Original article

Snakebite in Tocantins: ecological analysis of determinants and risk areas, 2007- 2015*

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Abstract

Objective: To investigate the epidemiological profile of snakebite accident cases, their determinants and risk areas in the state of Tocantins. **Methods:** This was an ecological study using data from the Notifiable Health Conditions Information System, from 2007 to 2015. Multiple linear regression and the Mann-Whitney and Kruskal-Wallis tests were used. **Results:** A total of 7,764 snakebite accidents were reported (incidence: 62.1/100,000 inhab.; lethality: 0.5%). The variables associated with snakebite were population density (Coeff.=1.36, 95%CI 0.72;1.99), farming work (Coeff.=0.02, 95%CI 0.01;0.03), municipal human development index (Coeff.=2.99 – 95%CI 0.60;5.38), area planted with cassava (Coeff.=8.49 – 95%CI 1.66;15.32), indigenous population (Coeff.=0,02 – 95%CI 0.00; 0.04), proportion of illiterate people (Coeff.=4.70 – 95%CI 0.61;8.79) and employed people (Coeff.=3.00 – 95%CI 0.93;5,06), which together accounted for 64.48% of the variation. The high-risk areas were Amor Perfect, Cantão, Cerrado Tocantins Araguaia and Mid-North Araguaia health regions. **Conclusion:** Municipal socioeconomic and demographic aspects were associated with snakebites.

Keywords: Snake Bites; Ecological Studies; Health Profile; Risk Zone.

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Introduction

Snakebite accidents persist as a Public Health problem, owing to the assiduity with which they occur and the morbidity and mortality they cause, principally in tropical countries where the world's most diverse snakes of medical importance are found.[1,2] This health condition frequently affects young male rural workers of economically active age.[1,3]

> *Knowledge about snakebites has advanced a great deal in recent decades,although there have been few investigations from a perspective of the spatial context considering the occurrence of this health condition as a complex societal event.*

In 2009, the World Health Organization (WHO) included snakebites on its list of neglected tropical diseases. In 2019 it was estimated that globally every year there are 2,700,000 cases of snakebite envenoming and between 81,000 and 138,000 deaths, as well as 400,000 victims who survive with physical disability and psychological harm.[2] Despite these estimates, global data are relatively incipient, and the total number of affected people is underestimated.[1,4,5]

In the period selected for the study, there were approximately 28,500 snakebite accidents a year in Brazil, with an incidence rate of 14.5/100,000 inhab. and 0.41% lethality,[6] this being nine times higher than the global estimate. Brazil's Northern region stands out due to its high incidence rate: 56.0 cases/100,000 inhab.[4,6,7]

Knowledge about snakebites has advanced a great deal in recent decades,[8] although there have been few investigations from a perspective of the spatial context considering the occurrence of this health condition as a complex societal event, given that socioeconomic and environmental conditions can be risk factors.[4,9]

The objective of this study was to investigate the profile of snakebite accident cases, their determinants and risk areas in the state of Tocantins, Brazil.

Methods

This was a multiple-group ecological study, in which municipalities were the units of analysis for the occurrence of snakebite accidents between 2007 and 2015 in the state of Tocantins.

Tocantins is part of Brazil's Northern region and its main economic activities are agriculture and livestock rearing.[10] The state has 139 municipalities, a territorial area of 277,720.567km² and an estimated population of 1,515,126 inhabitants.[11] Indigenous people account for approximately 5% of this population, distributed between nine ethnic groups: Apinayé; Xerente; Karajá; Krahô; Xambioá; Krahô-Kanela; Javaé; Pankararu; and Avá-Canoeiro.[10,11] Tocantins has a human development index (HDI) of 0.699 and a Gini index of 0.60: 32.36% of its population are in a situation of poverty.[11,12] The state is comprised of eight health regions: Mid-North Araguaia; Bico do Papagaio; Southeast; Cerrado Tocantins Araguaia; Ilha do Bananal; Capim Dourado; Cantão; and Amor Perfeito.[13]

All of the state's municipalities were included in the study, since all of them notified snakebite cases in the selected period.

Data relating to snakebite characterization were retrieved from the Tocantins State Health Department (SESAU/TO) Notifiable Health Conditions Information System (SINAN), by municipality of occurrence. The socioeconomic and demographic variables were obtained from the Brazilian Institute of Geography and Statistics (IBGE) and from the Brazilian Human Development Atlas. Data from the 2010 census was used, as were statistical projections for the intercensal periods.

The variables relating to affected people were:

a) sex (male; female);
b) age (in years: <15; 15-34; 35-54; 55 or over);
c) schooling (no schooling; up to complete elementary education; complete high school education; complete higher education; no information);
d) race/skin color (white; black; yellow; brown; indigenous; no information); and
e) occupation (farming; worker in general; no information).

