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Female motorcycle mortality in Brazilian municipalities, 2005, 2010 and 2015

A mortalidade feminina por acidentes de motocicleta nos municípios brasileiros, 2005, 2010 e 2015

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ABSTRACT: *Objective:* To analyze the spatial distribution of female mortality due to motorcycle accidents in Brazilian municipalities between 2005 and 2015, as well as the variation in rates in the same period. *Methods:* Female mortality rates for the years 2005, 2010 and 2015 were estimated considering a three-year moving average around the base year, standardized by the direct method. Rates were standardized using the same pattern (Brazilian females in 2010) for each year. Then, the empirical Bayes estimator was used to reduce the effect of the random fluctuation. The percentage variation of the standardized rates was also analyzed for different population sizes (less than ten thousand, less than 50 thousand, more than 100 thousand and more than one million inhabitants). *Results:* Bayesian rates showed a clear increase in female mortality due to motorcycle accidents, especially in the North, Northeast and Midwest regions. In the municipalities of the South and Southeast regions, mainly in the period between 2010 and 2015, there was an apparent decrease in mortality. The percentage variation showed a reduction in the indicator analyzed in the period between 2010 and 2015 for the largest municipalities in the South and Southeast regions. For almost all regions and population sizes, the period between 2010 and 2015 showed a deceleration in the growth of rates. *Conclusion:* The analysis clearly shows concentrations of municipalities with higher mortality, while also showing that the phenomenon has spread to a greater number of municipalities. The studied period allows the identification of different dynamics in female mortality, in a period of significant variation in mortality due to motorcycle accidents.

Keywords: Mortality. Females. Motorcycles. Municipalities.

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RESUMO: *Objetivo:* O objetivo deste artigo é analisar a distribuição espacial da mortalidade feminina por acidente de motocicleta nos municípios brasileiros entre 2005 e 2015, bem como a variação das taxas no mesmo período. *Métodos:* Estimaram-se as taxas de mortalidade femininas para os anos de 2005, 2010 e 2015 considerando-se a média móvel de três anos ao redor do ano base e padronizadas pelo método direto. Em seguida, utilizou-se o estimador bayesiano empírico para reduzir o efeito da flutuação aleatória. Analisou-se, também, a variação percentual das taxas padronizadas por diferentes portes populacionais (menor que dez mil, menor que 50 mil, maior que 100 mil e maior que um milhão de habitantes). *Resultados:* As taxas bayesianas mostraram clara ampliação da mortalidade feminina por acidente de motocicleta, especialmente nas regiões Norte, Nordeste e Centro-Oeste. Nos municípios das regiões Sul e Sudeste, principalmente no período entre 2010 e 2015, houve aparente diminuição da mortalidade. A variação percentual das taxas mostrou redução do indicador analisado no período entre 2010 e 2015 para os municípios de maior porte das regiões Sul e Sudeste. Para quase todas as regiões e portes populacionais, o período entre 2010 e 2015 apresentou desaceleração do crescimento das taxas. *Conclusões:* A análise deixa claro que há concentrações de municípios com mortalidade mais elevada, ao mesmo tempo que mostra ter havido crescimento do fenômeno para maior número de municípios. O recorte temporal estudado possibilita identificar diferentes dinâmicas na mortalidade feminina, em um período de importante variação da mortalidade por acidente de motocicleta.

Palavras-chave: Mortalidade. Mulheres. Motocicletas. Municípios.

INTRODUCTION

The growth of the motorcycle fleet and the increase in mortality from transport accidents in Brazil is a phenomenon that has gained the attention of researchers, traffic agencies and health services[1-10]. In 2019, the National Traffic Department (Denatran) reported a motorcycle fleet of over 22 million units[11]. In 1990, that number was under 1.5 million[1]. Between 1990 and 2015, the mortality rate due to motorcycle accidents, for both sexes, increased from 3.9 to 5.9 per 100 thousand inhabitants[6]. In some states, motorcycles make up the largest portion of the vehicle fleet; likewise, mortality rates vary significantly between municipalities, states and regions[1-8,11].

Accidents involving motorcycle riders are more common in men[1,2,4,10,12,13]. The Mortality Information System (SIM) shows that, in 2017, approximately 90% of motorcycle deaths registered were in the male population. In general, the explanations for male over-mortality involve biological and behavioral reasons[14-17]. Schünemann et al.[16], for example, estimate that behavioral factors explain about 70% of the differential. External causes are responsible for an important part of this picture[18-21].

