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Temporal trends in female firearm homicides across states in the Northeast of Brazil during the period 2000-2019

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Abstract *This article aims to analyze temporal trends in female firearm homicides in the Northeast of Brazil during the period 2000-2019. We conducted an ecological study using data on firearm homicides of women aged 10 years and over obtained from the Mortality Information System. The population data were taken from the 2010 Census. Homicide rates were calculated after correcting the data to account for differences in the quality and coverage of death records. Trends were assessed using negative binomial regression and described using relative risk and p values. Average annual percentage changes in homicide rates were also calculated. The regional firearm homicide rate during the study period was 4.40 per 100,000 women. Rates were highest in the state of Alagoas (5.40), the 15-19 age group (5.84) and in public thoroughfares (1.58). Trends were upward across all states except Pernambuco, where they were downward, and Alagoas, where rates were stationary. The place of occurrence with the highest percentage increase in firearm homicides over the study period was public thoroughfares. Female firearm homicides showed an upward trend across most northeastern states.*

Key words *Mortality, Homicide, Women, Gun violence, Gender-based violence*

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Introduction

Gender violence is recognized worldwide as a serious social problem and grave violation of human rights. It has a major social and economic impact and considerable effect on women's health. It is estimated that at least one-third of women aged 15 years and over have been subjected to physical and/or sexual violence at least once in their lifetime[1].

While men are more likely to be murdered than women, this pattern is different when it comes to intimate partner homicide. The proportion of female victims of this type of homicide is six times greater than that of men[2]. This data exposes the extremely grave consequences of gender violence and the most brutal manifestation of patriarchal power: femicide, the intentional murder of women because they are women[3].

In Brazil, rates of violence against women are alarming. In 2020, 1 in every 4 women aged 16 years and over was subjected to some type of violence[4]. More than 260.000 cases of bodily harm due to domestic violence, 54,453 cases of rape and 4,631 cases of attempted murder were reported. There were also 3,913 female homicides, corresponding to 3.6 deaths per 100,000 women. Of this total, 34.5% were considered femicides, and more than half were committed with a firearm[5]. In recent years, the Northeast has been the region that has reported the highest absolute number of intentional violent deaths of women, most of which involving a firearm[6].

At national level, data from the Mortality Information System (SIM, acronym in Portuguese) do not always make it clear whether female homicides are gender-related. This is partially due to the limitations of the SIM, which does not always show the relationship between the victim and the perpetrator[6-10], and the fact that the classification of deaths is the responsibility of the police, who are not always prepared to identify gender violence, especially because the legislation on femicide in Brazil is recent[5].

To contribute to the classification of gender violence, researchers have created indirect evaluation indicators[1,8,11-16]. In addition, the Institute for Applied Economic Research (IPEA) uses female homicides committed at home and female homicides perpetrated with a firearm as a proxy for femicide[14,15].

The use of this indicator is justified by the fact that the majority of female homicides[4-6,8-15] and homicides of women with prior notification of violence[7,16] in Brazil are committed with firearms. In addition, research indicates that previous history of intimate partner violence, carrying of a firearm by an intimate partner and living with an intimate partner are leading risk factors for femicide[1,2,17,18].

The present study therefore uses female firearm homicides as a proxy for femicides. The aim of this study was to analyze temporal trends in female firearm homicides in states in the Northeast of Brazil during the period 2000-2019 and calculate the proportion of homicides by race/skin color, place of occurrence and marital status.

Methods

Study design, data source and variables

We conducted an ecological study of temporal trends in female firearm homicides in states in the Northeast of Brazil during the period 2000-2019. We used data from the SIM, which is run by the national health system's Department of Informatics (SIM/DATASUS). The de-identified data are available in the public domain at the following website: https://datasus.saude.gov.br/mortalidade-desde-1996-pela-cid-10[19]. The Northeast is made up of nine states: Alagoas (AL), Bahia (BA), Ceará (CE), Maranhão (MA), Paraíba (PB), Pernambuco (PE), Piauí (PI), Rio Grande do Norte (RN) and Sergipe (SE).

We analyzed all records of deaths of women aged 10 years and over classified as female firearm homicides. We included the 10-14 year age group because childbearing age is assumed to start at age 10 in Brazil and sexual violence against girls, teenage pregnancy and teen marriage are common, increasing the risk of domestic violence and femicide[20]. In addition, homicide rates begin to rise from this age group[6-13].

The study variables were year of occurrence (2000-2019), state (AL, BA, CE, MA, PB, PE, PI, RN and SE), age group (10-14, 15-19, 20-39, 40-59 and 60 years and over), place of occurrence (hospital and other health facilities, at home, public thoroughfare, other and ignored), race/skin color (white, black [black and brown], yellow, indigenous and ignored), and marital status (single, married, widow, separated/other and ignored).

Deaths classified in the SIM as assault by firearm (X93 to X95) and events of undetermined intent (EUI) based on the 10th Revision of the International Statistical Classification of Diseases (Unspecified firearm discharge, undetermined

intent, Y22, Y23, Y24; and Unspecified event, undetermined intent, Y34) were included.

