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Green space and pregnancy outcomes: Evidence from Growing Up in New Zealand

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ABSTRACT

Objectives: To determine whether maternal exposure to green space during pregnancy is associated with birth weight and gestational age, and whether these associations are modified by demographic and residential factors.
Methods: Data describing 5091 mother-newborn pairs with residential address during pregnancy linked to data describing their green space exposure. Independent associations determined using linear mixed effects models.
Results: Maternal exposure to green space during pregnancy was not associated with birth weight and gestational age for the entire cohort. For pregnant women who have not acquired secondary school education, increased exposure to green space was associated with increased gestational age.
Conclusion: The provision of green space might prove to be beneficial in terms of increasing gestational age for pregnant women who have not acquired secondary school education qualifications.

1. Introduction

Low birth weight, defined by the World Health Organization (WHO) as a "birth weight of less than 2500 g", and preterm delivery, defined by the WHO as a "live birth born before 37 weeks completed gestation," are important determinants of infant mortality and morbidity in developing and developed nations (WHO and UNICEF, 2004). Both are associated with each other and an increased risk of poorer health in later life (Day et al., 2016; Hussain et al., 2015; Loret de Mola et al., 2014; Morse et al., 2009; WHO, 2015). In developed countries, the proportion of low birth weight and preterm births has increased in recent decades. For example, in Japan from 1980 to 2010, the proportion of low birth weight newborns increased from 5.2% to 9.6% and of preterm newborns from 4.1% to 5.7% (Yorifuji et al., 2012).

Recently, it has been recognized that increased exposure to green space, referred to as "land that is partly or completely covered with grass, trees, shrubs, or other vegetation" (USEPA, 2014), is associated with better pregnancy outcomes, including increased birth weight (Agay-Shay et al., 2014; Dadvand et al., 2012a, b, 2014; Ebisu et al., 2016; Hystad et al., 2014; i et al., 2013; Tiesler et al., 2014), a lower likelihood of low birth weight (Agay-Shay et al., 2014; Ebisu et al., 2016), and a lower likelihood of preterm birth (Casey et al., 2016; Hystad et al., 2014; Laurent et al., 2013). Mediators of associations between exposure to green space and pregnancy outcomes have been investigated. Physical activity during pregnancy being shown to lead to reductions in maternal stress and depression (Costa et al., 2003), and the associations between green space and pregnancy outcomes appear to be mediated in part through increased physical activity and in part through these effects on maternal stress and depression (Dadvand et al., 2012a, b). Living in areas with more green space can also improve social contact, emotional state, and cognition (Hartig et al., 2014), reduce exposure to air (Nowak et al., 2006), and noise pollution (Dzhambov and Dimitrova, 2014), and create a cooler living environment in hot climates (Dadvand et al., 2012a, b), therefore, creating additional mechanisms by which increases in birth weight and gestational age can be attained (Dadvand et al., 2012a, b).

Most studies suggest that, as well as being apparent across the population as a whole, the association between green space and general health appear to be more pronounced for people with lower levels of

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education (Maas et al., 2006) and those residing in rural locations (Maas et al., 2006). In addition, data from general population studies indicate a moderating effect of age on the association between green space and mental health (Barton and Pretty, 2010; Bos et al., 2016). In studies that have investigated the association between green space and birth weight, the association appears to be more pronounced for non-educated women (Dadvand et al., 2012a, b), less educated women (Dadvand et al., 2012a, b, 2014; Tiesler et al., 2014), or women living in more deprived areas (Agay-Shay et al., 2014), or those describing their ethnicity as 'White British' (Dadvand et al., 2014).

One major limitation that appears in many studies that have investigated the relationship between green space and pregnancy outcomes is the lack of adequate control for the socioeconomic status of cohort participants (Casey et al., 2016; Dadvand et al., 2012a, 2012b; Hystad et al., 2014; i et al., 2013; Tiesler et al., 2014). The aim of this current study, based in New Zealand, was to investigate whether exposure of pregnant women to green space is associated with an increase in birth weight and gestational age in their infants after accounting for confounders, including socioeconomic status. The design features of this cohort study also allowed us to determine if the relationship of exposure to green space with birth weight and gestational age varies according to the mother's demographics (e.g., age, education, and self-identified ethnicity) as well as by residential factors (e.g., area deprivation and residential rurality). Utilizing this cohort which enrolled a sample of women of a wide range of demographic and residential exposures and included measures of green space exposure in terms of green space areas within census area units, we investigated the potential effect modifications of these demographic and residential factors on the relationship between green space exposure and birth weight and gestational age.