However, although lower than among men, mortality from motorcycle accidents is also increasing among women and represents an important portion of the total number of female deaths. Considering women aged between 15 and 49, motorcycle accidents accounted for approximately 10% of deaths from external causes in 2015. These were responsible for 17% of all female deaths for that age group.

In motorcycle accidents, women are more often passengers[9,22-24]. In a survey conducted at a hospital in Teresina (PI)[23], in 2006, less than 5% of motorcycle drivers who received care were women. In 2012, in Pelotas (RS), 20.2% of the motorcycle drivers interviewed were women[22]. However, an important part of the care provided is registered in the female population[23-25]. The National Health Survey (PNS) shows that women accounted for 31.1% of reports of transport accidents[4]. The Hospital Information System (SIH) indicates an increase in their relative importance in total admissions for motorcycle accidents between 2005 (13.9%) and 2015 (17.4%).

The impact of transport accidents is observed in society, in individuals and in families[12,26-30]. According to the Institute for Applied Economic Research (IPEA), in 2014, the estimated cost of accidents on federal highways was BRL 12.3 billion. Low- and middle-income countries account for 90% of deaths from traffic accidents in the world and 50% of total vehicles[30]. The same study indicates that the reduction of traffic accidents in these countries would have a positive impact on the gross domestic product (GDP), since most of the victims belong to the economically active group[1,2,4,9,13,22].

The expansion of the motorcycle fleet is related to lower costs compared to other means of travel and to the available public transport modes[1,31,32]. The cost of traveling by motorcycle is lower than that of conventional public transport[1,31]. Carvalho[33] points out that several public policies have encouraged individual transport, at the same time that bus fares have increased above inflation since the beginning of the 2000s. The associated cost is directly related to the type of transport adopted by individuals[34].

Souza and Vasconcelos[32] note that one of the reasons for the growth of the motorcycle fleet in Mossoró (RN) is the inability of public transport to meet the commuting demands. The growth in mototaxi services largely reflects this demand, especially in low-income groups[32,35,36]. In 2017, 46% (2,560) of the municipalities had a mototaxi service, with the most significant concentration in medium-sized ones[37]. The same study indicates that only 30.1% (1,679) of the municipalities had some type of public transport available through municipal buses.

Brazilian municipalities are extremely heterogeneous and, of course, have different patterns of mortality. Analyzing the mortality dynamics of female motorcycle riders at the municipal level will help to understand the dimension of this phenomenon and its related challenges. In this context, this study aimed to analyze the spatial distribution of female mortality from motorcycle accidents in Brazilian municipalities between 2005 and 2015, as well as the variation in rates in the same period.

METHODOLOGY

This is a trend analysis study, using SIM data from 2005 to 2015. The analysis of the distribution of mortality rates was based on the empirical Bayesian estimator (EBE)[38-41]. Due to the small population, often a single death registered in a municipality significantly impacts

the estimated crude rate, not adequately representing the risk associated with the phenomenon of interest[38-41]. As observed by Assunção et al.[39], the degree of random variability is linked to the size of the units of analysis. EBE estimates risk rates with less influence from random fluctuation and thus minimizes the effects of small numbers on the denominator[38-40]. EBE also deals well with cases in which there was no record of death. Often there is no record of the phenomenon of interest in the analyzed period, which does not mean that the risk associated with the event is equal to zero.[38]

The process of smoothing crude rates through EBE considers a defined neighborhood structure. In other words, rates, especially for less populous municipalities, will be contracted towards the average rate for neighbors in such locations. Marshall[40] points out that a certain homogeneity between neighboring areas is implicit in the use of EBE. The estimator uses information from other locations to minimize random fluctuation[39]. The EBE weighting factor is inversely proportional to the population at risk[38,39]. That is, for the larger municipalities, the Bayesian estimator approaches the estimated gross rate.

