Homicide mortality in border regions in the State of Paraná, Brazil

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Abstract *A time series analysis was conducted to identify trends in homicide mortality in border regions in the State of Paraná, Brazil between 2002 and 2012. Homicide mortality rates were analyzed by sex, age group, region (border regions, non-border regions, and the state as a whole), and type of assault. Trend analysis was performed using polynomial regression. The findings showed that mortality rates were higher in the border regions; however the growth in homicide rates was greater in the non-border regions and in the state as a whole, with these states showing an upward trend in homicide rates (p < 0.001) and border regions showing a downward trend, although the latter was not significant. Mortality rates were higher among men across all regions and highest in the 20 to 29 age group. The findings regarding homicide rates in border regions provide compelling evidence of the urgent need for intersectoral prevention policies targeting the most affected groups.*
Key words *Homicide, Mortality, Border areas, External causes*

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Introduction

Homicide is the leading external cause of death in Brazil. The country recorded 59,080 homicides in 2015, which is equivalent to 28.9 deaths per 100,000 population and represents over 10% of all homicides worldwide. This cause of death causes changes in social, economic, demographic, and health dynamics[1].

Violence places a major burden on the country, having a significant impact on economic development, social indicators, and health costs and creating a sense of insecurity[2]. Violence and injury have been a major component of mortality and morbidity in Brazil since the 1980s and rates of violence are particularly high among young men[3]. The analysis of deaths from homicide helps understand trends and provides valuable inputs to inform health policies and community-based interventions designed to curb violence[4].

Border regions have traditionally been regarded as marginalized, peripheral areas characterized by social and economic exclusion, despite regional development and changes over time. This process has a direct impact on health, which is a primary component of the social integration of borderland populations. Given the economic dynamics of these regions, interventions to tackle violence and promote social inclusion, education, and national security have a direct influence on the success of public health policies[5].

More specifically, the State of Paraná, in Brazil's South region, is bordered by the states of Mato Grosso do Sul, São Paulo, and Santa Catarina, the Atlantic Ocean to the east, and Argentina and Paraguay to the west. The state's borders stretch over 2,458km, 447km of which with Argentina and Paraguay. The majority of the borders follow natural formations such as rivers and drainage divides, including the Paraná River, which separates Foz do Iguaçu, in Brazil, from Ciudad del Este, in Paraguay, and the Iguaçu River, separating Foz do Iguaçu from Puerto Iguazú, in Argentina[6].

International boundary lines have specific characteristics, with well-defined political boundaries, their own economic dynamics and social and cultural history, and free movement of people[7]. This has led to a diversification of causes of deaths in border regions like those in the State of Paraná, particularly homicides and transport accidents. Few studies have investigated homicides trends in border regions around the world and research is therefore lacking in this area both in Brazil and internationally. With a constant flow of people, international borders delimit countries with distinct realities. The magnitude of violence on Brazil's southern border demonstrates the need for more comprehensive research and public policies designed to curb violence and address the needs of the population of these areas. The aim of this study was therefore to investigate homicide trends in the border regions of the State of Paraná.

Methods

We conducted a time series analysis of trends in homicide mortality in the State of Paraná, in Brazil's South region, using official data from the national Mortality Information System (SIM, acronym in Portuguese).

Collected from the country's national health information system (Datasus), the data included deaths by residential address between 2002 and 2012. We used the International Classification of Diseases 10th Revision (ICD-10) to categorize deaths from assault (X-85 to Y-09). The demographic data was obtained from census data and population estimates made by the Brazilian Institute of Geography and Statistics (IBGE). For comparison purposes, we divided the stated into border regions (17 municipalities - Barracão, Bom Jesus do Sul, Capanema, Entre Rios do Oeste, Foz do Iguaçu, Guaíra, Itaipulândia, Marechal Cândido Rondon, Mercedes, Pato Bragado, Pérola d'Oeste, Planalto, Pranchita, Santa Helena, Santo Antônio do Sudoeste, São Miguel do Iguaçu, and Serranópolis do Iguaçu) and non-border regions (382 municipalities), as shown in Figure 1. Cases with missing information are not included in the description of the data.

