EXPOSURE TO GREENSPACE AND BIRTH WEIGHT IN A MIDDLE-INCOME COUNTRY

Maria Torres Toda[1,2,3], Mohammad Miri[4*], Lucia Alonso[1], Maria Dolores Gómez-Roig[5,6,7], Maria Foraster[1,2,3 δ], Payam Dadvand[1,2,3,4 δ *]

1. ISGlobal, Barcelona, Spain.
2. Pompeu FabraUniversity, Barcelona, Catalonia, Spain.
3. Ciber on Epidemiology and Public Health (CIBERESP), Madrid, Spain.
4. Non-communicable diseases Research Center, Department of Environmental Health, School of Public Health, Sabzevar University of Medical Sciences, Sabzevar, Iran.
5. BCNatal-Barcelona Center for Maternal-Fetal and Neonatal Medicine (Hospital Sant Joan de Deu and Hospital Clínic), Barcelona, Spain.
6. Institut de Recerca Sant Joan de Déu (IR-SJD), Barcelona, Spain
7. Spain Maternal and Child Health Development Network, RETICS funded by the PN I+D+I 2013-2016 (Spain), ISCIII- Sub-Directorate General for Research Assessment and Promotion and the European Regional Development Fund (ERDF), ref. RD16/0022, Madrid, Spain

δ These authors contributed equally.

***Corresponding authors:**

Payam Dadvand
Barcelona Instiute for Global Health (ISGlobal)
C/Doctor Aiguader 88, 08003
Barcelona, Spain
Email: payam.dadvand@isglobal.org
Tel: +34 93 214 73 29

Mohammad Miri
School of Public Health, Sabzevar University of Medical Sciences
Sabzevar, Iran
Email: M_miri87@ssu.ac.ir
Tel: +98 0912 935 7588

Abstract

An emerging body of evidence has associated exposure to greenspace during pregnancy with improved fetal growth; however, all available studies have been conducted in high-income countries and the available evidence evaluating such an association for visual access to greenspace, use of green spaces and indoor plants is non-existent. We aimed to evaluate the association between a comprehensive array of indicators of exposure to greenspace during pregnancy, including the aforementioned indicators, and birth weight, in a middle-income country and evaluating air pollution and visual access as possible mechanisms underlying the association. This study was based on 301 pregnant women residing in Sabzevar, Iran (2018). For each pregnant woman, we characterized exposure to residential surrounding greenspace, visual access to greenspace, residential proximity to green space, use of green spaces, and the number of plant pots at home. We used linear regression models adjusted for relevant covariates including measures of socioeconomic status. We found positive associations of maternal exposure to residential surrounding greenspace across a 100 m buffer, frequent viewing of greenspace through the window, percentage of window area covered by greenspace, residential proximity to any green space regardless of its area, time spent in public green spaces and total time spent in public and private green spaces with birth weight. We also observed positive associations of maternal exposure to residential surrounding greenspace across 300 m and 500 m buffers, residential proximity to a green space with an area ≥5000 m^2, and indoor plant pots with birth weight, but none of these associations were statistically significant. The magnitude of the associations tended to be higher among parents with lower socioeconomic status. Mediation through air pollution or visual access was not established. Findings from this study suggested a

positive role of different aspects of exposure to greenspace during pregnancy on birth weight in a middle-income country.

Keywords: Fetal growth; Nature; Parks; Prenatal; Greenness; Birth outcomes

1. INTRODUCTION

By mid-century, roughly two thirds of the world's population will be living in urban areas (*United Nations, 2018*). Urban residents, compared to those residing in sub-urban and rural areas, often have higher exposure to a number of environmental hazards such as air pollution, noise and heat and less access to natural environments including green spaces (*Nieuwenhuijsen M. et al., 2019*). Exposure to greenspace has been associated with a range of health benefits such as improved mental health and decreased physical morbidity and mortality *(Fong K. et al., 2018a ; Kondo M.C. et al., 2018; Rojas-rueda et al., 2019.; Twohig-Bennett and Jones, 2018).* Postulated mechanisms underlying such beneficial associations may relate to increasing routine and recreational physical activity, promoting mental health and reducing stress, facilitating social interaction and social cohesion, and mitigating the aforementioned urban-related environmental hazards *(Banay et al., 2017; Dzhambov et al., 2014; Fong K. et al., 2018a; Kondo M.C. et al., 2018; Twohig-Bennett and Jones, 2018).*

It is well established that the fetus is especially vulnerable to the effects of socio-environmental factors *(Nieuwenhuijsen M. et al., 2013).* The influence of these exposures during pregnancy on fetal growth and development is not limited to reproductive and childhood outcomes and can be extended later in life, determining health and disease in adulthood as described by the DOHaD (Developmental Origins of Health and Diseases) concept *(Law and Baird, 2006; Wadhwa P.D. et al., 2010).* Importantly, low birth weight (LBW, birth weight <2500g), as an indicator of impaired fetal growth *(Camerota and Bollen, 2016),* is not only one of the principal causes of perinatal mortality and morbidity and delayed development and neurodevelopment during childhood *(Baud and Berkane, 2019),* but also is associated with higher risk of cardiovascular disease, chronic kidney disease, diabetes and metabolic syndrome in adulthood *(Al Salmi et al., 2019)*. As such, the fetal period could be considered as a window of opportunity to promote health during the life course.

An emerging body of evidence has evaluated the association of maternal exposure to greenspace during pregnancy and improved pregnancy outcomes including fetal growth *(Banay et al., 2017; Dzhambov et al., 2014)*. A majority of these studies have suggested that residential exposure to surrounding greenspace and proximity to green spaces could be associated with higher birth weight or lower risk of LBW (*Fong K. et al., 2018b; Cusack et al., 2018*; *Nieuwenhuijsen M. et al., 2019*). However, some others only partially supported such an association *(Dadvand P. et al., 2012a; Abelt and McLafferty, 2017; Cusack et al., 2017b)*, i.e., they either did not find this association *(Abelt and McLafferty, 2017; Cusack et al., 2017b)* or found evidence for positive associations only among those participants belonging to lower socioeconomic groups *(Dadvand P. et al., 2012a)*.Moreover, a number of studies have explored the roles of physical activity *(James et al., 2015)*, air pollution *(Dadvand P. et al., 2012b; Dzhambov MA et al., 2019)* and maternal stress *(Bussières et al., 2015)* as potential mechanisms underlying the association between exposure to greenspace and fetal growth. To date, to our knowledge, no study has evaluated the latter association for other important aspects of exposure to greenspace such as visualization of greenspace through the home windows (i.e., visual access to greenspace), use of green spaces and indoor plants at home. Moreover, the available studies on the association of greenspace exposure with fetal growth have been exclusively conducted in high-income countries with no study available for low- and middle-income countries (LMICs) where much of the urbanization is projected to happen *(United Nations, 2018)*. Given the variation in the observed associations between greenspace exposure and fetal growth in different settings *(Cusack et al., 2017b; Glazer et al., 2018),*it is not clear to what extent the results from high-income countries can be generalized to LMICs. Accordingly, we aimed to evaluate the association between a comprehensive array of indicators of greenspace exposure, including residential surrounding greenspace, visual access to greenspace, residential proximity to green space, time spent in green spaces and indoor plant pots with birth weight in a LMIC (Iran). Furthermore, as secondary aims, we evaluated (i) the potential modification of these associations by socioeconomic status (SES), sex of the child and home type and (ii) the mediation of the association between immediate residential surrounding greenspace and birth weight by air pollution and by visual access to greenspace.

