DOI: 10.1590/1980-549720190011

ORIGINAL ARTICLE / *ARTIGO ORIGINAL*

Socioeconomic factors increase the adverse effects of air pollution and temperature on mortality

Fatores socioeconômicos aumentam os efeitos nocivos da poluição atmosférica e da temperatura na mortalidade

Poliany Cristiny de Oliveira Rodrigues[I], Eliane Ignotti[I], Sandra de Souza Hacon[II]

ABSTRACT: ***Objective:*** To verify the effects of $PM_{2.5}$ and temperature on mortality due to cardiovascular diseases according to socioeconomic status and traffic proximity. ***Method:*** Time series were used, using the generalized additive models with the Poisson regression option, at 5% significance level. Interaction between proximity of traffic and socioeconomic status was analyzed through stratification. The proximity to the traffic was divided into distances up to 150m or over 150m. Socioeconomic status in the residential environment was categorized as high and low based on the median (3.9%). The relative risk percentage (%RR) of cardiovascular disease deaths was calculated for each linear increase of 10 $\mu g/m^3$ at $PM_{2.5}$ and 1°C at the maximum temperature. ***Results:*** Mortality due to cardiovascular diseases presented %RR 1.64 (95%CI -0.03; 3.33), related to the maximum temperature and %RR 4.60 (95%CI 0.78; 8.56) related to $PM_{2.5}$, in areas with high traffic exposure. In areas with poor living conditions, %RR 1.34 (95%CI -0.31; 3.01) was observed, related to maximum temperature and RR% 3.95 (95%CI -0.27; 8.34) associated with $PM_{2.5}$. ***Conclusion:*** Areas with poor living conditions and high-exposure to vehicular traffic had an increased risk of cardiovascular disease mortality related to high temperature and $PM_{2.5}$.

Keywords: Time series studies. Climate change.Heat. Vehicle Emissions. Particulate matter.

[I]Universidade do Estado de Mato Grosso – Cáceres (MT), Brazil.

[II]Escola Nacional de Saúde Pública, Fundação Oswaldo Cruz – Rio de Janeiro (RJ), Brazil.

Corresponding author: PolianyCristiny de Oliveira Rodrigues. Rua 7, Quadra D, Lote 6, Residencial Marechal Rondon,CEP: 78200-000, Cáceres, MT, Brazil. E-mail: polianyrodrigues@unemat.br

Conflict of interests: nothing to declare – **Financial support:** Rede Brasileira de Pesquisas sobre Mudanças Climáticas Globais (convênio FINEP/Rede CLIMA 01.13.0353.00).

RESUMO: ***Objetivo:*** Verificar os efeitos do $PM_{2,5}$ e da temperatura na mortalidade por doenças cardiovasculares segundo *status* socioeconômico e proximidade do tráfego. ***Método:*** Utilizaram-se séries temporais por meio da classe dos modelos aditivos generalizados com a opção de regressão de Poisson, a 5% de significância. Analisou-se interação entre a proximidade do tráfego e o *status* socioeconômico por meio de estratificação. A proximidade do tráfego foi dividida em maior e menor que 150 m de distância. O *status* socioeconômico no entorno residencial foi categorizado em Alto e Baixo a partir da mediana (3,9%). Calculou-se o percentual de risco relativo (%RR) dos óbitos por doenças cardiovasculares para cada aumento linear de 10 $\mu g/m^3$ nos níveis de $PM_{2,5}$ e 1ºC na temperatura máxima. ***Resultados:*** A mortalidade por doenças cardiovasculares apresentou %RR 1,64 (IC95% -0,03; 3,33) relacionada à temperatura máxima e %RR 4,60 (IC95% 0,78; 8,56) relacionada ao $PM_{2,5}$, em áreas com alta exposição ao tráfego. Em áreas com condições de vida precárias, observou-se %RR 1,34 (IC95% -0,31; 3,01) relacionada à temperatura máxima e %RR 3,95 (IC95% -0,27; 8,34) associada ao $PM_{2,5}$. ***Conclusão:*** Áreas com condições de vida precárias e com alta exposição ao tráfego apresentaram maior risco de mortalidade por doenças cardiovasculares relacionados à temperatura e ao $PM_{2,5}$.

Palavras-chave: Séries temporais. Mudanças climáticas. Calor. Emissões de veículos. Material particulado.

