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Associations between multiple green space measures and birth weight across two US cities

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ABSTRACT

Introduction: Several measures of green space exposure have been used in epidemiological research, but their relevance to health, and representation of exposure pathways, remains unclear. Here we examine the relationships between multiple urban green space metrics and associations with term birth weight across two diverse US cities.

Methods: We used Vital Statistics data to create a birth cohort from 2005 to 2009 in the cities of Portland, Oregon (n = 90,265) and Austin, Texas (n = 88,807). These cities have similar green space levels but very different population and contextual characteristics. Green space metrics derived from mother's full residential address using multiple buffer distances (50–1000 m) included: Landsat Normalized Difference Vegetation Index (NDVI), % tree cover, % green space, % street tree buffering, and access to parks (using US EPA EnviroAtlas Data). Correlation between green space metrics were assessed and mixed models were used to determine associations with term birth weight, controlling for a comprehensive set of individual and neighborhood factors. City-specific models were run to determine how contextual and population differences affected green space associations with birth weight.

Results: We observed moderate to high degrees of correlation between different green space metrics (except park access), with similar patterns between cities. Unadjusted associations demonstrated consistent protective effects of NDVI, % green space, % tree cover, and % street tree buffering for most buffer sizes on birth weight; however, in fully adjusted models most metrics were no longer statistically significant and no clear patterns remained. For example, in Austin the difference in birth weight for the highest versus lowest quartile of % green space within 50 m was 38.3 g (95% CI: 30.4, 46.1) in unadjusted and −1.5 g (98% CI: −8.8, 6.3) in adjusted models compared to 55.7 g (95%CI: 47.9, −63.6) and 12.9 g (95% CI: 4.4, 21.4) in Portland. Maternal race, ethnicity and education had the largest impact on reducing green space and birth weight associations. However, consistent positive associations were observed for the high density areas of both cities using several green space metrics at small buffer distances.

Conclusions: This study highlights the importance of understanding the individual and contextual factors that may confound and/or modify green space and birth weight associations.

1. Introduction

A rapidly growing body of research suggests residential green space may be associated with a range of health outcomes, including positive birth outcomes such as small for gestational age (Ebisu et al., 2016), pre-term birth (Laurent et al., 2013) and term birth weight (Agay-Shay et al., 2014; Dadvand et al., 2012a, 2012b; Hystad et al., 2015). However, results have been inconsistent, with some recent large multi-city studies reporting no observed associations (Cusack et al., 2017) and others finding positive associations for both preterm birth and small for gestational age only in cities, and no associations with birth weight in cities or rural areas (Casey et al., 2016).

Green space may influence birth outcomes through a number of different pathways (e.g. air pollution, noise and heat reduction, physical activity, stress reduction, social cohesion, etc.). How green space is measured is therefore likely to impact what pathways are represented in epidemiological research. For example, the most common green space metric used in health studies is the satellite Normalized Difference Vegetation Index (NDVI) (e.g. Cusack et al., 2017; Hystad et al., 2015) but others are available, including measures of green land cover (Alcock et al., 2015; White et al., 2013), tree canopy cover (Donovan et al., 2013), park proximity (Hystad et al., 2015) and

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street tree vegetation buffering (Grazuleviciene et al., 2015; Reklaitiene et al., 2014; Wolch et al., 2014). NDVI and green land cover are composite measures of green vegetation that reflect all vegetation types, including lawns, fields, trees and parks for example. These measures may capture (partially) the variety of proposed pathways linking green space to health, such as access to parks for physical activity or reduction in air pollution and heat from trees or open green spaces. Tree cover may better reflect heat reduction, while street tree buffers along major roads may better capture air pollution and noise reductions (Tong et al., 2015) or represent visual exposures experienced during day-to-day activities and hence better reflect potential stress reducing and restorative effects of green space (Jiang, Chang, and Sullivan, 2014). Measures of park proximity may also better capture physical activity opportunities (Giles-Corti et al., 2005; Kaczynski et al., 2014).

The distance for which these measures are calculated (typically from 50 m to 1 km around a home location) will also influence the exposure pathway represented. A buffer of 100 m likely represents pathways that require viewing green space (e.g. through reducing psychological stress) or that have an immediate physical influence on buffering the impact or air pollution, noise and temperature, whereas larger buffer sizes may capture other proposed pathways, including the effects of green space on physical activity or social interactions. However, we cannot specifically characterize and define exact geographic areas of influence for green space and each proposed pathway and associated buffer distances are only starting points for understanding potential mechanisms. A buffer of 100 m likely represents pathways that require viewing green space (e.g. through reducing psychological stress) or that have an immediate physical influence on buffering the impact or air pollution, noise and temperature, whereas larger buffer sizes may capture other proposed pathways, including the effects of green space on physical activity or social interactions. However, we cannot specifically characterize and define exact geographic areas of influence for green space and each proposed pathway and these buffer distances are only starting points for understanding potential pathways." However, the lack of consistency in green space exposure assessment between epidemiological studies (Dadvand et al., 2012a, 2012b; Hystad et al., 2015; Nielsen et al., 2007) severely limits comparability and more research is needed to determine how different green space metrics relate to each other and to different pathways of influence.