2. Methods

2.1. Study design and study population

Data for this study were obtained from mothers recruited into the *Growing Up in New Zealand* study, a longitudinal child cohort study focusing on the multiple influences that shape children's development from before birth (Morton et al., 2013). *Growing Up in New Zealand* collects information on six inter-connected areas: family and *whānau* (a Māori term for extended family); societal context and neighborhood; education; health and well-being; psychological and cognitive development; and culture and identity. Mothers of the *Growing Up in New Zealand* cohort children were women with an expected delivery date between April 2009 and March 2010. The study region, a geographical area defined by the three adjacent District Health Board (DHB) regions of Auckland, Counties-Manukau and Waikato, was chosen because of its socioeconomic, ethnic and urban/rural diversity (Morton et al., 2013). The cohort of 6853 children were born to the 6822 women enrolled during pregnancy, approximately 11% of the births in New Zealand over the study recruitment period (Morton et al., 2013). The generalizability of the enrolled cohort to the national birth cohort from 2007 to 2010 has been demonstrated (Morton et al., 2015).

2.2. Categorization of green spaces

All green areas were categorized as green spaces and included parks, beaches, urban parklands/open spaces, forests, grasslands, croplands, and other green areas (e.g., domains and reserves). Other land-use types (described here as "non-green spaces") were excluded from the analyses. Examples of non-green spaces include built-up or settlement areas, land used for transport infrastructure, and water bodies. The percentage of green space in each urban or rural census area unit (CAU) was used as a surrogate for exposure to green space. All geocoded maternal residential addresses during pregnancy were assigned to their respective CAU. In New Zealand, each CAU is made up of mesh blocks which are the smallest census geographical units. Census area units are the second smallest geographical units (next to mesh blocks) and are defined as "non-administrative areas that are in between mesh blocks and territorial authorities in size." In terms of population size, each urban CAU has a population of 3000–5000 (Stat, 2006). We obtained data on green spaces in Auckland and Counties-Manukau DHB regions from the Auckland Council [AC] in form of a map (AC, 2016). Data on green spaces in the Waikato DHB region were obtained from the Waikato District Council in form of a map. Additionally, we extracted data on green spaces for our study region from the New Zealand Land Cover Database (LCDB) of the Land Resource Information Systems portal in form of a map (LCDB, 2013). That is, LCDB was used as a green space data source for all study participants. The advantage of combining the two different data sources is that the combined dataset provided more attributes than those obtained from a single data source. For example, data for beaches, domains, and reserves were available from the councils and not from the LCDB. Similarly, data for forests, grasslands, and croplands were available from the LCDB and not from the councils. The Waikato District Council's green space data had a scale of 1:50,000 and an accuracy of 90.0%. The LCDB data also had a scale of 1:50,000 and accuracy of 93.9% with a minimum mapping unit of one hectare (LCDB, 2013).

We utilized the 'union' and 'dissolve' tools in ArcGIS to determine the proportion of green space in each CAU (ESRI, 2006). Green space was expressed as a continuous variable ranging from 0.00% to 100.00%. ArcGIS Version 10.3 (ESRI, Redlands, California, USA) was used to determine the percentage of green space in all CAUs.

2.3. Data collection and sample size

For this study, data were collected at the computer assisted face-to-face interview completed by women during late pregnancy, at a telephone interview completed when their infant was approximately six weeks post their expected date of delivery and from linkage to the maternity hospital records to obtain recorded birth weight and gestational age at delivery (Morton et al., 2013). At the antenatal interview, data were collected from mothers that described personal and area-level characteristics, health history and health-related behaviors (Morton et al., 2013). The sample for analyses was created by restricting to those women who had a singleton pregnancy and for whom each maternal address could be geocoded to CAUs within the study region. Additionally, all cases of planned and emergency cesarean sections were excluded from the analyses. Consequently, the final sample size of 5091 mother-newborn pairs was utilized to determine the associations between green space and pregnancy outcomes.

2.4. Description of variables including confounders (Table 1)

2.4.1. Dependent variables

Birth weight, measured in grams, and gestational age, measured in weeks, were utilized as the dependent variables.

2.4.2. Independent or confounding variables (Table 1)

Maternal confounders included maternal demographics (age, self-identified ethnicity, education, and employment status), pregnancy-related behaviors (smoking cigarettes and alcohol consumption), the presence of pre-existing chronic disease (depression, heart disease or high blood pressure, and diabetes mellitus), parity, the relationship status with the biological father of the newborn infant (no relationship; dating, not cohabiting; cohabiting; and married or civil union), birth place (New Zealand, Australia, Other Oceania, Asia, Europe, Africa, and The Americas/Middle East/Other), time lived in current neighborhood (years) utilized as a surrogate for selective migration, residential rurality (urban or rural residence), access to health care during pregnancy, and socioeconomic status. Child confounders included