2. MATERIALS AND METHODS

2.1. Study area and population

Our study was conducted in Sabzevar city, located in the northeast of Iran (coordinates: 36°12′ N 57°35′, elevation: 977m) with a population of about 240 000 inhabitants (census 2016). It has an arid climate (Köppen climate classification *(Kottek M et al., 2006)*) with an average annual precipitation of about 180mm (mostly in winter). The annual minimum and maximum temperatures in Sabzevar are -2 and 45ºC, respectively, with an annual mean temperature of 18 ºC (Khorasan Razavi Meteorological Office (Province climate Khorasan Razavi meteorological organization, *2019.*)). Sabzevar has four distinct seasons with maximum vegetation during spring months. Based on land use map of Sabzevar (2016), about 27% (7.1 km^2) of Sabzevar is covered by greenspace resulting in a 29.4 m^2 of greenspace per capita.

The recruitment of the study participants was conducted at delivery between June and August 2018 at the Shahidan Mobayani university hospital, the only tertiary hospital in the city. We included women who: (i) were non-smokers, (ii) had a normal term pregnancy (37 to 42 weeks), (iii) had no history of diabetes or hypertension, (iv) had a normal vaginal delivery, (v) had no pregnancy complications (i.e., gestational diabetes or preeclampsia), (vi) spent their entire pregnancy in the same home address in Sabzevar and (vii) did not work outside home (i.e., housewives). Of about 1150 mothers admitted to the hospital over the study period, 301 mothers met the study inclusion criteria and agreed to participate in our study. We did not include women who worked outside to minimize the exposure misclassification due to exposures occurring in other microenvironments such as workplace or the commuting route between home and workplace.

Data on socio-demographic characteristics, SES, and lifestyle were obtained by questionnaires through face-to-face interviews during the time they were in the hospital after delivery. The informed consent form, approved by the Clinical Research Ethical Committee (IR.MEDSAB.REC.1395.82) of the Sabzevar University of Medical Science, Sabzevar, Iran, was signed by all the participants before their enrollment to the study.

2.2. Outcome Assessment

Birth weight was used as our outcome of interest. We extracted birth weight data from the hospital records. We were not able to use other birth outcomes, for example, LBW or small for gestational age (SGA, birth weight <10th percentile for the gestational age adjusted by gestational age and sex) due to our limited statistical power.

2.3. Exposure Assessment

We comprehensively characterized five different aspects of exposure to greenspace including: (1) residential surrounding greenspace, (2) visual access to greenspace, (3) residential proximity to green space, (4) time spent in green spaces and (5) number of plant pots at home.

2.3.1. Residential surrounding greenspace

We characterized the greenspace surrounding the residential address of each participant using the Normalized Difference Vegetation Index (NDVI) *(Dadvand et al., 2014)*. NDVI is a widely used indicator of greenspace obtained from satellite imagery based on land surface reflectance of visible (red) and near-infrared parts of the spectrum. Values of NDVI range from -1 to 1, with higher values indicating greater density of photosynthetically-active vegetation. NDVI values for this study area were calculated based on the images captured in June 14, 2018 by Landsat 8 at 30 m x 30 m resolution. For each participant, we abstracted residential surrounding greenspace as the average of NDVI within 100m, 300m and 500m radius buffer areas around the geocoded residential address *(Dadvand et al., 2014)*. Figure 1 shows our study area, location of air pollution monitoring stations, roads and vegetation cover in different parts of Sabzevar.

2.3.2. Visual access to greenspace

Visualization of greenspace through the window (from now onwards named "visual access to greenspace") at home was assessed by questionnaires through face-to-face interviews after delivery *(Ulrich RS, 1984.)*. Table 1 shows the visual access questions and the data processing of these variables. We obtained three categorical variables to evaluate visual access to greenspace: (1) having a window with greenspace view, (2) frequent viewing of greenspace through window and (3) window area covered by greenspace.

2.3.3. Residential proximity to green space

Residential proximity to the closest green space (i.e., urban parks, street greenery and gardens) was characterized as the Euclidean distance from the geocoded residential address to (a) the nearest green space of any size and (b) the nearest green space with an area ≥5000m^2 (i.e., a "major green space") *(Abareshi et al., 2020)*, using ArcGIS software, v.10.5 (Environmental Systems Research Institute, Inc.). We applied the land use map of Sabzevar (2016) provided by the municipality of Sabzevar to abstract these variables.

2.3.4. Use of green spaces

Data on the amount of time spent in green spaces during pregnancy was collected by questionnaires through face-to-face interviews during the stay of women in the hospital after delivery *(Dadvand et al., 2018)*. We obtained data separately for the time (hours/week) spent in (a) public green spaces (i.e., urban parks and public gardens) and (b) private green spaces (i.e., private gardens, courtyards and patios). For our analyses, we used data of the time spent in public green spaces as well as the sum of the total time spent in public and private green spaces. Given that the first and third quartiles of the time spent in private green spaces were both zero, it was not possible to scale this exposure and hence this exposure variable was not included in our analyses separately.

2.3.5. Number of indoor plant pots at home

Data on the number of indoor plant pots at home during pregnancy was obtained through a question asking participants to report the number of plant pots that they had at home *(Rahmani et al., 2020).*

2.4. Statistical analyses

2.4.1. Main analyses

We developed linear regression models with birth weight as the outcome and indicators of greenspace exposure (one at a time) as the predictor variables. All models were adjusted for *a priori* selected set of covariates including (i) gestational age at delivery (weeks, continuous), (ii) maternal age (years, continuous), (iii) maternal pre-gestational Body Mass Index (BMI) (kg/m^2, continuous), (iv) number of previous pregnancies (continuous), (v) exposure to environmental tobacco smoke (yes/no), (vi) three indicators of household SES including income (≥1.5 million Rials per month/1.5 to 3 million Rials per month / 3≤ million Rials per month), maternal and paternal education (elementary/high school/university), and (vii) two indicators of neighborhood SES including the percentage of illiterate (%) and the percentage of unemployment (%) at the census tract of the residential address. We divided our continuous exposures by their interquartile range (IQR) in order to provide comparable results for our different exposure indicators. Models with categorical exposures (visual access) were interpreted as the difference in the average of birth weight among categories. For all of our analyses, the level of statistical significance was set at $p<0.05$.