INTRODUCTION

Socioeconomic factors can modify the effects of exposure to particulate matter (PM) and temperature on human health[1]. In general, populations with worse living conditions are more affected by various health problems and are also more exposed to worse environmental conditions [2,3]. Some authors argue that negative environmental impacts can contribute to social health inequalities at local levels [3,4] while others refer to residential segregation as one of the main reasons why communities differ in relation to levels of exposure [1].

In scientific literature, three hypotheses have been discussed regarding the deleterious effects of temperature and pollution in certain subgroups. The first is related to differential exposure, i.e., the fact that groups with worse socioeconomic conditions may be more exposed to air pollution and extreme temperatures; the second refers to differential susceptibility, i.e., groups with precarious living conditions may be more susceptible to the effects of air pollution and temperature, because they have more overlapping risk factors, as well as difficulty in accessing health; and the third hypothesis suggests a multiplicative interaction of the first two factors, i.e., the combination of increased exposure and susceptibility [1,5].

Differential exposure may explain, in part, why the adverse effects of temperature and air pollution on the health of the population may differ according to the place of residence. The exposure to vehicular traffic can be a source of differential exposure to air pollution and temperature in the urban zone due to the high rate of paving and concrete constructions and the high emission of different pollutants [6,7].

Since the place of residence or the residential environment is the result of society's action on the space and its configuration incorporates the socioeconomic structure of a population, this study combines spatial techniques and time series analysis to verify the influence of socioeconomic status and vehicular traffic on the effects of fine particulate matter ($PM_{2.5}$) and temperature on mortality due to cardiovascular diseases (CVDs).

METHOD

STUDY DESIGN

A time series ecological study on the association between temperature and PM with mortality due to CVDs, stratified by socioeconomic status and traffic exposure.

POPULATION AND STUDY AREA

The study population is composed of individuals over 45 years of age living in the urban area of the municipalities of Cuiabá and Várzea Grande between April 2009 and December 2011. Deaths due to CVDs were selected according to Chapter IX of the Tenth Revision of the International Classification (ICD-10 - codes I00 to I99). The conurbation formed by the cities of Cuiabá and Várzea Grande which is located in the only metropolitan area in the state of MatoGrosso, has the highest rates of urbanization and the highest demographic densities in the state[8]. The region still suffers from the consequences of the accelerated urbanization process. Urban space is effected by social and income inequality, increasing the tendency of shantytowns , violence and social exclusion and making access to health difficult[9]. Despite high levels of municipal human development, 20% of the people are vulnerable to poverty and 6% of the population have precarious housing conditions [10].

DATA SOURCES

Death records came from the Mortality Information System of the Unified Health System (SIM / SUS) and were provided by the State Health Department with the residential address of each individual.

Individual data on the socioeconomic status in the residential environment and distance in meters referring to the proximity of the traffic were georeferenced and calculated in a previous study [11] and were made available for this study. Daily temperature and humidity averages were acquired on the National Institute of Meteorology (INMET) website.

Aerosol Optical Depth (AOD) data were provided by the Cuiabá-Miranda station on the Aerosol Robotic Network (AERONET) website. The daily $PM_{2.5}$ estimates were obtained by converting the AOD values (500 nm) by means of a calculation developed and validated for the Brazilian Amazon and Cerrado area [12], which has a spatial resolution of up to 10 km and represents the mean values for the entire atmospheric column.

DATA ANALYSIS

Time series regression was performed in the construction of explanatory models for death counts due to CVDs over time. The generalized additive models (GAM) with the Poisson regression, at 5 and 10% significance, were used to investigate the association between $PM_{2.5}$ and maximum temperature with mortality due to CVDs. The time-series methodology evaluates the acute effect of exposure, as well as the linear effects of this relationship, thus it is appropriate for ecological epidemiological studies [13-15].

In order to analyze the influence of the place of residence on mortality due to CVDs associated with $PM_{2.5}$ and at maximum temperature, the study population was stratified in two subgroups according to the respective residential address:

- proximity to vehicular traffic;
- socioeconomic status in the residential environment.

After stratifying the population based on the residential address, new time series regressions were performed for each stratum. The stratification method was chosen because it uses fewer parameters and offers a simple and quantitative comparison of the estimated effects of exposure in the different strata [13,14], by indicating the new characteristics of exposure after stratification [15].

The proximity to the traffic was divided into:

- up to 150 m in distance;
- over 150 m in distance.

