Living Near Greener Spaces is Associated with Lower Risk of Diabetes-Related Mortality in Brussels, Belgium: a 13-Year Mortality Follow-up Study

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INTRODUCTION
Introduction

• Indicative evidence of a relationship between exposure to residential urban green spaces (UGS) and diabetes

Mechanisms:
• Increased opportunities for physical activity
• Restoration and stress reduction, improved mental health
• Mitigation of environmental hazards (e.g. air pollution)
• Modulation of immune responses through cell signaling inhibition

• Few studies have explored the association between UGS and diabetes-related mortality


Richardson, 2012; Xu, 2017; James, 2016; Crouse, 2017.
Study setting

• Brussels Agglomeration: ≈ 1.4 million inhabitants; 573 km².
• Functional unit in terms of living, working, trade, education, trade, cultural experience and leisure; regardless of administrative boundaries.

Objectives

• To assess the relationship between exposure to residential green spaces and diabetes-related mortality in the Brussels agglomeration (Belgium).

• To examine potential effect modification by sociodemographic and socioeconomic characteristics in this association.
METHODOLOGY
Data design

**2001 Belgian Census**
- Detailed demographic and socio-economic information of the total population officially residing in Belgium

**National Mortality Database**: Register data on migration and mortality for the follow-up period 01 October 2001 – 31 December 2014 (13.25-year follow-up)
Data design

2001 Belgian Census

- Detailed demographic and socio-economic information of the total population officially residing in Belgium

National Mortality Database: Register data on migration and mortality for the follow-up period 01 October 2001 – 31 December 2014 (13.25-year follow-up)

Health outcomes

- **Diabetes-related mortality**: ICD-10 codes E10-E14.
  1. Diabetes as the original cause of death.
  2. Diabetes as any cause of death (immediate, intermediate, original or additional).
Data design

2001 Belgian Census

National Mortality Database: Register data on migration and mortality for the follow-up period 01 October 2001 – 31 December 2014 (13.25-year follow-up)

Residential living environment

Detailed demographic and socio-economic information of the total population officially residing in Belgium

Link to residential address
Data design

2001 Belgian Census

National Mortality Database: Register data on migration and mortality for the follow-up period 01 October 2001 – 31 December 2014 (13.25-year follow-up)

Residential living environment

Exposure to residential urban green spaces (UGS)

1. **Surrounding greenness**: Normalised Difference Vegetation Index (NDVI) within a 300m buffer (30m x 30m resolution); Landsat 5.
Data design

2001 Belgian Census

National Mortality Database: Register data on migration and mortality for the follow-up period 01 October 2001 – 31 December 2014 (13.25-year follow-up)

Residential living environment

Detailed demographic and socio-economic information of the total population officially residing in Belgium

Methodology

Exposure to residential urban green spaces (UGS)

1. Surrounding greenness: Normalised Difference Vegetation Index (NDVI) within a 300m buffer (30m x 30m resolution); Landsat 5.

2. Perceived neighbourhood greenness: % of households in the statistical ward reporting very good provision of green spaces in their neighbourhood.
Covariates

SOCIODEMOGRAPHIC CHARACTERISTICS

• Age
• Gender
• Household Living Arrangement: Single; Cohabiting.
• Migrant Background: Belgian; Other High-Income Country (HIC); Low and Middle-Income Country (LMIC).

(INDIVIDUAL) SOCIOECONOMIC POSITION

• (Highest) Educational Level: Tertiary; Higher Secondary; Lower Secondary; Primary/No Formal Education.
• Housing Tenure: Owner; Tenant.

(NEIGHBOURHOOD) SOCIOECONOMIC POSITION

• Percentage of Unemployment in the Statistical Ward Among the Total Active Working Population.
FIRST OBJECTIVE: Association between the two indicators of exposure to residential UGS (surrounding and perceived neighbourhood greenness) and each outcome of diabetes-related mortality (both diabetes as the original cause of death and diabetes as any cause of death)

• Cox proportional hazards models using age as the underlying time scale.
  • Hazard Ratios (HR) and 95% Confidence Intervals (95%CI)
  • Models adjusted by gender, migrant background, educational level, housing tenure, household living arrangement, PM$_{2.5}$ and neighbourhood SEP
  • Confounders included by stepwise entry

SECOND OBJECTIVE: Effect modification by demographic and socioeconomic characteristics

• Effect modification analyses
  • Interaction terms (UGS ## demographic and socioeconomic characteristics) and stratification
GREEN & QUIET BRUSSELS

RESULTS
Results

Table 1. Baseline characteristics of the study population and mortality and migration during follow-up (2001-2014).