We analyzed the relationship between deaths from homicide and the following variables: age (years), sex (male/female), region of residence (border regions/non-border regions/Paraná), and type of assault. For the latter variable, homicides were grouped as follows: X93 to X95 assault by firearms, X99 assault by sharp object, Y00 assault by blunt object, other types of assault.

Mortality rates were calculated as the ratio between the number of deaths over the year and the population at risk multiplied by 100,000 inhabitants. For comparison purposes, the data was standardized using direct age adjustment. This method uses a standard population to eliminate any possibility that observed differences could be a result of age differences in the population. It is used to compare two or more populations with

Mato Grosso do Sul

São Paulo

Paraguay

Argentina

Santa Catarina

Municipalities in the border region
1. Guaíra
2. Mercedes
3. Marechal Cândido Rondon
4. Pato Bragado
5. Entre Rios do Oeste
6. Santa Helena
7. Itaipulândia
8. Foz do Iguaçu
9. São Miguel do Iguaçu
10. Serranópolis do Iguaçu
11. Capanema
12. Planalto
13. Pérola d'Oeste
14. Pranchita
15. Santo Antônio do Sudoeste
16. Bom Jesus do Sul
17. Barracão

Figure 1. Map of the state of Paraná (Brazil) showing the border with Argentina and Paraguay.

Source: SIM/MS/DATASUS.

differences in age structure, or one population in different time periods. A standard population is created to serve as a reference for the time series[8]. For the purposes of this study, the standard population was the population in 2010, based on the most recent census conducted by the IBGE.

The homicide mortality rates were analyzed by sex, age group (10 to 19, 20 to 29, 30 to 39, 40 to 49, 50 to 59, and 60 years and over), and region (border regions, non-border regions, and the state as a whole). Trend analysis was performed using polynomial regression[9].

The dependent variables (Y) were the standardized homicide mortality rates and sequential years were used as independent variables (X), centered at the midpoint of the time series to avoid autocorrelation between terms in the regression equation (X - 2007). Scatter plots were used to determine which function best expressed the relationship between the independent vari-

ables. We then tested the first order ($Y = \beta_0 + \beta_1 x$), second order ($Y = \beta_0 + \beta_1 x + \beta_2 x^2$), third order ($Y = \beta_0 + \beta_1 x + \beta_2 x^2 + \beta_3 x^3$), and exponential function ($Y = e^{\beta_0 + \beta_1 x}$), where β_0 is the average coefficient for the period and β_1 is the average annual rate. This model was chosen based on the following criteria: best function according to the scatter diagram; best fit (normality of error distribution and homoscedasticity); higher level of statistical significance (ANOVA p-value); and higher coefficient of determination (R^2). In the case of statistically similar models, the simplest models were chosen. The significance level was set at 5%.

We constructed the indicators, standardized the homicide mortality rates, and prepared the tables and graphs using used Microsoft Excel 2007. The trend analysis was performed using the statistical software Bioestat 5.0, developed by the Federal University of State of Pará (UFPA), and Datsus' Tab for Windows function.

Results

There were 688,626 deaths in the State of Paraná during the study period, 96,039 of which were due to external causes (13.9% of total deaths). Of these, 34,200 (35.6%), were deaths from homicide. Table 1 shows the homicide mortality rates by sex and region. Overall mortality rates were higher in border regions up to 2007 when the situation was inverted. In these regions, the overall homicide rate fell from 71.2/100,000 population in 2002 to 60.0/100,000 population in 2012, which is equivalent to a drop of 15.7%. In contrast, in the non-border region and the state as a whole, rates increased by 38.0%. Rates in the border regions showed a sharp fall between 2007 and 2009, from 77.4/100,000 population to 52.2/100,000 population, which is equivalent to a drop of 32.5%.

