Greenness and allergies: evidence of differential associations in two areas in Germany

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ABSTRACT
Background Positive green effects on health are increasingly reported, although studies on allergic outcomes remain limited and conflicting. We examined whether residential greenness is associated with childhood doctor diagnosed allergic rhinitis, eyes and nose symptoms and aeroallergen sensitisation using two combined birth cohorts (GINIplus and LISAplus) followed from birth to 10 years in northern and southern Germany (Ntotal=5803).

Methods Mean residential greenness in a 500 m buffer around the 10-year home addresses was defined using the Normalized Difference Vegetation Index, a green biomass density indicator. Longitudinal associations were assessed per study area (GINI/LISA South and GINI/LISA North) using generalised estimation equations adjusted for host and environmental covariates.

Results Despite identical study designs and statistical modelling, greenness effects differed across the two study areas. Associations were elevated for allergic rhinitis and eyes and nose symptoms in the urban GINI/LISA South area. In contrast, risk estimates were significantly below one for these outcomes and aeroallergen sensitisation in rural GINI/LISA North. Area-specific associations were similar across buffer sizes and addresses (birth and 6 years) and remained heterogeneous after air pollution and population density stratification.

Conclusions Existing and future single-area studies on greenness and green spaces should be interpreted with caution.

INTRODUCTION
Recent studies generally indicate a beneficial relationship between green spaces and greenness and health outcomes.4–6 The evidence for allergies, however, remains limited and conflicting.7,8 The green environment may protect against allergies by increasing exposure to a greater number and diversity of microbes via mechanisms encompassed by the hygiene9 and biodiversity10 hypotheses, by encouraging outdoor play and by improving local air quality. However, the green environment is also a source of allergens, which may exacerbate allergic responses in themselves and via interactions with air pollutants.11

Using the “German Infant study on the influence of Nutrition Intervention plus environmental and genetic influences on allergy development” (GINIplus) and the “influence of Life-style factors on the development of the Immune System and Allergies in East and West Germany plus the influence of traffic emission and genetics” (LISAplus) prospective birth cohorts, we examined whether greenness around the home address was associated with allergic outcomes from 3 to 10 years in two areas in Germany. Associations were stratified by traffic-related air pollution levels, population density and parental education, as green effects on health may vary by urbanisation and socioeconomic status.3,4
Models were adjusted for age, sex, parental history of atopy, older siblings, maternal smoking during pregnancy, tobacco smoke exposure in the home (birth–4 years), cohort (GINIplus observation arm/GINIplus intervention arm/LISAplus) and parental education (highest number of years of education of either parent: <10 years, =10 years and >10 years).

Estimated concentrations of nitrogen dioxide (NO₂) and particulate matter with aerodynamic diameters less than 2.5 μg/m³ (PM₂.₅ mass), common measures of traffic-related air pollution, were derived from land-use regression models for the birth, 6- and 10-year addresses of participants. Population density in 5000 m buffers were obtained from the WiGeoGIS raster dataset with a spatial resolution of 125 m for 2008 and used as a proxy for urbanisation. Associations with NDVI were examined per area-specific NO₂, PM₂.₅ mass and population density tertiles. NDVI calculations were performed in ArcGIS 10.0 Geographical Information System (ESRI, Redlands, California, USA) and Geospatial Modelling Environment (Spatial Ecology LLC), and statistical analyses in R, V2.13.1 (http://www.R-project.org).

RESULTS

Health and NDVI data for at least one time point were available for 3306 children in GINI/LISA South and 2497 children in GINI/LISA North. The areas differed with respect to several population characteristics (see online supplementary material, table S1). For all buffers, surrounding greenness was lower for GINI/LISA South than GINI/LISA North (mean NDVI=0.35 (range 0.08–0.65) and 0.43 (0.18–0.65) for the 500 m buffer around the 10-year home addresses, respectively), and highly correlated across buffers and addresses (in combined population, Pearson’s correlation >0.7). Mean NO₂ and PM₂.₅ mass concentrations at the 10-year addresses were lower in GINI/LISA South (19.8 and 13.3 μg/m³, respectively) than GINI/LISA North (23.7 and 17.4 μg/m³, respectively).

Risk estimates for mean greenness in a 500 m buffer around the 10-year home address were elevated for doctor diagnosed allergic rhinitis and eyes and nose symptoms in GINI/LISA South (table 1). In contrast, estimates for GINI/LISA North were significantly below one for all outcomes. Associations were similar when stratified by indoor and outdoor aeroallergens. Adjustments for early-life farm and pet exposure slightly attenuated associations in GINI/LISA North only. Risk estimates were consistent across buffer sizes but generally not significant for the 3000 m buffer. Results were similar for greenness assessed at birth, 6- and 10-year addresses, especially for GINI/LISA North, but strongest at the latest address. Risk estimates for NDVI at the birth address appeared slightly stronger among those who never moved between birth and 10 years, although results were inconsistent across outcomes.

