

Mortality in motorcycle accidents in Alagoas (2001-2015): temporal and spatial modeling before and after the “lei seca”

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SUMMARY

OBJECTIVE: To analyze the epidemiological profile and the Spatio-temporal distribution of mortality in motorcycle accidents in Alagoas before (2001-2007) and after the “Lei seca” (2008-2015).

METHODS: This is a mixed ecologic study. All deaths in the state with the codes V20-V29 (ICD-10) as the basic cause were included in the study. Sociodemographic variables and mortality rates per sex were analyzed. For the temporal analysis, the inflection point regression model was used. For spatial analysis, the rates were smoothed by the Local Empirical Bayesian Model and, subsequently, the Global and Local Moran statistic was used to identify the spatial clusters of risk.

RESULTS: There were 1458 deaths caused by motorcycle accidents in the period studied; the following characteristics about the victims stand out: male (91.29%), economically active age (82.93%), and brown race (78.12%). In the male population, there was a growth trend between 2001 and 2007 (19.0%, $p < 0.001$), and a decline from 2008 (-11.2%, $p < 0.001$). Spatial modeling showed that the areas with the highest risk of mortality are located in the agreste and sertão of the state ($p = 0.01$).

CONCLUSION: Mortality in motorcycle accidents is an important public health problem in Alagoas, with an emphasis on male mortality and geographic concentration within the state.

KEYWORDS: Accidents, Traffic. Ecological Studies. Mortality Registries.

INTRODUCTION

Over the past decades, traffic-related deaths and injuries have become an important global public health problem. In 2016 alone, 1.35 million people died worldwide due to traffic accidents, and the mortality rate is three times higher in low-income countries¹.

In that same year, 37,345 deaths were reported due to traffic accidents in Brasil, with a rate of

18.1/100,000 inhabitants. Of these, 32% involved two- or three-wheel vehicles¹. It is estimated that the risk of a fatal outcome in a motorcycle accident is 20 times higher than in car accidents².

In 2008, in an attempt to reduce the number of traffic accidents, Law no. 11,705, popularly known as “Lei Seca”, was enacted. Assessing the impact of

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the legislation on the temporal and spatial pattern of traffic mortality is imperative for public health and safety^{3,4}, in view of the magnitude of the problem and the need to understand the phenomenon in different geographical regions of the country and identify priority areas for intervention⁴.

Considering alcohol as the main risk factor for traffic mortality and the motorcyclist population as the most vulnerable, this study aimed to analyze the epidemiological profile and the Spatio-temporal distribution of mortality in motorcycle accidents in Alagoas before (2001-2007) and after the *Lei Seca* (2008-2015).

METHODS

This is a mixed ecologic study. This work was carried out in Alagoas, considering the period 2001-2015. The temporal series was subdivided into two, and the temporal milestone adopted was the year 2008, when the law entered into force. The state comprises 102 municipalities and a population of over 3 million inhabitants; it is the most densely populated area in the Northeast Region (112.13 inhabitants/km²)⁵.

We included all deaths due to transport accidents involving motorcycles and tricycles (driver/passenger), considering ICD-10, codes V20-V29: V20 - Motorcycle rider injured in collision with pedestrian or animal; V21 - Motorcycle rider injured in collision with pedal cycle; V22 - Motorcycle rider injured in collision with two- or three-wheeled motor vehicle; V23 - Motorcycle rider injured in collision with car, pick-up truck or van; V24 - Motorcycle rider injured in collision with heavy transport vehicle or bus; V25 - Motorcycle rider injured in collision with railway train or railway vehicle; V26 - Motorcycle rider injured in collision with other nonmotor vehicle; V27 - Motorcycle rider injured in collision with fixed or stationary object; V28 - Motorcycle rider injured in noncollision transport accident V29 - Motorcycle rider injured in other and unspecified transport accidents - NE. These data were obtained from the Mortality Information System (SIM) from the Datasus platform (<http://datasus.saude.gov.br/>).

