Residential green space and birth outcomes in a coastal setting

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ABSTRACT

Background: Residential green space may improve birth outcomes, with prior studies reporting higher birth-weight among infants of women living in greener areas. However, results from studies evaluating associations between green space and preterm birth have been mixed. Further, the potential influence of residential proximity to water, or 'blue space', on health has not previously been evaluated.

Objectives: To evaluate associations between green and blue space and birth outcomes in a coastal area of the northeastern United States.

Methods: Using residential surrounding greenness (measured by Normalized Difference Vegetation Index [NDVI]) and proximity to recreational facilities, coastline, and freshwater as measures of green and blue space, we examined associations with preterm birth (PTB), term birthweight, and term small for gestational age (SGA) among 61,640 births in Rhode Island. We evaluated incremental adjustment for socioeconomic and environmental metrics.

Results: In models adjusted for individual – and neighborhood-level markers of socioeconomic status (SES), an interquartile range (IQR) increase in NDVI was associated with a 12% higher (95% CI: 4, 20%) odds of PTB and, conversely, living within 500 m of a recreational facility was associated with a 7% lower (95% CI: 1, 13%) odds of PTB. These associations were eliminated after further adjustment for town of residence. NDVI was associated with higher birthweight (7.4 g, 95% CI: 0.4–14.4 g) and lower odds of SGA (OR = 0.92, 95% CI: 0.87–0.98) when adjusted for individual-level markers of SES, but not when further adjusted for neighborhood SES or town. Living within 500 m of a freshwater body was associated with a higher birthweight of 10.1 g (95% CI: 2.0, 18.2) in fully adjusted models.

Conclusions: Findings from this study do not support the hypothesis that residential green space is associated with reduced risk of preterm birth or higher birthweight after adjustment for individual and contextual socioeconomic factors, but variation in results with incremental adjustment raises questions about the optimal degree of control for confounding by markers of SES. We found that living near a freshwater body was associated with higher birthweight. This result is novel and bears further investigation in other settings and populations.

1. Introduction

More than 80% of the U.S and 50% of the global population now lives in urban areas (U.S. Census Bureau, 2015; World Health Organization, 2016), where daily access to green environments with vegetation and open spaces is often limited. Residential neighborhood green space has been positively associated with overall self-perceived health (Maas et al., 2006) and with better mental (Alcock et al., 2014; Bowler et al., 2010; Gascon et al., 2015) and physical health and wellbeing (James et al., 2015; Lee and Maheswaran, 2011; Villeneuve

et al., 2012; Wilker et al., 2014). The putative health benefits of living in areas with more green space may be mediated by increased physical activity, reduced stress and improved psychosocial wellbeing, reduced noise and air pollution, and/or decreased ambient air temperature during periods of hot weather (Bowler et al., 2010; Dadvand et al., 2012a, 2014; Kihal-Talantikite et al., 2013; Laurent et al., 2013; Lee and Maheswaran, 2011).

Some studies suggest that residential green space may also be associated with better health during pregnancy and lower risk of adverse birth outcomes. Specifically, higher levels of green space surrounding the maternal residence, frequently evaluated by the Normalized Difference Vegetation Index (NDVI, a satellite-based measure of the distribution of live green vegetation), have been consistently associated with indicators of improved fetal growth (Agay-Shay et al., 2014; Dadvand et al., 2012a, 2012b, 2014; Donovan et al., 2011; Dzhambov et al., 2014; Ebisu et al., 2016; Hystad et al., 2014; Laurent et al., 2013; Markevych et al., 2014), although associations with gestational length remain unclear (Agay-Shay et al., 2014; Casey et al., 2016; Cusack et al., 2017; Dadvand et al., 2012a, 2012b; Grazuleviciene et al., 2015; Hystad et al., 2014; Laurent et al., 2013). More limited work has assessed the influence of residential proximity to parks and other recreational natural environments on birth outcomes, with mixed findings for both mean birthweight and risk of preterm birth (Agay-Shay et al., 2014; Dadvand et al., 2012a; Grazuleviciene et al., 2015).

The varying influence of indicators of socioeconomic status (SES) on these associations may help to explain disparate results across studies. Socioeconomic characteristics at the individual and aggregate level are typically associated with features of the residential environment (Kihal-Talantikite et al., 2013) and highly predictive of birth outcomes (Andersen and Mortensen, 2006; Racape et al., 2016; Weck et al., 2008). SES therefore likely has a considerable confounding influence on associations between residential green space, length of gestation, and fetal growth. However, it is important to balance the need to remove sources of confounding bias against the potential for overadjustment for highly correlated socioeconomic and environmental variables or variables on the pathway in question, for example if greener neighborhoods generate higher property values and drive measures of neighborhood SES (NSES) such as median household income higher (Chee et al., 2015; Cole et al., 2017). The optimal degree of adjustment to fully control confounding by individual- and neighborhood-level socioeconomic factors without attenuating estimation of the causal effect of interest has not been systematically parsed in the literature.