The population data were taken from the 2010 Census, conducted by the Brazilian Institute of Geography and Statistics, and intercensal estimates of population for the period 2000-2019 obtained from DATASUS.

Major differences in the quality and coverage of death records across states were observed during the study period[8-13], meaning that the data required correction.

Record correction and descriptive analysis

First, the death record data were corrected to improve information quality by performing a proportional redistribution according to year, age group and state involving the following stages proposed by Garcia *et al.*[8]: (1) calculation of the number of deaths classified as firearm homicides (X93 to X95) as a proportion of total deaths due to accidental and intentional external causes (self-harm, assault with a firearm, accidental trauma and legal intervention); (2) multiplication of the result of the first stage by total number of deaths classified as EUI under the codes Y22, Y23, Y24 and Y34; (3) the result of the second stage was then added to the total number of deaths originally classified as firearm homicides to give the corrected number of deaths; 4) We then applied the correction factors published by Queiroz *et al.*[21], which were obtained by using the adjusted Synthetic Extinct Generations method (SEG-adj)[22]. To maximize the reliability and trustworthiness of the correction process, the analyses were performed independently by two researchers. The correction process was performed for all states for firearm homicides according to race/skin color, marital status and place of occurrence.

After data correction, we calculated the uncorrected homicide rates, rates of EUI (Y22-Y24, and Y34) and corrected firearm homicide rates (all places of occurrence, public thoroughfare and at home) by age group and period.

After correcting the data by race/skin color, marital status and place of occurrence, we calculated the percentage of deaths for each variable and state by dividing the number of deaths for each variable category by total deaths during the period 2000-2019.

Mortality rates for the study period (2000-2019) were calculated by dividing the total number of deaths during the period by the total population during the period and multiplying by 100,000 women. The rates were standardized using the direct method to control for age, using the female population in Brazil according to the 2010 census as the standard population.

Temporal trends in corrected firearm homicide rates (all places of occurrence, public thoroughfare and at home) were assessed by calculating mortality rates smoothed by three-year moving averages to correct random fluctuations in annual mortality rates and create line charts[23].

Statistical methods

The analysis of the time series was performed using negative binomial regression and the Durbin-Watson statistic to check for the presence of serial autocorrelation[9,10]. The dependent variable for each state was number of deaths in each year () and the independent variable was the t-centered calendar year. *Negative Binomial regression models* were run, adding and an offset term as a natural logarithm of the at risk population in each state in the respective calendar year, represented by the following equation:

$$y_t \sim Negative\ Binomial\ (\mu_t, \theta)$$
$$log\ (\mu_t) = log\ (N_t) + \beta_0 + \beta_1\ (t - E(t)) + \epsilon_t$$
$$\epsilon_t \sim Gama\ (\theta, \theta)$$

Where μ is the number of expected deaths in year , θ is the dispersion parameter, N_t is the at risk population in year i, β_0 is the intercept, β_1 is the time-centered variable ($t - E(t)$) and ϵ_t is the random error with distribution. Overdispersion is considered in the estimate of variance

$$VAR\ (Y_t) = \mu_t + \frac{\mu_t^2}{\theta}\ .$$

Trends were classified as stationary, downward or upward, based on the relative risk (RR) value, calculated by exponentiating the regression coefficient (and respective 95% confidence intervals (95%CI) and p-values[24].

We then calculated the average annual percentage change in rates to determine whether the percentage increase or decrease was statistically different from zero using the two-tailed t-test with two degrees of freedom ($p<0.05$).

Ethical aspects

The study did not require ethical approval as it was conducted using exclusively secondary data available in the public domain. The study was conducted in accordance with the norms and standards set out in National Health Council Resolution 466 (12 December 2012).

Results

There were 13,733 female firearm homicides in the Northeast during the period 2000-2019 (3.06 homicides per 100,000 women) and 8,571 deaths classified as EUIs (1.91 deaths per 100,000 women). The state with the highest rate of EUIs was BA (2.98), followed by PE (2.82) and RN (2.14). The state with the lowest rate was AL (0.07), followed by PB (0.19) and MA (0.39) (Table 1).

After data correction, the homicide rate increased by 32.03%, from 3.06 to 4.04. The highest percentage increases were observed in BA (2.85 vs 4.03; +41.40%) and RN (2.96 vs 4.05; +36.82%) and the lowest increases were found in PB (3.31 vs 3.78;+14.20) and AL (4.68 vs 5.40;+15.38%) (Table 1).

The states in which corrected rates [1] were higher than the regional rate were PE, AL, CE, PI and RN. Rates were higher in women aged 15-19 years and 20-29 years across all states, with rates declining steadily with age. In contrast, the EUI rate showed a positive age gradient (Table 1). Firearm homicide rates were higher in public thoroughfares than at home across all states except PI and MA, where the rates for these places of occurrence were similar (Table 1).

The most common place of occurrence of firearm homicides was public thoroughfare across all states except MA and PE, where most deaths occurred in a hospital. Hospitals and other health facilities were also common places of occurrence of homicides. Black and single women were the most victimized groups, accounting for between 61.57% and 80.56% and 49.22% and 74.52% of firearm homicides, respectively (Table 2).

