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Epidemiology of envenomations by terrestrial venomous animals in Brazil based on case reporting: from obvious facts to contingencies

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Abstract

Background: Envenomation remains a neglected public health issue in most tropical countries. A better understanding of the epidemiology of bites and stings by venomous animals should facilitate their prevention and management. This study aimed to explore the benefits that could be derived from the compulsory notification of cases as it is now routinely practiced in Brazil.

Methods: The Brazilian Notifiable Diseases Information System (SINAN) was consulted online for the 2001–2012 period on all envenomations by venomous terrestrial animals. We studied the incidence, severity, number of deaths, gender, season of accident and time between the accident and hospital consultation.

Results: In total, 1,192,667 accidents and 2,664 deaths from terrestrial venomous animals (snakes, scorpions, spiders, bees and caterpillars) were reported in Brazil during these 12 years, the circumstances of which are detailed in this study. Most envenomations and deaths were caused by snakebites and scorpion stings. However, incidence and mortality showed high regional variations. During this period, the steady and parallel increase of the cases from all the species resulted from several factors including the human population increase, gradual improvement of data collection system and, probably, environmental and socioeconomic factors affecting in a different way the incidence of envenomation by each zoological group and by region.

Conclusion: Mandatory reporting of cases appears to be a useful tool to improve the management of envenomations. However, local studies should be continued to account for the variability of accident circumstances and refine measures necessary for their management.

Keywords: Envenomation, Snakes, Scorpions, Spiders, Caterpillars, Africanized bees, Brazil, Epidemiology

Background

The evaluation of the incidence and mortality of envenomation is necessary to advocate measures that aim to reduce the accidents by venomous animal attacks and promote preventive and therapeutic measures, including the supply of appropriate amounts of antivenoms in places where they are most needed [1]. In numerous tropical countries, envenomation remains a major neglected public health issue [2–4]. However, while the estimation of the burden becomes more precise, there is still no standardized methodology to assess the actual incidence and mortality from envenomations with a reasonable relevance and reliability. Several approaches have been suggested in the literature or by hospital and community surveys which, although providing consistent estimates, remain approximate at country scale, especially in the case of a vast and varied country [5–9].

In many ways, Brazil is an interesting model for other tropical countries [10]. Zoological, ecological and socioeconomic diversity of Brazil favors the comparison of epidemiological situations in different environmental contexts. In addition, envenomation is studied for over one century and researches in toxinology belong to the scientific – perhaps even political – Brazilian culture [11–13]. The notification of cases has been organized for thirty years, and since 2001 the data are directly

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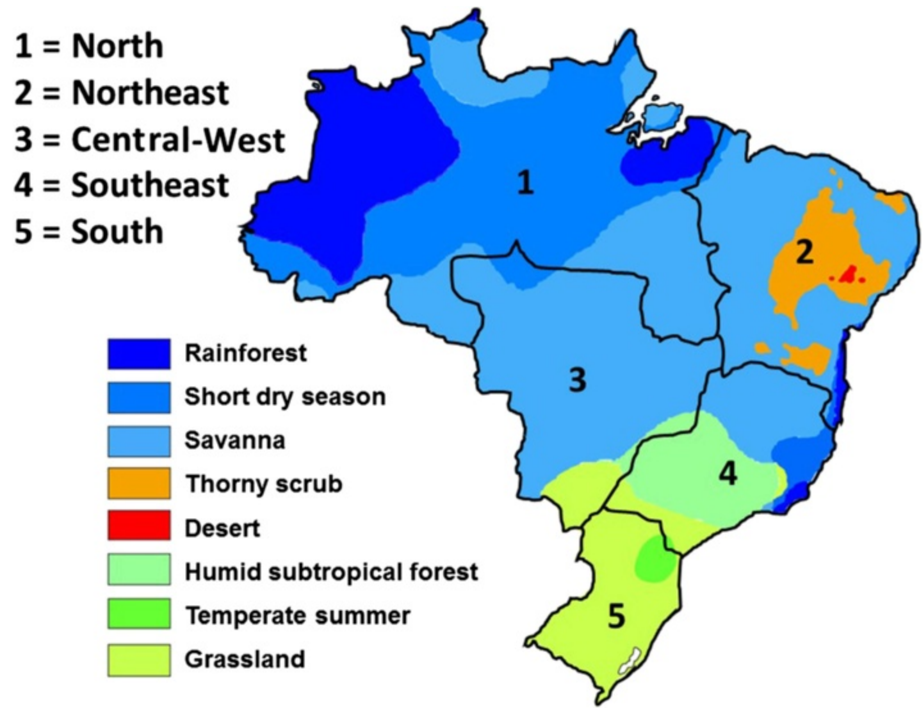

Fig. 1 Map indicating the five Brazilian macro-regions and their environmental characteristics

accessible online [11, 12]. In her recent review, Bochner [14] highlighted the inaccuracy of such an evaluation. Rightly, she pointed that the assessments made by most investigators, especially non-Brazilian ones, did not take sufficient account of the diversity of Brazil, which limited the generalizability of the results from focal studies. Since data collection now seems consolidated and functional, and that access to significant temporal series of data are ensured, it is now possible to make an analysis of the epidemiology of envenomation in Brazil. The first studies began, particularly regarding scorpionism which is predominant in Brazil [15].