2.4.2. Sensitivity analyses

We applied the Modified Soil Adjusted Vegetation Index ($MSAVI2_2$) as an alternative set of residential surrounding greenspace. We applied the same Landsat images used for calculating NDVI to abstract $MSAVI_2$. $MSAVI_2$ differs from NDVI in that it minimizes the background soil influences in the calculation of the vegetation *(Qi et al., 1994)*. For each participant, we obtained the average of $MSAVI_2$ within buffers of 100m, 300m and 500m around the geocoded residential address. We repeated the main analyses using $MSAVI_2$ instead of NDVI for the exposure to residential surrounding greenspace. $MSAVI_2$ values in different parts of Sabzevar are represented in Figure 1.

2.4.3. Further analyses

2.4.3.1. Stratified analyses

We stratified our main analyses to explore whether the association between exposure to greenspace and birth weight varied across strata of (a) paternal educational level (elementary/high school/university), (b) sex (girl/boy) and (c) type of residence (apartment/house). For these stratified analyses and to account for maternal and paternal educational level, we merged the data from both parents to create a new variable, named parental educational level, indicating the higher attained educational level by either of the parents.

2.4.3.2. Mediating role of air pollution and visual access

We hypothesized that exposure to ambient air pollution at home and visual access to greenspace through home windows could act as potential mechanisms underlying the association between greenspace surrounding the residential address and birth weight. As such, we analyzed the mediatory role of air pollution and visual access to greenspace for the association between immediate surrounding residential greenspace (NDVI at 100m buffer) and birth weight. Maternal exposure to particulate matter with aerodynamic diameter less than 1µm (PM_1), 2.5µm ($PM_{2.5}$), and 10 µm (PM_{10}) during pregnancy were estimated using land use regression models (LUR) *(Miri et al., 2019).* The monitoring campaign was performed from April 2017 to February 2018. More information about the air pollution assessment is available in Supplementary Materials, page 3.

We calculated the indirect effect as the estimate of the association between exposure to immediate surrounding residential greenspace and birth weight that can be attributed to mediation through the mediator, whereas the direct effect was the estimate of the association that can be attributed to the direct path between greenspace and birth weight (or to other mediators not included in the analysis) *(Lange and Hansen, 2011).*We estimated the direct effect of the associations adjusted for the mediator and the effect of the mediator on birth weight adjusted for NDVI 100m buffer (indirect effect). We added up the direct and indirect effect to obtain the total effect. After that, we obtained the percentage of mediation which was the ratio between the indirect effect and the total effect multiplied by 100 *(Tingley et al., 2013).* We used bootstrap to obtain percentile-based 95% confidence interval for the contribution of each mediator.

3. RESULTS

3.1. Study population

A total of 301 participants were included in our study. Most of the participants had previous pregnancies (94.3%), high school education (44.5%) and were not exposed to tobacco at home (79.4%). The median (IQR) age of women was 27.5 (8) years and the median (IQR) birth weight of newborns was 3260 (590) g. The description of the socio-demographic characteristics of the study participants are presented in Table 2.

3.2. Indicators of greenspace

The description of the indicators of exposure to greenspace is presented in Table 2. Out of all the participants who had more than half of the window area covered by greenspace, 23.5% reported that they frequently viewed greenspace through the window. The correlation matrix between the indicators of exposure to greenspace is presented in Figure 2. In general, correlations were high among the exposures belonging to the same group of indicator of greenspace. Visual access to greenspace, time spent in public green spaces and time spent in public and private green spaces were positively correlated with immediate residential surrounding greenspace. Visual access was negatively correlated with distance to any green space and distance to a major green space, but positively correlated with time spent in public green spaces and time spent in public and private green spaces. We found negative moderate correlations between the two indicators of distance to green spaces and use of green spaces. We also found strong correlations (Spearman's rank correlation = 0.9) between the two measures of residential surrounding greenspace (NDVI and $MSAVI_2$) at each buffer of 100m, 300m and 500m.

3.3. Main analyses

The estimated associations between indicators of exposure to greenspace and birth weight are presented in Table 3. Greater exposure to residential surrounding greenspace was associated with higher birth weight, with the association being higher and statistically significant for the surrounding greenspace across a 100m buffer around participants' residential address. Regarding visual access to greenspace, frequent viewing of greenspace through the window and window area covered by greenspace (> 50%) were significantly associated with higher birth weight, whereas having a window with greenspace view was not associated with birth weight. We also observed an association of residential proximity to any green space and proximity to a green space with an area of $\geq$ 5000 m^2 with higher birth weight; however, only the association for the proximity to any green space attained statistical significance. More time spent in public green spaces and time spent in public and private green spaces were associated with higher birth weight. Finally, we observed a direct association between the number of indoor plant pots and birth weight, but the association was not statistically significant.

3.4. Further analyses

3.4.1. Sensitivity analyses

The associations using $MSAVI_2$ as an alternative indicator of residential surrounding greenspace were consistent with those of main analyses based on NDVI (Supplementary Materials, page 4).

3.4.2. Stratified analyses

We observed different patterns of associations across strata of parental education for different indicators of exposure to greenspace; with some suggestions for potentially higher associations between exposure to greenspace and birth weight among children of parents with low-moderate educational level (Figure 3). In contrast, the association between different indicators of exposure to greenspace and birth weight did not show a notable variation across strata of the sex of the child and the type of residence (Supplementary Materials, page 5 and 6).

3.4.3. Mediating role of air pollution and visual access

As presented in Table 4, we did not observe a statistically significant mediatory role of air pollution or visual access for the association between immediate residential surrounding greenspace and birth weight.

4. DISCUSSION

This study evaluates the associations of maternal visual access to greenspace, use of green spaces, and indoor plants with birth weight (in addition to exposure to surrounding residential greenspace and proximity to green spaces), which adds to the very scarce available epidemiological evidence on other health benefits of these indicators. Moreover, this study investigates the relationship between exposure to greenspace and birth weight in a middle-income country which also adds to the limited number of available reports on health benefits of exposure to greenspace in LMICs.

We used data obtained from questionnaires, land cover maps, and satellite imagery to comprehensively characterize exposure to greenspace. We found positive associations between residential surrounding greenspace across 100 m buffer, frequent viewing of greenspace through the window, window area covered by greenspace, residential proximity to any green space regardless of its area, and use of public and also total use of public and private green spaces and birth weight. We also observed positive associations between residential surrounding greenspace across 300 m and 500 m buffers, residential proximity to a green space with an area ≥5000 m^2, and indoor plant pots and birth weight, but none of these associations were statistically significant. After stratifying the analyses based on parental education, we observed some suggestions for potentially higher associations between exposure to greenspace and birth weight for children whose parents had low-moderate educational level. We did not observe any indication for differences in the associations across strata of newborn sex and type of residence. Our mediation analyses showed weak evidence for a mediation of the association between immediate residential surrounding greenspace and birth weight by air pollution or visual access.