With regard to snakebite accidents, the variables investigated were:

a) municipality of occurrence;
b) zone (urban; rural; peri-urban; no information);
c) month of occurrence;
d) anatomic site of snakebite (torso; lower limbs; upper limbs; no information);
e) snake genus (*Bothrops*, *Crotalus*, *Micrurus*, *Lachesis*; not venomous; no information);

f) time elapsed between accident and health care (up to six hours; over six hours; no information);
g) stage (mild; moderate; severe; no information);
h) clinical evolution (cure; death; no information); and
i) work-related accident (yes; no; no information).

The following variables were investigated per municipality:

a) municipal human development index (MHDI);
b) Gini index;
c) gross domestic product (GDP) *per capita* (U$);
d) population employed (%);
e) area used for agriculture (%);
f) population employed in farming (%);
g) population with access to water and refuse collection (%);
h) proportion of illiteracy among people aged 15 years or over (%);
i) proportion of indigenous people in the municipality in relation to the overall municipal population (%);
j) population density (inhab./km^2); and
k) climatic aspect (dry period; rainy period).

The variables related to farming were selected based on the main activities developed in Tocantins, per municipality, taking 2015 as the reference year. The variables specifically relating to agriculture were the planted areas (in km^2) of rice, pineapple, banana, sugar cane, beans, cassava, water melon, corn, soya and sorghum. With regard to livestock rearing, we considered the effective total herd, per head of cattle, goat, horse, chicken and pig. All the socioeconomic data were retrieved from the IBGE database.

We calculated the snakebite incidence rate (number of cases divided by the population, per 100,000 inhab.), the snakebite mortality rate (number of deaths divided by the population, per 100,000 inhab.) and snakebite lethality (proportion of the number of deaths in relation to the number of cases), by year and by municipality. The epidemiological profile was described according to the absolute and relative frequencies of the variables relating to those who suffered snakebite accidents and to the accidents themselves.

In the multiple linear regression analysis, the municipal demographic and socioeconomic variables were considered to be exposure. Municipal snakebite cases recorded in the period were the response variable. Association between snakebite and the municipal demographic and socioeconomic variables was analyzed through multiple linear regression. Variables that reached a 5% significance level in the unadjusted model were selected and submitted to analysis. The results were presented as coefficients (Coeff.) and 95% confidence intervals (95%CI). The Akaike information criterion (AIC) was used to assess quality of model fit. In order to investigate seasonality, analysis was performed on association between monthly accident frequency per seasonal period (dry period, from May to September; and rainy period, from October to April), using the Mann-Whitney test. In order to identify risk areas, the Kruskal-Wallis non-parametric (adjusted p-value) test was used. The resulting clusters were classified as being low risk or high risk, based on the snakebite incidence coefficients. Maps were later produced for the purposes of spatial distribution analysis.

Stata® version 12.0 was used for linear regression, Mann-Whitney and Kruskal-Wallis test processing; and Tabwin version 3.6, available from the Brazilian National Health System Information Technology Department (DATASUS)/ Health Ministry), was used to produce the maps.

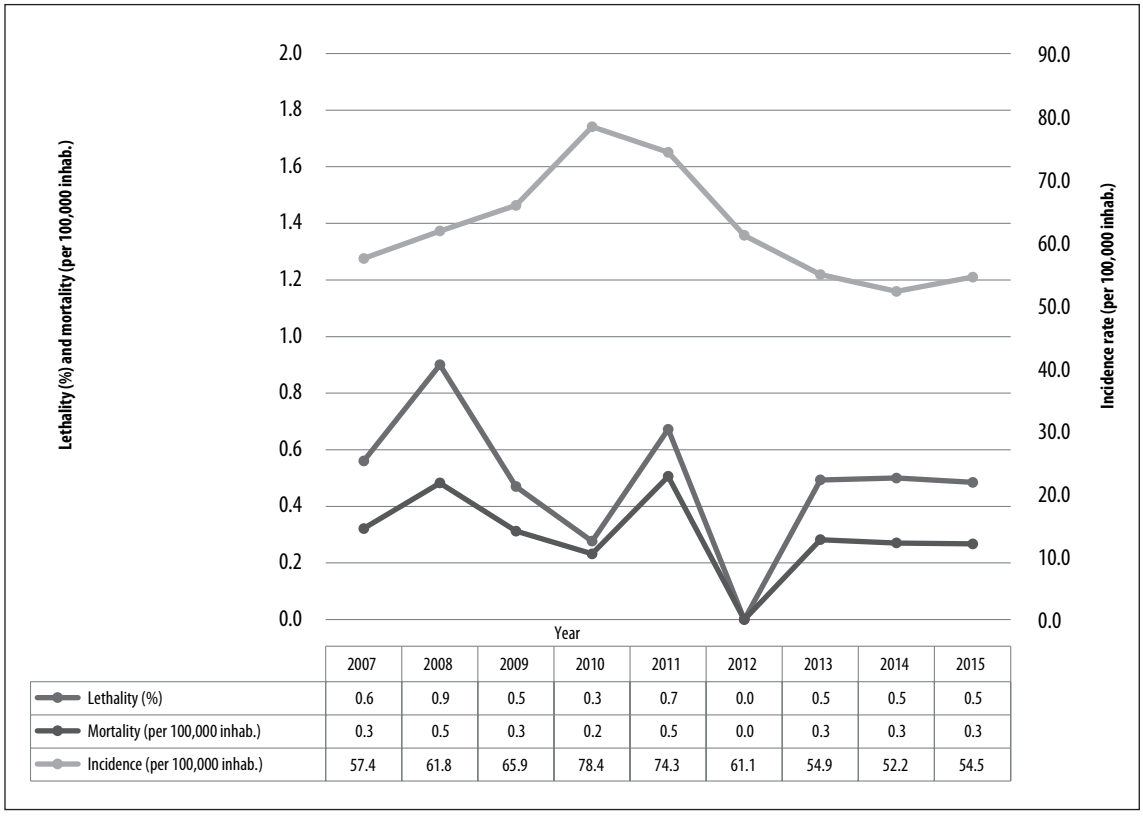
The study project was approved by the Federal University of Bahia Public Health Institute Research Ethics Committee (CEP/ISC/UFBA): Opinion No. 2.091.150, dated May 30th 2017.

