



Contents lists available at ScienceDirect

# International Journal of Hygiene and Environmental Health

journal homepage: [www.elsevier.com/locate/ijheh](http://www.elsevier.com/locate/ijheh)

## Surrounding greenness, proximity to city parks and pregnancy outcomes in Kaunas cohort study



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### ARTICLE INFO

#### Article history:

Received 13 January 2015

Received in revised form 11 February 2015

Accepted 15 February 2015

#### Keywords:

Green space

Surrounding greenness

Distance to park

Adverse pregnancy outcomes

Effect modification

### ABSTRACT

There is increasing evidence that green space can improve the health and well-being of urban residents. However, there has been no consistent evidence of the effect of city parks on reproductive health. We investigated whether surrounding greenness levels and/or distance to city parks affect birth outcomes. This study was based on 3292 singleton live-births from the Kaunas birth cohort, Lithuania (2007–2009), who were enrolled in the FP7 PHENOTYPE project study. Residential surrounding greenness level was ascertained as average of satellite-based normalized difference vegetation index (NDVI) within buffers of 100 m, 300 m, and 500 m of each maternal home and distance to a city park was defined as distance to boundaries of the nearest city park. For each indicator of green space exposure, linear or logistic regression models were constructed to estimate change in birth outcomes adjusted for relevant covariates. An increase in distance to a city parks was associated with an increase in risk of preterm birth and decrease of gestational age. We found a statistically significant association between low surrounding greenness and term low birth weight. After assessing effect modification based on the low surrounding greenness (NDVI-500 < median) and the distance to city parks (>1000 m), we found increased risks for low birth weight (OR 2.23, 1.20–4.15), term low birth weight (OR 2.97, 1.04–8.45) and preterm birth (OR 1.77, 1.10–2.81) for subjects with low surrounding greenness and farther distance from a park. Both higher surrounding greenness level and proximity to park have beneficial effects on pregnancy outcomes. A beneficial park effect on foetal growth is most apparent in the environment with low surrounding greenness level. Further investigation is needed to confirm this association.

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### Introduction

A number of epidemiological studies have shown an environmental exposure effect on reproductive health and pregnancy outcomes. It has been shown that women's health and pregnancy outcomes may be affected by many environmental factors, including the living environment, social status, noise, and chemical pollutants (Agay-Shay et al., 2014; Blumenshine et al., 2010;

Stillerman et al., 2008). A recent meta-analysis of the results of the environmental exposures and pregnancy outcomes reported statistically significant associations between environmental exposures such as environmental tobacco smoke, air pollution and chemicals and pregnancy outcomes (Nieuwenhuijsen et al., 2013). However, only a limited number of studies have reported impacts of green spaces on birth outcomes (Dadvand et al., 2012a,b; Donovan et al., 2011; Hystad et al., 2014; Laurent et al., 2013), and only for surrounding greenness and birth weight they all appear to go in the same directions although there is heterogeneity in effect sizes (Agay-Shay et al., 2014; Dadvand et al., 2014). Strongest associations were found for more deprived individuals for highest residential surrounding greenness and this association varied between different ethnic and socioeconomic groups. A recently published study (Laurent et al., 2013) has shown an increase in birth weight and a reduction in preterm birth associated with

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higher residential greenness, whereas other study reported no association of foetal growth with the presence of green spaces in neighbourhood (Markevych et al., 2014).

Poor foetal growth is a marker for the foetal environment and maternal psychological distress, and anxiety may have impact on changes in fetoplacental blood flow (Roos et al., 2014). The findings emphasize a growing appreciation of the potential importance of psychological well-being during pregnancy for infant development. Moreover, foetal growth rate is negatively associated with developmental delay and behaviour problems in children (Chatterji et al., 2014).

While the published studies have found that pregnancy outcomes may be related to the neighbourhood greenness assessed as average of satellite-based normalized difference vegetation index (NDVI) or proximity to parks, these findings are not consistent with respect to the magnitude of the effect on different adverse birth outcomes. All these studies analysed separate effect of residential surrounding greenness level (NDVI) and effect of distance to city parks on birth outcomes.

This study was conducted as part of the positive health effects of the natural outdoor environment in typical populations in different regions in Europe (PHENOTYPE) project funded by the European Commission Seventh Framework Programme (Nieuwenhuijsen et al., 2014). To our knowledge, this is the first study to examine the association between residential surrounding greenness, city parks and pregnancy outcomes in the East of Europe, controlling for various maternal characteristics and health parameters. We explored the modifying effect of surrounding greenness evaluating whether the associations of distance to city parks and adverse birth outcomes differ in women residing in areas with different surrounding greenness levels, while controlling for covariates that may influence on studied birth outcomes. In this paper, we hypothesized that the impact of the distance to city parks on adverse birth outcomes depends on the surrounding greenness level in the living environment.