The first step in the construction of EBE was the estimation of motorcycle mortality rates standardized by the direct method, by municipality, for the years 2005, 2010 and 2015. In the numerator of rates, the three-year average of deaths around the base years was considered. In addition to deaths registered under "motorcycle rider injured in transport accident" (V20-V29), the occurrences registered under "other land transport accidents" (OLTA) (V80-V89) were redistributed according to the proportion of deaths of motorcycle riders from the total deaths from transport accidents in each of the municipalities. OLTA represent an important portion of deaths due to transport accidents (TA) and, in general, indicate problems in the registration of these events, corresponding to causes that are not well defined in the chapter. For cases in which there were deaths registered as OLTA, but not as motorcycle accidents, the distribution considered the proportion of deaths of motorcycle riders in relation to all transport accidents in the microregion to which the municipality belonged. In both groups, motorcycle riders (V20-V29) and OLTA (V80-V89), deaths in which the record ignored age and/or municipality were redistributed considering the proportion of deaths per age group in the municipalities and states.

In the denominator of the rates, the resident female population for the years 2005 and 2015 was considered, based on population estimates made by the Interagency Network for Health Information (Ripsa)[42] and, for 2010, based on the Brazilian Census[43]. Rates were standardized considering the age structure of Brazilian women in 2010.

The neighborhood structure for the EBE estimate considered the 20 municipalities closest to each unit of analysis. The use of a defined number of neighbors ensures that all municipalities have similarly sized neighborhood structures. Alternatively, eight or 15 neighboring municipalities were considered, however, mainly in 2005, the smoothing proved to be less efficient when compared to the structure made considering 20 neighbors, especially due to the high number of municipalities without a death record that year.

The operationalization of EBE followed Marshall's proposal[40], as presented in Equation (1):

$$\hat{\theta} = m + c_i(x_i - \text{m}) \tag{1}$$

In which:

$\hat{\theta}$ = the empirical Bayesian estimator;

m = the average rate of neighbors;

c_i = the contraction factor;

x_i = the standardized rate for municipalities.

The analysis of the variation in mortality rates by region and by different population cuts (less than ten thousand, less than 50 thousand, more than 100 thousand and more than one million inhabitants in three different periods — 2005 to 2015, 2005 to 2010 and 2010 to 2015) sought to identify different regional dynamics. This analysis was based on the percentage variation in mortality rates between two periods. The rates were calculated, by population size and region, by the sum of the expected number of deaths considering the standardized rates of each municipality and the total population in each group, in the three years analyzed. The variation was calculated using the ratio of the rates observed in the second and first periods, subtracted by 1.

RESULTS

The evolution of mortality rates estimated with the empirical Bayesian estimator (Figures 1, 2 and 3) shows the increase in municipalities with registered deaths of female motorcyclists, as well as the increase in observed rates. The same range of classes was used on the maps to enable comparison between years. The highest concentration of municipalities with a high mortality rate is observed in the North, Northeast and Midwest regions throughout the period.