The proximity of the residence situated up to 150 m from a road with a heavy flow of vehicular traffic was used to characterize high traffic exposure, and any distance above that cut-off point was characterized as low traffic exposure. The Euclidean distance between the residential address on the day of death and the nearest main road was used [11].

Socioeconomic status in the residential environment was categorized as high and low according to the median (3.9%). This variable corresponds to the availability of regular garbage collection and sanitary sewage services in the census sector, characterizing the residential environment of the individuals. The calculation was based on the division of the number of households with open sewage and/or garbage systems within the census sector and the total number of households in the census sector, multiplied by 100[11].

In the regression analyzes of the time series, the time trend and the seasonality were controlled, including the variable day of the week and a *spline* of the variable of elapsed days, respectively. The adjustment of each final model was evaluated using the Akaike criterion (AIC) and partial autocorrelation (PACF). Different lags and moving averages were tested for each explanatory variable.Exposure associations were investigated in the current day with single lags (0 to 10 days). Only one Lag remained in the final model, in which the smallest lags were prioritized.

For the construction of the model of the relationship between $PM_{2.5}$ and mortality, the humidity and the mean temperature were used as adjustment variables; in the final model, lag 3 remained for the general population and stratified by socioeconomic status and lag 7 for stratification by the proximity to traffic. For the construction of the model of the relationship between maximum temperature and mortality, humidity and $PM_{2.5}$ were used as adjustment variables, and lag 5 was selected in the final models for all strata.

The percentage of relative risk (% RR) of deaths due to CVDs was calculated, which corresponds to the linear increase of 10 μg/m³ in the $PM_{2.5}$ levels and to the linear increase of 1°C for the maximum temperature.The time series regression analyzes were performed in the R 3.0.2 application using the Are s2[15] library. This study was approved by the Ethics Committee of the National School of Public Health (ENSP).

RESULTS

The time series continued for 983 days (April 2009 to December 2011) and consisted of 2,504 deaths. In the urban area of Cuiabá and Várzea Grande, there were 1,272 deaths in areas with high traffic exposure and 1,254 deaths in areas with precarious living conditions.

An average of 2.54 deaths/day was observed for the urban zone, about 1.25 deaths / day for strata of exposure to traffic and poor living conditions. The standard deviation of the deaths varied between 0.76 and 1.59, with a maximum value of 9 deaths / day and a minimum value of zero. The daily mean of $PM_{2.5}$ was 17,07 μg / m3, with values between 0.10 and 172.30 μg/m³. Only $PM_{2.5}$ presented 55 random days without information. The maximum value of the maximum temperature reached 42.3°C. The mean for humidity was 70.71% and a standard deviation of 11.35% (Table 1).

Mortality due to CVDs related to $PM_{2.5}$ presented RR% 4.60 (95%CI 0.78; 8.56) in areas up to 150 m away from vehicular traffic and RR% 3.95 (95%CI -0. 27; 8.34) in areas with low socioeconomic status in the residential environment. % RR -5.80 (95%CI -10.61; -0.73) was observed, characterizing a protective effect in areas whose residential environment had high socioeconomic status (Table 2).

Mortality due to CVDs related to maximum temperature presented %RR 1.64 (95%CI -0.03; 3.33) in areas up to 150 m away from vehicular traffic and RR% 1.34 (95%CI -0. 31; 3.01) in residential environments classified with low socioeconomic status. A protective effect was observed in areas over 150 m away from vehicular traffic, with % RR -1.46 (95%CI -2.98; 0.09) (Table 3).

DISCUSSION

Our results show a higher relative risk of mortality due to CVDs associated with $PM_{2.5}$ and temperature in areas with low socioeconomic status in the residential environment and in areas up to 150 m away from vehicular traffic. These findings suggest that the place of residence is related to a differential exposure to PM and temperature.To the detriment of individual socioeconomic conditions, some authors argue that the residential environment may have a greater influence on health because it is directly related to several sources of environmental exposure[1]. In addition, the places where people live and/or work are places

Table 1. Descriptive statistics of the variables under study. Cuiabá and Várzea Grande, Mato Grosso, Brazil, from 2009 to 2011.