In addition to different green space metrics and pathways, green space can vary substantially between, as well as within, cities. Cities are unique in terms of a multitude of factors (e.g. population socio-demographic characteristics, land use patterns, transportation, historical and cultural context, climate, etc.) and their spatial patterning that could impact how green space influences birth outcomes. Many of these factors are unmeasured in epidemiological studies and may confound observed associations. This is especially important for green space, which has been shown to be unequally distributed across racial, ethnic and SES groups within cities (Saporito and Casey, 2015; Hughey et al., 2017). The different correlation structures between different cities therefore offer opportunities to further explore if (and how) green space may influence health and what associations may be universal versus context specific.

Some research has specifically examined the interactions between green space, race, ethnicity and SES but findings are unclear. A recent review observed that minority populations do tend to have lower green space exposures (Saporito and Casey, 2015) and a study of ~3 million births across Texas observed strong dose-response relationships between NDVI and term birth weight in unadjusted analyses, which disappeared once adjusted for maternal education and ethnicity (Cusack et al., 2017). Alternatively, race and socio-economic position may be an effect modifier of green space due to different time-activity patterns (Mitchell et al., 2011) and opportunity structures for physical activity and stress reduction (Hughey et al., 2017). A number of studies have also found that green space is more beneficial to minority populations in terms of birth outcomes (Dadvand et al., 2012a) as well as overall health (Roe et al., 2016). Identifying and measuring green space associations in cities and neighborhoods with diverse socio-demographic and contextual characteristics is therefore important for improving our understanding of how green space may influence birth outcomes.

Here we examine the relationships between multiple urban green space measures and their associations with term birth weight across two US cities (Austin, Texas and Portland, Oregon). While both cities are ranked in the top 10 greenest U.S. cities (Svoboda, 2010) there are important differences in the distribution of green space. For example, 12% of Austin's population is located within walking distance to a park entrance (within 500 m) compared to 47% for Portland (Pickard et al., 2015). In addition, Portland has a more homogeneous population with approximately 74% being non-Hispanic Whites, compared to 54% non-Hispanic Whites in Austin. These two cities therefore have important similarities and differences for examining how different green space metrics may be associated with birth outcomes.

2. Methods

2.1. Birth cohorts

We used Vital Statistics data to create a birth cohort from 2005 to 2009 in Austin, Texas (n = 88,807) and Portland, Oregon (n = 90,265). Individual socio-demographic covariates were captured from the birth certificate data provided by Vital Statistics programs in Texas and Oregon, including: maternal and paternal age; education (coded as less than high school diploma, high school diploma, some college, college degree and post graduate degree); and race/ethnicity (Non-Hispanic White, Non-Hispanic Black, and Hispanic). Pregnancy data included parity (first birth or not); prenatal care received (yes/no); smoking during pregnancy (yes/no); gestational age (37–42); and month and year of birth. Full residential addresses were used to assign all green space exposure measures. Our study protocol was approved by Oregon State University IRB, the Texas Department of State Health Services, and Oregon Health Authority.

2.2. Residential green space measures

Maternal green space exposure estimates are based on the full residential addresses of mothers at the time of delivery. Multiple measures were derived for each address at varying buffer distances (i.e. 50 m, 250 m, 500 m, 1000 m), including satellite derived NDVI (Landsat 5, 30 m resolution), % green space, % tree cover, % street tree buffers, and park proximity (derived from EPA EnviroAtlas). Each of these measures is described in more detail below.

2.3. Satellite greenness index

Landsat 5 satellite imagery at a 30 m resolution was used to measure annual NDVI. NDVI is an indicator of overall greenness based on land surface reflectance of visible and near infrared parts of spectrum (Weier and Herring, 2011). Values range from −1 to1 with the higher numbers indicating more greenness. This measure does not discern types of vegetation but represents all green living vegetation. Estimates of annual NDVI at maternal residences were derived from Landsat 5 orthorectified satellite imagery. Annual averages consist of the mean NDVI from all images within the year after screening each image for water, snow, shadows, and cloud cover with the cloud mask band derived from the Fmask algorithm (Zhu and Woodcock, 2012).

2.4. Percent green space

Percent green space was based on the land cover data derived from