In the Northeast region, between 2005 and 2015, there was a clear increase in the number of municipalities with records of the analyzed event. In 2005, as Figure 1 indicates, there was a small concentration of those events with high rates in Piauí. In addition, with lower levels than those observed in this state, there was a concentration of municipalities in Maranhão, Ceará and Sergipe. In 2010 (Figure 2), motorcycle accident mortality spreads to cities in all states in the region. Also noteworthy is the increase in events in the group with higher rates, represented by darker tones in Figure 2 and Figure 3, mainly in Maranhão, Piauí and on the border between Ceará and Rio Grande do Norte. In Bahia, in a less expressive way, there is an increase in rates, especially in the central portion of the state.
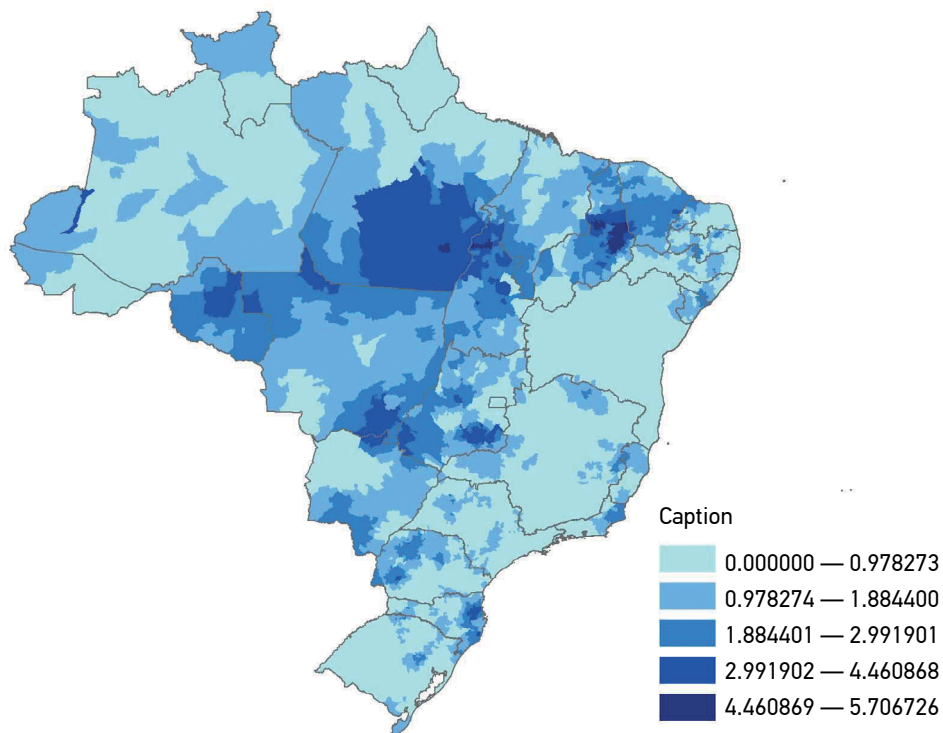
Between 2010 and 2015 (Figure 3), in the Northeast region, there was an increase in the level of rates in municipalities that were already in the group with higher rates. In the previous period (2005–2010), both the expansion of the phenomenon to a greater number of municipalities and the increase in the magnitude of rates were observed in locations that already had high levels.

In the Midwest Region, in 2005 (Figure 1), there was a large concentration of municipalities with high mortality rates. Between 2005 and 2015 (Figure 3), as well as in the Northeast, there was an increase in levels in municipalities in all states in the region. In the last year analyzed, only the surroundings of Brasilia were colored in the lightest shade of the scale used. The states of Rondônia, Tocantins and the southern portion of Pará, which already

had a set of municipalities with higher rates in 2005, showed an increase in these indicators and an increase in the number of municipalities in groups with high levels. Between 2005 and 2015, on a smaller scale, there was an increase in female mortality in municipalities in other states in the North Region.

In the Southeast Region, in 2005 (Figure 1), there were small groups of municipalities with higher rates in the north, in the Triangle and in the east of Minas Gerais, in the north of Espírito Santo and in the north of Rio de Janeiro, in addition to small spots in the west and in the center of São Paulo. In 2010, there was an increase in the distribution of municipalities with higher rates and a change in the shade of these spots, indicating an increase in mortality. The second period of analysis (2010–2015) seems to indicate a different trend. In the Southeast Region, there is both a decrease in the extent of concentrations of municipalities with high rates and an apparent decrease in them.

Municipalities in the South Region also showed an increase in mortality in the first period, followed by a decrease. In 2005 (Figure 1), the municipalities with the highest motorcycle mortality were concentrated basically in western Paraná and eastern Santa Catarina. In 2010 (Figure 2), there is an increase in mortality in these regions, as well as spreading to