Sociodemographic variables were collected in order to characterize the population studied: sex, age, race/color, formal education, marital status, place of death, and the ICD category. These variables were subjected to descriptive analysis. Then, the mortality rates in the general population and according to sex were calculated.

For the temporal analysis, we used the joinpoint

regression model⁶. The trends were classified as stationary, ascending, or descending, and the Annual Percentage change (APC) and the Average Annual Percent Change (AAPC) were calculated. We adopted a significance of 5% and a confidence interval of 95%.

Then, spatial analysis was conducted. Initially, we applied the local empirical Bayes model to the mortality rates to give greater stability to the data. After that, the spatial dependence of the indicators was evaluated using the statistic of the global Moran's statistic and the pseudo-significance test. Once global spatial dependency was observed, we applied the Local Index of Spatial Association - Lisa. From the Lisa, each municipality was placed in one quadrant of the Moran scatter plot: Q1 - High/high (positive values and positive means), Q2 - low/low (negative values and negative means), Q3 - high/low values (positive values and negative means), and Q4 - low/High (negative values and positive means). Based on the results obtained, the thematic maps were built to identify spatial clusters of higher risk of deaths⁷. For the analyses, we used the Terra View 4.2.2, QGIS 2.14.11, and Joinpoint Regression Program 4.5.0.1 software.

Since the study used secondary data from information systems of public domain, it was waived approval by the Research Ethics Committee.

RESULTS

Between 2001 and 2015, 1,458 deaths were recorded due to motorcycle accidents in the state of Alagoas, 1,331 (91.29%) of the victims were males, 39.09% (n=570) aged between 20 and 29 years, and 78.12% (n=1139) of mixed race. There was a predominance of deaths in hospital units (50.34%; n=734), followed by on public roads (44.58%; n=650) (Table 1); 50.14% (n=731) of deaths resulted from transport accidents without collision (Table 1).

The mortality rate in the period was 3.06 deaths/100 thousand inhabitants (5.69/100,000 for men, and 0.52/100,000 for women). In the period prior to the *Lei Seca* (2001-2007), there was a statistically significant growth of overall mortality (APC 18.9%; p<0.001) and among males (APC 19.0%; p<0.001). In the period after the law went into force (2008-2015), there was a trend reversal, with a decline of -11.3% (p<0.001) in the overall mortality and -11.2% (p<0.001) among men. Among women, the behavior was constant in both periods (Table 2).

The spatial distribution showed expansion of

TABLE 1. SOCIODEMOGRAPHIC CHARACTERISTICS OF DEATHS FROM MOTORCYCLE TRAFFIC ACCIDENTS. ALAGOAS, BRASIL, 2001-2015 (N=1,458).

Variable	Male 1,331 (91.29%)		Female 127 (8.71%)		Total 1,458 (100.0%)	
	n	%	n	%	n	%
Age range						
< 10 years	4	0.31	1	0.79	5	0.35
10 a 14	14	1.05	4	3.15	18	1.23
15 a 19	140	10.52	20	15.75	160	10.97
20 a 29	523	39.29	47	37.01	570	39.09
30 a 39	319	23.97	28	22.05	347	23.80
40 a 49	196	14.73	11	8.66	207	14.20
50 a 59	78	5.86	7	5.51	85	5.84
60 or more	57	4.29	9	7.09	66	4.52
Race/color						
White	96	7.21	17	13.39	113	7.75
Black	16	1.20	2	1.57	18	1.23
Yellow	2	0.15	1	0.79	3	0.21
Brown	1,050	78.89	89	70.08	1,139	78.12
Indigenous	1	0.08	0	0.00	1	0.07
Ignored	166	12.47	18	14.17	184	12.62
Years of formal education						
None	19	1.43	2	1.57	21	1.44
1 to 3 years	48	3.61	2	1.57	50	3.43
4 to 7 years	182	13.67	16	12.60	198	13.58
8 to 11 years	70	5.26	9	7.09	79	5.42
12 or more	7	0.53	0	0.00	7	0.48
Ignored	1,005	75.51	98	77.17	1103	75.65
Site						
Hospital	667	50.11	67	52.76	734	50.34
Other health establishments	4	0.30	0	0.00	4	0.27
Home	15	1.13	1	0.79	16	1.10
Public Road	594	44.63	56	44.09	650	44.58
Others	51	3.83	3	2.36	54	3.71
ICD-10 Category						
V20	10	0.75	0	0.00	10	0.69
V21*	-	-	-	-	-	-
V22	18	1.35	1	0.79	19	1.30
V23	82	6.16	14	11.02	96	6.58
V24	30	2.25	4	3.15	34	2.33
V25*	-	-	-	-	-	-
V26	11	0.83	0	0.00	11	0.75
V27	15	1.13	1	0.79	16	1.10
V28	674	50.64	57	44.88	731	50.14
V29	491	36.89	50	39.37	541	37.11

