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Ecological study of snakebites in Minas Gerais, Brazil, 2007 to 2019: mapping of risk areas and correlation with urbanization and agricultural work

Estudo ecológico do ofidismo em Minas Gerais, 2007 a 2019: mapeamento de áreas de risco e correlação com urbanização e trabalho agropecuário

Flávia Cappuccio de Resende[1], Priscila Moreira Tavares[1], Clara d'Ávila Fonseca Paiva de Paula Freitas[1], Mariana d'Ávila Fonseca Paiva de Paula Freitas[2], Giselle Agostini Cotta[1], Yukari Figueroa Mise[3]

ABSTRACT

Introduction: Ophidism is a neglected public health problem in many tropical countries. In Brazil, about 27,000 snakebites are recorded per year. The objective of this study is to describe the epidemiological profile of snakebite in Minas Gerais, Brazil, mapping risk areas, and correlating the incidence of accidents with urbanization and agricultural work. **Methods:** Ecological study that analised the 853 municipalities of Minas Gerais (2007-2019), using data from Notifiable Diseases Information System: municipality of occurrence, age, sex, education, race, time to care, snake, severity, clinical evolution. The degree of municipal urbanization and the percentage of agricultural workers were obtained on IBGE. We assessed and mapped risk areas for snakebite in the state. **Results:** The 41,725 reported cases affected mostly men (75.1%), young (40.5%), and brown (43.97%). The high-risk regions were Leste do Sul, Leste, Vale do Aço, and Nordeste. The incidence of snakebites was negatively correlated with level of urbanization (r=-0.22/p<0.0001) and positively correlated with percentage of agricultural workers (r=0.52/p<0.001). **Conclusions:** The characterization of snakebites in the state follows the national pattern. Risk areas are unevenly distributed, highlighting the roles of urbanization and agricultural work in the incidence of the injury.

Keywords: Snake bites; Risk assessment; Epidemiologic studies; Social determinants of health.

[1] Fundação Ezequiel Dias, Belo Horizonte. Minas Gerais, Brazil.

[2] Universidade Federal de Minas Gerais. Belo Horizonte, Minas Gerais, Brazil.

[3] Universidade Federal da Bahia. Salvador, BA, Brazil.

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Dr. Enio Roberto Pietra Pedroso

Faculty of Medicine of the Federal University of Minas Gerais Belo Horizonte/MG, Brazil

Corresponding author:

Flávia Cappuccio de Resende

E-mail: flavia.resende@funed.mg.gov.br

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RESUMO

Introdução: O ofidismo é um problema de saúde pública negligenciado em muitos países tropicais. No Brasil, são registrados cerca de 27.000 acidentes ofídicos por ano. O objetivo deste estudo é descrever o perfil epidemiológico dos acidentes ofídicos em Minas Gerais, Brasil, mapeando áreas de risco e correlacionando a incidência de acidentes com urbanização e trabalho agropecuário. **Métodos:** Estudo ecológico que analisou os 853 municípios de Minas Gerais (2007-2019), utilizando dados do Sistema de Notificação de Agravos de Notificação (SINAN): município de ocorrência, idade, sexo, escolaridade, raça, tempo de atendimento, serpente, gravidade, evolução clínica. O grau de urbanização municipal e o percentual de trabalhadores agrícolas foram obtidos no Instituto Brasileiro de Geografia e Estatística (IBGE). Avaliamos e mapeamos as áreas de risco para acidentes ofídicos no estado. **Resultados:** Os 41.725 casos notificados acometeram principalmente homens (75,1%), jovens (40,5%) e pardos (43,97%). As regiões de alto risco foram Leste do Sul, Leste, Vale do Aço e Nordeste. A incidência de acidentes ofídicos foi negativamente correlacionada com o nível de urbanização (r=-0,22/p<0,0001) e positivamente correlacionada com o percentual de trabalhadores agropecuários (r=0,52/p<0,001). **Conclusões:** A caracterização dos acidentes ofídicos no estado segue o padrão nacional, em que a maioria dos acidentes ocorre com serpentes dos gêneros *Bothrops* e *Crotalus*, com homens em idade produtiva, de baixa escolaridade e de cor parda. A maioria das vítimas recebe atendimento médico nas primeiras horas após o acidente, com alto percentual de casos que evoluem para cura. As áreas de risco estão distribuídas de forma desigual, destacando o papel da urbanização e do trabalho agropecuário na incidência do agravo.

Palavras-chave: Picadas de serpentes; Análise de risco; Estudos epidemiológicos; Determinantes sociais da saúde

Introduction

Ophidism is a neglected public health problem in many tropical countries[1]. The estimate of number of annual cases and deaths is variable. Chippaux (1998)[2] estimated that the occurrence of poisoning by snakes in the world is superior to five million annual cases, with 125,000 deaths. Kasturiratne et al. (2008)[3] present slightly more modest estimates of cases, with an annual occurrence of 1.2 to 5.5 million snakebites worldwide and 94,000 deaths. In Latin America and the Caribbean, it is estimated that 137,000 to 150,000 snakebites occur annually[4], of which about 27,000 are recorded per year in Brazil[5]. The *Bothrops* genus is responsible for most of these cases (70.5%) that occurred in the national territory, followed by *Crotalus* (7.5%), *Lachesis* (2.8%), and *Micrurus* (0.6%) genera[6]. In the remaining 18.6% of cases, there was no information on the genus of the snake, or no trace of poisoning was found[6].

Factors that determine the severity of the accident and lethality include the species of snake involved in the accident, the age of the victim, the place of the bite and the time between the accident and medical care[6]. A study carried out on snakebites in Brazil, between 2001 and 2012, revealed that snakes of genus *Micrurus* are responsible for the highest proportion of severe cases, regardless of the time between bite and medical care[6]. For accidents involving *Crotalus* snakes, there was a high correlation between accidents classified as serious and delay in medical care[6].

