Original article

Pedestrian mortality in road traffic accidents in Brazil: time trend analysis, 1996-2015*

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Abstract

Objective: to analyze the mortality coefficient trend for road traffic accidents involving pedestrians in Brazil, by sex, age range and macro-region, between 1996 and 2015. **Methods:** this was an ecological time series study using data from the Ministry of Health's Mortality Information System (SIM); Prais-Winstein generalized linear regression was used to calculate annual percentage change. **Results:** pedestrian deaths corresponded to 26.5% of deaths due to road traffic accidents; mortality among pedestrians decreased 63.2% in the country as a whole, with the standardized coefficient varying between 8.9 to 3.3 per 100,000 inhabitants, although the decrease in the country's North and the Northeast regions was slower than the national average; being run over was significantly higher among men and the elderly. **Conclusion:** although mortality among pedestrians is decreasing in all regions of the country, current figures still account for a large part of road traffic mortality.

Keywords: Accidents, Traffic; Pedestrians; Mortality; Time Series Studies.

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Introduction

Groups of public highway users at greater risk of accidents account for around half the total number of road traffic deaths worldwide. These include pedestrians (22.0%), cyclists (4.0%) and motorcyclists (23.0%), although the likelihood of accidents involving each of these groups varies depending on the region or country. This reflects, in part, the safety measures taken to protect different highway users and the most common forms of mobility according to each region or country.[1]

In Brazil, pedestrians are the third largest group of victims, after motorcyclists and car occupants.[1] In 2016, according to Ministry of Health Mortality Information System (SIM) data, available on the Brazilian National Health System Information Technology Department website, in Brazil there was a total of 38,265 deaths caused by land transport accidents. Of these deaths, 12,036 (31.5%) were motorcyclists, 8,899 (23.2%) car occupants and 6,158 (16.1%) pedestrians.

> *Traffic safety interventions aimed at pedestrians, such as improved street lighting, speed breakers and pedestrian crossings, can increase substantially pedestrian safety.*

Pedestrian safety can be representative of the population's quality of life. A study based on the global burden of disease (GBD) found that accidents involving pedestrians in Brazil are decreasing potential years of life and increasing years lived with disability, the so-called disability adjusted life years (DALY). In 1990, pedestrian accidents came in first place on the list of DALY coefficients in Brazil; in 2015, these coefficients had reduced by 51.4%, although still coming in second place after firearm homicides.[2]

Walking is a popular daily activity for most people, regardless of their main means of transport, especially in low- and middle-income countries.[3] This is not just because of need or option, but also because this means of locomotion is promoted for being recognized as being healthy and cheap, besides being an alternative that helps to reduce the number of vehicles in circulation. Once the perception that it is safe to walk on public highways is consolidated, there is greater encouragement of practicing physical activities outdoors, with consequent benefits for mental and physical health.[4] However, in many low- and middle-income countries, there are no policies on improving pedestrian safety and this places them at risk of injury and death on the roads.[3,4]

Some 91 countries, 9.0% of which are high-income, have policies to encourage people to walk or go by bike.[1] However, if these strategies are not accompanied by other strategies, such as effective speed control and pedestrian and cyclist accessibility, they may result in an increased number of injuries owing to traffic collisions. A key strategy for a traffic system that is safe for pedestrians and cyclists consists of separating them from motor vehicle drivers.[1,3,5]

Traffic safety interventions aimed at pedestrians, such as improved street lighting, speed breakers and pedestrian crossings, can increase substantially pedestrian safety.[6,7] In view of a scenario marked by traffic violence, the United Nations Organization (UNO) proclaimed the period 2011-2020 as the Decade of Action for Road Safety, whereby Member States have committed themselves to the objective of stabilizing and reducing traffic-related deaths and, consequently, have committed to targets defined to this end.[1,7] Brazil joined this global strategy with its Life in the Traffic Project (Vida no Trânsito), formalized by Interministerial Ordinance No. 2268, dated August 10th 2010. As one of the interventions forming part of the National Accident Reduction and Road Safety Plan for the Decade 2011-2020, by means of improved information, the Life in the Traffic Project provides for local interventions based on highlighting risk factors and behaviors and planned intersectoral actions, with the aim of reducing the number of deaths and serious injuries.[7]

Promoting knowledge about this issue will contribute to the development of efficient interventions, aimed at protecting and reducing the risk of road traffic accidents, this being one of the main objectives of traffic safety. Studies identifying pedestrian mortality magnitude and trends are scarce in Brazil, despite their great relevance and despite recently implanted public policies. The objective of this study was to analyze the trend of pedestrian mortality in road traffic accidents in Brazil and its macroregions between 1996 and 2015.