Results

In Tocantins, 7,764 snakebite accidents were notified between 2007 and 2015. Average incidence for the state as a whole was 62.1/100,000 inhab., varying between 52.2 and 78.4/100,000 inhab. (Figure 1). The municipal incidence rate varied between 2.8 and 288.8/100,000 inhab. The municipalities with the highest incidence were Recursolândia (288.8/100,000 inhab.), Centenário (260.4/100,000 inhab.), Tocantínia (252.8/100,000 inhab.), Santa Maria (240.0/100,000 inhab.) and Conceição do Tocantins (235.3/100,000 inhab.) (Figure 2).

The Mid-North Araguaia and Cerrado Tocantins Araguaia health regions notified the largest number of cases, accounting for 22.7% and 16.8% of the records, respectively. The Mid-North Araguaia and Cerrado Tocantins Araguaia health regions also had the highest incidence coefficients, 97.3/100,000 inhab. and 89.1/100,000 inhab., respectively (Table 1 and Figure 3).

In the period there were 36 deaths, so that average lethality for the state was 0.5%, varying between 0.3%



	2007	2008	2009	2010	2011	2012	2013	2014	2015
Lethality (%)	0.6	0.9	0.5	0.3	0.7	0.0	0.5	0.5	0.5
Mortality (per 100,000 inhab.)	0.3	0.5	0.3	0.2	0.5	0.0	0.3	0.3	0.3
Incidence (per 100,000 inhab.)	57.4	61.8	65.9	78.4	74.3	61.1	54.9	52.2	54.5

Sources: Notifiable Health Conditions Information System (SINAN)/Tocantins State Health Department (SESAU/TO) and Brazilian Institute of Geography and Statistics (IBGE).

Figure 1 – Incidence rate (per 100,000 inhab.), lethality (%) and mortality rate (per 100,000 inhab.) of snakebite accidents in the state of Tocantins, Brazil, 2007-2015