4.1. Interpretation of results in the context of available evidence

In general, we obtained relatively low values of residential surrounding greenspace compared to other similar studies conducted in other climates *(e.g. Cusack et al., 2017b; Dadvand et al., 2012; Markevych et al., 2014)*. Our observed median (IQR) of the NDVI averages across different buffers around the participants' residential addresses ranged from 0.06 to 0.07. These observations were in line with those of previous studies in the same study area *(Abareshi et al., 2020; Miri et al., 2018),* where average NDVIs for the same buffers ranged between 0.06-0.08. Given the arid climate of our study area and its location on the edges of the central desert of Iran *(Kottek M et al., 2006)* these values were expected.

In our study, estimates of the association between residential surrounding greenspace and birth weight for 1-IQR increase in the adjusted models were: 42.7g [95% CI: 4.7g-80.8g] for 100m buffer, 34.6g [95% CI: -3.3g, 72.5g] for 300m buffer, 38.2g [95%CI: -9.9g, 86.3g] for 500m buffer. The associations between residential surrounding greenspace and proximity to green spaces in the current study were in accordance with some of the previous studies *(Casey et al., 2016; Cusack et al., 2018; Ebisua, 2017; Fong K. et al., 2018b; Grazuleviciene et al., 2015; Markevych et al., 2014; Nieuwenhuijsen et al., 2019; Dadvand P. et al.,2012b)*. The three studies in North America reported that greater exposure to residential surrounding greenspace was associated with higher birth weight. In Connecticut, *Ebisua et al.,* found that an IQR increase in the fraction of greenspace within 250 m around residence was associated with 3.2g higher birth weight and 7.6% lower risk of LBW *(Ebisua et al., 2017)* . The Canadian Healthy Infant Longitudinal Development (CHILD) study found, for Vancouver and Toronto, an increase in birth weight of 41.2g [95% CI: 7.8g, 74.6g] for a 0.1 increase in residential surrounding greenspace within 500m buffer *(Cusack et al., 2018)*. A study of 780,435 births in Massachusetts *(Fong K. et al., 2018b)* found that higher residential surrounding greenspace exposure was associated with higher birth weight, and with lower odds of term low birth weight (TLBW) [OR: 0.98; 95% CI: 0.97, 0.99] and SGA [OR: 0.98; 95% CI: 0.97, 0.99]. Four other studies in Europe have also reported that higher residential surrounding greenspace and residential proximity to green spaces are beneficial for birth weight. *Nieuwenhuijsen et al.,* published a study about the influence of a long array of urban-related environmental exposures on birth weight, and concluded that the most consistent associations were observed between residential surrounding greenspace and higher birth weight and lower TLBW risk *(Nieuwenhuijsen et al., 2019)*. The Kaunas cohort study found higher risks for LBW [OR: 2.23; 95% CI: 1.20, 4.15] and TLBW [OR: 2.97; 95% CI: 1.04, 8.45] for subjects with low residential surrounding greenspace and low proximity from a park *(Grazuleviciene et al., 2015)*. In Germany, *Markevych et al., (Markevych et al., 2014)* reported that an IQR increase in residential surrounding greenspace in a 500m buffer was associated with an average birth weight increase of 17.6 g [95% CI: 0.5g, 34.6g]. In Spain, *Dadvand P et al., (Dadvand P et al., 2012b)* found associations between greater exposure to residential greenspace and higher birth weight [44.2 g; 95% CI: 20.2g, 68.2g] and head circumference [1.7mm; 95% CI: 0.5mm, 2.9mm] for an IQR increase in average residential surrounding greenspace within a 500m buffer. Not all studies that assessed the relationship between residential surrounding greenspace and proximity to green spaces with birth weight observed consistent associations, some of them partially support these associations *(Abelt and McLafferty, 2017; Cusack et al., 2017b, Cusack et al., 2017a; Dadvand et al., 2012a; Dzhambov et al., 2019; Eriksson et al., 2019; Glazer et al., 2018; Nichani et al., 2017)* For example, a study in New York *(Abelt and McLafferty, 2017)* did not identify any relationship between birth outcomes and residential surrounding greenspace, distance to major green space, or waterfront access. They only found a significant association between nearby street trees and higher odds of preterm birth for all participants. *Glazer et al., (Glazer et al., 2018)* investigated the association between residential surrounding greenspace and birth weight in a coastal area (northeastern United States). They found that NDVI was associated with higher birth weight [7.4g; 95% CI: 0.4g-14.4g] but results were attenuated after further adjustment for SES indicators. In Portland (Oregon) positive associations were observed between residential surrounding greenspace and birth weight but the same study observed negative associations in Austin (Texas) *(Cusack et al., 2017b).*

We were not able to compare our observed associations for our other indicators of greenspace exposure with findings of previous studies because visual access to greenspace, use of green spaces and number of indoor plant pots at home have not been evaluated in association with fetal growth. However, our findings are in line with a number of previous observations regarding other beneficial influences of these indicators on health. For example, in 1984, *Ulrich RS (Ulrich RS, 1984)* randomized post-operative patients into two groups by placing them in rooms with and without a window with greenspace view. They observed that patients placed in rooms with visual access to greenspace had a faster recovery after their surgery.

In our study, the association between exposure to greenspace and birth weight was suggestively higher for lower-middle socioeconomic groups compared to participants with higher SES. In 2012, a study by *Dadvand P et al., (Dadvand P. et al., 2012a)* reported direct associations of exposure to residential surrounding greenspace and residential proximity to green spaces with birth weight were evident only in the lowest SES group. Other studies also described more benefits of exposure to greenspace for participants from more deprived groups *(Nichani et al., 2017; Dadvand P. et al., 2012b).* Contrary to our results, a recent study in Massachusetts *(Fong K. et al., 2018b),* found that the magnitude of the positive associations were greater in participants with higher SES. Based on our results and according to one recent review by *Fong K et al., (Fong K. et al., 2018a)* there could exist an effect modification by SES. It is plausible that people from higher socioeconomic groups are able to compensate their lack of greenspace around their home by travelling and having access to other sources of greenspace away from their homes. In contrast, the population from lower socioeconomic groups could depend more on the greenspace close to their residence. We are not aware of any other studies stratifying the association between exposure to greenspace and birth weight by newborn sex or type of residence, and hence, we could not compare our results with them.

