press). However, exercise is unlikely to be the sole mechanism whereby trees affect birth outcomes, as increased tree-canopy cover within 50 m is a localized effect, and one would expect most exercise in a neighborhood to take place further than 50 m from a house.

Although no observational study can prove a causal relationship, consider the following strengths of the study. First, it builds on past experimental work demonstrating that trees can improve health outcomes (Ulrich, 1984). Second, if trees were merely proxies for positive neighborhood characteristics, one would expect that trees further than 50 m from a house would also be correlated with better birth outcomes, but they were not. Third, a wide range of individual and neighborhood characteristics, including many markers for socioeconomic status, were controlled for. Fourth, validation testing showed that results were not due to spurious correlation.

Our research also has limitations. Birth certificate data are subject to possible misclassification and residual confounding. For example, previous validation research has demonstrated that while birth weight reporting was very accurate, medical history data were less accurate (Buescher et al., 1993). Births to women living in multi-family homes were excluded, reducing the generalizability of results. In addition, both Portland's ethnic homogeneity and its high investment in green infrastructure are atypical, which may make our results less applicable in other cities. Finally, the magnitude of the effect of trees on birth outcomes was relatively modest.

In conclusion, urban trees may affect the health of a pregnant woman in ways that protect against SGA. Although the results are preliminary, they highlight the need for more research on the effect of the natural environment on reproductive health.

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