Mortality rates were constantly higher among men across all regions. In the border regions, the mortality rate for males dropped by 16.2% over the study period, while the State of Paraná as a whole saw a 37.6% rise in the same period, with increases being more pronounced between 2002 and 2008. In contrast, the mortality rate for females rose 3.7% in border regions and 42.5% across the state as a whole. The average male-to-female homicide mortality ratio over the period was 13:1 in border regions and 11:1 in non-border regions and the state as a whole.

Figure 2 shows trends in homicide mortality rates by sex, age group, and region in 2002, 2007,

and 2012. The data reveal that the 20 to 29 years age group showed the highest mortality rates across all regions among both sexes. Mortality rates rose by 56.7% and 43.4%, respectively, in non-border regions and the state as a whole, and fell by 25.8% in border regions among this age group over the study period. In the 60 years and over group, there was a reduction in homicide rates in both sexes. The fall in rates among males in this age group was more pronounced than that in the 50 to 59 years age group.

Assault by firearms was the most common cause of death across all regions (Table 2). In border regions, assault by firearms accounted for more than three-quarters of all homicides in every year of the time series, despite a slight decrease in the proportion of deaths in this category over the study period. In contrast, there was a rise in the percentage of deaths caused by assault by sharp objects over the study period. In the state as a whole, the percentage of deaths from assault by firearms was also high, showing and increase over the study period. In contrast, the percentage of deaths from assault by sharp object decreased over the study period. Finally, the percentage of deaths from unspecified types of assault fell over the study period in the state as a whole and non-border regions.

Table 3 shows the results of the trend analysis of homicide mortality rates by region (overall and by sex). For the state as a whole, the findings show a positive quadratic trend for overall ($R^2 = 0.762$; ($p < 0.001$) and male ($R^2 = 0.874$; $p < 0.001$) rates and a linear trend for female ($R^2 = 0.587$; $p = 0.001$) rates. For non-border regions, there was a positive linear trend for overall rates ($R^2 = 0.762$; ($p < 0.001$), a quadratic trend for male rates ($R^2 = 0.874$; $p < 0.001$), and an exponential trend for female rates ($R^2 = 0.587$; $p = 0.001$). Homicide mortality rates in the border regions were high across all groups and showed a downward trend with exponential trend for overall rates $R2 = 0,319$; $p = 0,041$, an exponential trend for male rates ($R2 = 0,307$; $p = 0,045$), and a cubic trend for female rates ($R2 = 0,525$; $p = 0,042$).

Discussion

The findings of this study provide an insight into differences in the homicide situation between two regions of the State of Paraná (border regions and non-border regions), thus providing important inputs to inform the formulation of more effective interventions. The data reveal high

Table 1. Homicide mortality rates (per 100,000 population) by sex and region. Paraná, Brazil, 2002-2012.

Year	Border regions			Non-border regions			Paraná		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
	Rate	Rate	Rate	Rate	Rate	Rate	Rate	Rate	Rate
2002	136.9	8.1	71.2	45.2	4.5	45.2	49.9	4.7	26.8
2003	114.6	10.0	61.3	52.6	4.9	52.6	55.7	5.1	29.9
2004	144.0	12.0	76.7	56.2	5.4	56.2	60.7	5.7	32.6
2005	140.6	9.9	73.8	58.6	5.0	58.6	62.8	5.2	33.3
2006	150.7	11.2	79.4	60.2	5.2	60.2	64.9	5.5	34.5
2007	145.4	11.8	77.4	58.7	4.6	58.7	63.2	5.0	33.5
2008	115.9	10.0	62.1	65.8	6.0	65.8	68.4	6.2	36.7
2009	97.9	7.9	52.2	70.7	6.9	70.7	72.2	6.9	38.9
2010	113.6	9.8	60.2	69.9	7.0	69.9	71.9	7.1	38.8
2011	99.5	7.0	51.9	65.1	5.8	65.1	66.7	5.9	35.6
2012	114.6	8.4	60.0	66.5	6.6	66.5	68.7	6.7	37.0

Source: SIM/MS/DATASUS.

homicide rates in the border regions, particularly among men.