Caption

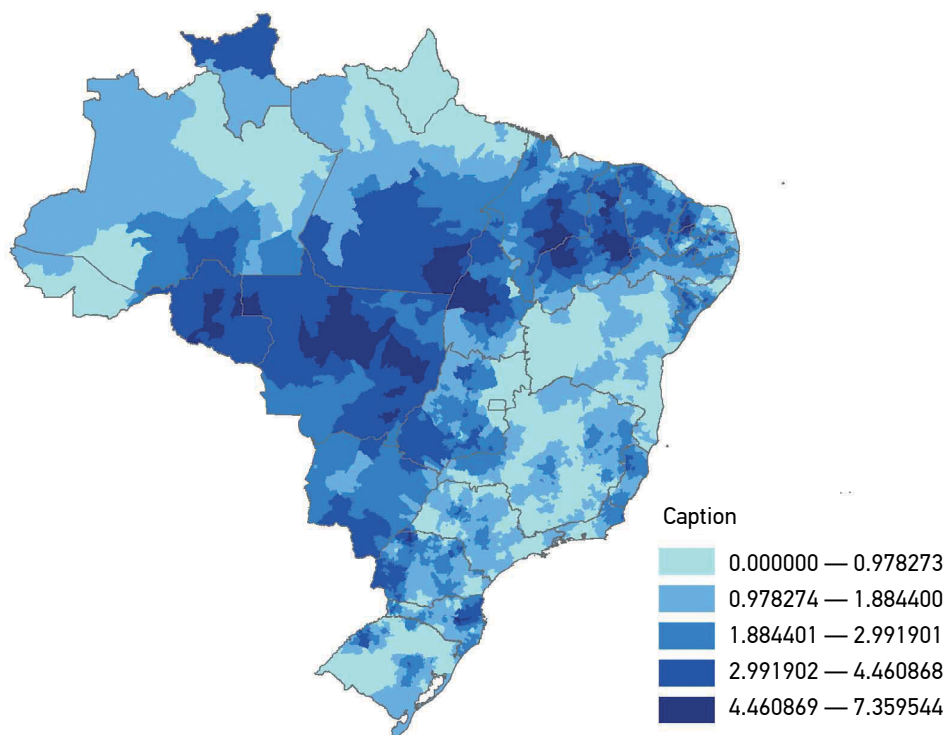|	
	0.000000 — 0.978273
	0.978274 — 1.884400
	1.884401 — 2.991901
	2.991902 — 4.460868
	4.460869 — 5.706726

Source: Mortality Information System (Informatics Department of the Brazilian Unified Health System — Datasus); Population estimates - Interagency Health Information Network — Ripsa (2005)[42].

Figure 1. Smoothed mortality rates (empirical Bayesian estimator — EBE), by municipality, women, Brazil, 2005.

other areas. In 2010, only a small number of municipalities in Paraná and Santa Catarina are located in the group with the lowest rates. Between 2010 and 2015, there was an apparent reduction of municipalities in the group with lower rates, as well as a decrease in classes among the municipalities that had higher rates in previous years.

Table 1 shows the percentage variation in female mortality rates due to motorcycle accidents for groups of municipalities with less than ten thousand, less than 50 thousand, more than 100 thousand and more than one million inhabitants in each region, considering the whole interval (2005–2015) and each of the periods in isolation (2005–2010 and 2010–2015). Taking the entire period into account, for all regions and population profiles, female mortality from motorcycle accidents increased. The variation was more expressive in smaller municipalities.
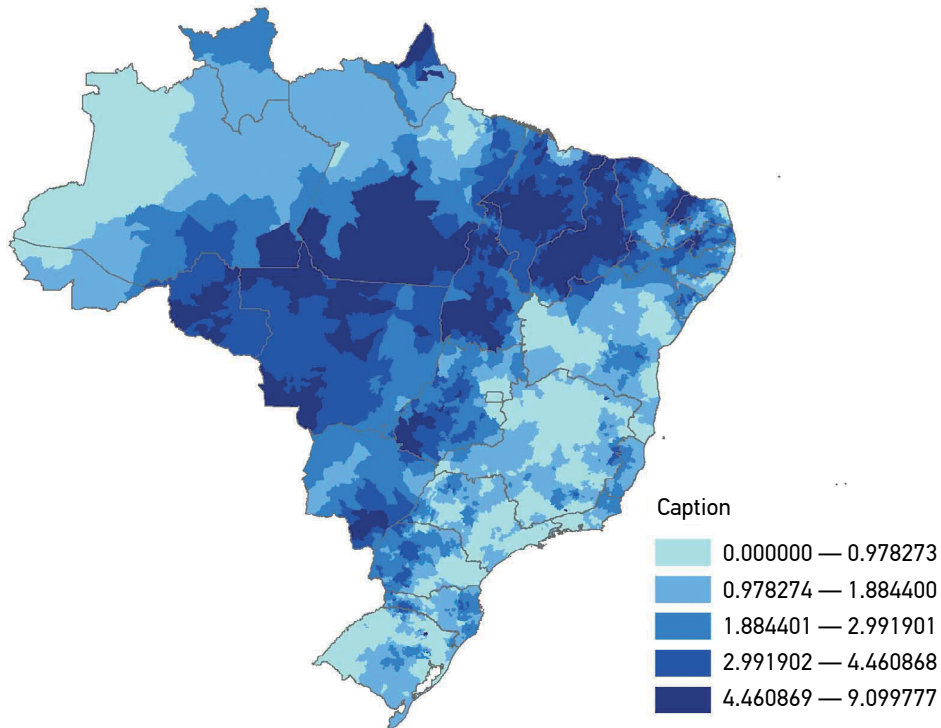
In the Northeast Region, for example, between 2005 and 2015, mortality increased by almost 200% in municipalities with less than 50 thousand inhabitants. For those with less than ten thousand inhabitants, the variation was always positive, in all regions and in both periods. For this same population group, between 2010 and 2015, with the exception of the Northeast region, the percentage variation was lower than in the first five years considered.

