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A novel land use approach for assessment of human health: The relationship between urban structure types and cardiorespiratory disease risk

Weeberb João Réquia Júnior [a,b,*], Henrique Llacer Roig [b,1], Petros Koutrakis [a,2]

[a] Harvard University, United States
[b] University of Brasília, Brazil

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ABSTRACT

Extensive evidence shows that in addition to lifestyle factors, environmental aspects are an important risk factor for human health. Numerous approaches have been used to estimate the relationship between environment and health. For example, the urban characteristics, especially the types of land use, are considered a potential proxy indicator to evaluate risk of disease. Although several studies have used land use variables to assess human health, none of them has used the concept of Urban Morphology by Urban Structure Types (USTs) as indicators of land use. The aim of this study was to assess the relationship between USTs and cardiorespiratory disease risks in the Federal District, Brazil. Toward this end, we used a quantile regression model to estimate risk. We used 21 types of UST. Income and population density were used as covariates in our sensitivity analysis. Our analysis showed an association between cardiorespiratory diseases risk and 10 UST variables (1 related to rural area, 6 related to residential area, 1 recreational area, 1 public area and 1 commercial area). Our findings suggest that the conventional land use method may be missing important information about the effect of land use on human health. The use of USTs can be an approach to complement the conventional method. This should be of interest to policy makers in order to enhance public health policies and to create future strategies in terms of urban planning, land use and environmental health.

1. Introduction

Cardiorespiratory diseases represent a large fraction of the global burden of diseases (Mortimer et al., 2012). According to the World Health Organization (WHO, 2014), in 2012 cardiovascular and respiratory diseases were responsible for 17.5 and 4 million deaths globally, respectively. Studies have shown that in addition to lifestyle factors, environmental factors are considered as an important risk factor for cardiorespiratory diseases (O'Toole et al., 2008).

Researchers have used numerous approaches to investigate the relationship between environment and health. For example, they have investigated the effects of land use on human health and have reported effects of land use types on mental diseases (Villanueva et al., 2013), obesity (Wall et al., 2012; Fraser et al., 2012), body mass index (James et al., 2014) and cardiorespiratory diseases (Chum and O'Campo, 2015).

The assumption that air pollution is directly related to disease is based on the following: 1) Air pollution is considered an important cause of cardiorespiratory diseases (Buonanno et al., 2013; Gonzalez-Barcala et al., 2013); 2) Vehicle traffic is a significant source of air pollution (Réquia Júnior et al., 2015b; Réquia Júnior et al., 2015a; Song et al., 2012). For example, Lozano et al. (2012) estimated that the particulate matter — $PM_{2.5}$ (main pollutant emitted by vehicles) contributes to approximately two million premature deaths per year, ranking it as the 13th leading cause of worldwide mortality, and; 3) We expected to find higher concentration of vehicles in urban land use (especially in the city centers) than in surrounding areas (Cervero, 2013). Also, we expected to find higher concentrations of air pollutants in land use characterized by tall buildings, which minimize the dispersion of gases and particulates (Baik et al., 2012; Pirjola et al., 2012); 4) Consequently, we expected that the urban center (especially where there are high-rise buildings) is likely to be the critical type of land use in terms of human exposure to air pollutants.

Although several studies have explored land use variables to assess human health, none of them has introduced the concept of Urban Morphology by Urban Structure Types (USTs) as proxy indicators of land use. According to Heiden et al. (2012), USTs are spatial indicators, which describe the urban system through their physical properties (e.g., size, surface materials), their environmental characteristics (e.g., climate, hydrology) and their function properties (e.g., land use). The UST approach is more specific than the conventional method because

* Corresponding author at: 401 Park Drive, Landmark Center West, Boston, MA 02215, United States.
E-mail addresses: weeberb@gmail.com (W.J. Réquia Júnior), roig@unb.br (H.L. Roig), petros@hsph.harvard.edu (P. Koutrakis).
[1] Campus Darcy Ribeiro, Brasília, Distrito Federal 70910900, Brazil.
[2] 401 Park Drive, Landmark Center West, Boston, MA 02215, United States.

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it identifies different types of morphology in housing, industrial buildings, commercial buildings, public buildings, green areas and open spaces in terms of the amount, aggregation, vegetation, impervious surfaces, density, design and connectivity (Heiden et al., 2012; Weber et al., 2014b).

While the UST approach has been used in some types of research, such as the assessment of water consumption (Hofer, 2013), climate change risk (Moon et al., 2009), urban heat island (Weber et al., 2014a), and traffic-induced noise level (Weber et al., 2014b), there have been no health studies that have evaluated USTs as predictors for assessment of human exposure. Therefore, the aim of this study was to assess the relationship between USTs and risk of cardiorespiratory disease.

