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# Inequality, green spaces, and pregnant women: Roles of ethnicity and individual and neighbourhood socioeconomic status

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ABSTRACT

Evidence of the impact of green spaces on pregnancy outcomes is limited with no report on how this impact might vary by ethnicity. We investigated the association between residential surrounding greenness and proximity to green spaces and birth weight and explored the modification of this association by ethnicity and indicators of individual (maternal education) and neighbourhood (Index of Multiple Deprivation) socioeconomic status. Our study was based on 10,780 singleton live-births from the Born in Bradford cohort, UK (2007–2010). We defined residential surrounding greenness as average of satellite-based Normalized Difference Vegetation Index (NDVI) in buffers of 50 m, 100 m, 250 m, 500 m and 1000 m around each maternal home address. Residential proximity to green spaces was defined as living within 300 m of a green space with an area of $\geq$5000 $m^2$. We utilized mixed effects models to estimate adjusted change in birth weight associated with residential surrounding greenness as well as proximity to green spaces. We found a positive association between birth weight and residential surrounding greenness. Furthermore, we observed an interaction between ethnicity and residential surrounding greenness in that for White British participants there was a positive association between birth weight and residential surrounding greenness whereas for participants of Pakistani origin there was no such an association. For surrounding greenness in larger buffers (500 m and 1000 m) there were some indications of stronger associations for participants with lower education and those living in more deprived neighbourhoods which were not replicated for surrounding greenness in smaller buffer sizes (i.e. 50 m, 100 m, and 250 m). The findings for residential proximity to a green space were not conclusive. Our study showed that residential surrounding greenness is associated with better foetal growth and this association could vary between different ethnic and socioeconomic groups.



## 1. Introduction

Contact with green spaces has been shown to improve both perceived and objective physical and mental health and well-being (Bowler et al., 2010; Lee and Maheswaran, 2011). More recently, a limited number of studies have reported beneficial impacts of green spaces on pregnancy outcomes (Dadvand et al., 2012a, 2012c; Donovan et al., 2011; Laurent et al., 2013; Markevych et al., 2014). These studies reported some benefits of maternal residential surrounding greenness for foetal growth, reflected by higher birth weight and head circumference and lower risk of low birth weight and small for gestational age (Dadvand et al., 2012a, 2012c; Donovan et al., 2011; Laurent et al., 2013; Markevych et al., 2014).

Socioeconomic inequality in health has been shown to have a multilevel structure in that individual and neighbourhood socioeconomic status (SES) could have independent associations with the susceptibility of individuals to disease (Pickett and Pearl, 2001; Ross and Mirowsky, 2008). A growing body of evidence has reported that individual SES can modify the health benefits of green spaces (De Vries et al., 2003;

*Abbreviations:* BiB, Born in Bradford; EOSDIS, Earth Observing System Data and Information System; IMD, Index of Multiple Deprivation; NDVI, Normalized Difference Vegetation Index; LSOA, lower level super output area; PHENOTYPE, Positive Health Effects of the Natural Outdoor Environment in Typical Populations of Different Regions in Europe; $PM_{2.5}$, particulate matter with aerodynamic diameter $\leq$ 2.5 μm; SES, socioeconomic status; TM, thematic mapper.

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Maas et al., 2009). In our previous studies of the impact of green spaces on pregnancy outcomes (Dadvand et al., 2012a, 2012c), we observed a larger benefit of green spaces for pregnant women with lower education qualifications (Dadvand et al., 2012a, 2012c). In this context, neighbourhood SES could also have a potential modifying effect on the association between green spaces and health.

The available studies on the potential modifying effect of ethnicity on health benefits of green spaces are scarce but suggestive of such an effect (Agyemang et al., 2007; Lee and Maheswaran, 2011). To our knowledge, there is no reported study on the modification of the association between green spaces and pregnancy outcomes by ethnicity.

This study aimed to investigate the association between contact with green spaces (in terms of residential surrounding greenness and proximity to green spaces) and foetal growth (in terms of birth weight) and to explore how this association might be modified by ethnicity and indicators of individual and neighbourhood SES.

## 2. Materials and methods

### 2.1. Study population

This analysis was carried out as part of the Born in Bradford (BiB) study which has been described in detail elsewhere (Wright et al., 2013). Briefly, BiB is a longitudinal multiethnic community birth cohort study aiming to examine the impact of environmental, psychological and genetic factors on maternal and child health and wellbeing (Wright et al., 2013). Participants were pregnant women at 26–28 week gestation who registered at the Bradford Royal Infirmary. For those consenting, the baseline questionnaire detailing information on socio-economic characteristics, ethnicity and family trees, lifestyle factors, environmental risk factors and physical and mental health was collected via an interview conducted in English, Mirpuri (a spoken variant of Punjabi) or Urdu.