The exploratory analysis of temporal trends in overall rates of firearm homicide and by place of occurrence revealed three patterns: (1) a reduction in rates from 2010 in AL, PB and PE; (2) an increase in rates in BA, CE and RN; and (3) an increase in rates with a reduction at the end of the time series in MA, SE and PI (Figures 1 and 2).

The trend analysis revealed an upward trend in firearm homicide rates in the region and across all states (RR>1; p<0.05), except AL (RR=1.01; 95%CI 0.98-1.04) and PB (RR=1.03; 95%CI 0.99-1.07), where the trend was stationary, and PE, which showed a downward trend (RR=0.98; 95%CI 0.96-0.99). The average annual percentage increase in the regional firearm homicide rate was 3.58%. The states with the highest percentage increase in rates were CE (11.39%), RN (7.43%) and MA (6.32%). Average annual percentage reduction was 2.32% (95%CI -3,35-1.29%) in PE (Table 3). Similar rates were found for firearm homicides committed at home (Table 3).

The rate of firearm homicides in public thoroughfares showed an upward trend in the region and across all states except AL (RR=1.013; 95%CI 0.97-1.05) and PE (RR=0.97; 95%CI 0.96-0.99). Firearm homicides committed in a public thoroughfare showed the highest average percentage increases, with the highest rate being found in CE (15.75%), followed by RN (12.14%) and PI (8.56%) (Table 3).

Discussion

Death record quality and coverage were similar across states during the study period. The highest rates of deaths classified as EUI (Y22-Y24 and Y34) were found in BA, PE and RN. The states with the lowest rates of deaths classified as EUI also had the poorest coverage by the SIM. After data correction to account for death record quality and coverage, the states with the highest female firearm homicide rates were PE, AL, CE, PI and RN. All states showed an upward trend in firearm homicide rates (all places of occurrence, at home and public thoroughfare), except AL and PB, where rates (overall and at home) were stationary, and PE, where the rate showed a downward trend.

Data correction is required in time trend analysis studies of areas with differing levels of death record quality and coverage, as changes in information system quality and coverage can lead to period effects in data, distorting trends and over or underestimating mortality rates[6,8,13,25,26].

Despite improvements in the quality of death certification, coverage and data completeness across all states, the proportion of deaths in the SIM where the underlying cause is a garbage code (undetermined intent) remains high[9,10]. While the proportion of deaths with ill-defined external causes decreased by 17.2% between 2009 and 2013[9], this rate increased by 25.6% between 2017 and 2018. Furthermore, five of the ten states with the lowest levels of quality of information on external causes were in the Northeast (BA, PE, RN, CE and SE), with rates of deaths classified as EUI exceeding 5.0 per 100,000 population[15].

Studies have shown increasing rates of female homicides with decreasing rates of rates of deaths classified as EUI and vice versa[6,12,13]. Similar results were reported with male homicides in PE between 1980 and 2014, with the reduced risk of

Table 1. Standardizeda rates of female firearm homicides and events of undetermined intent per 100,000 women by age group. Northeast, Brazil, 2000-2019.