The treatment of poisoning is based on the administration of antivenom. Critically ill patients require appropriate life support therapy, such as shock treatment, assisted ventilation and renal therapy[7]. Snakebites can result in permanent physical and psychological sequelae in an unknown number of people, causing significant personal and social suffering[7]. Studies indicate that the incidence of snakebites may be related to occupational, environmental and urban infrastructure activities[8,9]. In the state of Bahia, an ecological study considering the period from 2000 to 2009 showed that the incidence of snakebite was strongly associated with the characteristics of the municipality, such as areas of cocoa and coffee plantations, and the size of domestic bred and bovine livestock[8]. For Tocantins state (2007 to 2015), it was shown that the incidence of snakebite was associated with agricultural work, municipal development index, and area planted with cassava[9].

Although there is biological/social plausibility for the relationship between snakebite and agricultural work, it is necessary to investigate regional particularities. In Rio de Janeiro state, Bochner e Struchiner (2004)[10] found a protective effect against snakebite in tomato, cassava and rice crops. For the state of Minas Gerais, no studies were found that investigate the association of snakebite with occupational, environmental or urban infrastructure activities. Thus, investigating the relationship between the percentage of people employed in agriculture and the incidence of snakebites, as well as evaluating an association between the degree of urbanization of municipalities and the incidence of the accidents, is important to understand the occupational and environmental factors that are related to snakebite in Minas Gerais. In addition, so far, no risk areas for snakebite have been investigated in the state, and the identification of these areas is essential for the strengthening and capillarization of health surveillance actions and for the organization of health services in the treatment of victims. The present study aims to describe the epidemiological profile of snakebite in Minas Gerais, Brazil, assessing and mapping risk areas and correlating it with urbanization and agricultural work.

Methods

This is an ecological study of snakebite reported in Minas Gerais, whose unit of analysis corresponded to the 853 municipalities in Minas Gerais from 2007 to 2019. The state population is approximately 20 million people (IBGE, 2020) and the vegetation cover is composed of Cerrado, Atlantic Forest and Caatinga[11]. The state is composed of 14 health macro-regions: Centro, Centro-Sul, Jequitinhonha, Leste, Leste do Sul, Nordeste, Noroeste, Norte, Oeste, Sudeste, Sul, Triângulo do Norte, Triângulo do Sul, e Vale do Aço[12]. The sample for each municipality was obtained from the database of the Notifiable Diseases Information System (SINAN)[13], and the aggregated data were extracted through TabNet. The following variables were considered: municipality of occurrence, age (<15, 15-39, 40-59, ≥60 years old), sex (male, female), victims' schooling (illiterate, incomplete or complete elementary school, high school, and higher education), race (white, black, yellow, brown and indigenous), time elapsed between the bite and medical care (0-1h, 1-3h, 3-6h, 6-12h, 12-24h, >24h), type of snake (*Bothrops*, *Crotalus*, *Micrurus*, *Lachesis*, non-venomous), severity classification (mild, moderate and severe), evolution of the case (cure, death from the injury, death from other causes).

Annually and cumulatively for the period, the incidence coefficient (number of reported cases/population, per 100,000 inhabitants) and lethality (number of deaths from snakebite/number of reported cases of snakebite) were estimated for each municipality and for each health macro-region using the Microsoft Excel 19®. In order to analyze the seasonality of accidents, we performed Mann-Whitney test, grouping accidents that occurred in the rainy season (October to April) and dry season (May to September). Based on the incidence coefficient, we classified risk areas for snakebite, considering the health macro-regions, using the non-parametric Kruskal-Wallis test, adjusted to the p-value. For this, the program Stata® version 12.0 was used. The incidence coefficient of each macro-region was compared to the others. The p-value <0.05 indicated different risk and p-value>0.05 indicated similar risks. This way, the macro-regions could be grouped based on the statistical similarity between the areas, based on the incidence coefficient and p-value. Based on the incidence coefficients of the macro-regions that made up the groups resulting from the application of the test, the areas were classified according to risk.

In order to investigate the relationship between snakebite and agricultural work and urbanization, we used data from the Brazilian Institute of Geography and Statistics (IBGE). The percentage of people who carry out agricultural work in the municipality was calculated by dividing the number of people with occupation in agriculture (Agricultural Census – data for 2017)[14] by the total inhabitants of the municipality (intercensus projection for the year 2017 from census of 2010). The degree of municipal urbanization (presented in percentage values) was obtained from the Classification and Characterization of Rural and Urban Spaces in Brazil[15], and corresponds to the proportion of the total population residing in urban areas, according to the political-administrative division established by municipal administrations. A Spearman correlation was performed between the incidence of snakebites and the level of urbanization of municipalities in Minas Gerais, as well as between the incidence of accidents and the percentage of people employed in agriculture and livestock.

The spatial distribution of the number of cases for each type of snakebite and the accident incidence coefficients was performed using the ArcMap 10.1 program. GraphPad Prism was used to perform the statistical tests. Tests were considered significant when p<0.05. As this is a study using public domain data available on the internet, it was not necessary to submit the research protocol to the Research Ethics Committee.

Results

In the period investigated, 41,725 accidents with snakes were reported throughout the state of Minas Gerais. Most victims were between 15-39 years old (40.51%), male (75.08%), had incomplete 1st to 4th grade of elementary school (16.43%), brown or white (43.97% and 33.67%, respectively), received medical care up to three hours after the accident (75.41%) and had a good evolution, leading to cure (92.43%). Most accidents occurred with snakes of genus *Bothrops* (67.62%), followed by *Crotalus* (16.51%), *Micrurus*, (0.66%) and *Lachesis* (0.10%). The snake genus was not identified in 11.00% of cases. Accidents with non-venomous species corresponded to 4.11% of cases (Table 1).