## Methods

### Study population

This cohort study formed part of the PHENOTYPE green space and health program (Nieuwenhuijsen et al., 2014). The participants were pregnant women recruited between 2007 and 2009 in the city of Kaunas, Lithuania (Grazuleviciene et al., 2011). The women were recruited to the study in the early stages of pregnancy (97% up till 25 weeks). In total, 5202 women were approached; 79% of them agreed to participate in the study. In this green space and pregnancy outcomes study, women with multiple pregnancies (150), those with inconsistent data on the estimation of exposure (mostly, students who moved out of the city during pregnancy, 405), or those for who had not at least one year of residence at their current address (140) were excluded. The analyses here included 3292 female residents of Kaunas that were pregnant and were 20 to 45 years old at the time of the interview, delivered singleton newborn below 4500 g and had complete individual data regarding information on various covariates.

We obtained individual-level covariates through standardized interviews. The questionnaire comprised questions on demographics, chronic diseases (cardiovascular, respiratory, renal, and diabetes), duration of residence, age at inclusion, education, social status, marital status, smoking, alcohol consumption, previous pregnancy outcomes and other potential risk factors for adverse pregnancy outcomes. Women reported their social status at inclusion (worker, student, unemployed – low; housekeeper, officer – medium; manager, company owner – high). The perceived stress

by the women was measured by a question: “My daily activities are very tiring and stressful”. The four response options were: “this describes me very well” (1), “fairly well” (2), “not very well” (3), or “not at all” (4), were scored with 1–4 points, and were used to define stress. Values 1 and 2 were considered to represent “stress”, and values 3 or 4 – “no stress”.

The research protocol was approved by the Lithuanian Bioethics Committee and informed consent was obtained from all participants.

### Birth outcomes

The data base of this cohort includes a wide range of prospectively collected data on pregnancy outcomes that were obtained through birth certificates. We evaluated gestational age (GA, in weeks), preterm birth (PB, gestation length <37 gestational weeks), birth weight (BW, in g), low birth weight (LBW, birth weight below 2500 g independently of gestational age), term low birth weight (TLBW, birth weight below 2500 g for pregnancies with at least 37 completed weeks of gestation), and small for gestational age (SGA, birth weight below the 10th percentile of birth weight stratified by sex and gestational age in the referent population).

### Green space exposure assessment

To estimate surrounding greenness levels, we assigned the normalized difference vegetation index (NDVI) in different buffer sizes. The index represents the level of vegetation or greenness within a Kaunas location and was derived from LANDSAT\_5 Thematic Mapper (TM) images at 30 m × 30 m resolution. The map of NDVI was generated using the image that was obtained on 10 July 2011. NDVI provides an indication of the presence and condition of green vegetation. It ranges between –1 and 1 with higher numbers indicating more greenness. The value of “–1” means very high reflectance in the visible red band but with little near-infrared scattering such as from snow or cloud. The values of “–1 to 0” represent no vegetation or water bodies. Grids of major blue space were excluded from the ‘mean NDVI’ calculations, because the cells of coastal water and large inland lakes do not represent accessible areas and including them would lead to a misrepresentative NDVI value. Mean NDVI values of straight-line buffer sizes of 100, 300 and 500 m were calculated as estimations of the level of greenness within the immediately accessible neighbourhood.

Using Urban Atlas data for Kaunas, we estimated proximity to city parks as a straight line distance to the nearest city park. A binary variable was used to assess whether the maternal residential address was within a three (<300 m, 300–1000 m, and >1000 m) buffer sizes from boundaries of a nearest city park. All home addresses of the participants were geocoded and the distance to the nearest city park was estimated. All of the Kaunas city parks that were larger than 1 ha and generally had over 65% of their land covered with trees were regarded as city parks. In this study, to assess the association between the residence distance to city parks and birth outcomes we also used the distance measure as a continuous variable.

### Statistical analysis

We applied chi-square test to compare the values and frequencies of baseline maternal characteristics by green space exposures and adverse birth outcomes. The continuous variables are presented as mean value and standard error (SE). Predictor variables whose univariate test showed a statistically significant association ( $p < 0.05$ ) to the outcome were treated as possible risk factors for adverse birth outcome, and were included in the multiple regression models. We used logistic and linear regression

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