	Median	Standard deviation	Minimum	Maximum
Óbitos por DC (n)				
Exposure to traffic				
High exposure to traffic	1.29	1.15	0	6
Low exposure to traffic	1.25	1.11	0	7
Socioeconomic status				
Precarious living conditions	1.27	1.14	0	6
Better living conditions	1.27	1.12	0	6
Environment variables				
$PM_{2,5}$(µg/m³)*	17.07	15.66	0.10	172.30
Avergae temperature (ºC)	26.45	3.04	11.44	33.44
Maximum temperature (ºC)	33.69	3.88	13.30	42.30
Relative humidity (%)	70.71	11.35	35.00	97.00

CVDs: cardiovascular diseases; *55 days without information.

Table 2. Percentage of relative risk and 95% confidence intervals for mortality due to cardiovascular diseases related to the linear increase of 10µg/m³ of $PM_{2.5}$ by simple lag, according to socioeconomic status in the residential environment and proximity to vehicular traffic. Cuiabá and Várzea Grande, from 2009 to 2011.

		%RR	95%CI
General		*2.95***	5.67 – 0.30
Proximity to Vehicular traffic	Up to 150 m	4,08**	8.36 – -0.02
	Over 150 m	-1.45	3.35 – -6.02
Socioeconomic status in the residential environment	Low	3.95**	8.34 – -0.27
	High	*-5.80***	-0.73 – -10.61

%RR: relative risk percentage; 95%CI: 95% confidence intervals; ** p-value <0.05.

with continuous exposure, which can cause the gradual effects on health to become cumulative throughout their lives[7].

The proximity of the residential environment to a road with a heavy flow of vehicular traffic can be considered an important feature of the residential environment, since it may be related to the high exposure of air pollution from traffic[16], the worst socioeconomic conditions[7] and the highest prevalence of heat islands in the urban centers[17,18]. Residing in the vicinity of roads with heavy flows of traffic may be a risk factor for mortality due to CVDs. During discussions, the principal cause for this is the increased exposure to atmospheric pollutants emitted by vehicles such as carbon monoxide (CO), oxides of nitrogen (NOx), PM, sulfur dioxide (SO_2) and ozone (O_3)[16,19]. Each of these pollutants is related to adverse effects on human health[20,21], however, the most adverse effects of pollution from traffic have been observed at a distance of 150-300 m from roads with heavy flows of vehicular traffic[16,22]. This gradient is directly related to the type and volume of traffic in each city, as well as local meteorological conditions[7,23].

With respect to temperature, the proximity of the residential environment to the traffic may be related to the greater concentration of buildings, vehicles and industrial facilities, which contributes to an increase in the local temperature[24], creating the so-called heat islands in some places.

The increase in temperature in urban areas is related to the greater absorption and reflection of the sun by the concrete constructions and the pavement; reduced cooling is due to the obstruction of ventilation by buildings; and the release of anthropogenic heat from industries and transport[17]. The high population density and the high degree of urbanization have shown correlations with the hottest areas in large urban centers, mainly because they directly influence soil cover patterns[18].

Heat can also be considered an indirect measure of atmospheric pollutant emissions in urban areas[25], due to the strong relation between high temperatures with organic and

Table 3. Relative risk percentage (% RR) and 95% confidence intervals (95%CI) for mortality due to cardiovascular diseases related to the linear increase of 1ºC in the maximum temperature by simple lag, according to socioeconomic status in the residential environment and proximity to vehicular traffic . Cuiabá and Várzea Grande, from 2009 to 2011.

		RR%	95%CI
General		*0.76*	1.76 – -0.23
Proximity to Vehicular traffic	Up to 150 m	1,64**	3.33 – -0.03
	Over 150 m	-1,46*	0.09 – -2.98
Socioeconomic status in the residential environment	Low	1,34*	3.01 – -0.31
	High	*1,02*	2.71 – -0.64

**p-value ≤ 0.05; *p-value ≤0.10.

elemental carbon and sulfate[26], O_3[27] and the concentration of semivolatile particles[23].On the other hand, the synergistic effects between high temperatures and atmospheric pollutants, such as O_3 and PM, have been related to the increased risk of mortality due to CVDs[14,28]. Heat can overload the body's thermoregulation system and increase individual vulnerability to the effects of air pollutants[29].

Locations associated with intense traffic jams are gradually devalued by the real estate market, thus people with poor socioeconomic status tend to live near roads and/or places with heavier traffic and poorer air quality[1]. However, even in places where individuals with higher income and/or schooling are more exposed to pollution from traffic, individuals with worse living conditions have a higher probability of becoming ill as well as having higher mortality rates[1,3,30].