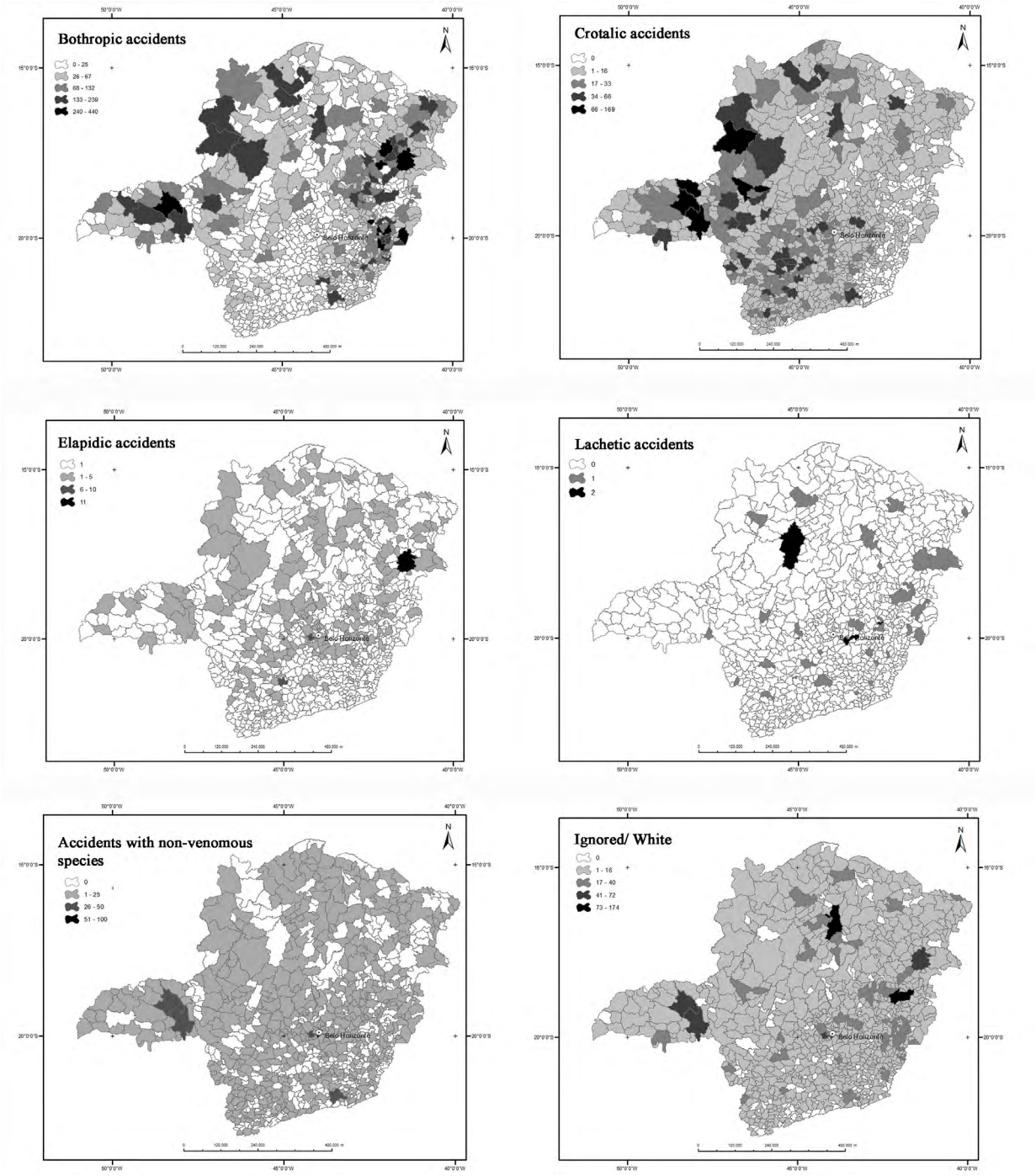
A seasonal pattern of snakebites was observed, since most accidents occurred in hot and humid months, corresponding to the period from October to April (71.07%) (p≤0.005). There was an average of 3,220 accidents per year with snakes in Minas Gerais (SD=429.6), with a range from 2,491 to 3,834 cases. Figure 1 represents the spatial distribution of cases according to the genus of the snake that caused the accident and the municipality of Minas Gerais where it occurred, with darker colors indicating a greater number of cases.

Table 1. Distribution of snakebite cases in the municipalities of the state of Minas Gerais, Brazil, 2007-2019.

Variables	2007-2009		2010-2012		2013-2015		2016-2019		Total	
Age group*	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**
<15 years	1449	14,68	1514	14,15	1025	11,75	1267	10,2	5255	12,6
15-39 years	4445	45,02	4297	40,15	3436	39,38	4726	38,04	16904	40,5
40-59 years	2978	30,16	3550	33,17	2954	33,85	4443	35,76	13925	33,4
≥60 years	997	10,1	1342	12,54	1310	15,01	1983	15,96	5632	13,5
No information	4	0,04	0	0,00	1	0,01	4	0,03	9	0,02
Sex*										
Male	7523	76,2	7997	74,72	6540	74,95	9265	74,58	31325	75,1
Female	2349	23,79	2705	25,27	2186	25,05	3156	25,4	10396	24,9
No information	1	0,01	1	0,01	0	0	2	0,02	4	0,01
Schooling*										
Illiterate	308	3,12	397	3,71	291	3,33	309	2,49	1305	3,13
Elementary school	4347	44,03	4317	40,34	3544	40,62	5209	41,93	17417	41,74
High school	559	5,66	816	7,62	924	10,59	2046	16,47	4345	10,41
Higher education	50	0,51	83	0,78	117	1,34	191	1,54	441	1,06
Not applicable	422	4,27	474	4,43	332	3,8	462	3,72	1690	4,05
No information	4187	42,41	4615	43,12	3532	40,41	4193	33,79	16527	39,61
Race*										
White	3510	35,55	3498	32,68	3000	34,38	4039	32,51	14047	33,67
Black	1031	10,44	1129	10,55	839	9,61	1185	9,54	4184	10,03
Yellow	155	1,57	162	1,51	99	1,13	148	1,19	564	1,35
Brown	3746	37,94	4361	40,75	3948	45,24	6293	50,66	18348	43,97
Indigenous	56	0,57	43	0,4	35	0,4	43	0,35	177	0,42
No information	1375	13,93	1510	14,11	805	9,23	715	5,76	4405	10,56
Time*										
0 to 1 hour	3174	32,15	3720	34,76	3545	40,63	4921	39,61	15360	36,81
1 to 3 hours	3969	40,2	4283	40,02	3380	38,73	4472	36	16104	38,6
3 to 6 hours	1206	12,22	1217	11,37	943	10,81	1610	12,96	4976	11,93
>6 hours	800	8,1	823	7,69	633	7,25	1066	8,57	3322	7,96
No information	724	7,33	660	6,17	225	2,58	354	2,85	1963	4,70
Type of snake*										
Bothrops	7026	71,16	7390	69,05	6033	69,14	7766	62,51	28215	67,62
Crotalus	1422	14,4	1759	16,43	1342	15,38	2364	19,03	6887	16,51
Micrurus	56	0,57	56	0,52	63	0,72	102	0,82	277	0,66
Lachesis	13	0,13	8	0,07	8	0,09	13	0,1	42	0,1
Non-venomous	217	2,2	282	2,63	422	4,84	792	6,38	1713	4,11
No information	1139	11,54	1208	11,29	858	9,83	1386	11,16	4591	11,00
Classification*										
Mild	4632	46,92	4871	45,51	4262	48,84	6374	51,31	20139	48,27
Moderate	3829	38,78	4384	40,96	3441	39,43	4500	36,22	16154	38,72
Severe	785	7,95	870	8,13	839	9,61	1255	10,1	3749	8,99
No information	621	6,35	584	5,45	184	2,11	294	2,37	1683	4,03
Evolution of the case*										
Cure	8994	91,1	9667	90,32	8402	96,29	11503	92,59	38566	92,43
Death from the injury	33	0,33	29	0,27	20	0,23	37	0,3	119	0,29
Death from something else	2	0,02	2	0,02	6	0,07	5	0,04	15	0,04
No information	844	8,55	1005	9,39	298	3,42	878	7,07	3025	7,25
Total	**9873**	**100**	**10703**	**100**	**8726**	**100**	**12423**	**100**	**41725**	**100**