Table 1 Total and area-specific associations between mean greenness in a 500 m buffer around the home address at 10 years and health outcomes during the first 10 years of life*

<table>
<thead>
<tr>
<th></th>
<th>Total Population</th>
<th></th>
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<tbody>
<tr>
<td></td>
<td>N</td>
<td>OR (95% CI)</td>
<td>N</td>
<td>OR (95% CI)</td>
</tr>
<tr>
<td>Allergic rhinitis</td>
<td>4538</td>
<td>1.03 (0.89 to 1.19)</td>
<td>2531</td>
<td>1.16 (0.99 to 1.36)</td>
</tr>
<tr>
<td>Eyes and nose symptoms</td>
<td>4538</td>
<td>1.00 (0.88 to 1.14)</td>
<td>2530</td>
<td>1.15 (1.01 to 1.31)</td>
</tr>
<tr>
<td>Aeroallergen sensitisation</td>
<td>2799</td>
<td>0.96 (0.85 to 1.07)</td>
<td>1669</td>
<td>1.06 (0.94 to 1.20)</td>
</tr>
</tbody>
</table>

*Bold indicates statistically significant result (p<0.05).

DISCUSSION

Residential greenness was differentially associated with allergic outcomes up to 10 years among children living in two areas in Germany. In the urban GINI/LISA South area, greenness appeared positively associated with allergic rhinitis and eyes and nose symptoms. In contrast, greenness was negatively associated with these outcomes and aeroallergen sensitisation in the rural GINI/LISA North area.

Model adjustments for altitude, population density, individual-level socioeconomic status and air pollution were unable to explain the contrasting trends. We thus hypothesise that differences in greenness types (vegetation), which cannot be distinguished using NDVI values, may account for some risk estimate heterogeneity. Greenness in GINI/LISA South, a predominantly urban area, is likely more seminatural or artificial and possibly of higher allergenicity (because of lower biodiversity, introduction of exotic species, botanical sexism, etc, as described in Ref. 19). The positive associations for GINI/LISA South agree with this speculation. Furthermore, effects were strongest in areas with high PM₂.₅ mass concentrations, which is consistent with the hypothesis that air pollutants may increase pollen allergenicity. In contrast, the greenness in GINI/LISA North is more natural and agricultural, which may protect against allergy development. The negative associations observed for GINI/LISA North agree with this hypothesis. Furthermore, the protective effects of increasing greenness were strongest in areas with lower air pollution and population density, which are likely the areas least affected by urbanisation. However, these proposed explanations remain hypotheses that require confirmation. Indeed, NDVI effects may be mediated by several other possible mechanisms, such as access to areas for physical activity, stress reduction and improvement of positive social interactions and mental health.

Greenness was objectively estimated using a standardised protocol to participants’ home addresses implicitly assuming that a smaller distance to greenness represents a greater aeroallergen exposure. This assessment captured both large and small-scale green spaces, but did not allow vegetation types and allergenic potential to be determined. Further, ‘blueness’ effects could not be examined as very few children resided within 500 m of water. Data on greenness accessibility, time spent...
outdoors, indoor greenness and greenness around schools were also not available. However, associations were similar for greenness assessed at the birth, 6- and 10-year home addresses, especially for GINI/LISA North, and when alternative cloud-free days were used to assign NDVI estimates.

This study is large, although statistical power may be limited for the stratified analyses. Identical protocols were used during the longitudinal, prospective assessment of health outcomes and area-specific associations were consistent across outcomes, one of which was objectively measured. Although several covariates were considered, residual confounding remains possible. For example, although models were adjusted for parental education as a marker of socioeconomic status, we cannot rule out the possibility that further residual confounding by socioeconomic status, both at the individual and area levels, may be affecting the results. However, any potential confounder would have to be differently associated with greenness and allergic outcomes across the study areas.

The heterogeneous associations observed across study areas are the most important results of this study. Caution is warranted when interpreting existing and future single-area epidemiological investigations. Studies varying in geography, urbanisation, vegetation types, air quality and populations are required.

Figure 1 Area-specific associations between greenness in a 500 m buffer around the 10-year home address and doctor diagnosed allergic rhinitis (squares), eyes and nose symptoms (stars) and aeroallergen sensitisation (triangles) up to 10 years of age stratified by area-specific PM$_{2.5}$ mass, NO$_2$ and population density tertiles. Models are adjusted for age, sex, parental history of atopy, older siblings, maternal smoking during pregnancy, tobacco smoke exposure in the home (1–4 years), parental education and cohort. ORs and 95% CIs are presented per IQR increase in greenness exposure.

What is already known on this subject

Greenness and green spaces are increasingly associated with several measures of improved health. However, epidemiological investigations on allergic health outcomes are few and conflicting. Additional prospective, longitudinal studies are required to further clarify the role of green environment proximity on allergies.

What this study adds

Despite the use of identical study designs and statistical modelling, heterogeneous associations between greenness with allergic rhinitis were observed in two study areas in Germany. These observations further emphasise that the effect of greenness and health is complex and multifaceted, and needs to be examined across studies that vary in geography, urbanisation, vegetation types, air quality and populations.
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Competing interests None.

Ethics approval Local Ethics Committees approved both studies and written consent was obtained from parents of participants.

Provenance and peer review Not commissioned; externally peer reviewed.

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REFERENCES