4.2. Potential mechanisms

In the two studies in Spain by *Dadvand P et al., (Dadvand P. et al., 2012a; Dadvand P. et al., 2012b)* associations between exposure to green spaces and birth weight were attenuated after further adjustment of the models by air pollution, which suggested a possible mediating role of air pollution in this association. But our mediation analyses did not provide a strong evidence for such role of air pollution. Other previous studies differed in our results, for example, in Munich, stronger associations were observed after further adjustment of their models by NO_2 and $PM_{2.5}$ *(Markevych et al., 2014)*. Similarly, we could not establish evidence of a mediation role of visual access in the studied associations and, to our knowledge, there are no previous studies addressing this mediation to compare our results. In summary, the role of air pollution and visual access as mediators of the association between exposure to greenspace and birth weight is yet to be established and requires further research.

A number of other potential mechanisms might have underlain our observed association between exposure to greenspace and birth weight. Increased physical activity has been suggested as a mechanism for the association *(James et al., 2015)*. Moreover, our observed associations between visual access to greenspace and birth weight could suggest a potential mechanistic role of stress reduction through visual access to greenspace. The stress reduction theory by *Ulrich R et al. (1991)* might partially explain our results. According to this theory, the subjects more exposed to natural environments rather than the ones exposed to urban environments have better stress recovery *(Ulrich R.S. et al., 1991)*. One previous meta-analysis evaluating 88 prospective studies (n= 5,889,930) suggested a significant association between maternal prenatal stress and lower birth weight *(Bussières et al., 2015)*. Therefore, reduced stress due to maternal exposure to greenspace could have been a potential mechanism underlying our observed associations. Also, the association between time spent in green spaces and birth weight might be explained by increased physical activity and stress reduction. There are several studies that have associated physical activity with stress reduction *(Kruk J., 2007)*.

Overall, our results suggest that examining the impact of exposure to greenspace in cities and neighborhoods with diverse socioeconomic, socio-demographic, contextual characteristics and situated in different regions is an important next step to determine specific pathways and improving our understanding of the studied association.

4.3. Limitations

Our study faced a number of limitations that warrant consideration. Our modest sample size did not allow us to investigate the association of greenspace exposure with other indicators of fetal growth such as LBW or SGA. Similarly, our stratified analyses based on education level, sex, and type of residence and our mediation analyses could have been under-powered. As such our observed lack of statistically significant findings should be interpreted with caution. Our study was performed on a well-characterized and controlled sample of women, which could reduce potential biases and increases internal validity. However, our relatively strict inclusion criteria might have potentially affected the generalizability of our findings. Despite the more comprehensive assessment of different greenspace indicators compared to previous studies, our exposure assessment did not take into account the type of vegetation or quality characteristics of green spaces, which could have influenced our findings for the residential surrounding greenspace and proximity to green spaces. Unsafe or unattractive green spaces, for example, could discourage pregnant women to visit the space and practice physical activity or engage in social interactions there. We used satellite imagery by Landsat 8 at 30x30m resolution to assess residential surrounding greenspace. Satellite imagery at this resolution is used by the vast majority of the studies but higher resolution might have led to more accurate exposure assessment and accordingly an improved estimation of our associations for the residential surrounding greenspace *(Su et al., 2019)*. Moreover, our characterization of visual access to greenspace was based on questionnaires which could have been prone to subjectivity and inaccurate recall, consequently leading to exposure misclassification, which, in turn, could have biased our association estimates towards or away from null or have resulted in wider confidence intervals for our estimates. Although, we controlled our analyses for a wide range of covariates, we did not have data on diet and other covariates which could have been relevant to our analyses. We did not have data on other potential mediators (e.g. exposure to other air pollutants such as NO_2, reduction in stress *(Lima et al., 2018)* or exposure to noise *(Nieuwenhuijsen et al., 2017)*) of the association between greenspace exposure and fetal growth. Mediation by these other factors remains as an open question for future studies.

4.4. Conclusions

Our findings suggest that exposure of pregnant women to greater residential surrounding greenspace, more visual access to greenspace, lower residential proximity to green space and more time spent in green spaces were associated with higher birth weight. The magnitude of the associations tended to be greater among participants with low-moderate educational levels. We did not observe any strong evidence for the mediation of the association between exposure to residential surrounding greenspace and birth weight by exposure to air pollution or visual access. Our findings for the association between indoor plant pots and birth weight were not conclusive. More studies should be conducted in LMICs to replicate our analyses and check the findings using larger sample sizes, while considering the quality and variety of greenspace type in their exposure assessment, relying on objective measures of visual access to greenspace and shedding light on mechanisms underlying this association. Moreover, future studies should contemplate creating an index greenspace exposure variable integrating different green exposure metrics.

Acknowledgements: This study was supported by Sabzevar University of Medical Sciences (Grant number: 97214). We thank the Shahidan Mobayani Hospital for their cooperation in this study and to all the participants for their generous collaboration. Maria Torres Toda is funded by a PFIS (Contrato Predoctoral de

Formación en Investigación en Salud) fellowship (FI17/00128) awarded by Instituto de Salud Carlos III. Maria Foraster is funded by the Beatriu de Pinós programme of the Government of Catalonia's Secretariat for Universities and Research of the Ministry of Economy and Knowledge. Payam Dadvand is funded by a Ramón y Cajal fellowship (RYC-2012-10995) awarded by the Spanish Ministry of Economy and Finance.

BIBLIOGRAPHY

Abareshi, F., Sharifi, Z., Hekmatshoar, R., Fallahi, M., Lari, M., 2020. Association of exposure to air pollution and green space with ovarian reserve hormones levels. Environ. Res. 184, 109342. https://doi.org/10.1016/j.envres.2020.109342

Abelt, K., McLafferty, S., 2017. Green streets: Urban green and birth outcomes. Int. J. Environ. Res. Public Health 14. https://doi.org/10.3390/ijerph14070771

Al Salmi, I., M Shaheen, F.A., Hannawi, S., 2019. Birth weight, gestational age, and blood pressure: Early life management strategy and population health perspective. Saudi J. Kidney Dis. Transpl. 30, 299–308. https://doi.org/10.4103/1319-2442.256836

Banay, R.F., Bezold, C.P., James, P., Hart, J.E., Laden, F., 2017. Residential greenness : current perspectives on its impact on maternal health and pregnancy outcomes 133–144.