A study conducted in health regions in Paraná investigating the period 1979 to 2005 revealed a high risk of homicide in the majority of regions and showed that this risk was more pronounced in border regions such as Foz do Iguaçu[10]. However, the present study points to a downward trend in mortality rates in border regions and an increase in deaths in non-border regions and the state as a whole over the study period. These findings are consistent with studies showing that state the has the highest homicide rates in the country's South region[1,10]. A nationwide study of violence showed different realities in states that have seen a decrease in homicide rates: Espírito Santo (-27.6%), Paraná (-23.4%), and Alagoas (-21.8%)[1]. These falls may have been due to the implementation of the Disarmament Statute, firearms collection campaigns, and enhanced police enforcement, leading to an increase in arrests and imprisonment, and projects designed to promote the social inclusion of young people[1,11].
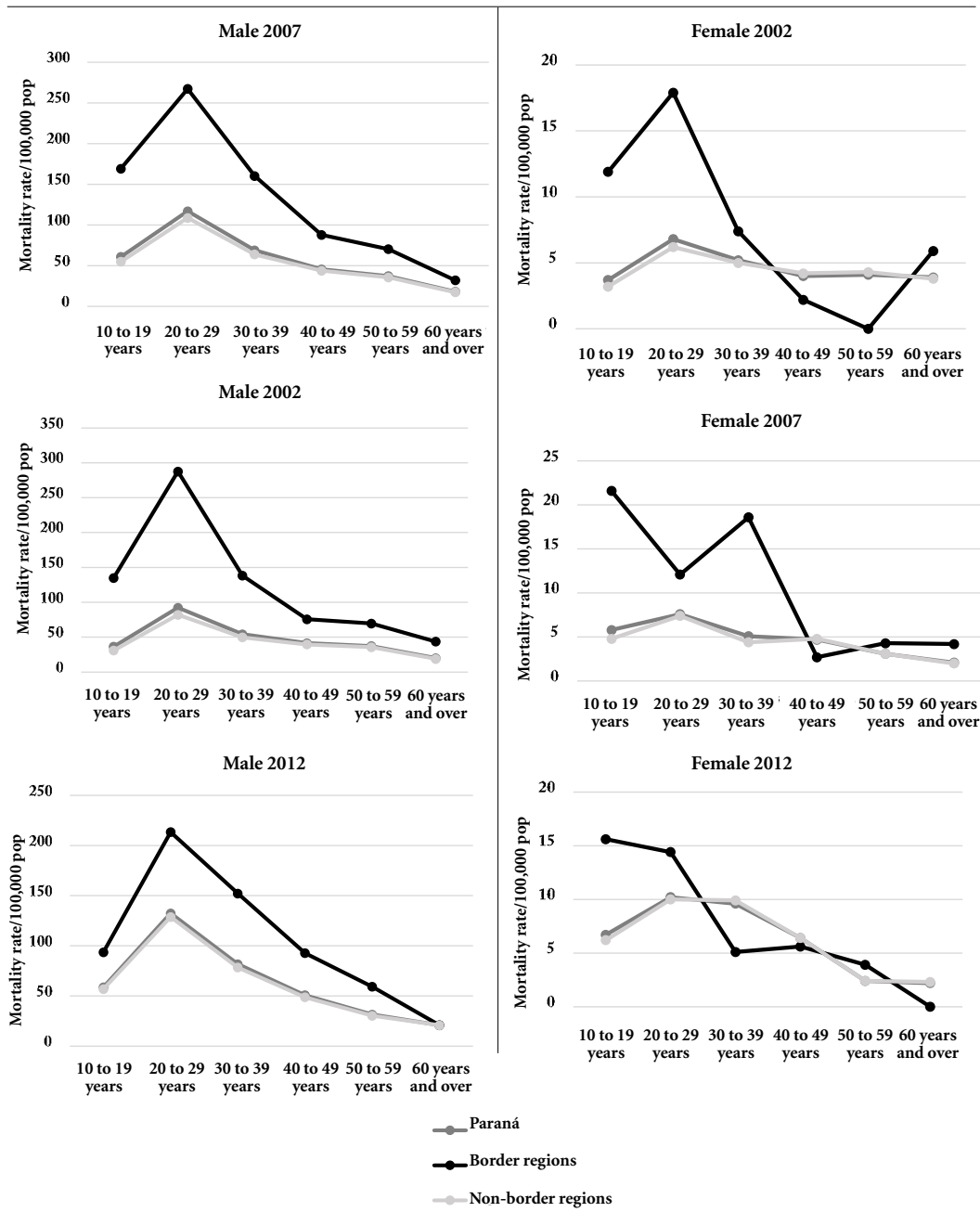
It is important to note, however, that, despite a general drop in homicide rates across the state, the municipalities that make up the border regions showed the highest homicide rates. Historically, Brazilian borderlands are generally underdeveloped, abandoned by the government, and marked by poor access to public goods and services, such as health care, education, and public security[12]. This can be said for both sides of the border, where constant cross-border flows

