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Risk factors in cardiovascular disease mortality associated with high exposure to vehicular traffic

Fatores de risco para mortalidade por doenças cardiovasculares associados à alta exposição ao tráfego veicular

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ABSTRACT: ***Objective:*** To identify areas and risk factors in cardiovascular disease (CD) mortality associated with air pollution from high exposure to vehicular traffic. ***Methods:*** Cross-sectional study of CD mortality in 2,617 individuals aged 45-85 years living in the urban area of Cuiabá and Várzea Grande, Mato Grosso State, Brazil, between 2009 and 2011. We used the residential proximity of up to 150 meters to a roadway of great vehicle flow as a proxy of high exposure to air pollution from vehicular traffic. The association between age, gender, income, and traffic intensity with vehicular traffic exposure was assessed through the multiple logistic regression. We conducted stratified analyses to observe the influence of seasons and groups of causes. We used Bernoulli's spatial model of probability to identify high-risk clusters. ***Results:*** Risk factors for CD mortality associated with high exposure to vehicular traffic were: living in census tracts with very unequal income (OR = 1.78; 95%CI 1.36 – 2.33), heavy traffic (OR = 1.20; 95%CI 1.01 – 1.43), and female gender (OR = 1.18; 95%CI 1.01 – 1.38). The CD mortality risk increases about 10% during the dry season period. We identified nine areas of risk. ***Conclusion:*** High exposure to traffic is associated with CD mortality in Cuiabá and Várzea Grande. Income inequality, traffic intensity, and female gender presented as the main determiners for this exposure. The dry season period enhances the effects of traffic exposure.

Keywords: Socioeconomic factors. Air pollution. Spatial analysis Epidemiological surveillance. Environmental management.

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RESUMO: ***Objetivo:*** Identificar áreas e fatores de risco para a mortalidade causada por doenças cardiovasculares (DC) associados à poluição do ar proveniente da alta exposição ao tráfego. ***Métodos:*** Estudo transversal da mortalidade por DC em 2.617 indivíduos de 45 a 85 anos residentes na zona urbana de Cuiabá e Várzea Grande, Mato Grosso, entre 2009 e 2011. Utilizou-se a proximidade residencial de até 150 metros de uma via de grande fluxo de veículos como *proxy* da alta exposição à poluição atmosférica proveniente do tráfego. A associação entre idade, sexo, renda e intensidade do trânsito com a exposição ao tráfego foi avaliada por meio de regressão logística múltipla. Foram realizadas análises estratificadas para observar a influência das estações do ano e dos grupos de causas. Utilizou-se modelo espacial de probabilidade de Bernoulli para identificação de áreas de risco. ***Resultados:*** Os principais fatores de risco para mortalidade por DC associados à alta exposição ao tráfego foram: residir em setores censitários com renda muito desigual (OR = 1,78; IC95% 1,36 – 2,33), trânsito intenso (OR = 1,20; IC95% 1,01 – 1,43) e sexo feminino (OR = 1,18; IC95% 1,01 – 1,38). O risco de mortalidade por DC aumenta cerca de 10% no período de seca. Foram identificadas nove áreas de risco. ***Conclusão:*** A alta exposição ao tráfego está associada à mortalidade por DC em Cuiabá e Várzea Grande. A desigualdade de renda, a intensidade do trânsito e o sexo feminino apresentaram-se como os principais determinantes dessa exposição, além da estação seca potencializá-la.

Palavras-chave: Fatores socioeconômicos. Poluição do ar. Análise espacial. Vigilância epidemiológica. Administração ambiental.

INTRODUCTION

The harmful effect of air pollution that results in cardiovascular diseases (CD) mortality has been widely demonstrated in literature[1]. Although the action mechanisms and characteristics of individuals still need to be identified more clearly, there is evidence that great part of the side effects for human health regarding air pollution in large urban centers may be attributed to emissions from vehicular traffic[2,3].

Car emissions represent a complex mixture of air pollutants, including carbon monoxide (CO), nitrogen oxides (NO_x), particulate matter (MP), sulfur dioxide (SO_2), and ozone (O_3). These emissions significantly contribute to the increase of air pollution levels, mainly around roadways[2]. Several epidemiological studies have pointed out that residential proximity to a great vehicle flow or to heavy traffic areas is associated with CD mortality[4-6].