State	Event	Age group (years)					RP***
		10-14	15-19	20-39	40-59	60 and over	
Alagoas	Firearm homicide (uncorrected)	1.65	6.71	6.50	3.59	1.60	4.68
	Event of undetermined intent*	0.00	0.03	0.03	0.03	0.41	0.07
	Firearm homicide (corrected)**	1.87	7.66	7.42	4.11	2.28	5.40
	Firearm homicide in a public thoroughfare (corrected)**	1.21	4.55	3.78	1.76	0.40	2.69
	Firearm homicide at home (corrected)**	0.21	1.15	1.65	1.30	0.48	1.20
Bahia	Firearm homicide (uncorrected)	0.99	4.63	4.10	1.89	0.71	2.85
	Event of undetermined intent*	0.69	1.60	1.93	2.38	10.77	2.98
	Firearm homicide (corrected)**	1.30	6.24	5.81	2.83	1.11	4.03
	Firearm homicide in a public thoroughfare (corrected)**	0.48	2.49	2.27	0.88	0.19	1.49
	Firearm homicide at home (corrected)**	0.23	0.97	1.14	0.77	0.35	0.83
Ceará	Firearm homicide (uncorrected)	1.40	5.37	4.66	2.35	0.96	3.32
	Event of undetermined intent*	0.21	0.55	0.74	1.11	8.63	1.77
	Firearm homicide (corrected)**	1.66	6.42	5.70	3.00	1.34	4.09
	Firearm homicide in a public thoroughfare (corrected)**	0.77	3.59	2.59	1.15	0.28	1.85
	Firearm homicide at home (corrected)**	0.17	0.70	0.97	0.67	0.38	0.70
Maranhão	Firearm homicide (uncorrected)	0.40	1.57	2.06	1.40	0.52	1.47
	Event of undetermined intent*	0.13	0.30	0.26	0.36	1.46	0.39
	Firearm homicide (corrected)**	0.65	2.57	3.37	2.31	0.86	2.40
	Firearm homicide in a public thoroughfare (corrected)**	0.20	0.87	0.97	0.52	0.06	0.66
	Firearm homicide at home (corrected)**	0.16	0.76	0.85	0.74	0.33	0.67
Paraíba	Firearm homicide (uncorrected)	1.14	4.81	5.04	2.14	1.14	3.31
	Event of undetermined intent*	0.03	0.09	0.13	0.19	0.54	0.19
	Firearm homicide (corrected)**	1.30	5.45	5.75	2.46	1.31	3.78
	Firearm homicide in a public thoroughfare (corrected)**	0.50	2.04	2.44	0.85	0.42	1.50
	Firearm homicide at home (corrected)**	0.13	1.05	1.20	0.74	0.37	0.84
Pernambuco	Firearm homicide (uncorrected)	1.46	6.87	6.22	2.90	1.40	4.29
	Event of undetermined intent*	0.41	0.80	1.11	2.15	12.83	2.82
	Firearm homicide (corrected)**	1.67	7.72	7.25	3.75	1.88	5.09
	Firearm homicide in a public thoroughfare (corrected)**	0.63	3.88	3.39	1.22	0.36	2.23
	Firearm homicide at home (corrected)**	0.29	1.01	1.43	0.98	0.89	1.08
Piauí	Firearm homicide (uncorrected)	0.49	1.59	1.57	0.94	0.31	1.14
	Event of undetermined intent*	0.16	0.20	0.40	0.61	7.76	1.31
	Firearm homicide (corrected)**	0.60	1.89	1.92	1.19	0.41	1.50
	Firearm homicide in a public thoroughfare (corrected)**	0.11	0.70	0.65	0.21	0.00	0.42
	Firearm homicide at home (corrected)**	0.04	0.66	0.51	0.44	0.15	0.42
Rio Grande do Norte	Firearm homicide (uncorrected)	1.29	4.87	4.24	2.01	0.72	2.96
	Event of undetermined intent*	0.61	1.23	1.30	1.44	7.97	2.14
	Firearm homicide (corrected)**	1.78	6.49	5.79	2.81	1.06	4.05
	Firearm homicide in a public thoroughfare (corrected)**	0.68	2.97	2.27	0.81	0.16	1.53
	Firearm homicide at home (corrected)**	0.35	1.25	1.53	0.90	0.36	1.06
Sergipe	Firearm homicide (uncorrected)	0.88	4.00	4.13	2.18	0.97	2.91
	Event of undetermined intent*	0.00	0.44	0.61	1.14	12.24	1.95
	Firearm homicide (corrected)**	0.97	4.62	4.87	2.70	1.25	3.45
	Firearm homicide in a public thoroughfare (corrected)**	0.27	2.14	1.77	0.00	0.11	1.26
	Firearm homicide at home (corrected)**	0.22	0.83	1.29	0.63	0.69	0.89
Northeast	Firearm homicide (uncorrected)	1.08	4.66	4.37	2.17	0.93	3.06
	Event of undetermined intent*	0.34	0.78	0.99	1.43	8.21	1.91
	Firearm homicide (corrected)**	1.38	5.84	5.70	3.03	1.41	4.04
	Firearm homicide in a public thoroughfare (corrected)**	0.54	2.69	2.34	0.96	0.23	1.58
	Firearm homicide at home (corrected)**	0.21	0.91	1.16	0.80	0.45	0.84

Key: [a] Rates standardized using the direct method based on population data from the 2010 Census; *Rates corrected to account for differences in quality and coverage of death records; ***Codes Y22 to Y24 and Y34; ***Rates over the period. TP***: Mortality rates for the period standardized by the direct method using the 2010 census as the standard female population.

Source: Mortality Information System (SIM/DATASUS).

Table 2. Proportion of female firearm homicides according to place of occurrence, race/skin color and marital status. Northeast, Brazil, 2000-2019.

Variables	Alagoas	Bahia	Ceará	Maranhão	Paraíba	Pernambuco	Piauí	Rio Grande do Norte	Sergipe
Race/skin color									
White	6.42	13.92	12.06	16.97	11.01	19.92	20.30	18.99	17.06
Black	80.56	74.13	61.57	80.50	81.52	74.29	74.60	72.28	74.85
Yellow	0.00	0.12	0.07	0.17	0.00	0.13	0.60	0.21	0.00
Indigenous	0.08	0.14	0.05	0.53	0.00	0.17	0.00	0.24	0.21
Ignored	12.94	11.69	26.25	1.83	7.47	5.49	4.50	8.28	7.88
Place of occurrence									
Hospital	20.02	32.72	24.47	28.69	17.38	30.88	29.16	27.40	28.61
Health facility	0.71	1.60	0.72	0.35	0.09	0.00	1.41	0.57	0.23
At home	22.64	20.18	18.35	28.34	22.76	27.93	21.12	25.36	26.58
Public thoroughfare	49.78	30.93	41.33	26.85	38.96	26.95	39.40	33.76	35.04
Other	6.77	13.83	13.25	15.02	19.04	13.65	7.68	12.36	7.65
Ignored	0.08	0.74	1.87	0.74	1.77	0.59	1.23	0.56	1.88
Marital status									
Single	64.49	71.25	71.89	62.55	49.22	66.69	47.43	66.87	74.52
Married	12.52	10.65	14.16	16.90	14.72	11.61	20.56	13.43	12.27
Widow	3.46	5.40	5.97	3.92	2.29	6.07	6.50	5.36	6.57
Separated/other	5.28	3.25	3.85	12.18	7.64	2.75	18.82	4.58	2.61
Ignored	14.25	9.45	4.14	4.46	26.14	12.88	6.69	9.76	4.03

Source: Mortality Information System (SIM/DATASUS).