Results are presented in absolute numbers and percentage values.

Figure 1. Snakebites in the municipalities of the state of Minas Gerais, Brazil. The different colors represent the number of accidents, with darker colors indicating more cases.



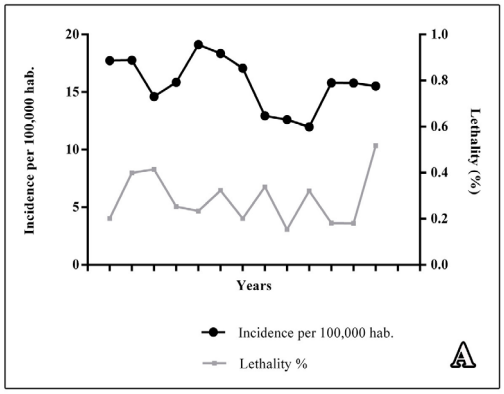
Source: Notifiable Diseases Information System (Sinan) – 2007 to 2019.

The cumulative incidence rate of snakebites in Minas Gerais between 2007 and 2019 was 15.8/100,000 inhabitants, with an annual variation from 11.98 to 19.13 (Figure 2A). In the investigated period, there were 119 deaths from the reported accident, with an average lethality rate for the state of 0.29%, ranging between 0.15% and 0.52% (Figure 2A). Deaths occurred mainly in men (71.2%) between 40 and 59 years old (36%), injured by snakes of the genus *Bothrops* (59.3%), followed by *Crotalus* (28.8%). Of the fatal victims, 52.5% received medical care within three hours after the accident. The percentages of fatal victims that received treatment between three and six hours, six to 24 hours, and after 24 hours were 12.7, 13.6, and 13.6, respectively. In 7.6% of deaths, information about the time of medical care was not completed. The municipalities with the highest incidence rates were: Água Comprida (154.6/100,000 inhabitants), Santana do Manhuaçu (154.4/100,000 inhabitants) and Durandé (130.6/100,000 inhabitants) (Figure 2B).

From the analysis to classify the risk areas of the 14 health macro-regions of Minas Gerais, we identify three distinct groups in relation to the incidence coefficients. These groups showed statistical similarity to each other. Group one, for presenting lower incidence coefficients in relation to the others, was classified as low risk. Group two, for having incidence coefficients with intermediate values, was classified as medium risk. Finally, group three, as it had the highest incidence coefficients, was classified as high risk. Thus, (i) the high-risk region comprises the macro-regions Leste do Sul (54,4/100.00), Leste (51,2/100.000), Vale do Aço (47,8/100.000), and Nordeste (46,9/100.000); (ii) the medium risk region comprises the macro-regions Noroeste (38,3/100.000), Triângulo do Sul (38,2/100.000), Sudeste (32,4/100.000), Jequitinhonha (32,1/100.000), Centro Sul (30,9/100.000), and Triângulo do Norte (28,8/100.000); and (iii) the low-risk region comprises the macro-regions Norte (24,6/100.000), Centro (21,3/100.000), Oeste (20,0/100.000) and Sul (17,1/100.000) (Table 2, Figure 2).

The degree of urbanization of municipalities in Minas Gerais ranged from 0 to 99.66%, with 81 municipalities having an urbanization level above 90% and 277 municipalities, less than 20%. The percentage of people employed in agriculture ranged from 0 to 83.84%, with 24 municipalities having more than 50% of the population employed in agriculture, and 464 municipalities having less than 20%. A negative and significant correlation was observed between the incidence of accidents and the level of urbanization of the municipalities (r= -0.22; p<0.0001) (Figure 3A). On the other hand, a positive correlation was observed between the percentage of people employed in agriculture and livestock and the incidence of snakebites in the municipalities of Minas Gerais (r=0.52; p<0.001) (Figure 3B).

Figure 2. A. Incidence rate (per 100,000 inhabitants) and lethality (%) of snakebites in the state of Minas Gerais, Brazil, 2007-2019; B. Map of snakebite incidence rates in the municipalities of Minas Gerais, Brazil, 2007-2019. Dark colors represent higher incidences.