Methods

This is an ecological time series study. The data on deaths, retrieved from SIM, a system coordinated by the

SUS Information Technology Department (DATASUS) (http://www.datasus.gov.br), refer to the period 1996-2015 and were collected according to place of residence. We used deaths classified as 'pedestrian injured in traffic accident', identified on the Death Certificate according to the coding provided by the International Statistical Classification of Diseases and Related Health Problems - 10th Revision (ICD-10): codes V01 and V09. In order to calculate the crude mortality coefficients we used population data retrieved from Brazilian Institute of Geography and Statistics (IBGE) estimates.

All variables were analyzed as to their completeness for the years 1996-2015 and the percentage of complete fields was calculated. Deaths with unknown sex and age – 2.16% of cases reported on SIM – were excluded from the analysis.

The crude mortality coefficients were calculated by dividing the number of deaths in the study population by the number of inhabitants estimated by IBGE for the same period, multiplied by 100,000 inhabitants. In order to control possible disparities between populations and adequate comparison between the Brazilian macroregions, we used the direct method of mortality coefficient standardization by age strata. The standard population used was that proposed by the World Health Organization (WHO) (http://www.who.int/healthinfo/paper31.pdf). The coefficients found for each region were multiplied by the respective populations in accordance with the international standard.

We used Excel in all stages performed up to the generation of the database. Following this the data were exported for analysis using Stata 13.0 statistical software. We used the Prais-Winsten generalized linear regression model for time trend analysis.[8,9] This model works to correct the effect referred to as first-order autocorrelation, when only one previous period in time is considered. This specification is also known as the autoregressive (AR) model. Dependence or correlation between time series data observations makes the use of the traditional technique of ordinary least squares regression coefficients infeasible.[8] The Prais-Winsten method is, therefore, an extension of traditional linear regression, since it transforms the original regression equation into an equivalent equation which can be estimated by the least squares method. It is a specialized method for cases of first-order autocorrelation.

A posteriori, the coefficients obtained via regression and their respective 95% confidence intervals (95%CI), were also transformed into average annual percentage change using the following formula suggested by Antunes & Waldman:[9]

The results generated by generalized linear regression enabled indication of the mortality trend: stationary ($p>0.05$), decreasing ($p<0.05$ and negative regression coefficient) or increasing ($p<0.05$ and positive regression coefficient).

The study project met the ethical requirements of National Health Council (CNS) Resolution No. 510, dated April 7th 2016; as it only uses publicly available data and does not identify those involved, it was exempt from submission to a Research Ethics Committee.

Results

Between 1996 and 2015, there were 194,601 pedestrian deaths in Brazil, corresponding to 26.5% of deaths caused by land traffic accidents in the period.

The mortality coefficients for accidents involving pedestrians decreased for Brazil as a whole and also in each of its macroregions (Figure 1). The highest coefficient related to the year 1996 (8.9/100,000 inhab.), while the lowest related to the year 2015 (3.3/100,000 inhab.) (Table 1).

Brazil reduced its pedestrian mortality coefficient by 63.2%, between 1996 and 2015, with standardized coefficient variation of 8.9 to 3.3/100,000 inhab. The lowest coefficient recorded in 2015 was found in the Northeast region (3.0/100,000 inhab.) while the highest was found in the Northern region (3.9/100,000 inhab.).