The most observed dose-response relationship has been for a proximity of up to 150 meters to a roadway of great vehicle flow[3]. However, this relationship may considerably increase or decrease, depending on traffic intensity, concentrations and kinds of emitted pollutants, and weather conditions. Some authors have also reported that low socioeconomic populations may present higher residential exposure to traffic and air pollution[7,8]. In addition, factors such as age, gender, race, and medical conditions might also enhance the harmful air pollution effects related to human health[9-11].

Knowledge of the factors associated with CD mortality associated with high traffic exposure may provide comprehension on the different risks in several subgroups and subsidize the creation of more effective socioenvironmental policies. Furthermore, residential proximity to heavy vehicular traffic roadways is presented as a simple and viable solution to capture the local variation of exposure to pollutants related to traffic, mainly in areas where season data are not available. This study aims to identify areas and risk factors in CD mortality associated with air pollution from high exposure to vehicular traffic.

MATERIALS AND METHOD

STUDY DESIGN

Cross-sectional study to identify areas and factors that result in CD mortality associated with high exposure to vehicle traffic.

STUDY POPULATION AND AREA

The study was carried out in the cities of Cuiabá and Várzea Grande that form a large urban area with around 800 thousand residents in the metropolitan area of Vale do Rio Cuiabá in Mato Grosso, Brazil. The demographic density is about 155.19 residents/km^2 and there is a 96% urbanization level[12]. The fleet size has had a huge increase in the area. For instance, during the 2004-212 period, this growth presented a percentage variation of 118% for Cuiabá and 127% for Várzea Grande. The cities are surrounded by important roadways in the state and federal scenario, which are responsible for a great vehicle flow in the main roadways[13].

The study population comprises 2,617 individuals aged 45-85 years living in the urban area of Cuiabá and Várzea Grande that died due to CD (Chapter IX of the Tenth Review of the International Classification of Diseases — ICD-10 — codes I00 to I99) between January 1st of 2009 and December 31st of 2011.

DATA SOURCE

Population and socioeconomic information and city digital mesh per census tracts were obtained from the Brazilian Institutes of Geography and Statistics (IBGE) by using data of the 2010 census. The area's road mesh was granted by the city hall of Várzea Grande. CD mortality data including information of gender, age, residential address, and date of death were taken from the Mortality Information System (SIM) and provided by the State Department of Health from Mato Grosso.

DATA ANALYSES

The dependent variable was used for investigating the risk factors that cause CD mortality associated with pollution from high traffic exposure; and the independent variables were the potential factors associated with CD death (age, gender, income ratio of census tract, and date of death). Variables that presented $p \leq 0.2$ in univariate analyses were included in the multiple logistic regression model. The final model only included variables that presented $p \leq 0.05$. The maximum likelihood estimation test verified the significance of the variables in the final model. The model final adjustment was assessed through Hosmer-Lemeshow test.

The logistic regression is part of a category of statistical models called generalized linear models (GLM) that aims to predict a dichotomic result for single cases by means of Bernoulli's probability model. Thus, the perspective of success or failure is calculated and the analysis results are presented as the probability ratio: the odds ratio (OR). This is obtained through a comparison of individuals that are only different in the interest characteristic and that have the values of other constant variables, herein named as: living close or not close to a roadway of heavy traffic[3,14].

The residential addresses of each individual were georeferenced through *GPS visualizer* free program (http://www.gpsvisualizer.com/geocoder/) by using *Google maps* database. The individual exposure to traffic was assessed by means of distance calculations between the residency address and the date of death and the closest roadway. Structural and main roadways[4-6] were used according to the classification followed by city halls[15], because they are large-sized roadways that aim to receive more vehicles and more vehicular traffic.

Individuals were classified according to two categories: (0) individuals with low traffic exposure; and (1) individuals with high traffic exposure. High exposure was defined as an individual's residential proximity of up to 150 meters to at least a roadway with a great number of vehicles, whereas low traffic exposure is related to a residential proximity above 150 meters to roadways with great vehicle flow. The group with low traffic exposure was used as the reference category in the analysis.