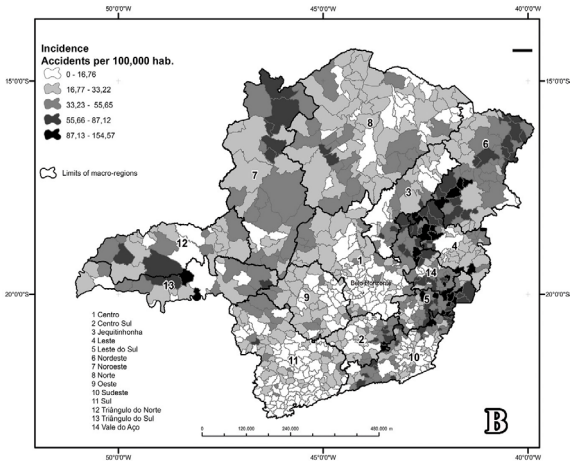


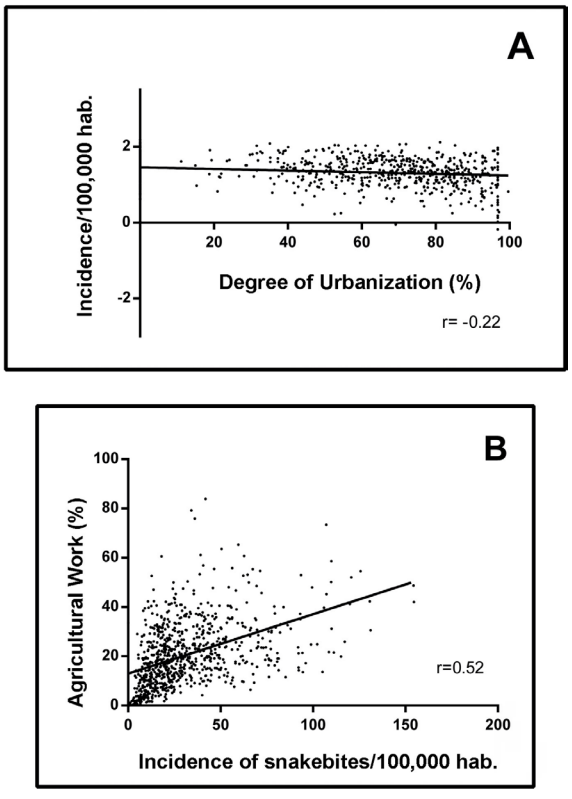
Table 2. Classification of risk areas for snakebites in the health regions of the state of Minas Gerais, Brazil, 2007-2019 with robust White correction.*

Health regions	SUL	OES	CEN	NOR	TRN	CSU	JEQ	SUD	TRS	NRO	NRD	AÇO	LES	LSU	Inci Coef. / 100,000 inhab.
SUL	-	2,013	0,223	**0,022**	**0,001**	**0,001**	**0,001**	**0,001**	**0,001**	**0,001**	**0,001**	**0,001**	**0,001**	**0,001**	17,1
OES	2,013	-	5,172	0,857	**0,003**	**0,001**	**0,001**	**0,001**	**0,001**	**0,001**	**0,001**	**0,001**	**0,001**	**0,001**	20,0
CEN	0,223	5,172	-	1,823	**0,004**	**0,001**	**0,001**	**0,001**	**0,001**	**0,001**	**0,001**	**0,001**	**0,001**	**0,001**	21,3
NOR	**0,022**	0,857	1,823	-	0,960	0,435	0,116	**0,048**	**0,003**	**0,007**	**0,007**	**0,001**	**0,003**	**0,001**	24,6
TRN	**0,001**	**0,003**	**0,004**	0,960	-	2,794	1,735	0,599	**0,008**	**0,029**	0,209	**0,003**	**0,007**	**0,001**	28,8
CSU	**0,001**	**0,001**	**0,001**	0,435	2,794	-	8,764	4,794	0,053	0,358	0,762	**0,008**	**0,015**	**0,001**	30,9
JEQ	**0,001**	**0,001**	**0,001**	0,116	1,735	8,764	-	13,71	0,466	1,201	1,077	**0,038**	**0,035**	**0,001**	32,1
SUD	**0,001**	**0,001**	**0,001**	**0,048**	0,599	4,794	13,71	-	0,193	1,201	1,075	0,052	**0,032**	**0,001**	32,4
TRS	**0,001**	**0,001**	**0,001**	**0,003**	**0,008**	0,053	0,466	0,193	-	12,86	5,565	1,077	0,360	**0,003**	38,2
NRO	**0,001**	**0,001**	**0,001**	**0,007**	**0,029**	0,358	1,201	1,201	12,86	-	4,799	0,962	0,497	**0,007**	38,3
NRD	**0,001**	**0,001**	**0,001**	**0,007**	0,209	0,762	1,077	1,075	5,565	4,799	-	11,44	6,399	3,195	46,9
AÇO	**0,001**	**0,001**	**0,001**	**0,001**	**0,003**	**0,008**	**0,038**	0,052	1,077	0,962	11,44	-	8,261	4,983	47,8
LES	**0,001**	**0,001**	**0,001**	**0,003**	**0,007**	**0,015**	**0,035**	**0,032**	0,360	0,497	6,399	8,261	-	10,62	51,2
LSU	**0,001**	**0,001**	**0,001**	**0,001**	**0,001**	**0,001**	**0,001**	**0,001**	**0,003**	**0,007**	3,195	4,983	10,62	-	54,4

Abbreviations of health macro-regions: AÇO: Vale do Aço; CEN: Centro; CSU: Centro-Sul; JEQ: Jequitinhonha; LES: Leste; LSU: Leste do Sul; NOR: Norte; NRD: Nordeste; NRO: Noroeste; OES: Oeste; SUD: Sudeste; SUL: Sul; TRN: Triângulo do Norte; TRS: Triângulo do Sul. Inci. Coef./100,000 inhab: incidence coefficient/100,000 inhabitants

* Values in bold means that the means are statistically different (p<0,05).

Figure 3. A. Correlation between the incidence of snakebites (log10) and the level of urbanization (%) of municipalities in the state of Minas Gerais; B. Correlation between the percentage of people employed in agriculture and livestock and the incidence rate of snakebites in the municipalities of the state of Minas Gerais, Brazil.