Legend: V20 - Motorcycle rider injured in collision with pedestrian or animal; V21 - Motorcycle rider injured in collision with pedal cycle; V22 - Motorcycle rider injured in collision with two- or three-wheeled motor vehicle; V23 - Motorcycle rider injured in collision with car, pick-up truck or van; V24 - Motorcycle rider injured in collision with heavy transport vehicle or bus; V25 - Motorcycle rider injured in collision with railway train or railway vehicle; V26 - Motorcycle rider injured in collision with other nonmotor vehicle; V27 - Motorcycle rider injured in collision with fixed or stationary object; V28 - Motorcycle rider injured in noncollision transport accident V29 - Motorcycle rider injured in other and unspecified transport accidents - NE. * No records of death in these categories.

TABLE 2. TEMPORAL EVOLUTION AND MORTALITY RATE TREND IN MOTORCYCLE TRAFFIC ACCIDENTS (PER 100,000 INHABITANTS), OVERALL AND ACCORDING TO SEX. ALAGOAS, BRASIL, 2001-2015 (N=1,458).

(a) Mortality rate in motorcycle accidents						
Year	Overall mortality		Male mortality		Female mortality	
	No. deaths	Rate/100,000	No. deaths	Rate/100,000	No. deaths	Rate/100,000
2001	33	1.12	29	2.00	4	0.27
2002	60	2.02	59	4.02	1	0.07
2003	70	2.32	64	4.31	6	0.39
2004	84	2.75	71	4.73	13	0.84
2005	103	3.34	94	6.19	9	0.57
2006	111	3.56	104	6.79	7	0.44
2007	129	4.10	118	7.63	11	0.69
2008	116	3.65	107	6.86	9	0.56
2009	118	3.68	109	6.94	9	0.55
2010	124	3.84	115	7.27	9	0.55
2011	118	3.62	108	6.78	10	0.60
2012	129	3.93	116	7.24	13	0.77
2013	142	4.30	126	7.83	16	0.95
2014	58	1.75	53	3.28	5	0.29
2015	63	1.89	58	3.57	5	0.29
2001-2015	1,458	3.06	1,331	5.69	127	0.52

(b) Joinpoint Regression Model			
Period	APC (CI 95%) p-value	APC (CI 95%) p-value	APC (CI 95%) p-value
2001-2007 ^a	18.9 (12.0 to 26.3) p<0.001*	19.0 (9.9 to 28.9) p<0.001*	4.9 (-3.3 to 13.9) p=0.2
2008-2015 ^b	-11.3 (-18.5 to -3.6) p<0.001*	-11.2 (-20.5 to -0.7) p<0.001*	4.9 (-3.3 to 13.9) p=0.2

Legend: * Statistical significance; APC: Annual Percent Change; AAPC: Average Annual Percent Change; CI 95%: Confidence interval of 95%; a Period before the Lei Seca went into force in Brasil; b Period the Lei Seca went into force in Brasil.