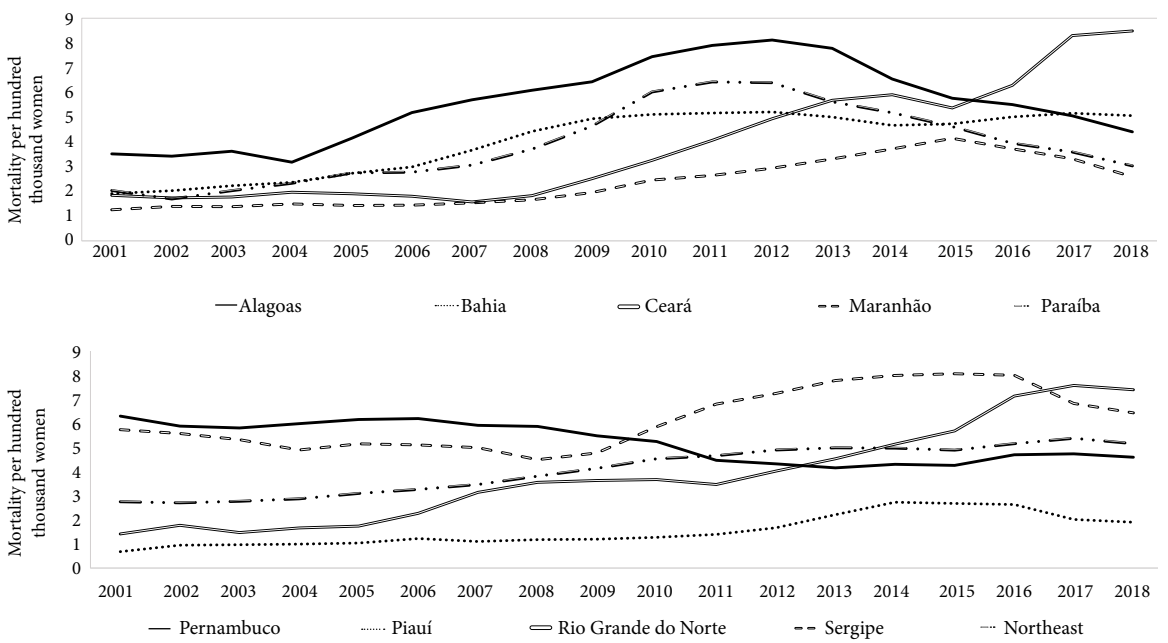

Figure 1. Temporal evolution of standardized homicide mortality rates.

Source: Mortality Information System (SIM/DATASUS).