Discussion

The profile of snakebites in Minas Gerais is similar to that found in Brazil, where most cases occur with male individuals, aged between 15 and, 59 years, with low schooling, and most victims receive medical care between one and three hours after the accident, with a high percentage of cases that progress to cure[6]. The distribution of snakebites in Minas Gerais is also similar to the pattern found for Brazil, where most accidents occur with snakes of the genera *Bothrops* and *Crotalus*[16]. While the percentage of bothropic accidents that occurred in Minas Gerais (67.69%) is comparable to the national average (69.93%), crotalic accidents notably have a higher relative contribution in Minas Gerais (16.51%) than the national average (8.81%)[16]. In the metropolitan region of Belo Horizonte, which is made up of 34 municipalities, the percentage of crotalic accidents is even higher, reaching 30% of cases. This differentiated distribution can be explained by the type of vegetation in the studied region, where Cerrado predominates[11], a biome preferably occupied by snakes of the genus *Crotalus*[17]. The rattlesnake *Crotalus durissus* occurs in dry formations from Mexico to northern Argentina[17], and there is evidence that this species can also occur in disturbed areas of the Atlantic Forest[18].

The percentage of accidents with *Micrurus* in the studied region is 0.66%, similar to the national average (0.90%)[16]. The rarity of these accidents can be explained by the fossorial habit and low aggressiveness of coral snakes, in addition to the small fixed anterior fangs and limited mouth opening angle, which makes it difficult to inject the venom[19]. It was reported 0.10% of lachetic accidents in the studied region; however, it is believed that this percentage may still be lower, since the municipalities that presented records of these accidents in the state of Minas Gerais do not correspond to the geographic distribution of *Lachesis muta*[20]. This species is restricted to forest fragments, inhabiting primary forests more frequently. Thus, the reported lachetic accidents may have been diagnostic errors, incorrect identification of animals, or even errors in filling out the notification form. In the present study, 42 cases were recorded as lachetic accidents; of these, 36 progressed to cure, and in the other six cases this information was not completed. Considering that the treatment of accidents with *Lachesis* snakes is done with antibothropic-lachetic serum[21], if these accidents were caused by snakes of the genus *Bothrops*, the treatment implemented would also have been appropriate, given the bivalence of the antivenom. Despite this, the lower availability of antibothropic-lachetic serum reinforces the importance for the correct deduction of the snake in order to use properly the immunobiological.

It was observed that in 11.00% of the cases, there was no information about the snake involved in the accident, similarly to the national average, which is 11.48%[16]. This fact has negative consequences for the planning of production and distribution of the antivenom serum in the state of Minas Gerais.

Although SINAN is a source of a large amount of high quality data, which allows us to draw an epidemiological profile for snakebites for different locations, we still have a large number of blank fields. The identification of the snake involved in the accident is essential for the use of adequate antivenom and the success of the treatment. To assist in the identification, protocols based on the manifestation of symptoms are important tools[22]. In addition, technological resources that allow health professionals access to snake specialists have been successfully used[6].

A seasonal pattern of snakebites was observed in the studied region, with a higher incidence in the rainy season in the state[23], since most accidents occur from October to April (71.07%). Between the months of July and September, we have the lowest percentage of accidents (14.53%). This pattern, already observed in other epidemiological studies, could be explained by the increase in snake activity in the hot and humid months, and, associated with this, this is the time when people are more exposed to natural areas, both in agricultural or leisure activities[6,24]. It should be noted that climate change in the region, with a forecast of an increase in average temperature for the next decades[25], may impact the seasonality profile of snakebites in the state, given that snakes are ectothermic and the activity pattern of these animals is influenced by temperature.

The highest proportion of serious accidents occurred with snakes of the genus *Micrurus*, followed by the genera *Crotalus*, *Lachesis* and, finally, *Bothrops*. The percentage of assistance in the first three hours after the accident in the studied region was similar to the average of the Southeast and South regions. In the studied region, 75.41% of the victims received medical care within three hours, while in the Southeast and South regions, these numbers are 73.3% and 79.9%, respectively[6].

The results found for sex and age emphasize that men of working age correspond to the people most affected by snake bites[6,26]. The low level of education of most victims found in this study provides evidence of a problem of social vulnerability. This pattern has been pointed out since Vital Brazil's work with snakebite individuals in southeastern Brazil in the early 20th century[27].

The negative correlation observed between the level of urbanization and the incidence of accidents demonstrates that municipalities in which the proportional occupation of urban space is greater present a lower risk for snakebites. Urbanization reduces the availability of vegetation that serves as a refuge for snakes, affects access to unpolluted bodies of water, changes the abiotic characteristics that favor the occurrence of the animal[28]. All these issues interfere in the presence of snakes and consequently in the possibility of snakebite accidents.

On the other hand, the positive correlation between the percentage of workers in agriculture and livestock and the incidence of snakebites reinforce the effect of rural work on the occurrence of the accidents. This relationship has already been observed in studies carried out in the states of Bahia and Tocantins, both with aggregated and individual data[8,9]. The centrality of agricultural work in the risk of snakebite goes back to Vital Brazil's observations, in the first systematized studies on snakebite in the country[27] and reinforces the need for this problem to be incorporated into workers' health guidelines. This way, special attention should be given to the agricultural worker, indicated by the literature[9,29] as the main victim of snakebite poisoning, and therefore, it should be the focus of policies and programs to protect workers' health.

The macro-regions "Centro" and "Oeste", which had a low risk of accidents, have an average of 12.9% and 16.6% of people employed in agriculture[14]. In these regions, most municipalities have the service and industry sector as their main activities. In the macro-regions "Norte" and "Sul", which also had a low risk of accidents, we have 27.8 and 21.1% of people employed in agriculture[14]. In these regions, most municipalities have agriculture as their main activity. More detailed studies regarding the type of agricultural activity in each municipality will be important to assess whether snakebite occurs more frequently in a specific type of crop or specific livestock practice. IBGE data referring to the 2017 agricultural census showed that in most agricultural establishments, the producer is male (85%), white (57.01%) or brown (35.58%). In most agricultural establishments (43.34%), the producer is between 45 and 65 years old[30]. These results coincide with those observed in relation to victims of snakebites.