The decrease was slower in the North and Northeast regions, with average annual variation (AAV) 2.1 and 1.4 times lower, respectively, than the national average. The Southeast region stood out for having a faster decrease, with AAV 1 x higher than the rest of the country. In chronological order, the mortality coefficients reduced until they reached their lowest level in the year 2000 (Figure 1). A new "dip" in the evolution of the national mortality coefficient trend was found in 2009. In 2010, the coefficients for the country as a whole, and also for each region, began to increase again, before falling with effect from 2011.

Male pedestrian mortality, although it remained higher than female mortality, showed the highest decrease over the time series: male mortality, -62.3%;

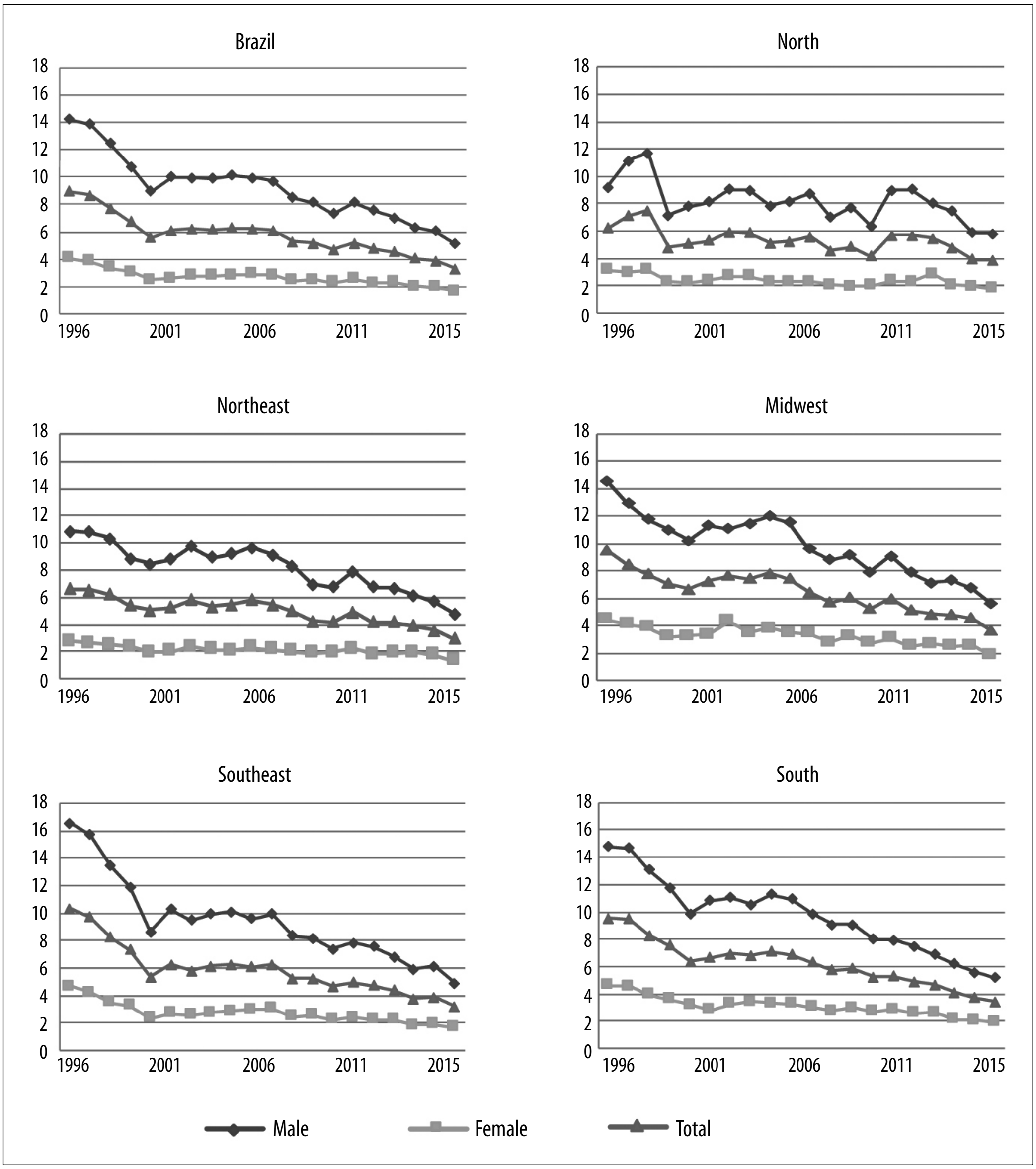

Figure 1 – Pedestrian accident standardized mortality coefficient time series (per 100,000 inhabitants), by sex and macroregions, Brazil, 1996-2015

