The evolution of omission of deaths due to accidents and violence in Brazil: a spatial analysis of the association between external causes of death and ill-defined death causes.

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Abstract

According to the Mortality Information System (SIM/MS), the rates due to external causes of death in Brazil has been considerably reduced in all regions from 1991 to 2010. However, as verified by Cerqueira (2012) in the State of Rio de Janeiro, there are strong evidences that such reduction has occurred partially due to mistakes in the classification of the deaths. In other words, we might assume that an increase in ill-defined causes of death is associated with a reduction on the number of deaths due to external causes. In order to test this hypothesis, this study use the data from the Ministry of Health for the years 1991, 2000 and 2010, and analyzed by sex, the spatial and temporal evolution of external causes of death in the 137 Brazilian mesoregions. Therefore, with the purpose of studying the association between both variables, this study make extensive use of spatial autoregressive models. The models indicate that for males, after controlling for relevant indicators – such as socioeconomic, health and geographic variables –, the increase of 1% in the number of ill-defined deaths in the mesoregions of Brazil reduces the percentage of external causes of death in 0.19% and 0.21% from 1991 to 2010. That is to say, each 10 deaths classified as ill-defined replaces from 1 to 2 deaths due to external causes. For females, this relation was also significant, however, with a reduced magnitude; 1% increase in ill-defined deaths reduces in 0.08% to 0.09% number of deaths due to external causes. In this context, when we consider the external causes of death as an indicator to the levels of car accident and violence in a certain place, we may also speculate that there is an omission of violence and traffic-related deaths in Brazil.

Keywords: External causes of Death; Ill-defined deaths; Vital Records

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I – Introduction

Since the 1980s, mortality due to external causes (in great deal deaths caused by injuries of homicides, suicides and traffic-related accidents) gain enormous importance in the several regions of Brazil. According to the 10th Review of the International Classification of Diseases – ICD – the term 'external causes' refers to factors outside of the human organism that cause injuries, poisoning or adverse effects to humans. They also have historically represented one of the main causes of sickness and death in the Brazilian population (OMS, 1993).

During the first decade of the 21st century, such deaths constituted the third group of causes in terms of importance, behind cardiovascular diseases and malign neoplasms (GOMES et al, 2007). Several other studies also report the increase in the incidence of external causes of death. According to Camargo (2002), for example, the proportion of external causes of death rose from 2.6% in 1930 to 14.9% in 1998. This death cause currently occupy the second position, behind mortality due to cardiovascular diseases. According to the Ministry of Health, from 1990 to 2010, the mortality rates of external causes of death, in Brazil, increased from 69.9 to 75.1 deaths by 100,000 inhabitants. On the other hand, during the same period, the proportion of external mortality has reduced in all regions, going from 15.1% to 13.6%.

The mainly source of mortality information is provided by Ministry of Health, and it is public available through the Mortality Information System (SIM/MS). This is an important source of mortality data, since it represents the only reliable database, with national, periodic and transparent coverage of death counts, which allows us to measure violent events with fatal outcomes (Cerqueira, 2012). However, estimates on mortality and the right knowledge on Brazilian mortality levels and trends are still limited due to the data quality. Furthermore, the most common problems faced by the vital records are the under-registration of death counts, age misreporting and the lack of information concerning the cause of death (Lima and Queiroz, 2011, 2014; Queiroz, et al. 2013).

The correct information on death causes are fundamentally important, since they offer subsides to evaluate the health condition of populations and to implement health policies (Paes, 2007). Thus, the high concentration of ill-defined causes of death may harm the studies of epidemiologic and health transitions among regions (Abouzhar; Boerma, 2005; Lima and Queiroz, 2011).

Regarding the information of external death causes, Cerqueira (2012) observed in the state of Rio de Janeiro, between 2006 and 2009, that the number of homicides was reduced in 28.7%. However, there are strong indications that this result is underestimated due to partially omission of external causes of death, which are sometimes classified as ill-defined.

In this context, it is necessary to get to a better knowledge about the association between the external and ill-defined causes of death. Therefore, the purpose of this study is to investigate whether or not there is an inverse association between these two causes of death. In other words, our work hypothesis states that an improvement on death records, through a better identification of the cause of death, may result on an increase in the number of external causes of death. In addition, we might state that the recent reduction in external causes of death in the country could be spurious and somewhat related with misclassification issues concerning the original death cause.