mortality over the time series, as well as a spatial dependency ($p=0.01$). Before the *Lei Seca*, the greatest overall rates corrected were found in Coité do Noia (7.8/100,000), Craíbas (7.22/100,000), and Arapiraca (6.93/100,000). These municipalities also occupied the top three positions in the ranking of male mortality (14.32/100,000, 13.8/100,000, and 6.93/100,000, respectively). In the female population, the municipalities of Coité do Noia (1.44/100,000), Feira Grande (1.56/100,000), and São Sebastião (1.51/100,000) stood out (Figure 1).

In the post-enforcement period, the municipalities of Taquarana (7.43/100,000), Arapiraca (6.91/100,000), and Cacimbinhas (6.86/100,000) stood out for the general mortality; Taquarana (14.13/100,000), Cacimbinhas (13.59/100,000), and Porto Real do Colégio (12.95/100,000) for male mortality; and Pão de Açúcar (2.11/100,000), São José da Tapera (2.11/100,000), and Monteirópolis (1.82/100,000) for female mortality (Figure 1).

The expansion of mortality was also observed in the Moran Map. For the overall mortality, the number of municipalities located in quadrant 1 (Q1) of the Moran scatter plot went from 20 (19.60%), before the *Lei Seca*, to 33 (32.35%) in the period after it went into force. In the male population, the growth was similar, from 21 (20.58%) to 32 (31.37%). In both cases, the municipalities were concentrated in the central region of the state (agreste of Alagoas and transition with the sertão). In the female population, the same number of municipalities was observed ($n=19$; 18.62%) in both periods; however, there was a change in the spatial pattern, with an expansion of mortality to the sertão of the state.

DISCUSSION

The male mortality rate 10.9 times higher than that of females observed in Alagoas corroborates the national and international literature^{8,1}. Of the 38,000

accidents with fatal victims recorded in Brasil in 2015, 82% of deaths were of men¹. Various aspects can justify this context, highlighting, initially, the higher consumption of motorcycles by the male population⁹. Approximately 85% of purchases of such vehicles in the country are by men, and 83% of purchasers are less than 40 years old¹⁰.

In association with the consumption profile, the male population has a higher prevalence of risk behaviors, such as the consumption of alcohol¹¹, excess speeding⁸, no use of personal protective equipment¹¹, driving without a license¹², and lack of knowledge of traffic legislation¹². These factors explain why the risk of motorcycle accidents is substantially higher in this group¹⁰.

The prevalence of deaths in the mixed-race group can be explained by the Brazilian demographic characteristic since 43.1% of the population belongs to this race/ethnicity¹³. In addition, a study by Malta et al.¹¹ pointed out that, in the Brazilian population, mixed-race individuals wear a helmet less often than white individuals, both as the driver (82.1 and 87.9%, respectively) and as a passenger (78.1 and 86.4%, respectively). This points to the existence of sociocultural