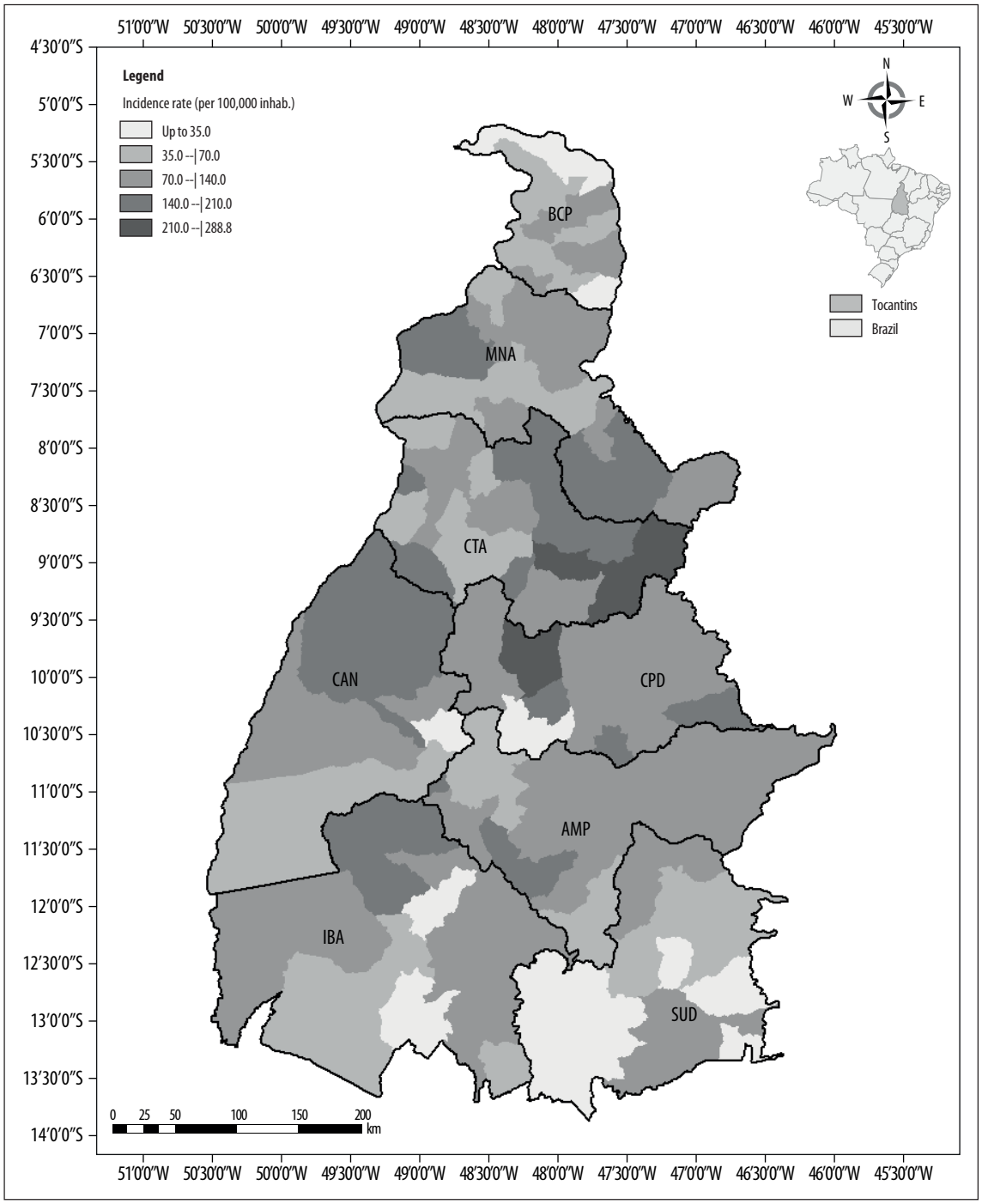
and 0.9%, while for the municipalities it varied between 0.0 and 8.7%. *Crotalus* accidents were the most lethal (1.4%), followed by *Bothrops* accidents (0.4%). No deaths due to *Micrurus* or *Lachesis* bites were recorded. Snake genus was not informed for three deaths. Mortality varied between 0.0 and 0.5/100,000 inhab. among the municipalities (Figure 1).

Accidents occurred mainly during the rainy period (65.3%) (p<0.001). The majority of the people who were bitten were male (76.9%) and aged between 15 and 34 years (36.3%). Information was missing on schooling in 21% of cases, while among case notifications that did have information on this variable, schooling no further than elementary education was predominant (61.7%). Occupation, when reported, identified farm workers (31.1%) as the most affected. With regard to race/skin color, 76.6% were of brown skin color and 4.1% were indigenous (Table 2).

The majority of accidents involved the *Bothrops* genus (77.2%). In 6.6% of cases the snake was not identified and in 5.2% the snake was not venomous. Most of the accidents occurred in the rural zone (83.0%), with medical care being provided in the first hours following snakebite (82.8%). The lower limbs were the most affected (82.2%). Cases were predominantly classified as being of mild severity (46.0%) and most cases were cured (95.7%). Accidents were work-related in 27.5% of cases (Table 2).

Following unadjusted analysis, the following variables achieved statistical significance (5%): MHDI (Coeff.=4.29 – 95%CI 2.04;6.55), Gini index (Coeff.=1.48 – 95%CI 0.63;4.32), population density (Coeff.=1.78 – 95%CI 0.99;2.58), proportion of illiteracy (Coeff.=4.78 – 95%CI 2.60;6.96), unemployment among over eighteen-year-olds (Coeff.=2.48 – 95%CI 0.63;4.32) and areas planted with soya (Coeff.=0.12 – 95%CI 0.02;0.21), cassava (Coeff.=20.60 – 95%CI 13.65;27.65), corn (Coeff.=0.31 – 95%CI 0.07;0.55), sorghum (Coeff.=5.56 – 95%CI 2.08;9.05), beans (Coeff.=4.67 – 95%CI 0.15;9.19) and bananas (Coeff.=58.58 – 95%CI 33.55;83.63).