Baud, O., Berkane, N., 2019. Hormonal changes associated with intra-uterine growth restriction: Impact on the developing brain and future neurodevelopment. Front. Endocrinol. (Lausanne). 10, 1–9. https://doi.org/10.3389/fendo.2019.00179

Bussières, E.L., Tarabulsy, G.M., Pearson, J., Tessier, R., Forest, J.C., Giguère, Y., 2015. Maternal prenatal stress and infant birth weight and gestational age: A meta-analysis of prospective studies. Dev. Rev. 36, 179–199. https://doi.org/10.1016/j.dr.2015.04.001

Camerota, M., Bollen, K.A., 2016. Birth weight, birth length, and gestational age as indicators of favorable fetal growth conditions in a us sample. PLoS One 11, 1–15. https://doi.org/10.1371/journal.pone.0153800

Casey, J.A., James, P., Rudolph, K.E., Wu, C. Da, Schwartz, B.S., 2016. Greenness and birth outcomes in a range of Pennsylvania communities. Int. J. Environ. Res. Public Health 13. https://doi.org/10.3390/ijerph13030311

Cusack, L., Larkin, A., Carozza, S., Hystad, P., 2017a. Associations between residential greenness and birth outcomes across Texas. Environ. Res. 152, 88–95. https://doi.org/10.1016/j.envres.2016.10.003

Cusack, L., Larkin, A., Carozza, S.E., Hystad, P., 2017b. Associations between multiple green space measures and birth weight across two US cities. Heal. Place 47, 36–43. https://doi.org/10.1016/j.healthplace.2017.07.002

Cusack, L., Sbihi, H., Larkin, A., Chow, A., Brook, Jeffrey R., Moraes, T., Mandhane, Piush J., Becker, Allan B., Azad, M.B., Subbarao, Padmaja, Kozyrskyj, A., Takaro, T.K., Sears, Malcolm R., Turvey, S.E., Hystad, Perry, Subbarao, P., Sears, M. R., Anand, S.S., Becker, A. B., Befus, A.D., Brauer, M., Brook, J. R., Chen, E., Cyr, M.M., Daley, D., Dell, S.D., Denburg, J.A., Duan, Q.L., Eiwegger, T., Grasemann, H., HayGlass, K., Hegele, R.G., Holness, D.L., Hystad, P., Kobor, M., Kollmann, T.R., Kozyrskyj, A.L., Laprise, C., Lou, W.Y.W., Macri, J., Mandhane, P. J., Miller, G., Moraes, T.J., Paré, P., Ramsey, C., Ratjen, F., Sandford, A., Scott, J.A., Scott, J., Silverman, F., Simons, E., Takaro, T., Tebbutt, S.J., To, T., 2018. Residential green space and pathways to term birth weight in the Canadian Healthy Infant Longitudinal Development (CHILD) Study. Int. J. Health Geogr. 17, 1–12.

https://doi.org/10.1186/s12942-018-0160-x

Dadvand, P., de Nazelle, A., Figueras, F., Basagaña, X., Su, J., Amoly, E., Jerrett, M., Vrijheid, M., Sunyer, J., Nieuwenhuijsen, M.J., 2012a. Green space, health inequality and pregnancy. Environ. Int. 40, 110–115. https://doi.org/10.1016/j.envint.2011.07.004

Dadvand P., Sunyer J, Basagaña X, Ballester F, Lertxundi A, Fernández-Somoano A, Estarlich M, García-Esteban R, Mendez M, and Nieuwenhuijsen, M.J., 2012b. Surrounding Greenness and Pregnancy Outcomes in Four Spanish Birth Cohorts. Environ. Health Perspect. 120, 1481–1487.

Dadvand, P., Tischer, C., Estarlich, M., Llop, S., Dalmau-bueno, A., López-vicente, M., Valentín, A., Keijzer, C. De, Fernández-somoano, A., Lertxundi, N., Rodriguez-dehli, C., Gascon, M., Guxens, M., Zugna, D., Basagaña, X., Nieuwenhuijsen, M.J., Ibarluzea, J., Ballester, F., Sunyer, J., 2014. Lifelong Residential Exposure to Green Space and Attention : A Population-based Prospective Study 1–8.

Dadvand, P., Poursafa, P., Heshmat, R., Motlagh, M.E., Qorbani, M., Basagaña, X., Kelishadi, R., 2018. Use of green spaces and blood glucose in children; a population-based CASPIAN-V study. Environ. Pollut. 243, 1134–1140. https://doi.org/10.1016/j.envpol.2018.09.094

Dzhambov, A.M., Dimitrova, D.D., Dimitrakova, E.D., 2014. Association between residential greenness and birth weight: Systematic review and meta-analysis. Urban For. Urban Green. 13, 621–629. https://doi.org/10.1016/j.ufug.2014.09.004

Dzhambov, A.M., Markevych, I., Lercher, P., 2019. Associations of residential greenness, traffic noise, and air pollution with birth outcomes across Alpine areas. Sci. Total Environ. 678, 399–408. https://doi.org/10.1016/j.scitotenv.2019.05.019

Ebisua, K.T.R.H.M.L.B., 2017. Association between Greenness, Urbanicity, and Birth

Weight. Sci Total Env. 176, 139–148. https://doi.org/10.1016/j.physbeh.2017.03.040

Eriksson, C., Lind, T., Ekström, S., Gruzieva, O., Georgelis, A., Bergström, A., Lõhmus, M., 2019. Neighbourhood greenness and birth outcomes in a Swedish birth cohort – A short communication. Heal. Place 57, 200–203. https://doi.org/10.1016/j.healthplace.2019.04.012

Fong, K., Hart, J.E., James, P., Medical, H., Pilgrim, H., Care, H., 2018a. A Review of Epidemiologic Studies on Greenness and Health: Updated Literature Through 2017 5, 77–87. https://doi.org/10.1007/s40572-018-0179-y

Fong, K., Kloog, I., Coull, B.A., Koutrakis, P., Laden, F., Schwartz, J.D., James, P., 2018b. Residential greenness and birthweight in the state of Massachusetts, USA. Int. J. Environ. Res. Public Health 15, 1–15. https://doi.org/10.3390/ijerph15061248

Glazer, K.B., Eliot, M.N., Danilack, V.A., Carlson, L., Phipps, M.G., Dadvand, P., Savitz, D.A., Wellenius, G.A., 2018. Residential green space and birth outcomes in a coastal setting. Environ. Res. 163, 97–107. https://doi.org/10.1016/j.envres.2018.01.006

Grazuleviciene, R., Danileviciute, A., Dedele, A., Vencloviene, J., Andrusaityte, S., Uždanaviciute, I., Nieuwenhuijsen, M.J., 2015. Surrounding greenness, proximity to city parks and pregnancy outcomes in Kaunas cohort study. Int. J. Hyg. Environ. Health 218, 358–365. https://doi.org/10.1016/j.ijheh.2015.02.004

James, P., Banay, R.F., Hart, J.E., Laden, F., 2015. A Review of the Health Benefits of Greenness. Curr Epidemiol Rep 10, 131–142. https://doi.org/10.3390/nu10030368

Kondo, M.C., Fluehr, J.M., McKeon, T., Branas, C.C., 2018. Urban green space and its impact on human health. Int. J. Environ. Res. Public Health 15.

https://doi.org/10.3390/ijerph15030445

Kottek, M., Grieser, J., Beck, C., Rudolf, B., Rubel, and F., 2006. World Map of the Köppen-Geiger climate classification updated. Meteorol. Zeitschrif 15, 259–263. https://doi.org/10.1127/0941-2948/2006/0130

Kruk, J., 2007. Physical activity in the prevention of the most frequent chronic diseases: An analysis of the recent evidence. Asian Pacific J. Cancer Prev. 8, 325–338.