Further, associations between green space and birth outcomes may differ across subgroups defined by demographic characteristics such as education, race, and neighborhood-level SES. For example, socioeconomically advantaged individuals often have greater mobility and capacity to access green spaces away from their homes, while those of lower SES may be more dependent on the built environment proximal to their residence (Maas, 2008; Maas et al., 2009; Schwanen et al., 2002). Additionally, people of low SES may be simultaneously more likely to live in neighborhoods with worse environmental problems and have poorer health status than those of higher SES (Galea and Vlahov, 2005). It is therefore plausible – as suggested by prior research examining heterogeneity of associations by education, occupation, ethnicity, and neighborhood-level SES – that individuals of lower SES may derive more advantage from immediate surrounding green space (Agay-Shay et al., 2014; Dadvand et al., 2012a, 2012b, 2014; Dzhambov et al., 2014; Maas et al., 2009). Additional characteristics that may modify associations between green space and birth outcomes, such as degree of urbanicity of the maternal residence and season of birth, have not been adequately explored in the literature (Casey et al., 2016; Ebisu et al., 2016).

Varying results across study settings suggest that associations between the residential environment and birth outcomes may be highly specific to the particular geographic context, and additional studies of green space and birth outcomes in diverse populations and locations that facilitate inclusion of a range of environmental metrics are needed to improve our understanding of the potential influence of green areas on human health. Additionally, we are not aware of existing studies evaluating the potential influence of proximity to fresh or saltwater bodies, or 'blue space', on pregnancy outcomes. It has been suggested that blue space has restorative potential for emotional and physical well-being (Völker and Kistemann, 2011, 2013; White et al., 2010), and there is some empirical evidence linking residential exposure to visible blue space to lower psychological distress (Nutsford et al., 2016), but this has not been examined in detail.

Accordingly, among 61,640 births delivered at a single hospital in Rhode Island, a region with a small coastal city with suburban and semi-rural surroundings, we evaluated the hypotheses that higher levels of residential green and blue space are associated with increased fetal growth as measured by higher birthweight and decreased risk of small for gestational age (SGA), and lower risk of preterm birth. The study location allowed us to assess green space as well as proximity to bodies of coastal and inland water, expanding what is currently known about the residential environment and pregnancy outcomes by considering multiple measures of green and blue space in a coastal geography.

2. Methods

2.1. Study population

Women & Infants Hospital of Rhode Island, located in the capital city of Providence, Rhode Island, is the tenth largest stand-alone obstetrical service in the U.S. with roughly 9000 deliveries per year. Approximately 75% of births to mothers residing in Rhode Island occur at Women & Infants Hospital, making this study nearly population-based. Hospital discharge records from live births at Women & Infants Hospital from 2001 to 2012 were obtained from the National Perinatal Information Center (NPIC) and merged with electronic birth certificate data from the Rhode Island Department of Health (RIDOH). Electronic data were available on residential address at the time of delivery, maternal demographic indicators, infant characteristics, maternal medical history, and International Classification of Diseases, Ninth Revision (ICD-9) diagnosis and procedure codes for the mother and newborn during and after delivery. A total of 95,948 discharge records from Women & Infants Hospital were available, and of these 79,154 (82.5%) were successfully merged with state birth certificate data. Geocoded U.S. Census data from 2010 were linked to 76,590 (96.8%) of these merged records. Closer examination revealed that few discharge records were matched to birth certificate data in 2001 (prior to implementation of a modern birth records system) or between July 2004 and December 2005 (as RIDOH transitioned to a newer birth records system). Thus, we restricted our analyses to 74,165 deliveries occurring during time periods with high match rates (> 88.6%, January 2002-June 2004 and January 2006-December 2012) and successfully matched to birth certificate data. We did not formally explore differences between matched and unmatched births because of the very limited data on those that did not match.

The study sample was further restricted to exclude women < 18 years of age at delivery or missing data on maternal age, those with multiple births (i.e. twins, triplets) or missing data on plurality, women with residential address outside of Rhode Island or missing address data, invalid gestational ages (< 22 or > 44 weeks), and birthweights below 500 or above 5000 g (g) or missing birthweight, resulting in a final sample size of 61,640 mother-infant pairs.

The study protocol was approved by the Institutional Review Boards of Brown University, Women & Infants Hospital of Rhode Island, and the Rhode Island Department of Health.

2.2. Exposure assessment

Residential home address at the time of delivery was obtained from