Multiple linear regression revealed strong snakebite association (p<0.001) with 7 of the 16 variables



Legend:
APE: Amor Perfeito
BCP: Bico do Papagaio
CAN: Cantão
CPD: Capim Dourado
CTA: Cerrado Tocantins-Araguaia
IBA: Ilha do Bananal
MNA: Mid-North Araguaia
SUD: Southeast

Source: Notifiable Health Conditions Information System (SINAN)/Tocantins State Health Department (SESAU/TO).

Figure 2 – Spatial distribution of snakebite accidents according to cumulative incidence rate (per 100,000 inhab.) in the municipalities comprising the health regions of the state of Tocantins, 2007-2015

investigated: population density; farm work; MHDI; area planted with cassava; indigenous people; illiteracy rate; and employment (Table 3). The proposed model explained 64.48% (R^2 adjusted = 0.6448) of snakebites in Tocantins.

Table 1 shows the results of the Kruskal-Wallis test. With regard to risk of snakebite accident, comparison between health regions identified two distinct areas ($p<0.005$): (i) a high-risk area with cumulative incidence of 85.7/100,000 inhab., comprised of the Amor Perfeito, Cantão, Cerrado Tocantins Araguaia and Mid-North Araguaia health regions; and a (ii) "low-risk" area with cumulative incidence of 44.7/100,000 inhab., comprised of the Bico do Papagaio, Capim Dourado, Ilha do Bananal and Southeast health regions.

Discussion

The analyses of notified snakebite cases in Tocantins between 2007 and 2015 provided evidence that this type of accident affects above all young male adult rural workers involving *Bothrops* envenoming of lower limbs. The cases were distributed unequally, delimitating high-risk areas (the Amor Perfeito, Cantão, Cerrado Tocantins Araguaia and Mid-North Araguaia health regions) and "low risk" areas (the Bico do Papagaio, Capim Dourado, Ilha do Bananal and Southeast regions). Snakebite accidents were related to population density, farm work, MHDI, areas planted with cassava, indigenous people, illiteracy rate and employment.

The epidemiological profile we found is in keeping with the global, national and regional patterns.[1-5,14,15] Early medical care found by us diverged from the tardiness commonly reported in the North Brazilian region,[7] probably because Tocantins differs within the region with regard to the main issues of geographic accessibility characteristic of the Amazon.[4,15]

In the period studied, Tocantins had the third highest snakebite incidence coefficient in Brazil as a whole and in the country's Northern region, after the states of Roraima and Pará.[6] In majority of the municipalities, incidence was higher than the national average.[6] This emphasizes the need for municipal health plans to address snakebite, circumstantially increasing effective health surveillance and health education focused on improving case notification quality and prevention. Agreements need to be reached between municipalities or health regions with the aim of building networks to provide timely health care.

In all the health regions, including those that comprise the region at "low risk" of snakebites, risk was

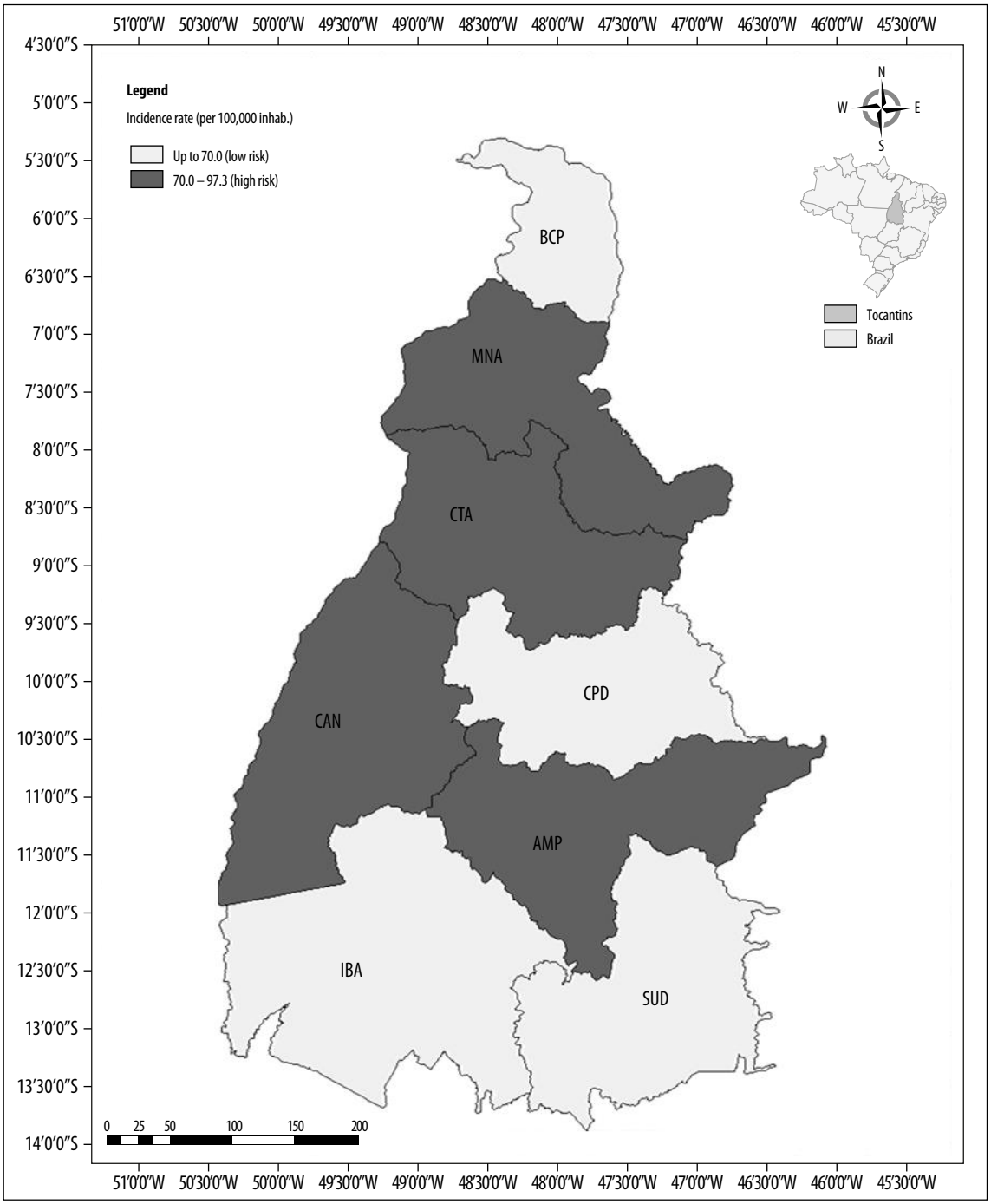
Table 1 – Classification of snakebite accident risk areas among the health regions of the state of Tocantins, Brazil, 2007-2015