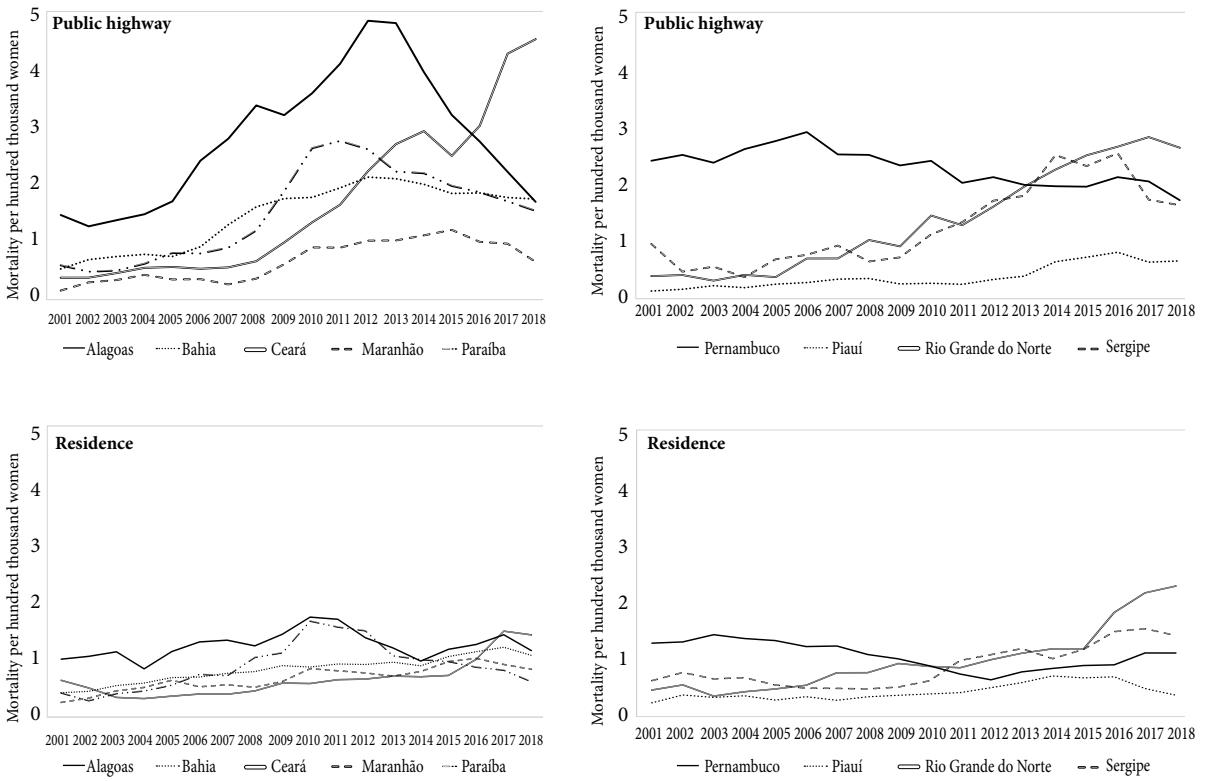

Figure 2. Temporal evolution of standardized mortality rates for female firearm homicides, according to place of occurrence, in the states of the Northeast region, Brazil, from 2000 to 2019.

Source: Mortality Information System (SIM/DATASUS).

homicide in the 2000s being accompanied by an increase in the classification of deaths as EUI[26]. These findings point to the need to correct death record data before analyzing temporal trends in rates of death due to external causes, which was done by the present study, resulting in an increase of more than 30% in the firearm homicide rate in Northeast as a whole and in the states of BA and RN.

Six countries (Brazil, United States, Mexico, Colombia, Venezuela and Guatemala) account for over half of worlwide deaths from firearm injuries[27]. In 2016, Brazil was the country with the highest number of firearm deaths (43,200), accounting for one-sixth of all fatalities worlwide[27]. In 2020, the country reported just over 50,000 intentional homicides, 78.0% of which were committed using a firearm[5]. Around 4,000 women are murdered each year in Brazil, corresponding to 5% of female victims of homicide worldwide, reiterating that violence against women is a serious public health problem[4,5].

Brazil's most violent region is the Northeast, accounting for 44.0% of total intentional violent deaths in 2020 and harboring the three states with the highest homicide rates (CE, BA and SE)[5]. Between 1980 and 2019, the female homicide rate grew faster than the male homicide rate, from 1.64 to 4.38 per 100,000 women (+167%)[6]. Different studies show that the most commonly used weapon was a firearm[4-15].

In the present study, the overall corrected average regional homicide rate was 4.04 per 100,000 women. The state with the highest rate was AL (5.40 per 100,000 women, which is 3.6 times higher than that of PI, with 1.50 deaths per 100,000 women). In concordance with the results of other studies, our findings show that rates

Table 3. Temporal trends in standardized[a] rates of female firearm homicides after correction to account for differences in quality and coverage of death records. Northeast, Brazil, 2000-2019.