and the presence of vulnerable groups directly influences indicators of violence.

Paraná's international borders are characterized by the movement of large numbers of people and vehicles, driven by an agriculture-based economy (soybeans, sugarcane, and corn), the transport of agricultural produce from "dry ports" in other regions of Brazil and in Paraguay and Argentina, and the regional food industry. Thus, the high homicide rates may be due to these and other factors, including urban agglomerations, the high proportion of young people, low levels of education, high Gini index (a commonly used measure of income inequality), and problems associated with migration[13-15].

Another factor that influences homicide rates in borderlands is the fact that these regions are hotbeds of drug trafficking. Given the country's proximity to drug producing countries and close links with European countries and the United States, the sharp rise in cocaine use in the 1980s turned Brazil into a major drug-trafficking route, leading to a surge in violence, organized crime, arms trafficking, and a range of other illegal activities, particularly in border regions[11].

Border regions are also marked by widespread human trafficking and diplomatic issues and are particularly difficult to monitor. These factors, tied with deep social inequalities and poor access to quality health services and education, help explain the homicide situation in these areas. It is also important to highlight that the majority of homicides occur mainly in towns in border re-

Male 2007

Male 2002

Male 2012

Female 2002

Female 2007

Female 2012

Paraná

Border regions

Non-border regions

Figure 2. Homicide mortality rates by age, sex, and region, Paraná, Brazil, 2002-2012.

Source: SIM/MS/Datasus.

gions with populations of between 200,000 and 300,000 inhabitants. Studies have shown that these towns are characterized by higher rates of violence, smuggling of electronic goods and cigarettes, and arms and drug trafficking[11].

The data presented reveal that homicide rates among young adults (20 to 39 years) are markedly higher among males than in females in border regions. A study in Maceió[16], the capital of the State of Alagoas, reported that 94.8% of homi-

Table 2. Percentage of homicides by type of assault and region. Paraná, Brazil, 2002-2012.

	Paraná										
	Years										
Cause of death	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
	%	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**
Assault by firearms (X93 to X95)	67.4	69.8	68.6	68.7	72.5	74.0	74.4	72.9	74.2	71.8	70.9
Assault by sharp object (X99)	18.3	16.9	18.2	17.4	16.4	15.1	14.3	15.2	13.8	16.0	16.3
Assault by blunt object (Y00)	6.8	6.0	5.5	6.0	5.0	5.4	5.0	5.5	5.2	5.6	6.6
Type of assault not specified (X85 to X92; X96 to X98; Y01 a Y09)	7.5	7.3	7.7	7.8	6.1	5.5	6.4	6.5	6.9	6.6	6.2
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	Non-border region										
	Years										
Cause of death	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
	%	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**
Assault by firearms (X93 to X95)	64.1	68.3	65.9	66.2	70.1	72.1	73.0	72.1	73.5	71.1	70.1
Assault by sharp object (X99)	19.9	17.4	19.6	18.7	17.7	16.1	14.9	15.4	13.9	16.4	16.5
Assault by blunt object (Y00)	7.5	6.3	6.0	6.4	5.4	5.7	5.2	5.7	5.3	5.7	6.9
Type of assault not specified (X85 to X92; X96 to X98; Y01 to Y09)	8.6	8.1	8.5	8.7	6.8	6.1	6.9	6.8	7.3	6.8	6.5
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	Border region										
	Years										
Cause of death	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
	%	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**
Assault by firearms (X93 to X95)	88.4	82.8	88.3	88.0	89.6	87.6	88.3	83.4	82.4	81.0	81.2
Assault by sharp object (X99)	8.3	12.6	7.5	7.5	6.8	8.0	7.7	11.9	11.6	10.6	13.2
Assault by blunt object (Y00)	2.3	3.4	2.1	3.0	2.5	3.6	2.7	2.8	4.0	4.6	2.4
Type of assault not specified (X85 to X92; X96 to X98; Y01 to Y09)	1.0	1.1	2.1	1.5	1.1	0.8	1.3	2.0	2.0	3.7	3.2
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: SIM/MS/Datasus.