Huang et al.[31] observed that residing in urban areas and/or areas with precarious living conditions is associated with an increase of 0.31% (95%CI 0.11; 0.51) in the risk of mortality due to CVD related to heat. Forastiere et al.[5]observed that there is a higher risk of mortality due to PM^{10} in people with lower income and lower socioeconomic status (1.9 and 1.4% per 10 mg/m^3, respectively)and those who are residents of areas with greater exposure to vehicular traffic.

Areas whose residential environment had a high socioeconomic status and areas over 150 m away from heavy vehicular traffic were presented as a protective factor regarding the adverse effects of $PM_{2.5}$ and the maximum temperature, respectively. According to Franchini and Mannucci[32], the higher the exposure the greater the risk; thus, deductively, we can conclude that the inverse relationship may also be true.

Basu[6] clarifies that the response to the exposure may be associated with individual extrinsic factors, such as socioeconomic factors, and may assume different relationships when coexposure to environmental factors is present, which include local meteorological conditions, air pollutants (indoor and outdoor), the presence of allergens, among others.Thus, this result suggests that areas with better living conditions, as well as less environmental exposure to agents that are harmful to health, may be associated with better health conditions.

A study in Rome by Forastiere et al.[5] observed that even in areas with high exposure, areas with high socioeconomic status did not suffer the adverse effects of air pollution regarding mortality due to CVDs. These authors discuss that areas with better living conditions have a greater number of people with high incomes and better jobs, which can consequently improve access to health services and disease prevention.In addition, according to Deguen and Zmirou-Navier[1], people with high socioeconomic status usually travel more or have holiday homes in the country or on the beach, and thus spend less time in their official residence.

Regarding the differential effects associated with temperature, McGeehin and Mirabelli[33] argue that people with better living conditions have access to adaptive measures that are better suited to both heat and cold, such as adequate homes, backyards, and more wooded residential environments, as well as more access to air conditioning. On the other hand, according to Zhou et al.[18] and Bagieński[24], areas farthest from urban and commercial centers tend to show a reduction of about 6ºC in temperature, especially at peak times.

In relation to the limitations of this study, it is important to mention the ecological character of the associations, which does not admit the confirmation of any causal effect; besides the fact that variables such as the use of air conditioning, the amount of vehicles and other environmental exposures, such as noise pollution, were not taken into account.

It is necessary to consider that the spatial distribution of mortality due to CVDs is subject to some classification misconceptions, since, in this study, we considered the distances of the roads with the heaviest flow of vehicles and the proportion of sewage and garbage in the census sector for the classification of individuals in their respective places of residence. These indicators were used only as a proxy for exposure and were derived from secondary data.The use of estimated PM data may also underestimate the actual amounts of individual PM exposure.

On the other hand, this is the first study that deals with the relationship of socioeconomic factors with pollution and temperature in the Cerrado region, and the analyzes used showed results compatible with those observed in other ecological studies. The results of this study highlight a new perspective on the effects of pollution and temperature in the region, suggesting that the process of urbanization can significantly influence the susceptibility of the population. Therefore, our findings can help in the foundation of future studies and in the planning of strategies aimed at mitigating the impact of air pollution and temperature on human health.

CONCLUSION

It was concluded that, in Cuiabá and Várzea Grande, the uneven geographic distribution of the living conditions of the population and traffic conditions present a differential exposure to the effects of temperature and PM, increasing the risk of death from CVDs. Therefore, investment in public transport and regulatory measures to reduce air pollution from traffic must be considered. However, the reduction of risks for the most disadvantaged populations should be prioritized in order to promote socio-environmental equity.

This study was approved by the Ethics Committee of the National School of Public Health (CAAE 18634613.0.0000.5240.)and is part of the thesis "Mortality due to cardiovascular diseases associated with PM and its interactions with meteorological and socioeconomic parameters in the Central-West Region", presented to the National School of Public Health, in May 2016, by PolianyCristiny de Oliveira Rodrigues.