The full BiB cohort recruited 12,453 women with 13,776 pregnancies who were receiving care from the city's maternity unit between 2007 and 2010, representing 54% of total Births during this time period (Wright et al., 2013). Compared with women who were not recruited, those in the BiB cohort had a lower proportion of younger ages (age: 20–24 years) and a higher proportion of South Asian origin and nulliparous women (Wright et al., 2013). Furthermore, those women recruited in the cohort tended to reside in slightly less deprived neighbourhoods (i.e. lower Index of Multiple Deprivation (IMD) scores described in Section 2.4.1) compared with those not recruited. This analysis included live-born singleton births with mothers who had completed the baseline questionnaire and had data available on birth outcomes (i.e. birth weight and gestational age at delivery), maternal ethnicity, and education.

Ethical approval for the data collection was granted by Bradford Research Ethics Committee (Ref 07/H1302/112).

### 2.2. Outcome measurement

Birth weight was recorded immediately after birth by the participant's midwife and was subsequently abstracted from medical records.

### 2.3. Exposure measurement

The exposure assessment of this study was carried out in the context of Positive Health Effects of the Natural Outdoor Environment in Typical Populations of Different Regions in Europe (PHENOTYPE) (Nieuwenhuijsen et al., 2014). The PHENOTYPE project aims at investigating the interconnections between exposure to natural outdoor environments and better human health and well-being across different parts of Europe. In this context, the PHENOTYPE project explores potential underlying mechanisms at work and examines the health impacts for different population groups (e.g. pregnant women and/or foetus, different age groups, socioeconomic status, ethnic minorities and patients).

We used residential surrounding greenness as a surrogate for general outdoor greenness of the living environment of study participants. To measure surrounding greenness, we applied the Normalized Difference Vegetation Index (NDVI) (Weier and Herring, 2011) derived from the Landsat 4–5 Thematic Mapper (TM) images at 30 m × 30 m resolution (US Geology Survey, 2011). NDVI is an indicator of greenness based on land surface reflectance of visible (red) and near-infrared parts of spectrum (Weier and Herring, 2011). It ranges between −1 and 1 with higher numbers indicating more greenness. To achieve maximum exposure contrast, we looked for available cloud-free Landsat TM images during the period between May and August (i.e. the maximum vegetation period of the year for our study region) of 2006–2011 (the relevant years to our study period) from the NASA's Earth Observing System Data and Information System (EOSDIS) website. Based on this search we generated our NDVI map using the image obtained on 10th June 2006 (Supplementary Fig. S1).

Each maternal address of residence was coordinated on the National Grid, with eastings and northings quoted to a resolution of 0.1 m. This was done for addresses where we found an exact match either 'automatic' or 'manually' with only a tiny percentage (0.01%) of the addresses for which we could not found a match. For each woman, surrounding greenness was abstracted as the average of NDVI in buffers of 50 m, 100 m, 250 m, 500 m, and 1000 m around her geocoded address of residence at the time of recruitment (Dadvand et al., 2012a, 2012b, 2012c; Donovan et al., 2011; Laurent et al., 2013; Lovasi et al., 2011, 2013; Markevych et al., 2014). We used different buffer sizes to abstract residential surrounding greenness in order to explore the consistency of our findings across different buffer sizes and robustness of our findings to our selection of buffer size. Furthermore, we hypothesized that immediate surrounding greenness (e.g. in a 50 m or 100 m buffer) could be more relevant to mechanisms like psychological restoration (because of visual access to greenness) and reduction in environmental exposure (e.g. air pollution, heat, and noise); whereas, greenness in larger buffer sizes could be more associated with other mechanisms like increase in physical activity. These measures of residential surrounding greenness using NDVI has been shown to strongly correlate with perception of the greenness of corresponding residential areas (Rhew et al., 2011) and be associated with more use of green spaces and physical activity (Almanza et al., 2012; Grigsby-Toussaint et al., 2011).

### 2.4. Regression models

#### 2.4.1. Main effect

In our dataset, there were 784 women with two pregnancies and 15 with three pregnancies included in the main effect analyses. To account for this, we constructed mixed effects models with the study participants as the random effect, birth weight as the outcome, and residential surrounding greenness as the predictor. The analyses were adjusted for gestational age at delivery (weeks, linear, quadratic and cubic terms), maternal age (<20, 20–25, 25–30, 30–35, 35–40, >40 years old), ethnicity (White British, Pakistani, other), education (less than five GCSEs, Five GCSE or A level equivalent, higher than A level equivalent, other), body mass index, tobacco smoking during pregnancy (yes, no), exposure to environmental tobacco smoke during pregnancy (yes, no), neighbourhood SES, parity (zero, one, two or more), alcohol consumption during pregnancy (yes, no), parity, conception year, and conception season (spring, summer, autumn, or winter).

We used maternal education as a surrogate measure of individual SES as it has been shown to be a main determinant of pregnancy outcomes that reliably correlates with other measures of SES and has been widely used in perinatal studies (Woodruff et al., 2010). We applied the tertiles of the Index of Multiple Deprivation 2010 (IMD 2010) at lower level super output area (LSOA) level as an indicator of neighbourhood SES (McLennan et al., 2011). In the UK census, Output Areas are the lowest geographical level for reporting census statistics.