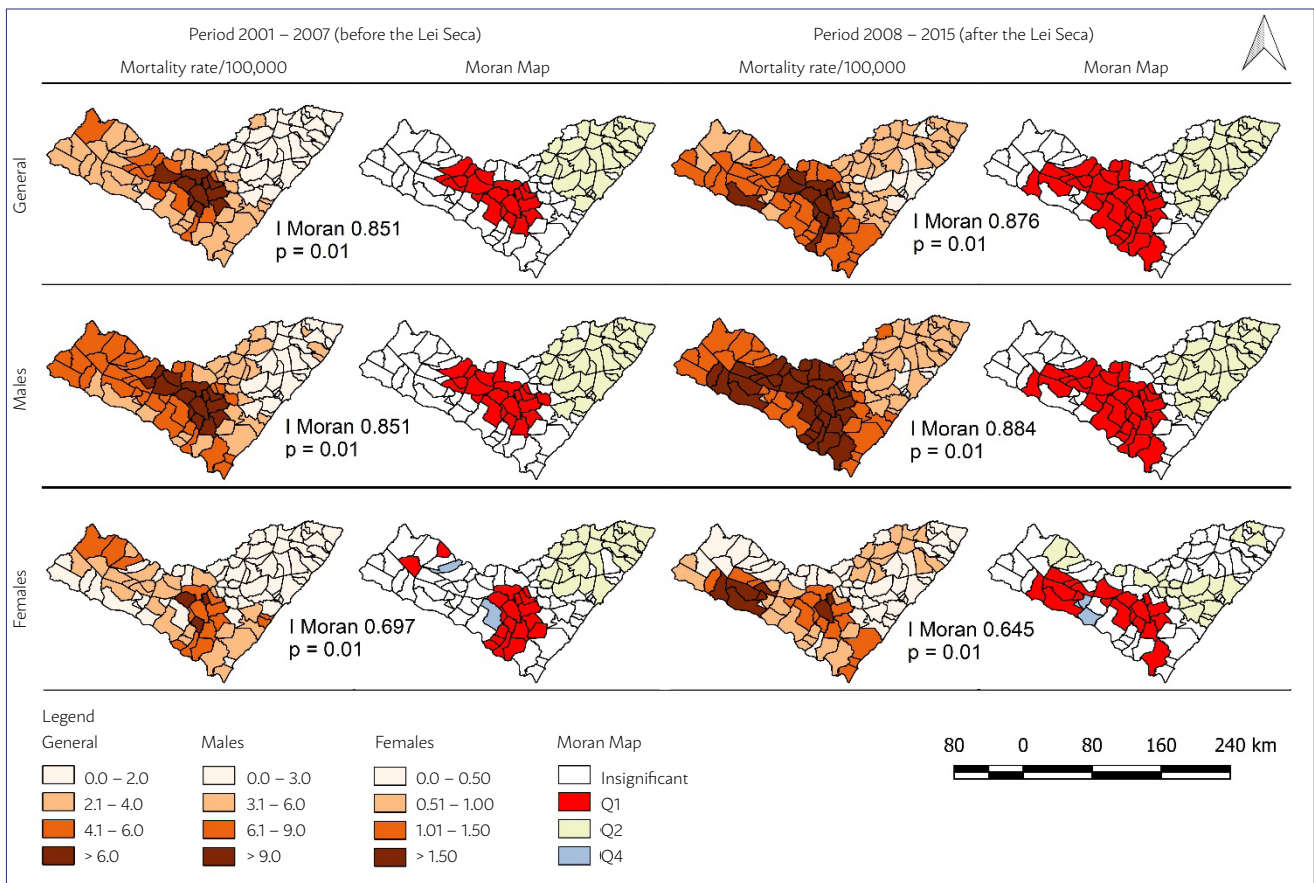
factors that determine the use of personal protective equipment.

In addition to all of these factors described, there has also been an increase in the number of motorcycles. In 2001, the number of two-wheeled vehicles in Alagoas was 33,209; in 2005, into was 58,579 (an increase of 76.3%)¹⁴. The epidemiological results of this entire context of vulnerabilities justify the upward trend in mortality, observed in our study between 2001 and 2007, with a percentage growth rate of 18.9% in the general population and 19.0% among males, as well as the geographic expansion of occurrences.

In addition to the proximal social determinants, it is pertinent to highlight those of a more distant sphere, i.e., the socioeconomic changes of the first decade of the 21st century, such as improved purchasing power, mainly in the North and Northeast regions of the country¹⁵, the percentage of the population that left the poverty range¹⁶, and the lower cost of motorcycles when compared to four-wheeled vehicles¹⁵. In addition, motorcycles assumed an important role in the dynamics of the Brazilian economy, since it has become an opportunity to scape unemployment¹⁷.