2. Materials and methods

2.1. Study area

The study was carried out in the Federal District (FD) region, where the city of Brasilia, the capital of Brazil, is located. The FD is between the parallels of 15° 30′ and 16° 03′ South Latitude and the meridians of 47° 25′ and 48°, 12′ West Longitude and covers an area of 5814 km^2 (Fig. 1).

Brasilia was founded in 1960 and was planned for approximately 600,000 inhabitants. The population in Brasilia increased to an estimated 2.8 million inhabitants by 2014, with a population density higher than 440 inhabitants/km^2. The population growth is concentrated in the 30 administrative regions (small towns, Fig. 1), which surround Brazil's capital. For 2030 a population of more than 3.7 million inhabitants is predicted in the FD. The main challenge of the substantial population growth in the FD is urban planning, which can impact directly the transportation system, environmental quality, and public health (IBGE, 2013).

2.2. Study design

We conducted a cross-sectional analysis of the association between USTs and hospital admissions. The study was performed in five stages (Fig. 2): i) data processing; ii) UST classification; iii) GIS technique used to consolidate a single geodatabase for health and USTs; iv) statistical analysis, and; v) sensitivity analysis.

2.3. Health data processing

The health data were provided by the National Health Database (Datasus, 2013). These data included the residential address of individuals admitted to FD hospitals between 2008 and 2013 for circulatory and respiratory illness.

Health data does not present a uniform spatial scale for addresses. In the FD the address system is composed of five levels of spatial scale. For some individuals, the address contains information just for level 1, for others individuals there is information just for levels 1 and 2, for others individuals just for levels 1, 2 and 3, and so on. Therefore, we summarized the health data with the purpose of combining hospital admissions for those who live in the same area (same address block) using the lowest area (address level) available for the data. Then we calculated the total (aggregation) counts of hospital admissions from each level of address. As a result, the total number of hospital admissions was 7307, which were grouped in 1547 address blocks.

We used the information from the census tracts to calculate the rate of hospital admissions (hospital admissions per population). These data were provided by IBGE (2012). The geographic polygons from the census tracts have different shapes and sizes compared with the polygons represented by the address blocks (health data). In this way, the population data was estimated for each health data polygon, taking into account the proportions of the areas of both the census tracts and the health data. As a result, 20 blocks (health data) presented populations below 1. Therefore, we removed these 20 blocks from the geodatabase, which then included 1527 address blocks (7269 hospital admissions). Fig. 3 shows the spatial distribution of the hospital admissions in the FD.

2.4. Urban structures type (UST) classification

The UST concept was developed in the 1960s and was used for urban planning in Germany's cities. Since then, the UST approach has been used in studies in order to understand the dynamic of the urban environment and to promote sustainable development (Raith, 2000).

USTs are spatial indicators, which describe an urban system using its physical properties, environmental characteristics, and function properties (Heiden et al., 2012) to describe the morphology of the city. According to Banzhaf and Höfer (2008), the UST approach considers the spatial scale (which ranges from the municipality to the building) and the amount of generalization (Appendix 1). For instance, Appendix 1 shows that the USTs can be defined using characteristics, such as density of features (density of buildings, urban structures per area), amount of green areas, and, connectivity between the features.

Different from the usual land use method deployed by environmental health studies, the UST method is more specific in terms of the spatial scale and amount of generalization. In Appendix 2, we compare the usual method and UST approach in a region of the FD.

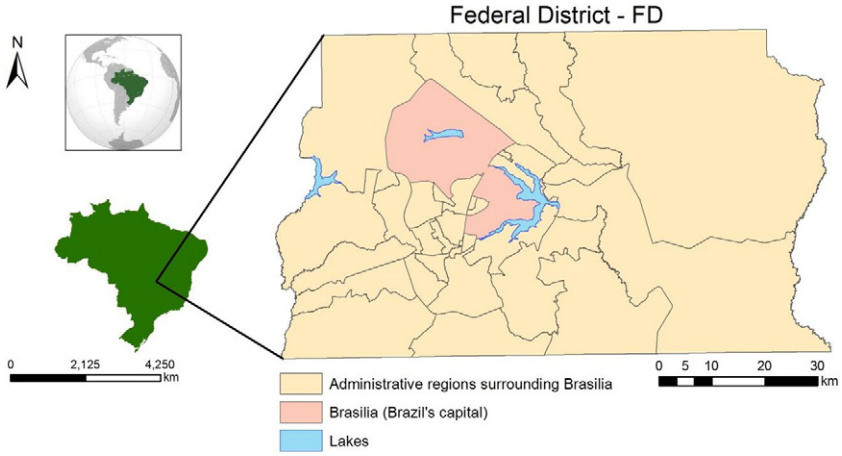

Fig. 1. Study area.