Lange, T., Hansen, J. V, 2011. Direct and Indirect Effects in a Survival Context 22. https://doi.org/10.1097/EDE.0b013e31821c680c

Law, C., Baird, J., 2006. Developmental origins of health and disease: Public-health perspectives. Dev. Orig. Heal. Dis. 353, 446–455. https://doi.org/10.1017/CBO9780511544699.035

Lima, S.A.M., El Dib, R.P., Rodrigues, M.R.K., Ferraz, G.A.R., Molina, A.C., Neto, C.A.P., De Lima, M.A.F., Rudge, M.V.C., 2018. Is the risk of low birth weight or preterm labor greater when maternal stress is experienced during pregnancy? A systematic review and meta-analysis of cohort studies. PLoS One 13, 1–15. https://doi.org/10.1371/journal.pone.0200594

Markevych, I., Fuertes, E., Tiesler, C.M.T., Birk, M., Bauer, C.P., Koletzko, S., von Berg, A., Berdel, D., Heinrich, J., 2014. Surrounding greenness and birth weight: Results from the GINIplus and LISAplus birth cohorts in Munich. Heal. Place 26, 39–46. https://doi.org/10.1016/j.healthplace.2013.12.001

Miri, M., Alahabadi, A., Ehrampoush, M.H., Ghaffari, H.R., Sakhvidi, M.J.Z., Eskandari, M., Rad, A., Lotfi, M.H., Sheikhha, M.H., 2018. Environmental determinants of polycyclic aromatic hydrocarbons exposure at home, at kindergartens and during a commute. Environ. Int. 118, 266–273. https://doi.org/10.1016/j.envint.2018.06.006

Miri, M., Ghassoun, Y., Dovlatabadi, A., Ebrahimnejad, A., Löwner, M.O., 2019. Estimate annual and seasonal PM 1 , PM 2.5 and PM 10 concentrations using land use regression model. Ecotoxicol. Environ. Saf. 174, 137–145. https://doi.org/10.1016/j.ecoenv.2019.02.070

Nichani, V., Dirks, K., Burns, B., Bird, A., Morton, S., Grant, C., 2017. Green space and pregnancy outcomes: Evidence from Growing Up in New Zealand. Heal. Place 46, 21–28. https://doi.org/10.1016/j.healthplace.2017.04.007

Nieuwenhuijsen, M.J., Ristovska, G., Dadvand, P., 2017. WHO environmental noise guidelines for the european region: A systematic review on environmental noise and adverse birth outcomes. Int. J. Environ. Res. Public Health 14. https://doi.org/10.3390/ijerph14101252

Nieuwenhuijsen, M.J., Agier, L., Basagaña, X., Urquiza, J., Tamayo-Uria, I., Giorgis-Allemand, L., Robinson, O., Siroux, V., Maitre, L., de Castro, M., Valentin, A., Donaire, D., Dadvand, P., Aasvang, G.M., Krog, N.H., Schwarze, P.E., Chatzi, L., Grazuleviciene, R., Andrusaityte, S., Dedele, A., McEachan, R., Wright, J., West, J., Ibarluzea, J., Ballester, F., Vrijheid, M., Slama, R., 2019. Influence of the urban exposome on birth weight. Environ. Health Perspect. 127. https://doi.org/10.1289/EHP3971

Nieuwenhuijsen, M.J., Dadvand, P., Grellier, J., Martinez, D., Vrijheid, M., 2013. Environmental risk factors of pregnancy outcomes : a summary of recent meta-analyses of epidemiological studies. Environ. Heal. 12, 1. https://doi.org/10.1186/1476-069X-12-6

Province climate Khorasan Razavi meteoroligal organization [WWW Document], n.d. URL https://www.razavimet.ir/fa/node/38 (accessed 11.25.19).

Qi, J., Chehbouni, A., Huete, A.R., Kerr, Y.H., Sorooshian, S., 1994. A modified soil adjusted vegetation index. Remote Sens. Environ. 48, 119–126. https://doi.org/10.1016/0034-4257(94)90134-1

Rahmani, A., Abroudi, M., Heydari, H., Adli, A., Miri, M., 2020. Maternal exposure to ambient particulate matter and green spaces and fetal renal function. Environ. Res. 184. https://doi.org/10.1016/j.envres.2020.109285

Su, J.G., Dadvand, P., Nieuwenhuijsen, M.J., Bartoll, X., Jerrett, M., 2019. Associations of green space metrics with health and behavior outcomes at different buffer sizes and remote sensing sensor resolutions. Environ. Int. 126, 162–170. https://doi.org/10.1016/j.envint.2019.02.008

Ulrich R.S., 1984. View Through a Window May Influence Recovery from surgery 224.

Ulrich R.S., Simons R.F., Losito B, Fiorito E, M.A.M. and M.Z., 1991. Stress recovery during exposure to natural and urban environments 201–230.

Rojas-rueda, D., Nieuwenhuijsen, M.J., Gascon, M., Perez-leon, D., Mudu, P., n.d. Green spaces and mortality : a systematic review and meta-analysis of cohort studies. Lancet Planet. Heal. 3, e469–e477. https://doi.org/10.1016/S2542-5196(19)30215-3

Tingley, D., Yamamoto, T., Hirose, K., Keele, L., 2013. Mediation : R Package for Causal Mediation Analysis.

Twohig-Bennett, C., Jones, A., 2018. The health benefits of the great outdoors: A systematic review and meta-analysis of greenspace exposure and health outcomes. Environ. Res. 166, 628–637. https://doi.org/10.1016/j.envres.2018.06.030

United Nations, 2018. World Urbanization Prospects 2018, Webpage.

Wadhwa P.D. , Buss C., Entringer S., Swanson J.M., 2010. Developmental Origins of Health and Disease: Brief History of the Approach and Current Focus on Epigenetic Mechanisms.

TABLES

Table 1. Processing of visual access to greenspace questions.

Original question	Original categories	Conversions for our analyses	Variable named
Can you see plants, trees, grass, flowers, etc. from any window of your home?	1=Yes 2=No	None	Have a window with greenspace view
If yes, how often do you see the vegetation through the window (s)?	1=Rarely 2=Sometimes 3=Always	An additional category was set to 0=Never for those participants who answered No in the previous question. We dichotomized the answers in: 1 or 0 as non-frequent 2 or 3 as frequent	Frequent viewing of greenspace through window
If yes, what proportion of the window surface is covered by vegetation? (If there are multiple windows, please describe the window most used)	1=25% 2=50% 3=100%	An additional category was set to 0=0% if the previous answer was Never or Rarely. We dichotomized the answers in: 0 or 1 as less than half 2 or 3 as more than half50%	Window area covered by greenspace

Table 2. Description of the characteristics of the study participants, birth outcomes and indicators of exposure to greenspace.