<table>
<thead>
<tr>
<th></th>
<th>Women (N = 253,533)</th>
<th>Men (N = 220,832)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Age at Baseline, mean (SD)</td>
<td>56.1 (11.1)</td>
<td>57.2 (11.5)</td>
</tr>
<tr>
<td>Diabetes as the Original Cause of Death, N (%)</td>
<td>684 (0.3)</td>
<td>661 (0.3)</td>
</tr>
<tr>
<td>Diabetes as Any Cause of Death, N (%)</td>
<td>2,442 (1.0)</td>
<td>2,899 (1.3)</td>
</tr>
<tr>
<td>Emigrations, N (%)</td>
<td>11,161 (4.4)</td>
<td>13,065 (5.9)</td>
</tr>
<tr>
<td>Migrant Background, N (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Belgian</td>
<td>191,294 (75.5)</td>
<td>160,906 (72.9)</td>
</tr>
<tr>
<td>Other HIC</td>
<td>38,220 (15.1)</td>
<td>34,147 (15.5)</td>
</tr>
<tr>
<td>LMIC</td>
<td>24,019 (9.5)</td>
<td>25,779 (11.7)</td>
</tr>
<tr>
<td>Educational Level, N (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tertiary</td>
<td>67,692 (26.7)</td>
<td>73,842 (33.4)</td>
</tr>
<tr>
<td>Higher Secondary</td>
<td>57,545 (22.7)</td>
<td>46,226 (20.9)</td>
</tr>
<tr>
<td>Lower Secondary</td>
<td>63,810 (25.2)</td>
<td>50,725 (23.0)</td>
</tr>
<tr>
<td>Primary/No education</td>
<td>64,486 (25.4)</td>
<td>50,039 (22.7)</td>
</tr>
<tr>
<td>Housing Tenure, N (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Owner</td>
<td>168,059 (66.3)</td>
<td>147,311 (66.7)</td>
</tr>
<tr>
<td>Tenant</td>
<td>85,474 (33.7)</td>
<td>73,521 (33.3)</td>
</tr>
<tr>
<td>Household Living Arrangement, N (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single</td>
<td>67,296 (26.5)</td>
<td>45,638 (20.7)</td>
</tr>
<tr>
<td>Cohabiting</td>
<td>153,658 (60.6)</td>
<td>164,698 (74.6)</td>
</tr>
<tr>
<td>Other</td>
<td>32,579 (12.9)</td>
<td>10,496 (4.8)</td>
</tr>
</tbody>
</table>

- Study population of **474,365** individuals between 40 and 80 years old and officially residing in the Brussels agglomeration in 2001.
## Results

Table 2. Median, interquartile range (IQR), and correlation matrix between indicators of the residential living environment and area-level SEP. Brussels agglomeration, 2001-2014.

<table>
<thead>
<tr>
<th></th>
<th>Median (IQR)</th>
<th>Perceived neighbourhood greenness</th>
<th>PM$_{2.5}$ [$\mu$g/m$^3$]</th>
<th>% Unemployment in the statistical ward</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surrounding greenness</td>
<td>0.5 (0.4 - 0.6)</td>
<td>27.5 (11.5 - 40.8)</td>
<td>18.9 (18.2 - 19.5)</td>
<td>13.0 (9.4 - 19.2)</td>
</tr>
<tr>
<td>Perceived neighbourhood greenness</td>
<td>1.000</td>
<td>0.7952*</td>
<td>1.000</td>
<td></td>
</tr>
<tr>
<td>PM$_{2.5}$ [$\mu$g/m$^3$]</td>
<td>-0.6498*</td>
<td>-0.4998*</td>
<td>1.000</td>
<td></td>
</tr>
<tr>
<td>% Unemployment in the statistical ward</td>
<td>-0.6758*</td>
<td>-0.5507*</td>
<td>0.4688*</td>
<td>1.000</td>
</tr>
</tbody>
</table>

* $p < 0.001$
Results

Figure 1. Stepwise adjustment of the associations (HR) and confidence intervals (95%CI) between IQR increments of surrounding and perceived neighborhood greenness and diabetes-related mortality (both as the original cause of death and as any cause of death). Brussels agglomeration, 2001-2014.