cide victims were male and 66.2% were aged between 15 and 29 years, corroborating the findings of the present study. Similar figures were reported by studies conducted in Chile, Colombia, and South Africa[17-19].

A study in Colombia found that the male-to-female homicide ratio was 10:1 and that mortality rate was highest among young adults[18]. In Brazil[20] injuries accounted for 10% of the country's disease burden and a male-to-female ratio for potential years of life lost due to injuries of 4:8. In the present study, the male-to-female homi-

cide mortality ratio in border regions was 13:1, which is higher than the overall rate in the state and that reported by von-Doellinger et al. This may be explained by the fact that men living in border regions are more exposed to risk factors associated with violent crime and victimization, which in turn leads to an increase in potential years of life lost due to homicide among this sex. Involvement in drug trafficking and smuggling, associated with manly, autocratic, and challenging behaviors and self-affirmation can result in a vicious circle of violence among young men. This

Table 3. Trend analysis of homicide mortality rates by region (overall and by sex), Paraná, Brazil, 2002-2012.

Mortality Rate	Model[*]	R²[**]	p[***]	Trend
Total Paraná	$Y = -0.1539x^2 + 2.8106x + 24.534$	0.865	<0.001	Upward
Male	$Y = -0.304x^2 + 5.4135x + 45.599$	0.895	<0.001	Upward
Female	$Y = 0.1937x + 4.6652$	0.601	0.003	Upward
Total border regions	$Y = 77.728e^{-0.029x}$	0.319	0.041	Downward
Male	$Y = 146.75e^{-0.029x}$	0.307	0.045	Downward
Feminino	$Y = 0.0264x^3 - 0.577x^2 + 3.4098x + 5.2828$	0.525	0.042	Downward
Total non-border regions	$Y = 1.1243x + 25.893$	0.762	<0.001	Upward
Male	$Y = -0.2795x^2 + 5.4227x + 41.188$	0.874	<0.001	Upward
Female	$Y = 4.4227^{e0.0382x}$	0.587	0.004	Upward

*Model: Y = Road traffic mortality rate per 100,000 population (overall and by victim category); X = year − 2007;
** R² = coefficient of determination; *** p-value from the F-Test.
Source: SIM/MS/DATASUS

behavior is likely to extend into adult life, with young adult males being more likely to perpetrate or be victims of violence[21,22]. This situation warrants urgent attention by authorities, since it affects an important segment of the productively active population in border regions, thus resulting in significant economic and health costs[4].

The increase in mortality rates among young women was also more pronounced in border regions. This trend may be linked to gender-based violence and a male-dominated culture in Brazil, Paraguay, and Argentina, resulting in a lack of protection against different forms of domestic violence and crimes of passion. These acts of violence often result in death and have a negative impact on the economy, society, and family. In 2006, Brazil introduced Law 11,340 (the Maria da Penha law) to combat domestic and family violence[23]. However, to date, this law has had only limited effectiveness and impunity risks becoming commonplace. The rise in the female homicide rate thus requires urgent attention from public managers to ensure that the law is effective in reducing violence against women. In this regard, future research should focus on violence against women in border regions.