State	Event*	Relative risk (95%CI)	APC** (95%CI)	Trend
Alagoas	Firearm homicide	1.01 (0.98-1.04) [a]	1.13% (-1.77 to 4.12%) [a]	Stationary
	Firearm homicide in a public thoroughfare	1.03 (0.97-1.05) [a]	1.27% (-2.65 to 5.36%) [a]	Stationary
	Firearm homicide at home	1.00 (0.97-1.03) [a]	0.23% (-2.60 to 3.24%) [a]	Stationary
Bahia	Firearm homicide	1.04 (1.01-1.06) [b]	3.75% (1.05 to 6.53%) [c]	Upward
	Firearm homicide in a public thoroughfare	1.04 (1.01-1.08) [b]	4.33% (0.89 to 7.89%) [c]	Upward
	Firearm homicide at home	1.04 (1.01-1.06) [c]	3.55% (1.14 to 6.02 %) [c]	Upward
Ceará	Firearm homicide	1.11 (1.09-1.14) [b]	11.39% (8.84 to 14.00%) [c]	Upward
	Firearm homicide in a public thoroughfare	1.16 (1.17-1.20) [b]	15.75% (11.61 to 20.05%) [c]	Upward
	Firearm homicide at home	1.09 (1.07-1.11) [b]	8.50% (6.57 to 10.47 %) [c]	Upward
Maranhão	Firearm homicide	1.06 (1.04-1.09) [b]	6.32% (3.82 to 8.89%%) [c]	Upward
	Firearm homicide in a public thoroughfare	1.08 (1.04-1.15) [b]	8.40% (1.95 to 15.20%) [c]	Upward
	Firearm homicide at home	1.04 (1.01-1.08) [b]	4.42% (1.18 to 7.75%) [c]	Upward
Paraíba	Firearm homicide	1.03 (0.99-1.07) [a]	2.99% (-0.40 to 6.51%) [a]	Stationary
	Firearm homicide in a public thoroughfare	1.07 (1.02-1.11) [c]	6.60% (2.24 to 11.50 %) [c]	Upward
	Firearm homicide at home	1.02 (0.97-1.07) [a]	2.50% (-2.05 to 2.50%) [a]	Stationary
Pernambuco	Firearm homicide	0.98 (0.96-0.99) [b]	-2.32% (-3.35 to -1.29%) [c]	Downward
	Firearm homicide in a public thoroughfare	0.97 (0.96-0.99) [b]	-2.36% (-3.24 to -1.47%) [c]	Downward
	Firearm homicide at home	0.97 (0.97-0.99) [b]	-2.20% (-4.24 to -0.12%) [c]	Downward
Piauí	Firearm homicide	1.06 (0.98-1.04) [a]	6.25% (3.02 to 9.59%) [c]	Upward
	Firearm homicide in a public thoroughfare	1.09 (1.04-1.13) [b]	8.56% (3.98 to 13.35%) [c]	Upward
	Firearm homicide at home	1.04 (0.99-1.07) [a]	3.65% (-0.14 to 7.58%) [a]	Stationary
Rio Grande do Norte	Firearm homicide	1.07 (1.04-1.11) [b]	7.43% (4.62 to 10.31%) [c]	Upward
	Firearm homicide in a public thoroughfare	1.12 (1.08-1.17) [b]	12.14% (7.78 to 16.19%) [c]	Upward
	Firearm homicide at home	1.09 (1.05-1.13) [b]	8.70% (4.75 to 12.80%) [c]	Upward
Sergipe	Firearm homicide	1.03 (1.01-1.04) [c]	2.68% (2.23% to 10.51%) [c]	Upward
	Firearm homicide in a public thoroughfare	1.08 (1.03-1.13) [b]	8.13% (3.13 to 13.37%) [c]	Upward
	Firearm homicide at home	1.07 (1.04-1.10) [b]	6.68% (3.54 to 10.34 %) [c]	Upward
Northeast	Firearm homicide	1.04 (1.02-1.05) [b]	3.58% (2.11 to 5.06%) [c]	Upward
	Firearm homicide in a public thoroughfare	1.05 (1.03-1.07) [b]	4.83 % (5.98 to 17.25%) [c]	Upward
	Firearm homicide at home	1.03 (1.02-1.04) [b]	3.02% (1.66 to 4.39%%) [c]	Upward

Key: [a] Rates standardized using the direct method based on population data from the 2010 Census; *Rates corrected to account for differences in quality and coveraere statistically different from zero ($p<0.05$); [a] $p>0.05$; [b] $p<0.001$; [c] $p<0.05$.

Source: Mortality Information System (SIM/DATASUS).

were higher among young, single black women, and that the most common place of occurrence among this group was a public thoroughfare[8,13-16].

Studies in Brazil reveal different trends in homicide rates between white and black women in the 2000s, with a downward trend among the former and upward trend in the latter. The difference in homicide rates between these groups increased from 48.5% in 2009 to 65.8% in 2019[15]. Racial disparities were greatest in states in the Northeast, with homicide rates among black women being 5.2 and 4.4 times higher than in white women in RN and SE, respectively. In AL, in 2019, all female victims of homicides were black[15].

Factors influencing violence are directly associated with unequal gender relations characterized by female submission. While all women are vulnerable to violence in a patriarchal, racist and capitalist society, factors such as skin color/race/ethnicity and material conditions can exacerbate the risk of violence[28]. Historically, due slavery and

structural racism, black people are more likely to experience violence and die violently. In addition, poor black women are at the bottom of the social pyramid and therefore encounter greater hardship in coping with situations of violence[27,29].

The firearm homicide rate was highest in single women across all northeastern states. This may be explained by the age effect, given that the risk of death was higher among younger women, most of whom are single[6,8,13,30-34]. However, the fact that victims were classified as single on the death certificate does not necessarily mean they were not in a non-formal relationship[16] or single women who were killed by their ex-partner.

Young women (15-39 years) are exposed to greater risk of gender violence and homicides because this group is exposed to multiple types of male violence, such as family violence, intimate partner and ex-partner violence and is more exposed to risk factors linked to machismo and sexism in public thoroughfares, especially at night[35-40]. Studies[29,32] show that women are more likely to be victims of intimate partner and ex-partner violence and gender violence, although rates vary across states, countries and continentes[33].

It is estimated that 87,000 women worldwide are victims of intentional homicide each year and 137 women are killed every day by a family member[33], which makes the home the most likely place of occurrence. In the present study, the main place of occurrence of homicides at regional level was a public thoroughfare (36.73%), followed by a hospital (27.75%) and at home (21.56%).

Place of occurrence is not a determinant of gender violence. This type of violence can take place in a range of different settings. Public thoroughfares would appear to be an opportunistic setting for homicides committed by ex-partners and partners who do not live with the victims[14,15]. A previous study reported that 25.2% of female homicides with previous reports of domestic violence between 2011 and 2016 were committed in a public thoroughfare[7].

Our findings reveal an upward trend in rates of firearm homicide at home and in public thoroughfares at regional level and across all states except AL (stationary) and PE (downward). Similar trends were reported in small, medium and large cities in northeastern states during the period 2000-2015[40]. The states with the highest annual percentage increase in rates of firearm homicide (all places of occurrence, public thoroughfare and at home) were CE, MA and RN.