REFERENCES

1. Deguen S, Zmirou-Navier D. Social inequalities resulting from health risks related to ambient air quality - A European review. Eur J Public Health 2010; 20(1): 27-35. https://doi.org/10.1093/eurpub/ckp220
2. Gouveia N, Fletcher T. Time series analysis of air pollution and mortality: effects by cause, age and socioeconomic status. J Epidemiol Community Health 2000; 54(10): 750-5. https://dx.doi.org/10.1136%2Fjech.54.10.750
3. Padilla CM, Kihal-Talantikite W, Vieira VM, Rosselo P, Le Nir G, Zmirou-Navier D, et al. Air quality and social deprivation in four French metropolitan areas – A localized spatiotemporal environmental inequality analysis. Environ Res 2014; 134: 315-24. https://doi.org/10.1016/j.envres.2014.07.017
4. Jerrett M, Burnett RT, Ma R, Pope CA, Krewski D, Newbold KB, et al. Spatial Analysis of Air Pollution and Mortality in Los Angeles. Epidemiology 2005; 16(6): 727-36.
5. Forastiere F, Stafoggia M, Tasco C, Picciotto S, Agabiti N, Cesaroni G, et al. Socioeconomic status, particulate air pollution, and daily mortality: differential exposure or differential susceptibility. Am J Ind Med 2007; 50(3): 208-16. https://doi.org/10.1002/ajim.20368
6. Basu R. High ambient temperature and mortality: a review of epidemiologic studies from 2001 to 2008. Environ Health 2009; 8: 40. https://dx.doi.org/10.1186%2F1476-069X-8-40
7. Lloyd-Jones D, Adams RJ, Brown TM, Carnethon M, Dai S, De Simone G, et al. Executive Summary: Heart Disease and Stroke Statistics - 2010 Update A Report From the American Heart Association. Circulation 2010; 121(7): 948-54. https://doi.org/10.1161/CIRCULATIONAHA.109.192666
8. Instituto Brasileiro de Geografia e Estatística. IBGE Cidades: indicadores e dados populacionais [Internet]. Brasília: Instituto Brasileiro de Geografia e Estatística; 2010 [acessado em 6 maio 2013]. Disponível em: http://www.ibge.gov.br/cidadesat/xtras/perfil.php?codmun=510340&search=mato-grosso|cuiaba
9. Margarit E. O processo de ocupação do espaço ao longo da BR-163: uma leitura a partir do planejamento regional estratégico da Amazônia durante o governo militar. Geografia em Questão 2013; 6(1): 12-31.
10. Instituto de Pesquisa Econômica Aplicada. Atlas of Human Development in 2013 [Internet]. Brasil: Instituto de Pesquisa Econômica Aplicada; 2013. Disponível em: http://atlasbrasil.org.br/2013/pt/perfil/
11. Rodrigues PCO, Santos ES, Ignotti E, Hacon SS. Space-Time Analysis to Identify Areas at Risk of Mortality from Cardiovascular Disease. Bio Med Res Int [Internet]. 2015 [acessado em 6 out. 2015];2015. Disponível em: http://www.hindawi.com/journals/bmri/2015/841645/abs/ http://dx.doi.org/10.1155/2015/841645
12. Paixão M. Optical properties of natural aerosols and from burning of the Amazon [dissertação] [Internet]. São Paulo: Instituto de Física, Universidade de São Paulo; 2011 [acessado em 22 jul. 2016]. Disponível em: http://www.teses.usp.br/teses/disponiveis/43/43134/tde-30092011-150552/
13. Meng X, Zhang Y, Zhao Z, Duan X, Xu X, Kan H. Temperature modifies the acute effect of particulate air pollution on mortality in eight Chinese cities. Sci Total Environ 2012; 435-436: 215-21. https://doi.org/10.1016/j.scitotenv.2012.07.008
14. Pinheiro S de L, Saldiva PH, Schwartz J, Zanobetti A. Isolated and synergistic effects of PM10 and average temperature on cardiovascular and respiratory mortality. Rev Saúde Pública 2014; 48(6): 881-8. https://doi.org/10.1590/S0034-8910.2014048005218
15. Junger W, de Leon AP. Ares: A Library for Time Series Analysis in Air Pollution and Health Effects Studies Using R. Epidemiology 2009; 20(6): S217. https://doi.org/10.1097/01.ede.0000362727.55583.4a
16. Brugge D, Durant JL, Rioux C. Near-highway pollutants in motor vehicle exhaust: A review of epidemiologic evidence of cardiac and pulmonary health risks. Environ Health 2007; 6(1): 23. https://dx.doi.org/10.1186%2F1476-069X-6-23
17. Buscail C, Upegui E, Viel J-F. Mapping heatwave health risk at the community level for public health action. Int J Health Geogr 2012; 11(1): 38. https://doi.org/10.1186/1476-072X-11-38
18. Zhou D, Zhang L, Hao L, Sun G, Liu Y, Zhu C. Spatiotemporal trends of urban heat island effect along the urban development intensity gradient in China. Sci Total Environ 2016; 544: 617-26. https://doi.org/10.1016/j.scitotenv.2015.11.168
19. Brender JD, Maantay JA, Chakraborty J. Residential proximity to environmental hazards and adverse health outcomes. Am J Public Health 2011;101(Supl. 1): S37-52. https://doi.org/10.2105/AJPH.2011.300183
20. Chakraborty J. Automobiles, Air Toxics, and Adverse Health Risks: Environmental Inequities in Tampa Bay, Florida. Ann Assoc Am Geogr 2009; 99(4): 674-97. https://doi.org/10.1080/00045600903066490