Health regions	APE	BCP	CAN	CPD	CTA	IBA	MNA	SUD	Risk classification	Incidence coefficient (per 100,000 inhab.)
APE	–	Different	Same	Different	Same	Different	Same	Different	High	80.9
BCP	Different	–	Different	Same	Different	Same	Different	Same	Low	43.9
CAN	Same	Same	–	Different	Same	Different	Same	Different	High	75.3
CPD	Different	Different	Different	–	Different	Same	Different	Same	Low	40.8
CTA	Same	Different	Same	Different	–	Different	Same	Different	High	89.1
IBA	Different	Same	Different	Different	Different	–	Different	Same	Low	48.4
MNA	Different	Different	Same	Different	Same	Different	–	Different	High	97.3
SUD	Different	Same	Different	Same	Different	Same	Different	–	Low	45.7

a) According to the Kruskal-Wallis test, with White robust correction.

Legend:
APE: Amor Perfeito
BCP: Bico do Papagaio
CAN: Cantão
CPD: Capim Dourado
CTA: Cerrado Tocantins-Araguaia
IBA: Ilha do Bananal
MNA: Mid-North Araguaia
SUD: Southeast

Note:
In this comparison between median municipal incidence for each health region, (i) 'different' means that the medians are statistically distinct, and (ii) 'same' means that there is no statistically significant difference between the regions.



Legend:
APE: Amor Perfeito
BCP: Bico do Papagaio
CAN: Cantão
CPD: Capim Dourado
IBA: Ilha do Bananal
CTA: Cerrado Tocantins-Araguaia
SUD: Sudeste
MNA: Médio Norte Araguaia

Figure 3 – Map of snakebite accident risk areas in the health regions of the state of Tocantins, 2007-2015

Table 2 – Distribution of snakebite cases according to associated characteristics, by triennium, in the municipalities (139) of the state of Tocantins, 2007-2015