female mortality, -21.7%. The biggest fall in the rates by gender occurred in the Southeast region, with an annual percentage change of -70.7% among males. The reduction in the Northern region was lower when compared to the other regions (-30.9%), falling from 9.2 to 5.8/100,000 males between 1996 and 2015 (Table 2).

The mortality coefficient for Brazil was highest among pedestrians over 60 years old in relation to the other age groups analyzed (18.5/100,000 inhab. in 1996; 9.9/100,000 inhab. in 2015). The lowest coefficient per age group was found among children and young people aged 0-19 (4.2/100,000 inhab. in 1996; 1.0/100,000 inhab. in 2015); a mean coefficient was found among adults aged 20-59 (6.6/100,000 inhab. in 1996; 3.2/100,000 inhab. in 2015). In 2015, elderly pedestrians had approximately 9.6 and 4.2 times more risk of dying than people aged 0-19 and 20-59 years, respectively (Figure 2).

Table 1 – Standardized mortality coefficient[a] for pedestrian accidents (per 100,000 inhabitants), by macroregion, Brazil, 1996-2015

Year	Brazil	North	Midwest	Northeast	Southeast	South
1996	8.94	6.21	9.47	6.62	10.32	9.51
1997	8.65	7.13	8.47	6.55	9.68	9.44
1998	7.71	7.50	7.79	6.20	8.22	8.29
1999	6.76	4.78	7.10	5.42	7.34	7.54
2000	5.56	5.05	6.70	5.06	5.33	6.37
2001	6.11	5.30	7.28	5.23	6.25	6.25
2002	6.20	5.90	7.65	5.83	5.83	6.94
2003	6.16	5.86	7.45	5.35	6.12	6.80
2004	6.28	5.11	7.84	5.47	6.26	7.08
2005	6.23	5.27	7.45	5.78	6.08	6.86
2006	6.10	5.58	6.47	5.45	6.24	6.27
2007	5.30	4.56	5.71	5.00	5.25	5.74
2008	5.16	4.86	6.08	4.27	5.21	5.86
2009	4.69	4.19	5.27	4.19	4.65	5.21
2010	5.17	5.68	5.99	4.90	4.95	5.28
2011	4.74	5.70	5.14	4.15	4.71	4.90
2012	4.52	5.49	4.84	4.16	4.36	4.63
2013	4.04	4.80	4.82	3.91	3.75	4.07
2014	3.87	3.95	4.57	3.57	3.90	3.72
2015	3.29	3.89	3.65	2.95	3.20	3.44

a) Coefficient standardized according to the global population (World Health Organization - WHO).

Discussion

There was a considerable fall in traffic accidents involving pedestrians both in Brazil as a whole and in all the country's regions – despite the coefficient decrease rate having been different between the country's five regions both by sex and by age range. Global data on road safety in 181 countries, accounting for 6.8 million people of different nationalities, found that pedestrian mortality coefficients decreased significantly between 2007 (4.2/100,000 inhab.) and 2010 (3.9/100,000 inhab.), with a global reduction of 8.1%.[3]

Isolated studies in different countries also found a fall in this outcome. In Cali, a large Colombian city, there was a decreasing trend in pedestrian mortality, with the occurrence of deaths falling from 1.1 deaths per 10,000 people/year in 2008, to 0.6 deaths in 2010.[10] In the City of Mexico, between 1994 and 1997 and between 2004 and 2007, there was a 17.5% decrease.[11] In Iran, there was a 20% decrease between 2009 and 2015, with an average decrease of 4% per annum.12 In Spain, the crude pedestrian mortality coefficient fell by 67% between 1993 and 2011.[13]