The increase in mortality rates was smaller among women aged 60 years and over than in those in the 50 to 59 years age group, showing that the latter group is more vulnerable than the former. Other studies have shown similar findings in relation to this age group[24,25]. However, it should be noted that this difference may be due to the relatively small number of people in this group, meaning that small changes in the number of deaths can greatly affect the rate. A

study in Chile covering the period 2000 to 2012 reported that the 60 years and over group was the third most vulnerable age group, behind the 25-39 and 40-59 years groups[17]. A study conducted in Foz do Iguaçu[24] covering the period 2002 to 2010 documented a 25.7% drop in the homicide mortality rate among women aged 50 to 59 years. However, despite this drop in rates in Paraná's largest border city, the overall rate in border regions continued to rise. This suggests that the risk of homicide among women aged 50 to 59 years is greater in smaller border towns, requiring further investigation. However, as mentioned above, the relatively small number of people in this group means that small changes in the number of deaths can greatly affect the rate.

With regard to type of assault, it is important to highlight that assault by firearms accounted for more homicides than all other types of assault put together across all regions, corroborating the findings of other studies in Brazil and research conducted in Colombia and South Africa[13,18,19]. Shooting has long been the most common cause of death in homicides, followed by cold weapons[16,20,26], suggesting intention to kill and reducing the victim's chances of survival.

In 2013, Brazil introduced Law 10,826, governing the registration, possession, and sale of firearms and ammunition and a number of voluntary gun handover and buyback campaigns have been launched since[27]. A study conducted in Paraná showed that a voluntary disarmament campaign did not produce significant results in the short-term because of the small scale of the initiative in comparison to the large stock of guns in the country and the fact that criminals or

people who show a greater propensity to commit violent acts do not hand in arms[28]. The present study showed that the proportion of assaults by firearms was constantly high during the study period, reaching over 70% across all regions and 81.2% in border regions. In this respect, despite police and government efforts to curb illicit activities, border regions, notably Foz do Iguaçu, remain hot beds of gun and drug trafficking[24].

It is also interesting to note that assault by cold weapons increased over the study period. The use of cold weapons to commit homicide is common among men, especially young adults and adolescents[29]. The increase in the use of cold weapons in the border region may be related to a reduction in gun and ammunition trafficking in this region, leading to the use of other more easily accessible means.

One of the limitations of this study are SIM data quality issues, whereby inaccurate reporting of deaths due to external causes can result in incomplete information about causes of death and underrecording of homicides[30]. The underrecording of homicides can hinder the construction of indicators that better represent the reality in border regions. However, it is important to highlight that the quality of the certification of the cause of death due to external causes has improved throughout the country. The lower rate of deaths from homicide among women does not mean that the magnitude of this problem among this group should be underestimated. Rather, this problem should be seen as a major concern that reflects the sociocultural and gender dimension of violence, suggesting the urgent need for initiatives targeting this risk group.

Our findings show that, despite a drop in rates in border regions over the study period, homicide rates remain higher than in non-border regions and the state as a whole, providing evidence of the need for increased efforts to address this problem. The data show that young men, who represent a large proportion of the country's economically active population, are the most vulnerable group. Our findings show the groups at greatest risk and temporal trends in mortality rates, providing valuable inputs to inform intersectoral prevention policies directed at the groups most affected by homicide. Making this problem a public health priority is a major challenge for health workers, public managers, and political authorities alike. It is hoped that the insights into the magnitude of the problem and trends in homicide mortality provided by this study can contribute to the formulation and implementation of effective violence reduction and prevention actions.

Collaborations

VD Nogueira contributed to study conception and design, data collection, analysis and interpretation, drafting of this manuscript, and approving the final version to be published. LMX Gomes contributed to study conception and design, critical revision of the article, and approving the final version to be published. TLA Barbosa, contributed to study conception and design, data collection, analysis and interpretation, drafting of this manuscript, and approving the final version to be published.

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