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Residential greenness and risk of prostate cancer: A case-control study in Montreal, Canada

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ABSTRACT

Background: Recent studies suggest that exposure to greenness favors several health outcomes. We assessed whether living in the proximity of greener areas was related to prostate cancer incidence in a population-based case-control study in Montreal, Canada.
Materials and methods: Interviews eliciting lifetime addresses were conducted with 1933 prostate cancer cases diagnosed in 2005–2009 and 1994 population controls. Odds ratios (OR) and 95% confidence intervals (CI) estimated the association between residential greenness, both at recruitment (2005–2009) and about ten years prior (1996), defined by the normalized difference vegetation index (NDVI) around the home, and prostate cancer risk. Three models were developed adjusting for age, individual characteristics, and individual and ecological characteristics, estimating relative risk in relation to an interquartile range (IQR) increase of the NDVI.
Results: We observed inverse associations between greenness measured within home buffers of 150 m, 300 m, 500 m and 1000 m, at both time points, and risk of prostate cancer, independently of individual and ecological characteristics. For instance, using a buffer of 300 m, the OR for an IQR increase of 0.11 in NDVI at the time of recruitment was 0.82 (95%CI 0.74–0.92). The corresponding OR for an IQR increase of 0.15 in NDVI in 1996 was 0.86 (95%CI 0.74–1.00). There were little differences in risks according to buffer size, the time point of exposure, when considering prostate cancer aggressiveness, or when restricting controls to men recently screened for prostate cancer to reduce the likelihood of undiagnosed cancer among them.
Conclusion: Men living in greener areas, either recently or about a decade earlier, had lower risks of prostate cancer, independently of socio-demographic and lifestyle factors. These observations are novel and require confirmation.

1. Introduction

The causes of prostate cancer (PCa) remain elusive. The currently recognized risk factors are age, family history and Sub-Saharan ancestry. Other factors showing suggestive evidence include obesity, alcohol intake, physical activity, air pollution and exposure to pesticides (Koutros et al., 2013; Kruk and Czerniak, 2013; McGregor et al., 2013; WCRF and AICR, 2014). Genetic factors identified to date explain only a modest proportion of familial risk (Eeles et al., 2014).

It has long been suspected that some PCa have environmental origins (Haas and Sakr, 1997; Hsing and Chokkalingam, 2006), with supporting evidence from migrant studies (Haenszel and Kurihara, 1968). Striking geographic variations in PCa occurrence and progression are observed at international, national, and local levels (Klassen and Platz, 2006). The use of spatially referenced data thus represents a promising approach to better understand the factors associated with this cancer.

Evidence is accruing for a beneficial effect of a natural outdoor environment in health (Bowler et al., 2010). For instance, use of spatial data has recently suggested an association between exposure to greenness and a lower risk of all-cause (non-accidental) and cancer mortality in women (James et al., 2016).

Neighborhood greenness has been associated with increased physical activity, lower odds of being overweight or obese, and lower exposure to air pollution (Hartig et al., 2014; James et al., 2015), each of which may in turn influence PCa risk (Parent et al., 2013; WCRF and AICR, 2014; Wekesa et al., 2015).

Abbreviations: PCa, prostate cancer; PSA, prostate screening antigen; DRE, digital rectal examination; NDVI, normalized difference vegetation index; CI, confidence interval.

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To our knowledge, the association between living in greener areas, recently and in the past, and PCa incidence has never been documented. Using data collected as part of a large case-control study conducted in Montreal, we assessed whether residential greenness was associated with PCa incidence at the time of diagnosis or recruitment, as well as about a decade earlier to take into account a potential latency period (Salinas et al., 2014). A wide array of potential personal and contextual factors, including PCa screening practices, was considered.

2. Materials and methods

2.1. Study population

We used data from The Prostate Cancer & Environment Study (PROtEuS), a large population-based case-control study conducted in Montreal, Canada. This study has been described previously (Blanc-Lapierre et al., 2015).

Eligible participants were men younger than 76 years old at diagnosis or selection, who were residents of the greater Montreal area (Montreal Island, North and South Shores), and registered on Quebec's permanent electoral list (continually updated). Cases were all patients newly diagnosed with primary PCa, actively ascertained through pathology departments across French-speaking hospitals in the Montreal area between September 2005 and December 2009. This covered over 80% of all PCa cases diagnosed in Montreal during the study period. Control subjects were selected concurrently from the population-based provincial electoral French-speaking list, and frequency-matched to cases by 5-year age group. Potential controls with a history of PCa were excluded.

Participation rates among eligible subjects were 79.4% for cases and 55.5% for controls.

