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Association between greenness, urbanicity, and birth weight

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HIGHLIGHTS

- We explored green and urban land-use effects on birth weight in Connecticut, U.S.
- Green and urban spaces are associated with birth weight.
- Associations are generally robust after controlling for air pollution and traffic exposures.
- Our findings encourage policy makers to consider built environment factors.

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ABSTRACT

Background: More than half of the world's population lives in urban environments. Due to urban related factors (e.g. higher air pollution), urban residents may face higher risk of adverse health outcomes, while access to green space could benefit health.
Purpose: We explored associations between urban and green land-use and birth weight.
Methods: Connecticut, U.S., birth certificate data (2000–2006) were acquired ($n = 239{,}811$), and land-use data were obtained from the National Land Cover Database. We focused on three land-uses; urban space, urban open space, and green space (i.e. forest, shrub, herbaceous, and cultivated land). We estimated fractions of greenness and urbanicity within 250 m from residence. A linear mixed effects model was conducted for birth weight and a logistic mixed effects model for low birth weight (LBW) and small for gestational age (SGA).
Results: An interquartile range (IQR) increment in the fraction of green space within 250 m of residence was associated with 3.2 g (95% Confidence Interval [0.4, 6.0]) higher birth weight. Similarly, an IQR increase in green space was associated with 7.6% [2.6, 12.4] decreased risk of LBW. Exposure to urban space was negatively correlated with green space (Pearson correlation $= -0.88$), and it showed negative association with birth outcomes. Results were generally robust with different buffer sizes and controlling for fine particles ($PM_{2.5}$) and traffic.
Conclusions: We found protective associations by green space on birth outcomes. Increasing green space and/or reducing urban space (e.g. the greening of city environments) may reduce the risk of adverse birth outcomes such as LBW and SGA. Populations living in urban environments will grow in the next half century, and allocation of green space among urban areas may play a critical role for public health in urban planning.

1. Introduction

Urbanization has accelerated in recent decades and is expected to accelerate further in the next few decades. Conversely, green spaces are decreasing in many areas. Currently, more than half of people live in urban environments, as defined as areas of intensive use of the land covered by structures (Anderson et al., 1975), and about 70% of people will live in developed areas by 2050 (United Nations, 2011). While urban environments may provide several health advantages (e.g. better access to health care) (Chan et al., 2006), urban residents can face higher risk of adverse health outcomes. For instance, a U.S. study found that urban land-use was associated with the severity of wheeze symptoms in infants (Ebisu et al., 2011). Urban environments are also associated with shorter sleeping duration for infants (Bottino et al., 2012). These studies used the degree of urbanicity around residence to represent integrated environmental exposures that are prevalent in urban environments such as noise, traffic emission, and other factors. In general, urbanicity and greenness show negative correlations, and

Abbreviations: SES, socio-economic status; NO_2, nitrogen dioxide; $PM_{2.5}$, particulate matter with aerodynamic diameter ≤ 2.5 μm; LBW, low birth weight; SGA, small for gestational age; IQR, interquartile range.

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several researchers focused on greenness rather than urbanicity. A British study reported that moving to greener areas was associated with improved mental health (Alcock et al., 2014). Hospitalization risk for cardiovascular disease was lower for those living in a green area in Australia (Pereira et al., 2012). These findings could implicate that access to green space leads to lower exposures to contaminants (e.g., air pollution), increase physical activity, reduce psychological stress, and/or reflect differences in other factors compared to more urban space, resulting in health benefits (Alcock et al., 2014; Hystad et al., 2014; Pereira et al., 2012).

Research on land-use and birth outcomes is still limited. Beneficial associations between green space and fetal growth were observed in European studies (Dadvand et al., 2012a; Markevych et al., 2014). These associations are the strongest among mothers with low socioeconomic status (SES). Similarly, a protective association between green space and birth weight was found in Southern California (Laurent et al., 2013). Although several studies have examined associations between green space and birth outcomes, none have examined this issue in the eastern U.S., a relatively populated area. Furthermore, no studies investigated association between urbanicity and birth outcomes. While greenness and urbanicity are related, they are not perfectly correlated, and both urban and green space warrant attention as they may affect birth outcomes through different pathways. In an era of urbanization, studies relating health and built environment are emerging (Hystad et al., 2014; Miranda et al., 2012), and further studies are warranted.