The approval of the Brazilian Traffic Code, in

FIGURE 1



1997¹⁸, did not have the expected effect; there was a reduction only in the first years when the number of deaths from traffic accidents dropped from 35,000 (1997) to 29,000 (2000)^{19,20}. Due to the need for new mechanisms capable of making the Brazilian traffic safer, the *Lei Seca* (Law No. 11.705/2008) was created in an attempt to prevent drinking and driving²¹. A national study showed a less pronounced growth of mortality after it went into force²⁰, resembling the temporal pattern observed in Alagoas from 2008. In 2013, the decision 432 of the National Traffic Council lowered the levels of alcohol accepted in the blood-alcohol content test and raised the value of the fines for offenders²², making the law even more severe.

It is also necessary to discuss the geographical distribution of these deaths and raise potential local factors associated with patterns of mortality. In this study, the areas of greatest risk were concentrated in the agreste and sertão in municipalities with a smaller population. Similar results were found in Pernambuco, where the highest mortality rates were in the interior of the state²³. In addition, national research pointed to municipalities with up to 20,000 inhabitants and from 20,000 to 100,000 at higher risk of mortality in comparison to larger municipalities²³. In Alagoas, only Maceió and Arapiraca have a population of over 200,000 inhabitants. In these municipalities, the determinant factors previously discussed are heightened by the absence of a state supervisory power²³.

RESUMO

OBJETIVO: Analisar o perfil epidemiológico e a distribuição espaço-temporal da mortalidade em acidentes motociclísticos em Alagoas antes (2001-2007) e após a lei seca (2008-2015).

MÉTODOS: Estudo ecológico misto. Foram incluídos no estudo todos os óbitos ocorridos no estado que tiveram como causa básica os códigos V20-V29 (CID-10). Foram analisadas as variáveis sociodemográficas e as taxas de mortalidade calculadas segundo sexo. Para a análise temporal, empregou-se o modelo de regressão por pontos de inflexão. Para análise espacial, as taxas foram suavizadas pelo Modelo Bayesiano Empírico Local e, posteriormente, foi empregada a estatística de Moran Global e Local para a identificação dos aglomerados espaciais de risco.

RESULTADOS: Foram registrados 1.458 óbitos em acidentes motociclísticos no período estudado, destacando-se: sexo masculino (91,29%), idade economicamente ativa (82,93%) e raça parda (78,12%). Na população masculina, verificou-se tendência de crescimento entre 2001 e 2007 (19,0%; $p < 0,001$) e de declínio a partir de 2008 (-11,2%; $p < 0,001$). A modelagem espacial mostrou que as áreas de maior risco de mortalidade estão situadas no agreste e sertão do estado ($p = 0,01$).

CONCLUSÃO: A mortalidade em acidentes motociclísticos é um importante problema de saúde pública em Alagoas, com destaque para a mortalidade masculina e concentração geográfica no interior do estado.

PALAVRAS-CHAVE: Acidentes de trânsito. Estudos ecológicos. Registros de mortalidade.

CONCLUSION

The study showed consistent evidence that mortality from motorcycle traffic accidents is an important public health problem in the state of Alagoas, even after considering the positive impacts of the *Lei Seca*. We highlighted the male mortality and geographic expansion of deaths, which were concentrated on the interior of Alagoas (agreste and sertão regions).

Conflicts of interest:

None. No financial funding was received. This study was waived approval by the Research Ethics Committee.

Contribution of the authors

Carlos Dornels Freire de Souza; Leonardo Feitosa da Silva; Thiago Cavalcanti Leal; João Paulo Silva de Paiva: Participated in the development of the concept, planning of the study, data collection and analysis, discussion of the results, scientific writing, as well as in the review and approval of the final version of the work.

Michael Ferreira Machado; Maria Deysiane Porto de Araújo: Participated in the writing of the results, discussion, scientific writing, as well as in the review and approval of the final version of the work.

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