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Mapping distance-decay of cardiorespiratory disease risk related to neighborhood environments

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ABSTRACT

Neighborhood characteristics affect an individual's quality of life. Although several studies have examined the relationship between neighborhood environments and human health, we are unaware of studies that have examined the distance-decay of this effect and then presented the risk results spatially. Our study is unique in that is explores the health effects in a less developed country compared to most studies that have focused on developed countries. The objective of our study is to quantify the distance-decay cardiorespiratory diseases risk related to 28 neighborhood aspects in the Federal District, Brazil and present this information spatially through risk maps of the region. Toward this end, we used a quantile regression model to estimate risk and GIS modeling techniques to create risk maps. Our analysis produced the following findings: i) a 2500 m increase in highway length was associated with a 46% increase in cardiorespiratory diseases; ii) 46,000 light vehicles in circulation (considering a buffer of $\leq$500 m from residences) was associated with 6 hospital admissions (95% CI: 2.6, 14.6) per cardiorespiratory diseases; iii) 74,000 m^2 of commercial areas (buffer $\leq$1700 m) was associated with 12 hospital admissions (95% CI: 2.2, 20.8); iv) 1 km^2 increase in green areas intra urban was associated with less two hospital admissions, and; vi) those who live $\leq$500 m from the nearest point of wildfire are more likely to have cardiorespiratory diseases that those living $>$500 m. Our findings suggest that the approach used in this study can be an option to improve the public health policies.

1. Introduction

Neighborhood characteristics, which include the built environment, socioeconomic conditions and environmental factors affect an individual's quality of life. Studies have identified predictive relationships between these factors, social behaviors and human health (Sampson et al., 2002; Yen and Syme 1999; Pauleit and Duhme 2000; Baldauf et al., 2013). The prevalence of tobacco consumption has been shown to be positively correlated to the concentration of convenience stores within a neighborhood (Chuang et al., 2005). Neighborhoods with few parks and a low perceived safety were correlated to increased obesity rates in children (Wall et al., 2012). The design of the neighborhoods can both support and reduce the amount of physical activity by residents, particularly their walking and cycling rates (Sallis et al., 2012; Lee et al., 2007; Brian et al., 2012). The neighborhood built environment includes associations to mental illness (Villanueva et al., 2013) cardiovascular diseases (Chum and Patricia, 2015), noise and air pollution exposure (Adams and Kanaroglou, 2016; Weber et al., 2014) and body mass index (James et al., 2014).

The large body of research connecting the neighborhood environment with quality of life has supported the need for public and private-sector policies to promote healthier communities. Policies that improve the physical, social and service environments of neighborhoods (CBHA, 2015; Diez-Roux, 2007). The impact goes beyond quality of life, Nowak and Heisler (2010) demonstrate that the presence of green spaces in U.S neighborhoods provide a $500 million savings per year to the economy because the green spaces are responsible for air pollution removal, which is one of the main causes of cardiorespiratory disease (Mortimer et al., 2012;

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Buonanno et al., 2013; Valdés et al., 2012). Additionally, Wang et al. (2005) reported that every dollar invested in building bike and pedestrian trails reduces $3 dollars in medical costs.

Although several studies have examined the relationship between neighborhood environments and human health, we are unaware of studies that have examined the distance-decay of this effect and then presented the risk results spatially. Our study is unique in that is explores the health effects in a less developed country compared to most studies that have focused on developed countries. Specifically in Brazil, an example of country in development, to our knowledge there are no studies that have assessed the relationship between neighborhoods environments and health. The objective of our study is to quantify the distance-decay cardiorespiratory diseases risk related to 28 neighborhood aspects in the Federal District, Brazil and present this information spatially through risk maps of the region.

2. Materials and methods

2.1. Study design and overview

We conducted a cross-sectional study to examine the effects of neighborhood environment on hospital admissions for cardiorespiratory diseases. We examined the Federal District (FD) in Brazil, which is located in central Brazil at 15° 47′ 02″ S and 47° 49′ 09″W, the region has an area of 5802 km^2 and a population of 2.5 million. The health data were provided from the Brazilian National Health Database (Datasus, 2013) and included the residential addresses of individuals (all ages) admitted to FD hospitals between 2008 and 2013 for cardiorespiratory illness.