Note: Cox proportional hazards models using age as the underlying time scale, follow-up period 1st October 2001 – 31st December 2014. Surrounding greenness IQR: 0.2; Perceived neighbourhood greenness IQR: 29.3.

M1: crude model (age as the underlying time scale)
M2: M1 + gender
M3: M2 + migrant background
M4: M3 + educational level + housing tenure + household living arrangement
M5: M4 + PM$_{2.5}$
M6: M5 + neighbourhood SEP
Results

**INTERACTION TERMS** between each residential UGS indicator and gender, migrant background, educational level and neighbourhood SEP were included in each fully adjusted model for both diabetes-related mortality outcomes.

- No significant interaction with migrant background and educational level was found.

- **Diabetes as the original cause of death**
  - *Surrounding greenness*: Significant interaction with neighbourhood SEP.
  - *Perceived neighbourhood greenness*: Significant interaction with gender.

- **Diabetes as any cause of death**
  - *Surrounding greenness and perceived neighbourhood greenness*: Significant interaction with gender.
Figure 2. Associations (HR) and confidence intervals (95%CI) of the association between IQR increments of surrounding greenness and diabetes as the original cause of death, by quartiles of neighbourhood SEP (% of unemployment in the statistical area). Brussels agglomeration, 2001-2014.

Note: Cox proportional hazards models using age as the underlying time scale, follow-up period 1st October 2001 – 31st December 2014. Model adjusted by gender, migrant background, educational level, housing tenure, household living arrangement and PM$_{2.5}$. Surrounding greenness IQR: 0.2. Quartiles of neighbourhood SEP (% of unemployment in the statistical ward): Q1 (1.4%-9.4%); Q2 (9.4%-13%); Q3 (13%-19.2%); Q4 (19.3%-56.3%).
Results

Figure 3. Associations (HR) and confidence intervals (95%CI) of the association between IQR increments of perceived neighbourhood greenness and diabetes as the original cause of death, by gender. Brussels agglomeration, 2001-2014.

Note: Cox proportional hazards models using age as the underlying time scale, follow-up period 1st October 2001 – 31st December 2014. Model adjusted by migrant background, educational level, housing tenure, household living arrangement and PM$_{2.5}$ and neighbourhood SEP.

Perceived neighbourhood greenness IQR: 29.3.
Results

Figure 4. Associations (HR) and confidence intervals (95%CI) of the association between IQR increments of *surrounding and perceived neighbourhood greenness* and *diabetes as any cause of death*, by gender. Brussels agglomeration, 2001-2014.

**Diabetes as any cause of death**

**Surrounding greenness**

**Perceived neighbourhood greenness**

*Note:* Cox proportional hazards models using age as the underlying time scale, follow-up period 1st October 2001 – 31st December 2014. Model adjusted by migrant background, educational level, housing tenure, household living arrangement and PM$_{2.5}$ and neighbourhood SEP. Surrounding greenness IQR: 0.2; Perceived neighbourhood greenness IQR: 29.3.
Limitations

• Unable to control for lifestyle factors
• No time-varying information on covariates available
• Residential address at baseline
• Exposure misclassification (only based on residential address)
• No information on quality of green spaces

Strengths

• Large register dataset
• High resolution living environment indicators
• Individual exposure
• Subjective indicator of residential urban green space
• Long follow-up (13.25 years)
CONCLUSIONS
Conclusions

• **Living near greener spaces** might help *reduce the risk of diabetes-related mortality*.

• Higher levels of **surrounding greenness** near the residence might *especially reduce the risk* of death from diabetes as the original cause in *deprived neighbourhoods*.

• **Perceived neighbourhood greenness** is inversely associated with both indicators of diabetes-related mortality among *women*, but not among men.

• Further research is needed in order to elucidate the mechanisms underlying these associations.
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