The average incidence found for Minas Gerais (15.8.0/100,000 inhabitants) is similar to the national average (14.84/100,000 inhabitants) and the average lethality for the state (0.29%) is lower than the national average for the year 2020 (0.39%) [16]. It may be a reflection of better conditions of health services in the state, both to identify cases and make the effective notification, and for the management of bitten patients, reducing the probability of lethal success[16]. It is worth noting the role of the State Health Department as a guide for state actions and the importance of enhancing health surveillance actions, improving accident reporting, deduction of the presumed snake taxon, and correct assessment of staging and subsequent indication of serum therapy appropriate for the severity of the poisoning. The macro-regions that presented a high risk of accidents (Leste do Sul, Leste, Vale do Aço and Nordeste) have an average of 28.8%, respectively; 18.1%; 17.5% and 19.5% of the population employed in agriculture[15]. The municipalities that make up these macro-regions are located in Zona da Mata, Vale do Rio Doce, Vale do Mucuri and Jequitinhonha.

The analysis of risk regions for snakebites can complement health surveillance actions and assist in the organization of health services and in the distribution of snakebite sera[9]. The definition of municipalities with service stations for victims, the planning of accident prevention campaigns, as well as the training of health professionals to diagnose accidents are some of the actions that can be intensified, taking into account the analysis of accident risk.

As there are different patterns of snakebites in different regions of Brazil, the study of specific regions is important for the development of local public health policies[8]. Knowing the epidemiology of accidents with snakes in all municipalities in Minas Gerais, as well as knowing the people who are affected by this condition, is essential for accident prevention actions and treatment of victims. The incorporation of data on the victim's occupation, especially, if the accident occurred during work, as well as the environment in which the victim was at the time of the bite, may be important for a better understanding of this health issue. Additionally, it is necessary to address, in training courses for health professionals, the importance of completing the notification forms, given the high percentage of fields not completed. It is necessary to disseminate to these professionals that the information on the notification forms is used to plan the production, storage and distribution of antivenom, as well as to plan the training of specialized teams in snakebite treatment[6]. The high proportion of accidents in which the type of snake was indeterminate is indicative of the need for training health professionals[6], given that it is the combination of the presumed snake taxon with the intensity of clinical manifestations that determines the type of serum and the number of ampoules.

The therapeutic approach adopted for a "snake indeterminate" patient may imply the use of inappropriate antivenom[6].

As limitations of the study, we can mention the underreporting of cases, the quality of the information present in the Sinan database, and that this is a retrospective study. In particular, it is important to point out the incompleteness of the data, especially in the socioeconomic variables that historically present problems in reporting and mask social vulnerabilities.

We concluded that the distribution of snakebites in Minas Gerais follows the national profile in terms of morbidity, mortality and characterization of the cases. Men of working age, with low schooling and brown color are the main victims. Most accidents occur with snakes of the genera *Bothrops* and *Crotalus,* however, crotalic accidents notably have a higher relative contribution in Minas Gerais compared to the whole country. Most victims receive medical care between one and three hours after the accident, with a high percentage of cases that progress to cure. The risk areas are unevenly distributed in the state, being more concentrated in Zona da Mata, Vale do Rio Doce, Vale do Mucuri and Jequitinhonha, which demands additional investigations on the incidence of snakebite associated with the productive profile of each area, the sensitivity of the health services, as well as other macrostructuring elements. The presence of environmental and occupational determinants for the risk of snakebites in the state, such as the degree of urbanization and agricultural work, indicates that tackling this issue requires integrated actions that go beyond the health sector.

Copyright

Ethics Committee

As this is a study using public domain data available on the internet, it was not necessary to submit the research protocol to the Research Ethics Committee.

Authors' Contribution

FCR participated in the conception and design of the study, data collection and analysis, writing of the article. PMT participated in the conception and design of the study, data collection and analysis, critical review of the article. CDFPPF participated in the conception and design of the study, data collection and analysis, critical review of the article in English. GAC participated in the conception and design of the study, data collection and analysis, writing of the article. MDFPPF participated in the conception and design of the study, data collection and analysis, preparation of maps, critical review of the article. YFM: participated in the conception and design of the study, data analysis, and writing of the article.

References

1. World Health Organization (WHO). Rabies and envenomings: a neglected public health issue: report of a Consultative Meeting. Geneva: WHO; 2007; [access in 2021 Feb 02]. http://www.who.int/bloodproducts/animal_sera/Rabies.pdf
2. Chippaux JP. Snake-bites: appraisal of the global situation. Bull World Health Organ. 1998;76(5):515-24.
3. Kasturiratne A, Wickremasinghe AR, Silva N, Gunawardena NK, Pathmeswaran A, Premaratna R, et al. The global burden of snakebite: a literature analysis and modelling based on regional estimates of envenoming and deaths. PLoS Med. 2008; 5(11):1591-604.
4. Gutiérrez JM, Calvete JJ, Habib AG, Harrison RA, Williams DJ, Warrell DA. Snakebite envenoming. Nat Rev Dis Prim. 2017;3:17063.
5. Schneider MC, Min KD, Hamrick PN, Montebello LR, Ranieri TM, Mardini L, et al. Overview of snakebite in brazil: Possible drivers and a tool for risk mapping. PLoS Negl Trop Dis. 2021;15(1):e0009044.
6. Bochner R, Fiszon JT, Machado C. A profile of snake bites in Brazil, 2001 to 2012. J Clin Toxicol. 2014;4(3):1-7.
7. Malaque CMS, Gutiérrez JM. Snakebite envenomation in central and South America. In: Brent J, Burkhart K, Dargan P, Hatten B, Megarbane B, Palmer R, et al., eds. Critical care toxicology. Switzerland: Springer; 2015. p. 1-22.
8. Feitosa SB, Mise YF, Mota ELA. Ofidismo no Tocantins: análise ecológica de determinantes e áreas de risco, 2007-2015. Epidemiol Serv Saude 2020;29(4):e2020033.
9. Mise YF, Lira-da-Silva RM, Carvalho FM. Agriculture and snakebite in Bahia, Brazil - an ecological study. Ann Agric Environ Med. 2016;23(3):416-9.
10. Bochner R, Struchiner CJ. Aspectos ambientais e sócio-econômicos relacionados à incidência de acidentes ofídicos no Estado do Rio de Janeiro de 1990 a 1996: uma análise exploratória. Cad Saude Publica. 2004;20(4):976-85.
11. Scolforo J, Carvalho L. Mapeamento e inventário da flora nativa e dos reflorestamentos de Minas Gerais. Lavras: Editora UFLA; 2006.
12. Governo do Estado de Minas Gerais (BR). Secretaria de Estado de Saúde de Minas Gerais. Plano Diretor de Regionalização da Saúde de Minas Gerais [Internet]. Belo Horizonte: PDR/MG; 2020; [access in 2021 Aug 15]. Available from: https://www.saude.mg.gov.br/images/1_noticias/10_2020/2_out-nov-dez/28-10_PLANO-DIRETOR-DE-REGIONALIZACAO-DA-SAUDE-DE-MINAS-GERAIS_PDRMG.pdf
13. Ministry of Health (BR). Sistema de Informação de Agravos de Notificação (SINAN) [Internet]. Brasília (DF): Ministry of Health; 2020; [access in 2021 Mar 15]. Available from: http://portalsinan.saude.gov.br/sinan-net
14. Instituto Brasileiro de Geografia e Estatística (IBGE). Resultados do Censo Agro 2017 [Internet]. Rio de Janeiro: IBGE; 2020; [access in 2021 Jun 29]. Available from: https://censoagro2017.ibge.gov.br/templates/censo_agro/resultadosagro/produtores.html?localidade=31