II - Data and Methods

We make an extensive use of mortality data provided by the Ministry of Health for the years of 1991, 2000 and 2010. For each sex is analyzed the spatial and the temporal evolution of the external causes of death in the 137 Brazilian mesoregions[3]. The choice for this geographic unit offers two important advantages. The first one refers to size. The mesoregions are spatial units small enough to make possible analyses of the spatial distribution of any phenomena in space. In addition to that, since its creation in 1989 (IBGE, 1990), the mesoregions went through no geographical emancipations or territorial divisions, and that allows comparative studies throughout time.

[3] The Geographic Mesoregions are a set of contiguous municipalities, belonging to the same Federation Unit “that show manners to organize the geographic space defined by the following dimensions: the social process, as a determining factor, the natural setting, as a conditioning factor, and the network of communication and locations, as a spatial articulation element. These three dimensions allow the space delimited as a mesoregion to have a regional identity. This identity is a reality that is built with time by the society that was originated there” (IBGE, 1990).

Autoregressive spatial models are applied in order to study the association between both variables. Such application is very important, since these models try to evaluate the association between one or more variables, considering the neighborhood structure (or neighborhood matrix) that describes the observed phenomenon. In other words, these models take into account – in addition to the control variables that describe regional characteristics – the influence of the spatial “context” of the variable in question (ANSELIN, 1988). This spatial context may suggest several community-related characteristics and idiosyncrasies of the localities that are usually not captured by the usual regression models.

The model specification used in our analysis are Simultaneous Autoregressive Models and the spatial dependence is tested according to two specifications: 1) spatial *lagged* and 2) spatial *error* model. The spatial lagged *y* model is appropriate when we believe that the values of *y* in one unit *i* are directly influenced by the values of *y* found in *i'*s neighbors. More important, this influence is above and beyond other covariates specific of *i*. If it is believed that *y* is not influenced directly by the value of *y* as such among neighbors, but rather that there is some spatially clustered feature that influence the value of *y* for *i* and its neighbors but is omitted from the model specification. In the case, we may consider an alternative model with spatially correlated errors (Ward and Gleditsch, 2007).

In all models, a spatial dependence diagnosis test of Lagrange Multipliers is applied. This test is important because it identifies the best spatial autocorrelation specification (lagged or error) to be used in the analyses. In the cases that the spatial dependence is not verified, a regular linear model is adjusted.

The response variable of the study is the proportion of external causes of death. The covariate of interest to test our initial hypothesis is the proportion of ill-defined deaths in each mesoregion (Cavalini et al., 2007; Cerqueira, 2012). As socioeconomic controls, the income and education were introduced in the models. Such controls are important due to the fact that it is not possible to ignore the fact that the reduction on mortality due to external causes in Brazil are also related to several factors, which may be from individual, social, economic and cultural order (Gawryszewski et al., 2004). Some studies also show that the elderly population is more prone to be victim of accidents such as falls (Mello Jorge et al., 2007), while the adult-young population has also been frequently indicated as the main victims of external causes of death (Gonzaga et al., 2012; Matos et al., 2013). Furthermore, it is expected that the young adult age groups be more exposed to the risks of external mortality, because they are more prone to search for new emotions and dangerous situations, take impulsive actions and to have easy access to guns, alcohol and drugs (Matos et al., 2013). Due to these reasons, demographic controls — such as the proportion of young and adult population (population between 20 and 39 years old) and aging index — are also introduced in the model.

The availability of health services was measured through the *proxy* covariate health expenditure. This variable is also very important, since it reflects the investments of health public policies and the improvements on its services (Andrade Barbosa et al., 2013). Other covariate that may also influence the mortality due to external causes is the degree of registration of death counts. We can argue that high levels of under-registration of death counts might also underestimate the death rates due to external causes (IBGE, 2009).