Similar results have been observed by other studies showing an increase in the rate of female homicides across all regions during the period 1980-2014, except the Southeast, where there was a downward trend[6], in most northeastern states[13], and in health regions in RN during the period 2000-2016[30]. In all northeastern states except SE, there was an increase in the risk of death in the 2000s after data correction when compared to the baseline period 1995-1999[13]. In addition, there was an increase in the likelihood of death among women born after the 1960s.

This situation may be linked to the conservative culture of this region and the fact that younger generations of women went through significant sociocultural changes, questioning the role assigned to women in a patriarchal society[6,13,37,39]. Daring not to play traditional gender roles increases the likelihood of exposure to gender violence due to the reaction of the patriarchy, which uses violence, including lethal violence, to force women to reoccupy their original position[36-39]. In addition, in the 2000s the Northeast witnessed the spread and interiorization of violence, with a significant increase in rates of homicide in small, medium and large towns and cities (2000-2015)[40]. Studies have reported a correlation between male[8-10,14,15] and female homicides in cities and regions marked by organized crime and drug disputes, resulting in armed conflict, disrespect for human rights and gender violence[11,31,36,37].

The results of the present study are worrying because of the high rates of firearm homicide among women living in the Northeast, both at home and in public thoroughfares, showing that these settings are unsafe for women in most states with upward trends in mortality. During the 2000s, the government implemented policies to curb violence against women, reducing the circulation of firearms through the Disarmament Statute. Other legislation includes Law 11,340/2006, known as the Maria da Penha Law, which is the country's most important legal milestone on the road to tackling violence against women. Creating mechanisms to curb domestic and family violence, the law establishes more severe punishments for perpetrators and introduces measures to protect women exposed to violence[41,42]. A reduction in rates of homicide due to this group of causes was therefore expected[14,15,41,42].

However, these policies have not been sufficient to contain the increase in violence against women. Twelve years after the creation of the Maria da Penha Law, only 137 (2.4%) of Brazil's 5,570 municipalities have shelters for wom-

en exposed to domestic violence. These shelters are concentrated in large cities in the South and Southeast and less than 10% of the country's municipalities offered specialist services for women suffering sexual violence, and only 8.3% of cities had police stations that deal specifically with crimes involving female victims[43,44]. During the period 2017-2019, there was a 75% reduction in funding for the "2016 Program: Policies for Women: Promoting Autonomy and Combating Violence"[45]. Underfunding of social services and women's and child protection services is a reflection of government disinterest in the life of women[45,46].

In addition to the above, there has been a reduction in funding for tackling violence against women. Since 2019, the federal government has introduced 11 decrees, one law and 15 army regulations weakening firearms and munitions control and enforcement[14,15], exacerbating the risk of domestic violence, femicide, suicide and accidents involving children[47-50]. In Brazil, as in other countries, policies restricting access to guns have resulted in a reduction in homicides[17,18,47-52]. A recent decree issued by Brazil's new government is therefore an important step forward. Decree 11,366, introduced earlier this year, suspends the issuing of new firearms licenses for hunters, sport shooters, collectors and private owners, reduces the maximum limit for purchases of permitted guns and ammunition, suspends the issuing of new firearms licenses for shooting clubs and schools, and sets up a working group to propose new regulations for the 2003 Disarmament Statute[53].

This study has some limitations. First, the use of secondary data with incomplete entries and inconsistencies may have influenced the results, especially given the number of records where death was classified as a EUI (Y22-Y24 and Y34) and changes in coverage of records over the study period. However, this limitation was partially addressed by data correction.

Another limitation was the use of an indirect indicator of femicides due to the lack of a specific database with this information. However, it is important to highlight that we adopted a proxy used by the IPEA[14,15]. The use of all female homicides as an indirect indicator of femicide can lead to the overestimation of gender-related killings. In this respect, public security data indicate that 34.5% of female homicides are femicides[5].

Despite these limitations, our findings provide important insights for the planning and evaluation of violence prevention policies in the Northeast, as the generation of information about this grave public health problem can help push measures to tackle violence onto health and development agendas and contribute to the implementation of policies targeting specific groups.

Conclusion

Most of the states in the Northeast showed an upward trend in female firearm homicides, both at home and in public thoroughfares. The findings signal the need for health services to report cases of violence against women and promote health education, especially in primary care settings, focusing on prevention and lines of care for women exposed to violence. It is therefore important that health services promote coordinated actions with security and social protection services to ensure the provision of assistance and care to women in situations of violence. Finally, there is an urgent need to increase funding for violence prevention and protection measures.

Collaborations

KC Meira and SFC Oliveira contributed to the conception and design of the study, methodology, analysis, interpretation of results, validation, writing and review of the manuscript. C Magnago and TC Simões contributed to the analysis and interpretation of the results and to the writing and critical review of the manuscript content. ESO Dantas, RT Jomar and PGB Silva contributed to the analysis and interpretation of the results. All authors approved the final version of the manuscript and are responsible for all aspects of it, including ensuring its accuracy and integrity.

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