Age was divided into: (0) 45 to 64 years old and (1) 65 to 85 years old. The date of death was used as an indirect measure of pollutant concentration. Weekdays were then divided, according to the traffic intensity, into: (0) light traffic (Saturdays and Sundays); and (1) heavy traffic (Mondays to Fridays). There are not data available regarding each individual profit; therefore, the census income ratio was used as a proxy of their socioeconomic condition, which was classified from percentile 90 into: not very unequal (≤ 5.2) and very unequal (> 5.2). The variable was calculated by dividing the proportion of individuals with an income lower than one minimum wage and the income higher than five minimum wages.

Stratified analyses were conducted to analyze the influence of seasons and groups of cause on CD mortality risk associated with high traffic exposure. Two categorical variables were used: (1) dry season period (May to October) and wet season period (November to April); (2) hypertensive heart diseases, ischemic heart diseases, and cerebrovascular diseases.

A purely spatial analysis was performed to identify high-risk clusters for CD mortality associated with high vehicular exposure, in which Bernoulli's probability model was used under a round ray of 1,713.86 meters[16] and considering a cluster of up to 50% of the risk population. The parameters used in this exam were: number of deaths per census tract (adjusted by gender, age, and income ratio) and plane coordinates (UTM Projection, South Fuse 21, metric units) of the centroids from the census tracts. Each potential cluster followed a maximum likelihood estimate to test the null hypothesis for spatial randomization[17]. The p-value was obtained through Monte Carlo tests (999 iterations) at a 5% significance level. Only statistically significant clusters were considered.

The logistic regression analyses were conducted using the SPSS 20 program. The spatial scan statistical tests were performed in the SaTScan™ software, version 9.3 (www.satscan.org). Calculation of the residential distances and map edition were carried out at ArcGis 10. The Ethics Committee of *Escola Nacional de Saúde Pública* approved this study under CAAE 18634613.0.0000.5240.

RESULTS

The total urban population of individuals aged 45-85 years from Cuiabá and Várzea Grande was around 492,040 residents, distributed into 1,160 census tracts based on 2010 census. About 48.02% of this population, distributed into 488 census tracts, were classified as living in areas of high vehicular traffic exposure, i.e. up to 150 meters distant to a roadway of great vehicle flow.

Between 2009 and 2010, 2,617 deaths were registered and 50.17% of them occurred in areas of great vehicular source. Among residents of these areas, the highest rate of deaths due to CD occurred in 65-85-year-old aged subjects (65.65%), in male individuals (54.07%), during the dry season period (53.62%), and in heavy traffic days (74.49%) (Table 1).

In the multivariate logistic model for the entire period, living in census tracts with very unequal income (OR = 1.78, 95%CI 1.36 – 2.33); heavy traffic days (OR = 1.20, 95%CI 1.01 – 1.43); and female gender (OR = 1.18, 95%CI 1.01 – 1.38) remained independently associated with death by CD in areas of high exposure to vehicle traffic. In the multivariate model stratified by seasons, the risk of CD mortality in these areas increases around 15% during the dry season period for all variables (Table 2).

In the multivariate model stratified by group of causes, only 'living in census tracts with a very unequal income' (OR = 2.03; 95%CI 0.99 – 4.18) remained a factor associated with deaths by hypertensive heart diseases in areas of high exposure to traffic. Only the variable 'heavy traffic days' (OR = 1.38; 95%CI 0.99 – 1.92) remained associated with deaths by ischemic heart diseases in these areas (Table 3).

Nine high-risk clusters for CD mortality related to high traffic exposure were identified. The highest related risk (RR) was observed for cluster 5 (RR = 2.04), while the lowest RR was seen for cluster 4 (RR = 1.58). The primary cluster (cluster 1), which is located in Cuiabá central part, included 111 census tracts and presented RR = 1.65 (Figure 1). The clusters remained the same before and after adjustment, but clusters 8 and 9 only presented statistical significance after adjustments by age, gender, and income inequality.