Spatial controls are also introduced in the model, namely: the longitude and latitude geographical coordinates of the centroids of each mesoregion. These controls are important because they reflect certain level of spatial dependency, avoiding criticism concerning the possible spatial concentration of external causes of death in the coast, Southern and Southeastern regions of the country (more developed, urbanized and industrialized areas), which the population can be more exposed to the risks of external mortality. Similarly, a regional control is introduced in the models. All data analyses were conducted using procedures from the software R version 3.0.3.

III – Results

Figure 1 shows the spatial distribution of the external causes of death, according to each sex, for the Brazilian mesoregions in 1991, 2000 and 2010. It is observed that there was a large percentage reduction of external causes of death. The large decrease is identified among males, for which the maximal percentage of external causes of death was reduced from 59% to 36% in 19 years. The mesoregion of Brasília, and its surroundings areas, was one of the few areas that did not show expressive changes in the percentage of this cause of mortality. Among females, we also observed a reduction on the percentage of such death causes. However, it was less expressive in comparison with males (the maximal percentage declined from 29% in 1991 to 13% in 2010).

Furthermore, we also observed changes in the spatial distribution of such deaths throughout the years. Among males, we see an increase on the number of areas with a percentage of external causes of death above 25%. This is visible especially on the regions of the Amazon and some mesoregions of the Mid-West Brazil, locations that are usually known for agribusiness and soybean cultivation. Moreover, in 2010 we also observe an increasing number of localities with high proportion of external mortality, especially toward the coast of Rio de Janeiro and Espírito Santo, extending to the Northeastern coast of the country.

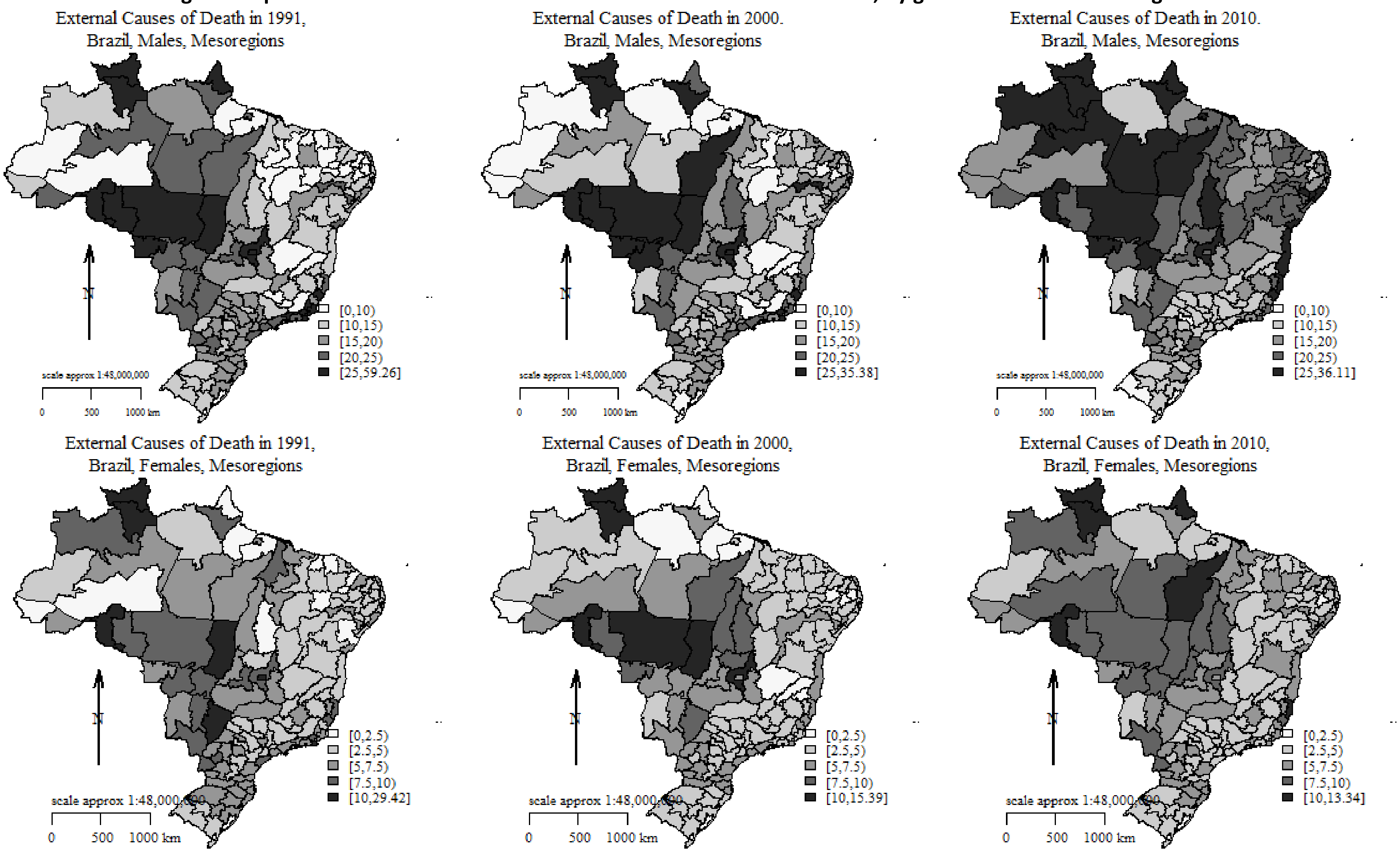
Temporal changes are also verified across mesoregions. For example, between 1991 and 2010, we verified that, despite the generalized reduction, several mesoregions — mainly in the Northern and Central Northeastern regions of the country (including the state of Minas Gerais) — started to present increasing percentage of deaths due to external causes[4]. That may be an evidence of two scenarios: 1) A recent increase in the number of deaths due to external causes in those areas, or 2) Improvements in the death registration coverage, leading to a large number of deaths recorded as external causes (IBGE, 2009). Among women, similar changes are observed. There is a reduction on the number of localities with very few percentages of deaths due to external causes (0 to 2.5%). In 1991, there were 11 mesoregions with maximum 2.5% of deaths classified as external and, in 2010, we can identify only 1 mesoregion with maximum 2.5% of its death classified as external.