2.2. Data collection

Between 2005 and 2012, in-person interviews collected information on socio-demographic characteristics, family history of cancer, medical history, PCa screening history, lifetime physical activity, smoking, alcohol consumption, dietary intake, and self-reported weight and height. The degree of aggressiveness of PCa, defined by the Gleason score, was extracted from prostate biopsy pathology reports. Residential addresses at the time of diagnosis of cases were extracted from hospital records; those of controls were obtained from electoral lists at the time of recruitment. Lifetime residential addresses were elicited through follow-up telephone interviews. All addresses were geocoded with the ArcGIS geographic information system (GIS, ESRI, Redlands, CA) using the geodatabase "Adresses Québec" that covers the whole province of Quebec, then linked to greenness exposure variables.

Exposure to nitrogen dioxide ($N0_2$) was used as a marker of traffic-related air pollution. Using land-use regression models, concentrations of NO_2 at the subjects' home address at index date were estimated at a resolution of 5 m^2 for people living in the Island of Montreal (Crouse et al., 2009a; Parent et al., 2013). Annual exposure averages were based on measurements taken on three occasions (spring, summer and winter). NO_2 values were only available for a subset of our sample (1242 cases and 1239 controls) as the survey was conducted on the Montreal Island and did not cover subjects living on the North or South Shores.

2.3. Residential greenness exposure

PCa tumors in older men are thought to have a latency period of 10 years between initial growth and their clinically detectable state, with a shorter period for those younger (Salinas et al., 2014). With a potential etiological role in mind, it was thus of interest to look at past greenness exposure. We selected two time points of exposure, i.e., the time of recruitment and 1996, the latter corresponding to about 10 years prior to the year of diagnosis of earlier cases (late 2005), or slightly longer for cases diagnosed in 2009. Assessing past exposure to greenness around or prior to the onset of tumor growth allowed us to consider address changes, and thus possible differences in greenness exposure, between the two time points. We elected to not assess earlier exposure, as errors in self-reported residential history could compromise analyses.

Satellite images covering the Montreal region, captured on August 5, 1996 and June 27, 2005 from Landsat TM5, were used to evaluate the greenness around the subjects' residences in 1996 and close to the time of diagnosis or recruitment (index date), respectively. Both images were corrected for atmospheric effects using the dark object subtraction method with the following assumptions: null downwelling diffuse irradiance and atmospheric transmittance equals to 1 (Song et al., 2001).

Landsat TM5 scans one location on Earth every 16 days. The normalized difference vegetation index (NDVI) for Montreal can only be calculated during summer months (late June to mid-September) as there is no green vegetation during winter, leading to about 6 timeslots for useable satellite imagery. Adding cloud cover constraints left only 1 image for 2005 (June 27, 2005), and we selected the August image for 1996, as vegetation had reached its highest level of photosynthesis activity.

Greenness was determined using the NDVI, an indicator of the density of green vegetation or biomass (Weier and David, 2000). Green vegetation reflects more infrared radiation and absorbs more energy in red wavelengths than non-vegetated surfaces. NDVI is calculated according to the level of reflectance of near-infrared (NIR) and visible red (VR) wavelength spectra detected by satellite. Using spectral data available at a 30-m by 30-m resolution (band 3 and 4), NDVI is calculated as: $NDVI = (NIR - VR) / (NIR + VR)$. Scores range from -1 to $+1$, with higher positive values indicating denser levels of healthy vegetation.

Average NDVI values from Landsat TM5 images were computed within 150 m, 300 m, 500 m and 1000 m radii buffers around each home address, for both time points (in 1996 and at the index date). Using several buffers of varying sizes allowed assessing sensitivity of exposure effects at various scales.

2.4. Statistical analyses

Odds ratios (OR) and 95% confidence intervals (CI) for the association between exposure to residential greenness and PCa risk were estimated using unconditional logistic regression models. A first model (Model 1) adjusted for age only. A second model (Model 2) adjusted for the following potential individual confounders: age (continuous), ancestry (Sub-Saharan, Asian, European, Other), first-degree family history of PCa (Yes, No), education (Elementary, High school, College, University), reported family income, in CAN$ (<20,000, 20,000–29,999, 30,000–49,999, 50,000–79,999, ≥80,000), marital status (married or common law, separated, divorced or widower, single, member of religious order, other), smoking (cigarette pack-years), alcohol consumption (drink-years), dietary habits (frequency of use of fruit and vegetables 2 years earlier) and a history of diabetes (Yes, No). A third model (Model 3) further adjusted for neighborhood material and social deprivation. The latter were represented by a deprivation index constructed by Pampalon et al. (2000) available at the Dissemination Area level (small census unit inhabited by 400–700 persons). The social and material deprivation indices were derived from a principal component analysis conducted on six census data variables (the proportion of persons without high-school diploma, the ratio of employment in the population, the average income, the proportion of persons who are separated, divorced or widowed, the proportion of single-parent families and the proportion of people living alone). The first resulting component reflects variations in education, employment and income, emphasizing the material aspect of deprivation. The second component reflects variations in the indicators associated with the social aspect of deprivation (the proportions of widowed, separated and divorced persons, of single-parent families and of persons living alone). For our