In Brazil, when comparing the year 2000 with the year 2010, a study of traffic accident mortality coefficients and population size found a reduction in changes in the risk of pedestrian mortality in the majority of the country's states. The highest coefficients were found in municipalities with between 100,000 and 500,000 inhabitants in 2000, and in those with more than 500,000 inhabitants in 2010. The lowest coefficients occurred in municipalities with fewer than 20,000 inhabitants, in the periods studied.[14] The authors of that study also found that pedestrians were at greater risk of death between 2000 and 2007, although this risk decreased in the years that followed and by 2010 it was lower than that of car occupants and motorcycle riders.[14]

As a general rule, the lower a country's income, the higher the number of pedestrian deaths.[1] Low-

Table 2 – Pedestrian accident mortality trends, by sex and macroregions, Brazil, 1996-2015

Region	APC[a]	95%CI[b]	p-value	Conclusion
Brazil				
Male	-62.33	-71.94;-49.41	<0.001	Decrease
Female	-21.66	-29.46;-12.93	<0.001	Decrease
Total	-45.27	-55.09;-33.27	<0.001	Decrease
North				
Male	-30.98	-46.77;-10.50	0.003	Decrease
Female	-11.08	-12.56;-3.83	<0.001	Decrease
Total	-21.42	-33.41;-7.27	<0.001	Decrease
Midwest				
Male	-59.33	-68.61;-47.28	<0.001	Decrease
Female	-20.43	-26.24;-14.11	<0.001	Decrease
Total	-44.22	-52.99;-50.87	<0.001	Decrease
Northeast				
Male	-47.32	-57.10;-35.35	<0.001	Decrease
Female	-10.90	-15.28;-6.34	<0.001	Decrease
Total	-31.08	-38.78;-22.46	<0.001	Decrease
Southeast				
Male	-70.70	-81.48;-53.62	<0.001	Decrease
Female	-26.37	-36.82;-14.03	<0.001	Decrease
Total	-52.79	-65.18;-36.03	<0.001	Decrease
South				
Male	-65.77	-73.22;-56.23	<0.001	Decrease
Female	-24.86	-32.21;-16.70	<0.001	Decrease
Total	-49.00	-57.06;-32.21	<0.001	Decrease

a) VPA: variação percentual anual – tradução do inglês annual percentage change (APC).
b) IC95%: intervalo de confiança de 95%.

income countries account for 45.0% of these deaths globally, while middle- and high-income countries account for 29.0% and 18.0% of these deaths, respectively.[1] A global study that analyzed data on 181 countries indicated that gross domestic product (GDP) played a positive role in reducing pedestrian deaths in 2007.[3] One hypothesis explaining that finding could be that higher GDP may contribute to safer and more preventive urban and highway design interventions. On the other hand, in 2010, national traffic safety legislation was the best variable for predicting pedestrian mortality, providing evidence that the factors underlying the occurrence of these accidents alter over time on the global level.[3] Legislation and its adequate enforcement are important for achieving the target of reducing traffic accident deaths to approximately 5 million people over the next decade worldwide.[3]

Our analysis showed that despite an overall fall in Brazil, when looking at the country's regions, the North and Northeast regions had a differentiated falling trend as it was slower. This points to the need for greater regional investment in and attention to reducing pedestrian deaths. On the other hand, the Southeast stood out owing to a faster reduction in pedestrian deaths. As discussed above, there is an association between the economic context of a region and greater occurrence of pedestrians being run over.[1,3,15,16] The lowest per capita GDP in Brazil is found in the North and Northeast regions, where the proportion of municipalities with GDP higher than the national GDP is no more than 12.5%. These are