DISCUSSION

This paper results are in agreement with several recent studies[5,7,18,19], which show that a residential proximity of up to 150 meters to a roadway of great vehicle flow increases the risk in CD mortality. Residential proximity to traffic is a measure of indirect exposure used as a proxy of exposure to air pollutants from traffic. It has also been used to mainly characterize the chronic exposure to these pollutants, considering the residential place might

Table 1. Characteristics of the study population according to exposure classification.

	High exposure to vehicular traffic		Low exposure to vehicular traffic	
	n	%	n	%
Age (years)				
45 – 64	451	34.35	495	37.96
65 – 85	862	65.65	809	62.04
Gender				
Male	710	54.07	758	58.13
Female	603	45.93	546	41.87
Income of the census tracts				
Not very unequal	1,145	87.2	1,203	92.90
Very unequal	158	12.0	92	7.10
Group of mortality cause				
Ischemic heart diseases	303	23.08	309	23.70
Cerebrovascular diseases	251	19.12	244	18.71
Hypertensive heart diseases	359	27.34	347	26.61
Other diagnoses	400	30.46	404	30.98
Season period				
Wet	609	46.38	629	48.24
Dry	704	53.62	675	51.76
Traffic intensity				
Light traffic	335	25.51	381	29.22
Heavy traffic	978	74.49	923	70.78

Table 2. Multivariate logistic model of the determining factors of cardiovascular diseases mortality in high exposure areas to vehicular traffic pollution for the entire period and stratified by seasons.

	Entire period			Wet			Dry		
	OR	95%CI		OR	95%CI		OR	95%CI	
Income of the census tract									
Not very unequal	1.00	–	–	1.00	–	–	1.00	–	–
Very unequal	1.78*	1.36	2.33	1.76*	1.22	2.53	1.86*	1.24	2.80
Traffic intensity									
Light traffic	1.00	–	–	1.00	–	–	1.00	–	–
Heavy traffic	1.20*	1.01	1.43	1.07	0.83	1.38	1.34*	1.05	1.70
Gender									
Male	1.00	–	–	1.00	–	–	1.00	–	–
Female	1.17*	1.01	1.37	1.03	0.82	1.30	1.30*	1.05	1.62
Age (years)									
45 – 64	1.00	–	–	1.00	–	–	1.00	–	–
65 – 85	1.14	0.97	1.33	1.06	0.84	1.34	1.20	0.96	1.50

OR: *Odds Ratio*; 95%CI: 95% confidence interval; *p ≤ 0.05.

Table 3. Multivariate logistic model stratified by group of causes.

	Hypertensive			Ischemic			Cerebrovascular		
	OR	95%CI		OR	95%CI		OR	95%CI	
Income of the census tract									
Not very unequal	1.00	–	–	1.00	–	–	1.00	–	–
Very unequal	2.03*	0.99	4.18	2.01	1.21	3.35	1.26	0.77	2.05
Traffic intensity									
Light traffic	1.00	–	–	1.00	–	–	1.00	–	–
Heavy traffic	1.18	0.79	1.76	1.38*	0.99	1.92	1.07	0.78	1.47
Gender									
Male	1.00	–	–	1.00	–	–	1.00	–	–
Female	1.10	0.77	1.57	1.08	0.79	1.48	1.22	0.92	1.61
Age (years)									
45 – 64	1.00	–	–	1.00	–	–	1.00	–	–
65 – 85	1.37	0.94	1.99	1.27	0.94	1.72	1.06	0.79	1.42

OR: *odds ratio*; 95%CI: 95% confidence interval; *p ≤ 0.05.

be related to continuous exposure, which would make the effects gradual on health and cumulative throughout life[7,19].

Several authors have found that chronic exposure to air pollution from vehicular traffic increases the progression and instability of atherosclerosis through inflammatory processes, thus promoting other ischemic events[4,5,18] that not only create the disease, but also enhance an existing pathological condition[4,6]. Data analyzed in this study did not allow to define the correct time that the individual lives in the provided address and the place of death occurrence. However, our studies show more vulnerability of individuals that lived closer to roadways of great vehicle flow. Therefore, such relations might be associated with high exposure to several air pollutants, considering that vehicular traffic is one of the most important sources of air pollution in urban areas[18,20] and has been reported as an important risk factor in CD in many studies[1].