Figure 2 shows Kernel[5] density maps that are useful to identify localities that are more exposed to the risk of deaths due to external causes (or hotspots). The Gaussian Kernel density method allows us to estimate the likelihood of an event occurring in each cell of a regular grid. Each cell of the grid is estimated through the weighted average of all the values of its neighbors. The weights are attributed using a

[4] Many areas left the category 0 to 10% external deaths to the category of 15 to 25% from 1991 to 2010.
[5] Although the Kernel maps are an exploratory method with a subjective interpretation, they offer a quick and easy view of the localities exposed to different degrees of risk of a certain event in space.

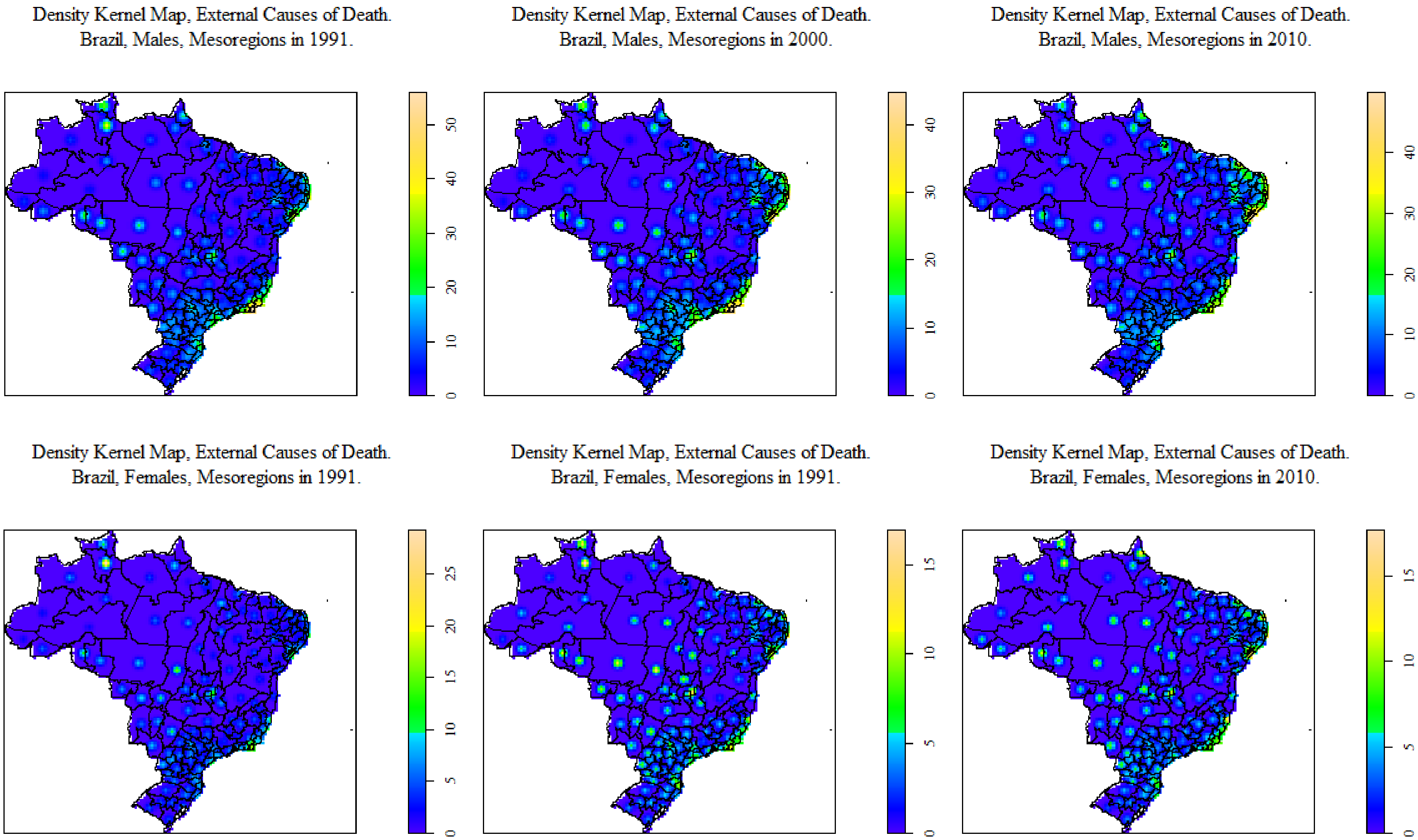
probability distribution function. In this study, the Gaussian distribution is applied (see Bailey and Gatrell, 1995).

Figure 1: Spatial distribution of the ratios of deaths due to external causes, by gender. Brazilian mesoregions – 1991 to 2010.



Source: SIM, 1991, 2000 and 2010. DATASUS, 1991 to 2010.

Figure 2: Concentration of deaths due to external causes, by gender (Kernel density). Brazilian mesoregions – 1991 to 2010.



Source: SIM, 1991, 2000 and 2010. DATASUS, 1991 to 2010.

The set of maps indicates evolution hotspots of the risk of mortality due to external causes of death. Therefore, we see that between 1991 and 2010, for both sexes, the risk zones of external causes of death have considerably expand beyond the cost of the Southeastern region. In the last analysis period, many areas also presented increasing risks of external mortality, mainly in the Northern and Central Northeastern regions of the country. Nevertheless, several locations in the Mid-West and Amazonas borders have also become hotspots of the risk of deaths due to external causes in 2010.

III.1 – Analysis of the regression models

Tables 1 and 2 show the results of the linear regression models and SAR models (only adjusted for males) of the proportion of external causes of death in Brazil, by sex and mesoregions from 1991 to 2010. For females, the spatial dependence tests of Lagrange multipliers do not show statistical significance, indicating that a better adjustment occur via a regular linear regression model.

Thus, we observed that, except for some periods and covariates, the group of socioeconomic variables do not show important explanatory power. This indicates that other factors, in addition to regional development, are more important to explain the evolution of the external causes of mortality in the country.