Air pollution is one factor of an urban environment that may affect health, and many studies link birth outcomes to air pollution, such as nitrogen dioxide (NO_2) or particulate matter (PM) (Ebisu and Bell, 2012). Although ambient pollutants likely affect birth outcomes (Sapkota et al., 2012), many other factors also impact birth outcomes. For instance, low SES is associated with adverse birth outcomes (Blumenshine et al., 2010), which may relate to nutrition, baseline health status, or other factors. Lobel et al. found that pregnancy-specific stress is associated with low birth weight (LBW) (Lobel et al., 2008). Furthermore, noise levels were associated with birth weight after adjustment for air pollution (Gehring et al., 2014). Many of these potential risk factors are related; low SES populations tend to live in urban areas, leading to higher air pollutant exposure than other populations (Bell et al., 2011; Ebisu et al., 2014). Ideally research would include complete information on all potential risk factors, but such studies are difficult due to cost and intense data sampling. Land-use around residence has been used to represent integrated environmental exposures (Bottino et al., 2012; Cyril et al., 2013; Ebisu et al., 2011), reflecting a suite of exposures including noise, air pollution, and other factors.

We explored associations between green/urban land-uses and birth weight in Connecticut, U.S. LBW increases risk of perinatal morbidity and mortality, and affects health later in life (Stillerman et al., 2008). The U.S. Department of Health and Human Services aims to decrease LBW rate from 8.2% in 2007 to 7.8% in 2020 (U.S. Department of Health and Human Services. Office of Disease Prevention and Health Promotion, 2010). To achieve this goal, it is critical to unveil what factors lower birth weight. As over 80% of U.S. residents live in an urban environment (United Nations, 2011), understanding green and urban space effects on human health is crucial.

2. Methods

2.1. Birth data

Birth certificate data for 2000/1/1 to 2006/12/31 were provided by the Connecticut Department of Public Health. Analysis was restricted to singleton births with gestational age from 37 to 44 weeks and births whose residential addresses at delivery were successfully geocoded (geocoding score ≥ 95). We excluded births with congenital defects or impossible gestational age and birth weight combinations (Alexander et al., 1996). Neighborhood SES variables at census tract level, the smallest available geographic unit, were obtained from the American Community Survey 2009 for the fractions of: educational attainment less than high school among those ≥25 years, unemployment among those ≥16 years, and households with income below the poverty line as defined by family income and size, and price index. Further description of the data is available elsewhere (Ebisu et al., 2014).

We considered birth weight as a continuous variable, LBW (birth weight < 2500 g), and small for gestational age (SGA; birth weight < 10th percentile for gestational age and sex based on 1999 and 2000 U.S. births) (Oken et al., 2003). IRB approvals were obtained from the Yale University Human Investigation Committee and Connecticut Department of Public Health.

2.2. Land-use data

Land-use data were acquired through the National Land Cover Database (NLCD) 2001, which is the timeframe of available data closest to the midpoint of our study period (Homer et al., 2007). Data were 30 × 30 m resolution pixels, and each pixel was assigned a unique land-use type based on Landsat satellite images (Homer et al., 2007). The original data had 16 land-use categories. Many of these land-uses are rare in our study area (e.g. barren land), and we focused on greenness and urban-related variables. There are four types of greenness-related land-uses in NLCD: forest (i.e. deciduous, evergreen, and mixed forest), shrub, herbaceous, and cultivated land. For forest land-use, each pixel is dominated by trees higher than 5 m and at least 20% of the pixel is dominated by vegetation cover. For shrub land-use, each pixel is dominated by shrubs less than 5 m and at least 20% of the pixel is dominated by vegetation cover. Herbaceous land-use is defined as the pixel dominated by herbaceous more than 80% of total vegetation. Cultivated land is the pixel used for the production of crops, which account for more than 20% of total vegetation. These land-uses were treated as green space.

Urbanicity has been defined in several ways; population size, population density, access to health service, etc. (Cyril et al., 2013). We defined urbanicity as land 'comprised of areas of intensive use with much of the land covered by structures', as was proposed by Anderson et al. (Anderson et al., 1975). We applied two urban-related categories. "Urban open space" was defined as a pixel mostly dominated by lawn grasses with a mixture of constructed materials (e.g. parking lot), and impervious surfaces accounting for <20% of each pixel. We contrast urban open space with "urban space" in which impervious surfaces account for ≥20% of each pixel. This includes areas where people reside or work (e.g. single-family housing units or commercial buildings).

For each birth, we defined land-use exposure as the proportion of each land-use (urban, urban open, or green) within 250 m from residence at time of birth. The 250 m buffer size (i.e. circle with 250 m radius) was determined by literature review, (Dadvand et al., 2012b; Markevych et al., 2014) with other distances explored as sensitivity analysis. Supplementary Fig. 1 shows a land-use map and example of residential locations with 250 m buffer.

2.3. Statistical analysis

Linear mixed effects models were conducted for birth weight and logistic mixed effects models for LBW and SGA. Census block group was used for random intercepts. We explored the effect of urban space, urban open space, and green space in separate models; the fraction of each land-use in the buffer around the residence was included in each model. Other included variables were: sex; gestational week; maternal age, race/ethnicity, education attainment, and marital status; trimester care started; alcohol consumption and smoking status during pregnancy; birth order (first or later); birth season; birth year; neighborhood SES variables; and average apparent temperature of each trimester,