Variable	**Description (n=301)**
Maternal, pregnancy factors and lifestyle	
Maternal age (y) (median, IQR)	27.5 (8)
Sex of the child (n, %)	
Male	151 (50.2%)
Female	150 (49.8%)
Previous pregnancies (n, %)	
Yes	284 (94.3%)
No	17 (5.6%)
Exposure to tobacco at home (n, %)	
Yes	62 (20.6%)
No	239 (79.4%)
Maternal Body Mass Index (BMI, kg/m2) (median, IQR)	24 (5.3)
Birth weight (g) (median, IQR)	3260 (590)
Gestational age (weeks) (median, IQR)	39.7 (1.7)
Socioeconomic characteristics	
Maternal education (n, %)	
Elementary	90 (29.9%)
High school	134 (44.5%)
University	77 (25.6%)
Paternal education (n, %)	
Elementary	130 (43.2%)
High school	105 (34.9%)
University	66 (21.9%)
Percent of illiterate per census tract (median, IQR)	24.4 (14.8)
Percent of unemployment per census tract (median, IQR)	7 (4.7)
Income (n, %)	
<1.5 milion	225 (74.7%)
1.5-3milion	62 (20.6%)
>3milion	14 (4.6%)
Type of house (n, %)	
Apartment	158 (52.5%)
House	143 (47.51%)
Indicators of greenspace	
Residential surrounding greenspace (NDVI, range:-1 to 1)	
100m buffer (median, IQR)	0.06 (0.01)
300m buffer (median, IQR)	0.07 (0.01)
500m buffer (median, IQR)	0.07 (0.01)
Visual access	
Have a window with greenspace view (n, %)	
Yes	177 (58.8%)
No	124 (41.2%)
Frequent viewing of greenspace through window (n, %)	
Yes	99 (32.9%)
No	202 (67.1%)
Window area covered by greenspace (n, %)	
>50%	72 (23.9%)
≤50%	229 (76.1%)
Residential proximity to green space (m)	
Distance to any green space (median, IQR)	92.5 (121.9)

Distance to ≥5000m^2 green space (median, IQR)	175.4 (225.3)
Use of green spaces (hours/week)	
Time spent in public green spaces (median, IQR)	2 (5)
Time spent in public and private green spaces (median, IQR)	3 (5.5)
Plants	
Number of plant pots (n) (median, IQR)	2 (6)

Table 3. Linear regression models for exposure to greenspace indicators and difference in average of birth weight (g) and corresponding 95% confidence interval. Regression coefficients for 1-IQR increase in each continuous indicator of exposure to greenspace and for 1-category difference in each categorical indicator (visual access).

Indicator of exposure to greenspace		**Estimate (95% CI)**
Residential surrounding greenspace		
100m buffer	Unadjusted	**50.4 (13.0, 87.8)***
	Adjusted [(a)]	**42.7 (4.7, 80.8)***
300m buffer	Unadjusted	31.6 (-6.2, 69.6)
	Adjusted	34.6 (-3.3, 72.5)
500m buffer	Unadjusted	33.7 (-14.5, 82.0)
	Adjusted	38.2 (-9.9, 86.3)
Visual access		
Have a window with greenspace view (1)	Unadjusted	17.4 (-74.7, 109.6)
	Adjusted	-10.2 (-102.1, 81.6)
Frequent viewing of greenspace through window (2)	Unadjusted	**96.7 (0.7, 192.7)***
	Adjusted	**100.0 (4.9, 195.2)***
Window area covered by greenspace (3)	Unadjusted	**203.4 (99.5, 307.3)***
	Adjusted	**192.5 (88.8, 296.1)***
Residential proximity to green space		
Distance to any green space	Unadjusted	**-65.0 (-126.3, -3.7)***
	Adjusted	**-64.4 (-124.7, -4.1)***
Distance to a green space with area >5000m^2	Unadjusted	-11.1 (-73.7, 51.5)
	Adjusted	-13.4(-78.9, 48.0)
Use of green spaces		
Time spent in public green spaces	Unadjusted	**175.2(123.1, 227.2)***
	Adjusted	**168.9 (116.4, 221.4)***
Time spent in public and private green spaces	Unadjusted	**91.6 (55.5, 127.6)***
	Adjusted	**88.8 (53.1, 124.6)***
Number of plant pots		
	Unadjusted	40.8 (-4.5, 86.2)
	Adjusted	39.3 (-5.9, 84.5)

[(a)] All the adjusted models were adjusted for: gestational age, maternal age, BMI of mother before pregnancy, number of previous pregnancies, percent of illiterate per census tract, percent of unemployment per census tract, paternal education, maternal education, income and tobacco exposure at home

* $p<0.05$

Table 4. Percentage of mediation (95% Confidence Interval) of the association between residential surrounding greenspace at 100m buffer and birth weight by air pollution and visual access to greenspace.

	Percentage of mediation	
Mediators	**Estimate (95% CI)**	**p-value(*)**
Air pollution:		
PM_1	9% (-80%, 140%)	0.712
$PM_{2.5}$	30% (-110%, 300%)	0.352
PM_{10}	105% (-80%, 160%)	0.530
Visual access:		
Have a window with greenspace view	-1% (-40%, 20%)	0.816
Frequent viewing of greenspace through window	8% (-40%, 30%)	0.560
Window area covered by greenspace	10% (-16%, 0.9%)	0.860

(*) level of statistical significance $p<0.05$

FIGURE LEGENDS

Figure 1. Study area, location of air pollution monitoring stations, roads and vegetation cover in different parts of Sabzevar city.

Figure 2. Correlation matrix between the different indicators of exposure to greenspace. The correlation coefficient was estimated by different methods depending on the variables: Spearman's correlation, poliserial correlation or polychoric correlation.

*Visual access 1= Have a window with greenspace view, Visual access 2= Frequent viewing of greenspace through window, Visual access 3= Window area covered by greenspace.

Figure 3. Linear regression adjusted [(a)] models for exposure to greenspace indicators and difference in average of birth weight (g) and corresponding 95% confidence interval stratified by maternal and paternal education. Regression coefficients for 1-IQR increase in each continuous indicator of exposure to greenspace and for 1-category difference in each categorical indicator (visual access).

[(a)]All the models were adjusted for: gestational age, maternal age, BMI of mother before pregnancy, number of previous pregnancies, percent of illiterate per census tract, percent of unemployment per census tract, paternal education, maternal education, income and tobacco exposure at home.
[(b)] p-value represents the p-value of each model.
* $p<0.05$