Living in areas of poor socioeconomic conditions has been associated with 78% of the mortality risk by CD associated with high exposure to traffic, which might double for hypertensive and ischemic heart disease bearers. Several authors have found that people with

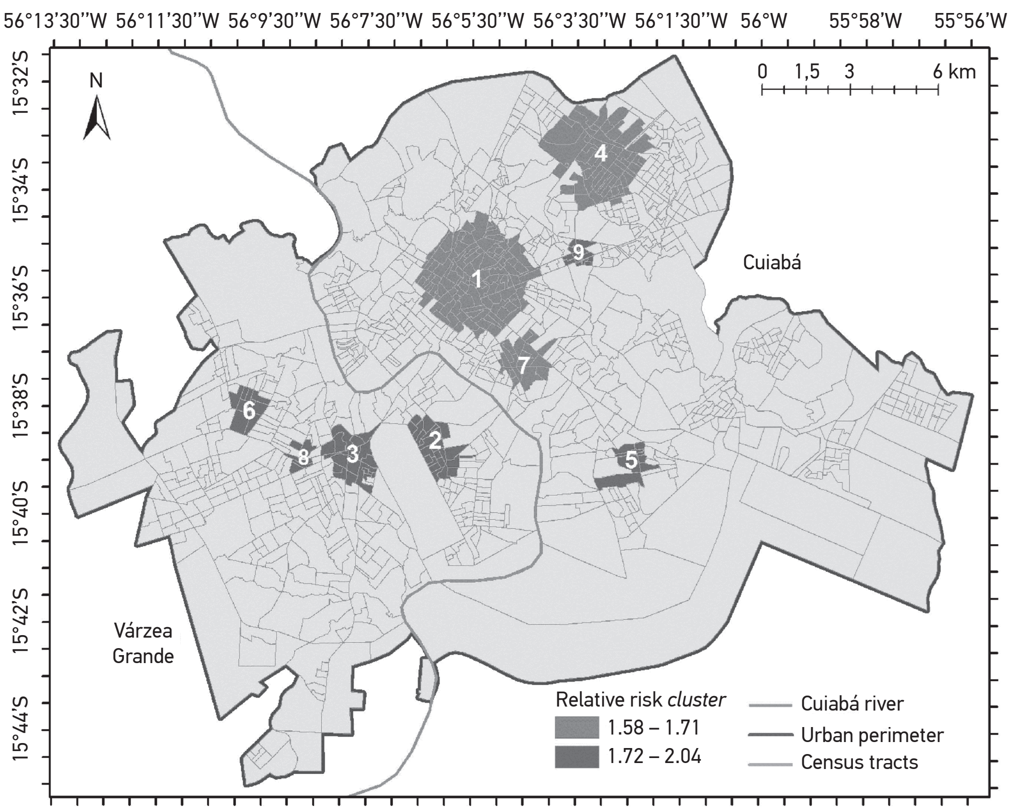

Figure 1. High-risk mortality clusters due to cardiovascular diseases related to high vehicular traffic exposure adjusted by age, gender, and income ratio.

lower socioeconomic status tend to live closer to roadways of great vehicle flow[7,8], mainly because these areas are not very valued by the real state market[21]. On the other hand, this relation might be associated with the fact that people of poor socioeconomic conditions might be exposed to a higher number of risk factors. Income inequality is connected to several social inequalities, such as low educational levels, poor households, preexisting morbidities, difficulty regarding health services access, as well as higher exposure to the most different environmental and occupational risks[22,23]. Some authors also believe that people with lower purchasing power tend to have more difficulties in modifying their risk behaviors, such as stopping smoking, enhancing their diet, and working out more, which could raise the expectation for cardiovascular diseases[21,24].