The purpose of this study was to describe the epidemiology of envenomation in Brazil from the data obtained

Table 1 Yearly number of envenomations by terrestrial venomous animals in Brazil, 2001-2012

Year	Unknown	Snake	Spider	Scorpion	Caterpillar	Bee	Total
2001	2,512	18,743	10,785	18,230	528	2,084	52,354
2002	2,543	23,777	13,047	22,867	821	2,536	64,770
2003	2,261	26,870	15,999	24,593	1,141	3,018	72,741
2004	2,990	27,671	18,170	30,298	1,759	3,849	82,978
2005	2,988	28,655	19,525	36,041	2,254	4,454	91,663
2006	2,751	28,901	19,299	37,697	2,215	4,827	93,475
2007	6,351	26,573	22,772	37,368	3,290	5,370	101,724
2008	6,540	27,685	21,559	40,283	4,081	5,884	106,032
2009	7,916	29,638	24,459	50,239	4,240	7,122	123,614
2010	7,951	29,662	24,719	51,754	3,414	7,372	124,872
2011	8,931	30,226	26,377	59,430	3,843	9,632	138,439
2012	9,389	28,080	24,942	63,619	3,840	10,135	140,005
Total	63,123	326,481	241,653	472,419	22,708	66,283	1,192,667
Mean ±95 % CI	5,260.3 ± 1,602	27,206.8 ± 1,798.5	20,137.8 ± 2,805.5	39,368.3 ± 8,182.3	2,618.8 ± 756.4	5,523.6 ± 1,484.6	99,388.9 ± 16,134.6

Table 2 Yearly number of deaths caused by envenomation in Brazil, 2001-2012

Years	Unknown	Snake	Spider	Scorpion	Caterpillar	Bee	Total
2001	6	70	9	44	0	5	134
2002	3	114	2	58	0	15	192
2003	9	120	5	51	0	7	192
2004	4	114	5	42	4	9	178
2005	4	113	9	48	3	13	190
2006	2	76	9	28	0	13	128
2007	13	132	20	66	0	19	250
2008	17	122	22	88	4	11	264
2009	14	131	21	94	1	33	294
2010	12	132	17	67	2	30	260
2011	17	143	19	86	4	31	300
2012	10	127	16	97	2	30	282
Total	111	1,394	154	769	20	216	2,664
Mean ±95 % CI	9.25 ± 3.1	116.17 ± 12.5	12.83 ± 4	64,08 ± 12.9	1.7 ± 0.9	18 ± 5.8	222 ± 34.2
CFR (%)	0.18	0.43	0.06	0.16	0.06	0.33	0.22

CFR: case fatality rate; 95 % CI: 95 % confidence interval

from the mandatory reporting of cases in order to characterize the indicators by identifying at-risk people and circumstances according to geographical regions and major zoological groups. Based on such analysis, it will then be possible to define explanatory criteria of envenomation by venomous animal in Brazil to sustain preventive measures and management of cases and discuss the relevance and reliability of case reporting system to assess incidence and severity of envenomations. This inventory should also help comparisons with the situations in neighboring countries and validate methods for estimating the incidence and severity from other sources than the notification of cases, such as the meta-analysis of epidemiological studies in health facilities or from households, an approach that was already used in Africa and Europe [5–7].

Methods

Basic demographic (population, densities, age and gender distributions) and socioeconomic (Gross Domestic Product – GDP and Human Development Index – HDI) information was collected from the site of the Brazilian Institute of Geography and Statistics (IBGE, http://www.ibge.gov.br/home/). Epidemiological data on envenomation come from the Brazilian Notifiable Diseases Information System (SINAN – http://dtr2004.saude.gov.br/sinanweb/tabnet/dh?sinan/animaisp/bases/animaisbr.def, for the years 2001–2006 and http://dtr2004.saude.gov.br/sinanweb/index.php, for the years 2007–2012). These websites were accessed between April 15 and July 31, 2014.

Several variables – including the age, gender, year and season of the accident, time between the accident and arrival at hospital, severity and mortality of envenomations – were analyzed and compared, first between the different states of each region, and after aggregation at the regional and national levels for each zoological group of venomous animals, particularly snake and scorpion. The sex ratio expresses the incidence ratio of male to female.