Variables	2007-2009		2010-2012		2013-2015		2007-2015	
	N (2,356)	(%)	N (2,991)	(%)	N (2,417)	(%)	N (7,764)	(%)
Sex								
Male	1,839	78.1	2,275	76.1	1,856	76.8	5,970	76.9
Female	517	21.9	716	23.9	561	23.2	1,794	23.1
Age (years)								
<15	404	17.1	566	18.9	436	18.0	1,406	18.1
15-34	926	39.4	1,078	36.0	815	33.8	2,819	36.3
35-54	691	29.3	893	29.9	743	30.7	2,327	30.0
≥55	335	14.2	454	15.2	423	17.5	1,212	15.6
Schooling								
No schooling	139	5.9	145	4.8	111	4.6	395	5.1
Complete elementary education	1,639	69.6	1,812	60.6	1,330	55.0	4,781	61.7
Complete high school education	97	4.1	197	6.6	212	8.8	506	6.5
Complete higher education	13	0.6	23	0.8	29	1.1	65	0.8
Not applicable	114	4.8	142	4.7	127	5.3	383	4.9
No information	354	15.0	672	22.5	608	25.2	1,634	21.0
Occupation								
Farming	750	31.8	969	32.4	693	28.7	2,412	31.1
Work in general	159	6.7	202	6.8	223	9.2	584	7.4
Other	556	23.6	674	22.5	576	23.8	1,806	23.3
No information	891	37.9	1,146	38.3	925	38.3	2,962	38.2
Race/skin color								
White	278	11.8	245	8.2	178	7.4	701	9.0
Black	204	8.7	232	7.8	174	7.2	610	7.9
Yellow	40	1.6	30	1.0	34	1.4	104	1.3
Brown	1,724	73.2	2,330	77.9	1,895	78.4	5,949	76.6
Indigenous	87	3.7	123	4.1	107	4.4	317	4.1
No information	23	1.0	31	1.0	29	1.2	5,970	1.1
Snake genus								
Bothrops	1,761	74.8	2,390	79.9	1,840	76.1	5,991	77.2
Crotalus	262	11.1	260	8.7	243	10.1	765	9.9
Micrurus	19	0.8	17	0.6	12	0.5	48	0.6
Lachesis	18	0.8	13	0.4	7	0.3	38	0.5
Not venomous	133	5.6	128	4.3	151	6.2	412	5.2
No information	163	6.9	183	6.1	164	6.8	510	6.6
Zone of occurrence								
Urban	308	13.1	365	12.2	366	15.1	1,039	13.4
Rural	1,970	83.6	2,514	84.1	1,963	81.2	6,447	83.0
Peri-urban	42	1.8	54	1.8	38	1.6	134	1.7
No information	36	1.5	58	1.9	50	2.1	144	1.9

to be continue

continuation

Table 2 – Distribution of snakebite cases according to associated characteristics, by triennium, in the municipalities (139) of the state of Tocantins, 2007-2015

Variables	2007-2009		2010-2012		2013-2015		2007-2015	
	N (2,356)	(%)	N (2,991)	(%)	N (2,417)	(%)	N (7,764)	(%)
Climatic aspect – rainfall								
More rain	1,480	62.8	2,009	67.2	1,582	65.5	5,071	65.3
Less rain	876	37.2	982	32.8	835	34.5	2,693	34.7
No information	–	0.0	–	0.0	–	0.0	–	0.0
Time elapsed between accident and care								
Up to six hours	1,912	81.1	2,500	83.6	2,018	83.4	6,430	82.8
Over six hours	324	13.8	362	12.1	301	12.5	987	12.7
No information	120	5.1	129	4.3	98	4.1	347	4.5
Anatomic site of snakebite								
Torso	22	0.9	33	1.1	29	1.2	84	1.1
Lower limbs	1,951	82.8	2,434	81.4	1,996	82.6	6,381	82.2
Upper limbs	358	15.2	480	16.0	361	14.9	1,199	15.4
No information	25	1.1	44	1.5	31	1.3	100	1.3
Stage								
Mild	1,140	48.4	1,311	43.9	1,123	46.5	3,574	46.0
Moderate	947	40.2	1,361	45.5	1,012	41.9	3,320	42.8
Severe	169	7.2	160	5.3	166	6.9	495	6.4
No information	100	4.2	159	5.3	116	4.8	375	4.8
Clinical evolution								
Cure	2,314	98.2	2,896	96.8	2,212	91.5	7,422	95.7
Death	17	0.7	11	0.4	14	0.6	36	0.5
No information	25	1.1	84	2.8	191	7.9	300	3.8
Work-related accident								
Yes	687	29.2	906	30.3	542	22.4	2,135	27.5
No	1,574	66.8	1,926	64.4	1,644	68.0	5,144	66.3
No information	95	4.0	159	5.3	231	9.6	485	6.2

three times higher in relation to national parameters when taking the same period studied as a reference.[6] When compared to the national pattern, all of the Tocantins health regions are high risk.

Situation analysis of this health condition in the state, including "low-risk" and high-risk snakebite areas, seasonality and geographical barriers, needs to be taken into account to guide strategies for antiophidic sera distribution and surveillance action strengthening. This dedication to continuous and timely analysis is imperative in view of possible problems regarding access to certain areas, low sera stock levels and lack of availability of these immunobiologics in the municipalities, either because they are not considered risk areas or because health centers there are not adequately prepared to provide serotherapy.[16]

Average lethality for the state was comparable to the national average for the same period. However, the estimate found for the municipality of Tupirama is problematic, given that antiophidic sera are available through Brazil's public health network.[17] Lethality is known to be a complex outcome influenced by diverse factors, such as snake genus, use of tourniquets and snakebites on the extremities of the body (fingers and toes), as well as by the time elapsed between the accident and health care (above all in cases coming from the rural zone), type of serum and number of phials used, whereby these three latter factors are health service-related.[18] These factors must be considered when analyzing the