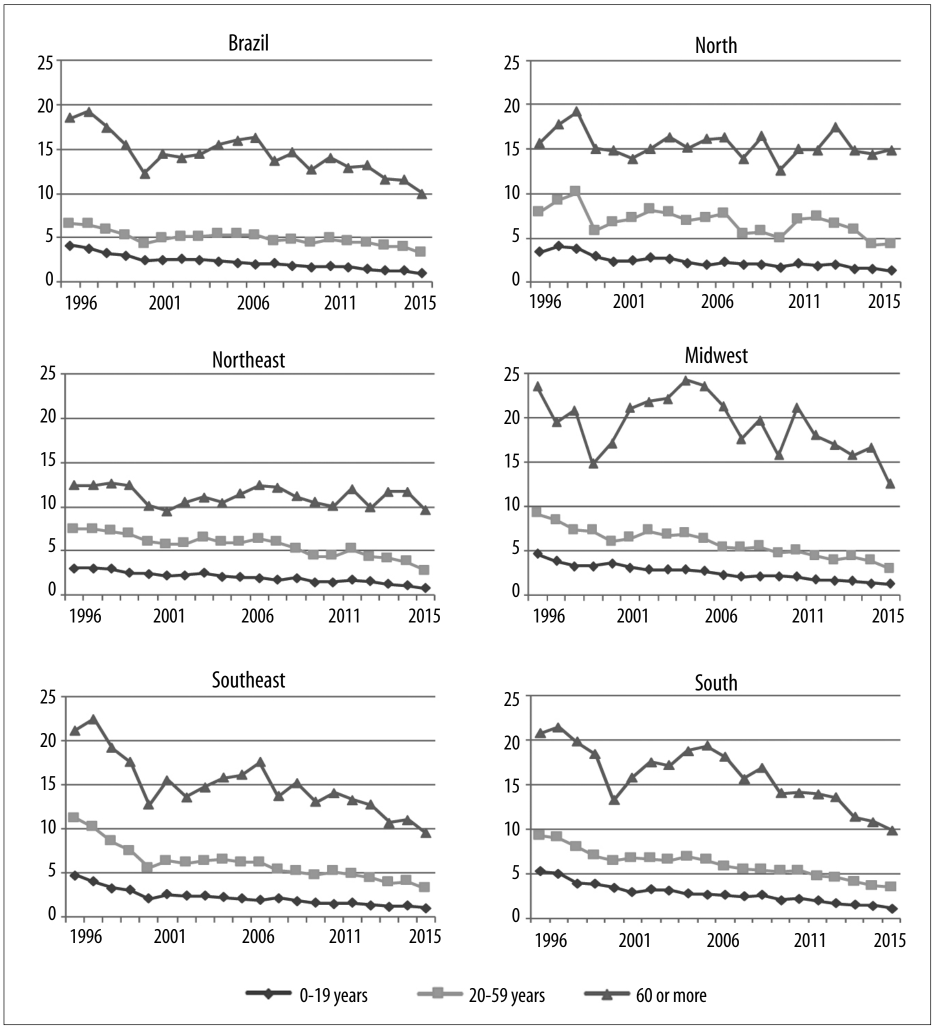

Figure 2 – Pedestrian accident mortality coefficient time series (per 100,000 inhabitants), by age range and macroregion, Brazil, 1996-2015

also regions with the highest proportions of deaths among these more vulnerable public highway users, when compared to other users.[15] Another hypothesis to be considered is the highly unequal road structure conditions and regional inspection measures: the North and Northeast were given the worst national classifications, with 76.6% and 63.1% of their road networks having some kind of defect and having their overall status being assessed as regular, bad or appalling.[17] With regard to pedestrian safety, factors such as unmarked traffic lanes, unmarked highways, precarious public lighting, two-way highways, road works, three-lane highways as well as the summer period factor, contribute to increased likelihood of death. Speed limits are another crucial factor: the risk of fatal accidents is greater on highways where the speed limit is ≥70 km/h.[5]

During the period analyzed points on the trend line showing greater falls were also observed, possibly related to historical landmarks in the field of Brazil traffic legislation and inspection. The National Traffic Department (DETRAN) made important interventions in the period preceding the year 2000.[18] Moreover, the "dip" identified in the trend line for the country corresponding to the year 2009, especially in the line representing males, coincides with the enactment of Law No. 11705, dated June 19th 2008: known as the "Dry

Law", it contributed to a significant proportional reduction in the risk of traffic accident deaths and hospitalizations.[19,20] There was a reduction in the risk of death for Brazil as a whole (-7.4%) and for the state capitals (-11.8%), principally among males (-8.3% and -12.6%, respectively), between 2007 and 2009.[19] As soon as the Dry Law came into force, intense control was undertaken on some highways. However, these measures gradually slackened, leaving doubts as to whether the aims of the Law were met. The result in the slackening of control was soon noted in the reversal of the falling trend in the accident rate.[20]