The female gender presented 17 to 30% of higher mortality risk due to CD related to high traffic exposure. Although the relation between gender and pollution is still contradictory in literature, many studies have observed that women are more susceptible to the effects of air pollution, especially adolescents and elderly or when the residential exposure assessment is used[25]. Increase of female gender risk has also been observed for CD morbimortality related to $PM_{2.5-10}$, O_3, NO_x and SO_2[9,11,26,27]. This association might be related to the biological mechanisms through which air pollution might affect men and women, such as size of airways, genetic factors, or hormone differences[11,28]. Another possibility is in different exposures and patterns of activities to which men and women would be related to, such as kind of physical activity, free air time, time spent on traffic, kind of diet, consumption of cigarettes and alcohol, stress, among others that are directly connected to psychosocial and socioeconomic factors[25,27].

An increase of almost 15% in the mortality risk by CD associated with high traffic exposure during the dry season period was observed. In the same region of the study, some authors observed an increase of morbidity and mortality during the same period. They approached that such advance is associated with increase of air pollutants related to the prevalence of biomass burns in the region[16,29-31]. Urban waste burning, which is a common practice in Cuiabá and Várzea Grande, can also contribute to the concentration increase of air pollutants, as well as to their toxicity, because they present more proximity of the individual and have a great mixture of toxic components (plastic, fuel, electronic device)[32]. The local weather variability should also be considered because weather parameters, such as temperature, humidity, and seasons, can change the effects of air pollution related to CD mortality[33-35].

The traffic activity presents strong patterns of daily, weekly and seasonal distribution; therefore, weekdays can be considered an indirect measure of the concentration of pollutants. Heavy traffic days present a 20-34% risk in CD mortality related to high traffic exposure in our study, which suggests that the higher the air pollutant concentration, the higher the death risk by CD. Higher concentrations of pollutants from traffic are usually observed in the beginning of the morning and in the end of afternoon ("rush hour") and, mainly, during business days (Mondays to Fridays), in which the traditional workflow happens. On the other hand, weekends, holidays and vacation months are correlated with lower concentrations of air pollutants[36,37]. In Cuiába, larger concentrations of PM_{10} were registered from Mondays to Fridays, not only in wet season periods but also in dry season periods, and the average weekly concentrations of PM_{10} reached 88 μg/m³ during the dry season period and did not overcome 33 μg /m³ during the wet season period[38].

High-risk clusters for CD mortality associated with high traffic exposure were identified in areas where the largest concentrations of roadways of great vehicle flow are located. The adjustment by income, age and gender inequality did not eliminate agglomerates, so the harmful effects of air pollution from traffic might occur independently of these factors. These areas show how priority actions regarding air pollution should be directed and point how the use of geoprocessing and spatial analysis techniques are useful tools to report on public policies and determine the areas that deserve specific intervention.

Padilla et al.[23,39] and Jerrett et al.[40,41] have used spatial analysis techniques to find priority areas of intervention and to test the efficiency of policy measures taken regarding the effects of urban air pollution. They discuss that air pollution might create or enhance socioeconomic inequalities regarding many diseases, including cancer, asthma, and CD[39,42]. Therefore, intervention and mitigation measures in high-risk areas should be considered a priority for the effects of air pollution.

The main limitation of this study concerns the measure of exposure to air pollutants from traffic, which are the result of residential address georeferencing. Considering that the address is a self-referred variable and there is a lack of standardization of city public areas, these may result in exposure classification mistakes. In addition, this study did not consider proximity to another roadway, amount and kinds of vehicle circulating through these roads, period of individual activity spent at home and/or traffic, traffic noises, weather conditions, time living in the provided address, topography and/or standards for land use, among other factors that might work as a cause, confusion or interact by changing the associations between air pollution and mortality. Anyhow, the results should be considered conservative, considering that inherent limitations point out underestimation of risks. It is noteworthy this is a cross-sectional epidemiological study of ecological base, in which it is not possible to stablish links of causality at individual level.

CONCLUSION

Living closer to roadways of great vehicle flow is related to a higher risk in CD mortality in elderly individuals from the cities of Cuiabá and Várzea Grande. In addition, the dry season period might enhance the effects of this exposure. The historical burns of the Southern Amazon are not the only source of air pollution in the region. Vehicular traffic and weather variability might significantly contribute to the harmful effects to human health. Other methodological designs might respond on the processes interfering in the dynamics of the health situation related to pollution from vehicular traffic in the area; however, our results might be useful as a basis for future analyses on the theme.

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