Caption

- 0.000000 — 0.978273
- 0.978274 — 1.884400
- 1.884401 — 2.991901
- 2.991902 — 4.460868
- 4.460869 — 7.359544

Source: Mortality Information System (Informatics Department of the Brazilian Unified Health System — Datasus); 2010 Population Census[43].

Figure 2. Smoothed mortality rates (empirical Bayesian estimator — EBE), by municipality, women, Brazil, 2010.

When we take the analysis to the other population sections, Table 1 reinforces the impression that female mortality from motorcycle accidents decreased between 2010 and 2015 in the South and Southeast regions, as highlighted in the analysis of Figures 2 and 3.

Caption

	0.000000 — 0.978273
	0.978274 — 1.884400
	1.884401 — 2.991901
	2.991902 — 4.460868
	4.460869 — 9.099777

Source: Mortality Information System (Informatics Department of the Brazilian Unified Health System — Datasus); Population estimates - Interagency Health Information Network — Ripsa (2015)[42].

Figure 3. Smoothed mortality rates (empirical Bayesian estimator — EBE), by municipality, women, Brazil, 2015.

Table 1. Percentage variation of standardized mortality rates, by size of municipality and region, Brazil, women, 2005–2015.

Region	More than 100,000			More than 1,000,000			Less than 10,000			Less than 50,000		
	2005–2010	2010–2015	2005–2015	2005–2010	2010–2015	2005–2015	2005–2010	2010–2015	2010–2015	2005–2010	2010–2015	2005–2015
Midwest	73%	8%	87%	151%	-20%	102%	103%	19%	142%	54%	30%	101%
North	44%	30%	87%	26%	107%	160%	91%	52%	190%	48%	35%	99%
Northeast	95%	31%	156%	56%	26%	96%	60%	65%	164%	99%	49%	197%
South	57%	-15%	34%	91%	-22%	49%	75%	4%	82%	107%	-17%	71%
Southeast	70%	-10%	54%	60%	-5%	53%	122%	16%	157%	104%	-1%	101%

Source: Mortality Information System (Informatics Department of the Brazilian Unified Health System — Datasus); 2010 Population Census[43]; Population estimates (Interagency Health Information Network — Ripsa) 2005 and 2015[42].

In the municipalities with 50 thousand inhabitants or less, in those with 100 thousand and one million or more, mortality decreased between 2010 and 2015. The negative percentage variation was, in all population segments, more expressive in the South. For municipalities with more than one million inhabitants, the Midwest Region joins the South and Southeast regions in the negative variation recorded between 2010 and 2015.

DISCUSSION

The results presented point to an increase in motorcycle accident mortality between 2005 and 2015 for the female population, as well as for the male and general population[2-8]. Among the main determinants of motorcycle accidents, we can list the vulnerability of the vehicle, the increase in the fleet, road and vehicle safety, risky behavior, the growing use of motorcycles as a work tool, inexperience in driving the vehicle, sex, age, alcohol consumption and attention level[4,24].

The spatial distribution of the municipalities with the highest rates in Figures 1, 2 and 3 is largely similar to the distribution observed in other studies, with significant concentration in the municipalities of the Midwest, Northeast and North regions[3-8]. In addition, the maps presented show that the empirical Bayesian estimator was a good tool to deal with the random fluctuation of small numbers and enabled visualization gains in relation to standardized rates[3,38-41].

The South and Southeast regions presented, in all years and in relation to the other regions, a less expressive distribution of municipalities with high rates. To some extent, this result may reflect the protective effect of higher levels of development in relation to mortality[43-45]. The relationship between mortality from transport accidents and economic development has an inverted "U" shape[44-46]. In other words, for lower income levels, economic growth can be associated with increased mortality; once a certain degree of development is reached, this relationship is reversed.