To preserve patient privacy the health data were provided at the *lote* address level. In the FD the address system is composed of five gradations, which include, from coarse to fine: i) administrative region - coarse, ii) sector, iii) street, iv) conjunct, and v) *lote* - fine. Only 560 of the 7307 hospital admissions were provided at the *lote* level, which occurred in 65 different *lote* areas. The sample size (N=7307) represents a subset with address information. In Table 1, we present the number of admissions and the number of different regions where an admission occurred by address level. Appendix 1 shows a map to provide context (spatial extent and scale) for each spatial unit of the FD address system.

The method used to link the health data to address blocks has previously been used by our research group (Réquia et al., 2015a, 2015b). In short, we used an address matching process directly with the blocks. There was no loss during the geolocation procedure.

2.2. Predictor variables

We generated 28 predictor variables that were used in the GIS processing and statistical analysis to explore their effects on hospital emissions for cardiorespiratory diseases. These variables were grouped into six categories: i) transportation - 6 variables, ii) land use - 10 variables, iii) air pollution inventory - 6 variables, iv) meteorological and terrain - 3 variables, v) demographic and economic - 2 variables, and vi) Natural Issues - 1 variable.

The transportation attributes consisted of the length of highways, the length of the streets and avenues, vehicle counts (light vehicles, heavy vehicles and motorcycles) and the number of bus terminals. The roads network and bus terminals data were provided by the Brazil Secretary of State for Habitation (Sedhab, 2012). The vehicle count data were obtained from three sources: the Transit Department of the FD (Detran, 2009), the Route Department (DER, 2010), and the report on Urban Transport of the FD - PDTU (GDF, 2008). The temporal scale of the vehicle count data is

Table 1
Health data structure.

Address level	Number of unique address blocks (geographic polygons)	Number of hospital admissions in all address blocks
1 – AR	0	0
2- Sector	37	1286
3- Street	361	3090
4- Conjunct	1084	2371
5- *Lote*	65	560
TOTAL	1547	7307

"AR: Administrative Region; TOTAL: aggregation".

daily average (Monday to Friday). Vehicle count data were assigned in the GIS to the corresponding road link (233 traffic roads). These 233 roads (approximately 615 km) do not represent the total road segments in the FD. It represent the roads linked to the vehicle count data provided. We present in Appendix 2 a map with the 233 traffic roads considered in our analysis.

The land use categories included industrial, commercial, urban, exposed soil, civil construction, and natural environment (water and green area). These areas were identified using the database provided by Sedhab (2012).

The air pollution category included vehicular emissions along the 233 traffic routes within the FD. This inventory was previously calculated by our research group and more information can be found in Réquia et al. (2015a, 2015b). We used a bottom-up method to estimate emissions for road segments, which were represented by the vectors. In order to create a surface to represent the vehicular emissions for the entire FD area, we used the Inverse Distance Weighting (IDW) interpolation method. CO_2 was the pollutant with the highest emissions, at more than 30 million tons. On average, approximately 130,000 tons of CO_2 are emitted per year among the 233 routes. Conversely, CH_4 exhibited the lowest emissions, approximately 4000 tons.

The meteorological and terrain category included temperature, humidity, and slope – relief. The temperature and humidity data were obtained from Environmental Institute of Brasilia (Ibram, 2013), and the slope – relief data were obtained from Sedhab (2012). We the IDW interpolation method to model a surface with the values of temperature and humidity.

The demographic and economic category included population and income. These data were obtained from the census tracts of the FD (IBGE, 2012). Natural issues included wildfire locations, which were provided by the National Institute of Spatial Research of Brazil (Inpe, 2013).

Table 2 presents a summary of all 28 attribute datasets that were explored in this study.

2.3. GIS techniques for estimating predictor variables

First, we defined 15 buffers around each of 1547 address blocks (Table 1). The buffers were specified using a logarithmic scale, as suggested by some air pollution monitoring studies (Su et al., 2009; Liu et al., 2009). The buffer sizes (meters) include 50, 500, 870, 1140, 1350, 1540, 1700, 840, 1,960, 2080, 2180, 2280, 2370, 2450, and 2520.

Subsequently, we used GIS techniques to estimate each predictor variable inside each buffer. This process was performed for all 1547 address blocks. For example, in the hypothetical address block "A" there is 1292 and 120,290 m of street and avenue within the 50 and 1350 m buffers, respectively (Fig. 1). All GIS calculations were performed in ESRI's ArcGIS, version 10.3.