Data quality indicators, such as the degree of death count registration, have a strong explanatory power, especially in models for males. It is also interesting to notice the evolution of the relationship between the response variable and this explanatory variable. Another point that must be highlighted is the direction of such statistical association. In 2000, the relationship between the proportion of external causes of death and the mortality coverage was positive, indicating that a large part of the increase of mortality, due to external causes, occurred as a result of improvements in death counts registration (IBGE, 2009). Recent periods, this relationship becomes negative, an unexpected fact that deserves to be further analyzed. A possible explanation may be the existence of an interaction (and/or confounding) effect among the covariates in the model. Other possible explanation is that there is a real temporal inversion of relationship between response and explanatory variable. Thus, for females, the relationship was negative and it becomes positive since 2000. However, only during that year the association is statistically significant.

Moreover, we observe that the adult-young population is positively associated with deaths due to external causes, as indicated by some studies (Gonzaga et al., 2012; Matos et al., 2013). This relationship is temporally more consistent and strong among males (increase of 1% in the adult-young population in the mesoregion, corresponding to a 1% increase of deaths due to external causes for the years 2000-2010). For females, since 2000 we see a positive and significant association, however, not as strong as in the male models.

Finally, regarding the variable of interested, we see an important association between the proportion of ill-defined deaths and the proportion of external causes of death in all periods analyzed. This association was statistically significant, even after the control by other important confounding variables.

Therefore, the models show that for each addition of 1% in the number of ill-defined deaths in the mesoregions of Brazil, the percentage of external mortality reduces 0.19% in 1991, 0.11% in 2000 and 0.21% in 2010. In other words, for each 10 ill-defined deaths counted, 1 to 2 external causes of death might be omitted. For females, this relationship was also statically significant; however, it is a lesser strong relationship. A 1% increase of ill-defined deaths are associated with a reduction 0.08% in deaths due to external causes in 1991, 0.06% in 2000 and 0.09% in 2010.

Another way to evaluate this relationship is by temporal variation (see Tables 3 and 4). This time, we try to verify if there is an association between the temporal changes in the proportion of ill-defined deaths and the changes in the proportion of external causes of death.

As we can see, despite the reduction in effects, the negative direction of the association remains, corroborating with the initial hypothesis of this study, which indicates the existence of a inverse relationship between both causes of death. This means that (as the cross-sectional associations identified in the models in Tables 1 and 2) similarly associations are found while the temporal evolution of the phenomena (measured by variations in proportions) are taken into account.

Table 1- Simultaneous Autoregressive Models of the Proportion of Deaths Classified as External. Brazil, Males, Mesoregions between 1991 and 2010.

	1991		2000		2010	
	Beta	p-value	Beta	p-value	Beta	p-value
Intercept	15.03	*	-10.00	*	10.34	***
Proportion of ill-defined deaths	-0.19	***	-0.11	***	-0.21	***
Average income	0.02	*	0.002		0.001	
Average education	-0.30	*	-0.08		0.02	
Proportion of adult-young population	0.53	***	1.58	***	1.29	***
Aging index	-0.27		0.37	***	0.04	
Health expenditures in 1992	-0.02	*	—		—	
Health expenditures in 2000	—		-0.01	**	—	
Health expenditures in 2007	—		—		-0.003	
Coverage degree of deaths	8.68	**	5.80	**	-6.06	**
Geographic coordinate – longitude	0.01		0.04		0.09	
Geographic coordinate – latitude	0.00		-0.04		-0.03	
Southeast/South ref.	—		—		—	
North	1.59		1.03		1.10	
Northeast	2.14		0.44		-0.80	
Mid-West	2.38		1.18		0.94	

Table 2- Linear Regression Models of the Proportion of Deaths Classified as External. Brazil, Females, Mesoregions between 1991 and 2010.

	1991		2000		2010	
	Beta	p-value	Beta	p-value	Beta	p-value
Intercept	11.10	**	0.26		2.36	
Proportion of ill-defined deaths	-0.08	***	-0.06	***	-0.09	***
Average income	0.005		0.004	*	0.002	
Average education	-0.03		-0.07		-0.02	
Proportion of adult-young population	0.05		0.50	***	0.63	***
Aging index	-0.18	*	-0.03		-0.01	
Health expenditures in 1992	-0.005		—		—	
Health expenditures in 2000	—		-0.001		—	
Health expenditures in 2007	—		—		-0.00	
Coverage degree of deaths	-0.24		3.03	***	0.21	
Geographic coordinate – longitude	-0.01		0.01		0.00	
Geographic coordinate – latitude	0.02		-0.03		-0.02	
Southeast/South ref.	—		—		—	
North	-1.02		0.89		0.37	
Northeast	0.76		1.29	*	-0.23	
Mid-West	0.66		1.01		0.34	

Note: p < 0.01 ***, p < 0.05 **, p < 0.1 *.
The spatial dependence tests were significant, in Lagrange multipliers, only for male models.
Source: SIM, 1991, 2000 and 2010, DATASUS, 1991 to 2010.