The results point to the growing importance of motorcycles as a means of transportation for women. This phenomenon is probably related to the lack of public transport and/or high fares[1,32,36,37]. Carvalho and Pereira[47] show that, between 1995 and 2008, the price of bus, subway and train fares in nine capitals increased above inflation, and that rising prices affect the demand for public transport. The same authors point out that persistent increases in the price of fares, accompanied by an increase in income, may lead to the substitution of the use of public transport for private means of transport. In addition, in recent years, there has been a government incentive for the purchase of automobiles and motorcycles through tax exemption[1,33,47]. Vasconcellos[1] notes that the cost of a seven-kilometer motorcycle trip in large and medium-sized cities corresponds to a third of the public transport fare and the same fraction of time spent.

For all population segments, in all regions, the period between 2005 and 2010 indicated an increase in female mortality from motorcycle accidents. Analyzing Brazil as a whole,

Morais Neto et al.[5] identify a positive variation in motorcycle mortality (both sexes) for all population sizes. In the second period (2010–2015), the variation of municipalities with less than ten thousand inhabitants was positive, albeit at lower levels. In the Northeast Region, the variation in the second period was greater for this group. Smaller municipalities and less developed regions, due to the lack of public transport infrastructure, are probably those that depend most heavily on motorcycle as a means of transport[8,32,36,37]. A study by the National Public Transport Association (ANTP)[48] with municipalities with at least 60 thousand inhabitants shows that, in 2016, the share of commutes made by public transport decreased with the size of the municipalities. The situation is likely to be even more significant in even smaller municipalities.

In addition, the low regulatory and inspection capacity in smaller municipalities may also explain part of the increase in mortality in the period. In general, only the largest municipalities have municipal inspection actions, which results in a low capacity to impose fines and carry out regulatory actions[11,49,50]. Sloan et al.[51] note, for example, that the presence of police officers negatively impacted mortality due to transport accidents. Greater police presence would increase the chances of punishment for inappropriate behavior. In 2014[52], 22.7% of the municipalities had a public security department. In 2017, around 25% did not have a municipal transport management agency[37]. The percentage of motorcycle accident victims who declare not wearing a helmet and having consumed alcohol is quite high in some capitals. It is likely to be even lower in smaller municipalities[23,24].

Between 2005 and 2015, the Brazilian GDP showed growth and retraction movements[53]. There are a number of studies that portray a pro-cyclical relationship between economic dynamism and mortality from transport accidents[54-57]. In times of crisis, there is a decrease in the circulation of people and, consequently, less exposure to risk[58]. GDP grew annually between 2005 and 2010, with the exception of 2009[53]. The same period showed an increase in female mortality due to motorcycle accidents. Especially for the lower income classes, the increase in income allows the purchase of a first vehicle, often a motorcycle[8]. To a large extent, the regions that concentrate municipalities with high mortality rates are regions of outstanding economic dynamism[3,8].

In the second analysis period (2010–2015), after 2014, there was a significant drop in GDP and an increase in unemployment, especially in 2015 and 2016[53]. The reduction in mortality, especially in the South and Southeast, may, to some extent, reflect a slowdown in economic activity.[54-56]. In the same sense, in other regions, in practically all population segments, there was a deceleration in the growth rate of mortality due to motorcycle accidents between 2010 and 2015.

The present study demonstrated that the period between 2005 and 2015 was marked by major changes in female mortality from motorcycle accidents, a phenomenon that was already observed for the male population. The analysis makes it clear that there are concentrations of municipalities with higher mortality, while showing that the phenomenon has grown for a larger number of municipalities. Among the possible explanations, the lacking public transport in many municipalities can be highlighted. This, to a large extent, explains

the growing importance of motorcycles as a means of transport and the low regulatory capacity in small cities.

This time frame allowed the identification of different dynamics in female mortality, in a period of significant variation in mortality due to motorcycle accidents at the municipal level. Likewise, the period was marked by different cycles in economic activity, which, in turn, may have influenced the observed rates. The results presented show that exploring the relationship between economic variables and motorcycle accident mortality can be an important line of research to expand knowledge about the phenomenon and its implications.

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