Table 3 – Final model of snakebite accident multiple linear regression analysis according to farming, geographical and socioeconomic variables in the municipalities (139) of the state of Tocantins, 2007-2015

Variables	Coefficient	T-test	p-value >| t |[a]	95%CI[b]
Population density (inhab./km^2)	1.36	4.23	0.001	0.72;1.99
Farming work	0.02	3.54	0.001	0.01;0.03
MHDI[c]	2.99	2.47	0.015	0.60;5.38
Area planted with cassava (km^2)	8.49	2.46	0.015	1.66;15.32
Indigenous population	0.02	2.32	0.022	0.00; 0.04
Illiteracy	4.70	2.28	0.024	0.61; 8.79
Employment	3.00	2.87	0.005	0.93;5.06
Constant (cases/100,000 inhab.)	-540.38	-4.39	0.001	-784.15;-296.60

a) P-value derived from T-test.
b) 95%CI: 95% confidence interval.
c) MHDI: municipal human development index.

Note:
R^2 adjusted = 0.6448.
Akaike information criterion (AIC) = 460.45..

occurrence of severe cases and, consequently, deaths due to snake envenoming.

In Tocantins, farm work was associated with snakebites. Social weaknesses such as low schooling and illiteracy, typical among people affected by snakebites, are recurrent in this occupational group.[19] This situation appears to reflect the invisibility of these workers when formulating occupational health policies and protection programs. The scenario is particularly serious when snakebite is a condition that is easy to prevent by making personal protective equipment (PPE) available, but which is constantly not used during farming activities.[18] Areas planted with cassava (*Manihot esculenta* Crantz) (in planted km^2), were particularly associated with snakebite in the state. Growing this crop involves intense use of the ground and preparation of the soil for planting can cause deforestation impacts.[20,21]

Association between MHDI and snakebite may be related to the farming economy predominant in the state. Population density was strongly associated with snakebite in Tocantins. This pattern is consistent with findings for the American continent in 2017, although different to findings for Rio de Janeiro in 2004.[21,9] As Tocantins is Brazil's most recent state, it is undergoing demographic expansion, with greater population dynamics in municipalities where farming activities are intense and encouraged through tax incentives for large corporations.[22] This scenario is propitious to people being recruited for rural work. In keeping with this association, the 'employment' variable was related to snakebite, probably due to the economic profile of the municipalities being predominantly farming-related.[11] These findings suggest that job activities related to agriculture (planting, harvesting, packing, transport etc.) and livestock rearing are carried out without adequate protection, this being a classic snakebite scenario.[23]

Absence of schooling as a determining factor provides evidence of a social vulnerability problem. This pattern has been pointed to since the work of Vital Brazil with snake-bitten individuals in Southeast Brazil at the beginning of the 20th century.[24] It is therefore essential to address this form of vulnerability with public policies that prioritize effective actions for provision of PPEs to rural workers and raising their awareness as to their use, taking into consideration local aspects of seasonality and farming activities.

Association between snakebite and indigenous populations reinforces the need for studies involving them. It is a complex theme found in scarce scientific studies about snakebites in this ethnic group. Specific knowledge about the epidemiological situation of snake envenoming in these populations is essential for the formulation of effective public policies aimed at improving health care for indigenous people. However, it is also essential to expand the discussion about environmental preservation beyond indigenous areas, as a strategy for avoiding snakes taking refuge and becoming concentrated close to this ethnic group.

The results of this study should be considered in the light of certain limiting conditions, such as underreporting and incompleteness of notification data on the SINAN system, especially with regard to

socioeconomic variables. Historically, these attributes have been subject to problems in notification, notwithstanding the quality of data filling-in having improved more recently. Another issue to bear in mind are the methodological limitations inherent to the ecological study design.

We conclude that there is high snakebite incidence in Tocantins and that it is strongly associated with sociodemographic attributes and the municipal farming profile. The study also pointed out areas of greater occurrence. This result can assist with the planning of antiophidic sera distribution in the state. Vulnerable societal groups were strongly associated with snakebites in Tocantins, as were municipal farming and demographic characteristics related to social inequalities, impacts on ways of life and new health needs of rural workers.

Snakebite accident surveillance in Tocantins needs to be prioritized, in the sense of strengthening health education in relation to prevention, provision of first aid, diagnosis and treatment, as well as clinical management and efficient antivenom distribution. As such, it is fundamental to take into consideration risk areas, spatial and seasonal distribution of cases and geographic barriers to access to health care.

Authors' contributions

Feitosa SB and Mise YF contributed to the study concept and design, analysis and interpretation of the results, drafting and critically reviewing the contents of the manuscript. Mota ELA contributed to analysis and interpretation of the results, drafting and critically reviewing the contents of the manuscript. All three authors have approved the final version of the manuscript and are responsible for all aspects thereof, including the guarantee of its accuracy and integrity.

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