Table 3 – Linear Regression Models of the variation of proportion of deaths classified as external between 1991 and 2000. Brazil, Mesoregions.

	Males		Females	
	Beta	p-value	Beta	p-value
Intercept	4.40		-2.57	
Variation in ill-defined deaths	-0.10	***	-0.08	***
Variation in average income	-0.01		0.00	
Variation in average education	0.01		0.00	
Variation in adult-young population	0.27	**	0.07	*
Variation in the aging index	-0.16		0.06	
Variation in health expenditures between 1992 and 2000	0.01		0.00	
Variation in coverage degrees of deaths	-0.02		-0.005	
Geographic coordinate – longitude	0.09		0.02	
Geographic coordinate – latitude	-0.03		-0.07	
Southeast/South ref.				
North	-0.77		2.63	
Northeast	1.14		1.11	
Central-West	0.88		0.88	

Table 4 – Linear Regression Models of the variation of proportion of deaths classified as external between 2000 and 2010. Brazil, Mesoregions.

	Males		Females	
	Beta	p-value	Beta	p-value
Intercept	6.24	*	4.41	**
Variation in ill-defined deaths	-0.06	*	-0.03	*
Variation in average income	0.00		0.00	
Variation in average education	-0.14		-0.15	**
Variation in adult-young population	1.37	***	0.55	***
Variation in the aging index	-0.11		-0.07	*
Variation in health expenditures between 1992 and 2000	0.00		0.00	
Variation in coverage degrees of deaths	0.12	***	0.04	**
Geographic coordinate – longitude	0.01		0.00	
Geographic coordinate – latitude	0.06		0.06	
Southeast/South ref.				
North	0.19		-0.58	
Northeast	-1.38		-0.94	
Central-West	-0.19		-0.72	

Note: p < 0.01 ***, p < 0.05 ** and p < 0.1 *.
The spatial dependence tests were not significant for any of the estimated models.
Source: SIM, 1991, 2000 and 2010, DATASUS, 1991 to 2010.

Conclusions

Number of deaths and causes of death are fundamental information in order to plan public health measures in most countries of the world. In addition to that, the data quality evaluation is an important step to reach high levels of quality regarding mortality-related information (Rao et al., 2005).

In Brazil, some studies has showed that the death record system has considerably improved throughout the years (Lima and Queiroz, 2011, 2014; Queiroz, et al. 2013). However, this study is one of the few that has tried to investigate the quality of the information of causes of death in small areas (mesoregions) in Brazil, focusing the analyses on external causes of death. The importance to understand this death cause relies on the fact that external mortality in Brazil occupies second (sometimes third) place in the total amount of deaths, indicating that the phenomena needs to be studied in a broader context of social problems that affect the country (Minayo, 2009).

Regarding our analyses, the findings of this study confirms our initial hypothesis, which states: an improvement on death records – by better identifying the cause of death – may result in an increase in the number of external causes of death. In other words, we might believe that the recent reduction of deaths due to external causes in Brazil is partially explained by the misreport of the original cause of death. This finding corroborates with the results of Cerqueira (2012) for the State of Rio de Janeiro. Therefore, when we consider external mortality as an indicator of the levels of car accidents and violence in certain place, it is also possible to state that there is an omission phenomenon going on — maybe by the Brazilian administrative authorities — regarding traffic accidents and homicides in Brazil.

Therefore, it is worth to point out that this study also intends to promote other discussions involving the quality of the mortality data in small areas in Brazil. The lack and the need for further studies in smaller levels of geographic aggregation, such as microregions and municipalities, may guide several other analyses with the purpose of explore the quality of the information of vital records in Brazil.

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