In 2010, once again Brazil experienced high traffic death rates,[19] with a peak in the number of victims run over with fatal consequences in that year. With effect from 2011, with the implantation of the Life in the Traffic Project in some Brazilian cities, as an initiative of Decade of Action for Road Safety (2011-2020), a falling trend in mortality rates can be seen and was found by our study until the end of the period analyzed. After two years, percentage achievement of the targets of the intervention programs increased, such as speed control and police blitzes to test for alcohol, with an increase in the number of tests and a reduction in the respective percentage of positive results.[21] Traffic accident mortality was found to have reduced in three state capitals that joined the Program.[21]

With regard to our study, the results demonstrate that mortality coefficients among males are significantly higher than among females, regardless of region or age group. This finding corroborates the results of the majority of the studies on this subject.[15,22] Although the reasons for this gender differentiation between the mortality coefficients involving pedestrians are not well understood, some studies have provided explanatory findings:[23] (i) male pedestrians are involved in collisions of greater intrinsic severity; (ii) the traffic collision lethality coefficient explains 79.0% of the discrepancy in the mortality coefficients between the sexes according to a study conducted by Zhu et al.;[23] (iii) collisions at night are more serious than those occurring during daylight; and (iv) it is more frequent for men to walk at night.[24,25] Although these reasons for gender differentiation between mortality coefficients involving pedestrians are not sufficiently understood or analyzed, some studies raise hypotheses in this regard,[23] such as, for example, significant gender-related differences in attitude when walking and in perception of the environment; and women pedestrians are more sensitive to traffic safety, having fewer risk behaviors.[24] Notwithstanding, further research is needed to discover the reasons that lead males to be more prone to death from being run over.[24,25]

The data analyzed also reveal a significant discrepancy in mortality by age range. The results of our study clearly show a higher number of pedestrian deaths among people aged over 60, confirming the findings of other studies.[2,15,22] Factors inherent to aging may explain the fact of the elderly being more exposed to risk of collision with a vehicle over longer periods of time. Alterations in the way of walking and in walking speed require more time to cover the same distance, increasing the risk of crossing a road, for example.[26] The time allowed to pedestrians by traffic lights is not always sufficient for the elderly to cross the road before the lights change against them. Other limiting factors related to advancing age, such as lack of attention, loss of balance, seeing and hearing difficulties, can contribute to accidents.[11] Cognitive impairment is another factor much pointed to by studies of the involvement of elderly pedestrians in accidents. And when this impairment is related to dementia, such as Alzheimer's disease, the elderly person in question can be at greater risk.[27]

Regarding the limitations of our study, we highlight the use of secondary data which depend on the accuracy and completeness of the information system consulted. It is important to consider the possibility of shortcomings in SIM form filling, coding or its coverage of national data. The scenario of problems with the filling out of Death Certificates also points to the need for improved quality of the information registered.[28] Moreover, as they are traffic accident data, information may be underreported and hidden.[5,15] It should be highlighted that the Mortality Information System is the oldest health information system in Brazil, and the quality and reach of its data has increased gradually: currently its degree of adequacy is around 90.0%.[28]

The data presented here demonstrate that although mortality among pedestrians is decreasing throughout the country and in each of its regions, there is still a high number of fatal traffic outcomes, affecting above all males and the elderly. These results demonstrate the need to develop interventions targeting these groups, aimed at meeting specific accident reduction needs and improving the safety of these pedestrians. Successful experiences have occurred and been analyzed in other countries that could be adopted in Brazil. In this way, Brazil could get closer to achieving the levels found in countries with lower mortality, as well as meeting the targets set by the United Nations Organization for the Decade of Action for Road Safety.

Authors' contribution

Fernandes CM and Boing AC contributed to the conception and design of the article, data analysis and interpretation, writing the first version of the manuscript and critically reviewing it. Both authors approved the final version of the manuscript and are responsible for all its aspects, including the guarantee of its accuracy and integrity.

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