21. Brook RD. Cardiovascular effects of air pollution. Clin Sci Lond Engl 2008; 115(6): 175-87. https://doi.org/10.1042/CS20070444
22. Health Effects Institute. Traffic-related air pollution: a critical review of the literature on emissions, exposure, and health effects. Boston: Health Effects Institute; 2010. (Panel on the Health Effects of Traffic-Related Air Pollution; v. Special Report 17).
23. Seinfeld JH, Pandis SN. Atmospheric chemistry and physics: from air pollution to climate change. Hoboken: John Wiley; 2006.
24. Bagieński Z. Traffic air quality index. Sci Total Environ 2015; 505: 606-14. https://doi.org/10.1016/j.scitotenv.2014.10.041
25. Kioumourtzoglou M-A, Schwartz J, James P, Dominici F, Zanobetti A. PM2.5 and mortality in 207 US cities: Modification by temperature and city characteristics. Epidemiol Camb Mass 2016; 27(2): 221-7. https://doi.org/10.1097/EDE.0000000000000422
26. Tai APK, Mickley LJ, Jacob DJ. Correlations between fine particulate matter (PM2.5) and meteorological variables in the United States: Implications for the sensitivity of PM2.5 to climate change. Atmos Environ 2010; 44(32): 3976-84. https://doi.org/10.1016/j.atmosenv.2010.06.060
27. Bell ML, McDermott A, Zeger SL, Samet JM, Dominici F. Ozone and short-term mortality in 95 US urban communities, 1987-2000. JAMA 2004; 292(19): 2372-8. https://doi.org/10.1001/jama.292.19.2372
28. Rodrigues PC de O, Pinheiro S de L, Junger W, Ignotti E, Hacon S de S. Climatic variability and morbidity and mortality associated with particulate matter. Rev Saúde Pública 2017; 51: 91. http://dx.doi.org/10.11606/s1518-8787.2017051006952
29. Cheng X, Su H. Effects of climatic temperature stress on cardiovascular diseases. Eur J Intern Med 2010; 21(3): 164-7. https://doi.org/10.1016/j.ejim.2010.03.001
30. Fiscella K, Tancredi D. Socioeconomic status and coronary heart disease risk prediction. J Am Med Assoc 2008; 300(22): 2666-8. https://doi.org/10.1001/jama.2008.792
31. Huang Z, Lin H, Liu Y, Zhou M, Liu T, Xiao J, et al. Individual-level and community-level effect modifiers of the temperature–mortality relationship in 66 Chinese communities. BMJ Open 2015; 5(9): e009172. http://dx.doi.org/10.1136/bmjopen-2015-009172
32. Franchini M, Mannucci PM. Air pollution and cardiovascular disease. Thromb Res 2012; 129(3): 230-4. https://doi.org/10.1016/j.thromres.2011.10.030
33. McGeehin MA, Mirabelli M. The potential impacts of climate variability and change on temperature-related morbidity and mortality in the United States. Environ Health Perspect 2001; 109(Supl. 2): 185-9. https://dx.doi.org/10.1289%2Fehp.109-1240665

Received: 06/12/2017
Final version presented: 11/23/2017
Approved: 12/01/2017

Authors' contributions: PolianyCristiny de Oliveira Rodrigues performed the study design, data acquisition, analysis and interpretation of the data and the preparation of the manuscript. ElianeIgnotti and Sandra de Souza Hacon participated in the interpretation of the data and the critical revision of the manuscript.