15. Instituto Brasileiro de Geografia e Estatística (IBGE). Classificação e Caracterização dos Espaços Rurais e Urbanos do Brasil | Uma primeira aproximação [Internet]. Rio de Janeiro: IBGE; 2017; [access in 2020 Jun 29]. Available from: https://www.ibge.gov.br/geociencias/organizacao-do-territorio/tipologias-do-territorio/15790-classificacao-e-caracterizacao-dos-espacos-rurais-e-urbanos-do-brasil.html?=&t=downloads

16. Ministério da Saúde (BR). Epidemiologia dos acidentes ofídicos no Brasil em 2020. Brasília (DF): Ministério da Saúde; 2021.

17. Campbell J, Lamar W, Brodie E. Venomous reptiles of the western hemisphere. 2nd ed. Ithaca: Comstock Publishing Associates Cornell University Press; 2004.

18. Bastos EGM, Araújo AFB, Silva HR. Records of the rattlesnakes *Crotalus durissus terrificus* (Laurenti)(Serpentes, Viperidae) in the State of Rio de Janeiro, Brazil: a possible case of invasion facilitated by deforestation. Rev Bras Zool. 2005 Sep;22(3):812-5.

19. Almeida PCR, Prudente ALC, Curcio FF, Rodrigues MTU. Biologia e história natural das cobras-corais. In: Silva Junior NJ, ed. As cobras corais do Brasil: biologia, taxonomia, venenos e envenenamentos. Goiânia: Editora da PUC Goiás; 2016. p. 168-215.

20. Fernandes DS, Franco FL, Fernandes R. Systematic revision of the genus Lachesis Daudin, 1803 (Serpentes, Viperidae). Herpetologica. 2004;60(2):245-60.

21. Fundação Ezequiel Dias (Funed). Soro antibotrópico (pentavalente) e antilaquético [Internet]. Belo Horizonte: Funed: 2020; [access in 2020 Nov 17]. Available from: http://www.funed.mg.gov.br/wp-content/uploads/2020/04/Bula-para-o-profissional-do-soro-antibotr%C3%B3pico-e-antilaqu%C3%A9tico_v16042020.pdf

22. Pathmeswaran A, Kasturiratne A, Fonseka M, Nandasena S, Lalloo DG, Silva HJ. Identifying the biting species in snakebite by clinical features: an epidemiological tool for community surveys. Trans R Soc Trop Med Hyg. 2006;100(9):874-8.

23. Reboita MS, Rodrigues M, Silva LF, Alves MA. Aspectos climáticos do estado de Minas Gerais. Rev Bras Climatol. 2015;17:206-26.

24. Lima JS, Martelli Júnior H, Martelli DRB, Silva MS, Carvalho SFG, Canela JR, et al. Perfil dos acidentes ofídicos no norte do Estado de Minas Gerais, Brasil. Rev Soc Bras Med Trop [Internet]. 2009 Oct;42(5):561-4.

25. Reboita MS, Marrafon VHA, Llopart M, Rocha RP. Cenários de mudanças climáticas projetados para o Estado de Minas Gerais. Rev Bras Climatol. 2018;1:110-28.

26. Nunes DCO, Franco PS, Rodrigues VM, Mendes MM. Clinical-epidemiologic aspects of ophidian accidents occurred in Triângulo Mineiro Region, Minas Gerais State, Brazil: retrospective case series. Biosci J. 2014;30(6):1942-51.

27. Mott ML, Alves OSF, Dias CESB, Fernandes CS, Ibañez N. A defesa contra o ofidismo de Vital Brazil e a sua contribuição à Saude Pública Brasileira. Cad Hist Ciênc. 2011;VII(2):89-110.

28. French SS, Webb AC, Hudson SB, Virgin EE. Integrative and comparative biology town and country reptiles: a review of reptilian responses to urbanization. 2018 Jun;58(5):948-66.

29. Borges CC, Sadahiro M, Santos MC. Aspectos epidemiológicos e clínicos dos acidentes ofídicos ocorridos nos municípios do Estado do Amazonas. Rev Soc Bras Med Trop. 1999 Dec;32(6):637-46.

30. Instituto Brasileiro de Geografia e Estatística (IBGE). Número de estabelecimentos agropecuários com pessoal ocupado/Pessoal ocupado em estabelecimentos agropecuários/Número de estabelecimentos agropecuários com pessoal ocupado com laço de parentesco com o produtor/Pessoal ocupado em estabelecimentos agropecuários com laço de parentesco com o produtor, por tipologia, sexo, faixas de idade, condição do produtor em relação às terras e grupos de atividade econômica [Internet]. Rio de Janeiro: IBGE; 2017; [access in 2020 Jun 29]. Available from: https://sidra.ibge.gov.br/tabela/6884