All the data were transferred and analyzed using Excel® software. The trend curves and R^2 correlation indices were

Table 3 Annual incidence of envenomations per 100,000 population in Brazil according to the venomous animal, 2001-2012

Year	Snake	Spider	Scorpion	Caterpillar	Bee
2001	10.7	6.2	10.5	–	1.2
2002	13.5	7.4	13	–	1.4
2003	15.1	9	13.8	–	1.7
2004	15.3	10.1	16.8	–	2.1
2005	15.7	10.7	19.7	–	2.4
2006	15.6	10.4	20.4	–	2.6
2007	14.2	12.2	20	1.8	2.9
2008	14.7	11.4	21.3	2.2	3.1
2009	15.5	12.8	26.3	2.2	3.7
2010	15.4	12.8	26.8	1.8	3.8
2011	15.5	13.5	30.5	2	4.9
2012	14.3	12.7	32.3	1.9	5.1

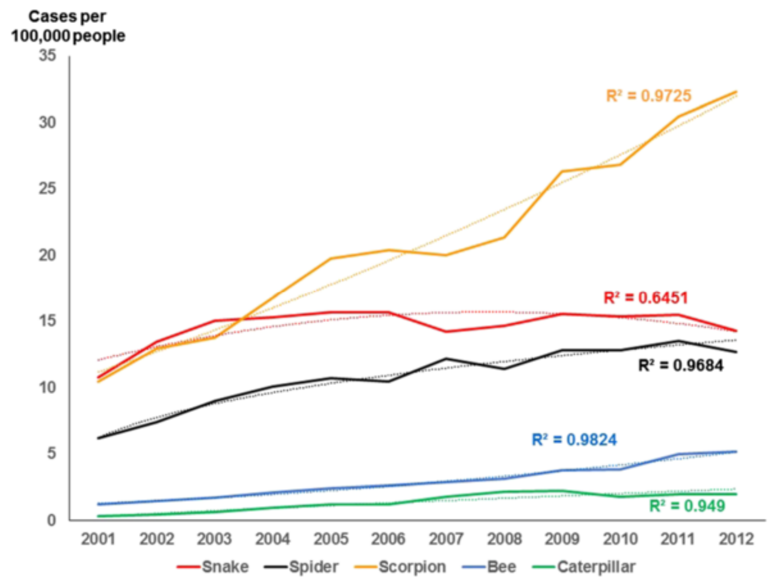

Fig. 2 Trends of annual incidence of envenomations per 100,000 people in Brazil, 2001–2012

calculated through Excel®. The comparisons were made using parametric tests (*t*-test, χ^2 and Pearson correlation) or non-parametric (Mann–Whitney), depending on the distribution of studied variables and number of cases/groups. The significance level was equal to 0.05. Statistical analyzes were performed using the BiostatTGV online software (http://marne.u707.jussieu.fr/biostatgv/).

Results

Brazil is a wide country divided into five regions, each relatively homogeneous in terms of climate, environmental and socioeconomic aspects (Fig. 1). Roughly, the climate of northern Brazil is humid equatorial, the center and east regions are dry tropical, and southern shows a Mediterranean climate, with temperate trends. The mountainous areas are limited (less than 3 % of the area of the country exceed 900 m above sea level).

Between 2001 and 2012, 1,192,667 attacks by terrestrial venomous animals were reported (Table 1). They resulted in 2,664 deaths (Table 2), showing an overall case fatality rate of 0.22 %. The involved animal species was not identified in 63,123 cases (5.29 %) and 111 deaths (4.17 %). For all venomous animals, the average case fatality rate was less than 0.5 %. The highest case fatality rates were observed after snakebite (0.43 %) and bee stings (0.33 %), while the lowest involved spider bites (0.06 %). Case fatality rates showed neither significant irregularities nor significant changes between 2001 and 2012, regardless of the venomous species.

The average annual incidence (52 attacks per 100,000 population) increased steadily and similarly for all venomous species between 2001 and 2012 (Table 3, Fig. 2). The average annual mortality (0,117 deaths per 100,000 inhabitants) increased in the same proportion (Table 4, Fig. 3).

Regional incidences and mortalities (Table 5) showed: a predominance of snake envenomations in northern Brazil (North, Central-West and Northeast regions); a wide distribution of scorpion stings in all the country, although a higher incidence occurred in Northeast; incidence of spider bites mostly in southern Brazil; and insect attacks (bees and caterpillars) in the South. Incidence variations are detailed in Table 6.

Table 4 Annual mortality associated with envenomations per 100,000 population in Brazil according to the venomous animal, 2001-2012

Year	Snake	Spider	Scorpion	Caterpillar	Bee
2001	0.040	0.005	0.025	–	0.003
2002	0.065	0.001	0.033	–	0.008
2003	0.067	0.003	0.029	–	0.004
2004	0.063	0.003	0.023	0.002	0.005
2005	0.062	0.005	0.026	0.002	0.007
2006	0.041	0.005	0.015	–	0.007
2007	0.071	0.011	0.035	0.000	0.010
2008	0.065	0.012	0.047	0.002	0.006
2009	0.069	0.011	0.049	0.001	0.017
2010	0.068	0.009	0.035	0.001	0.016
2011	0.073	0.010	0.044	0.002	0.016
2012	0.064	0.008	0.049	0.001	0.015

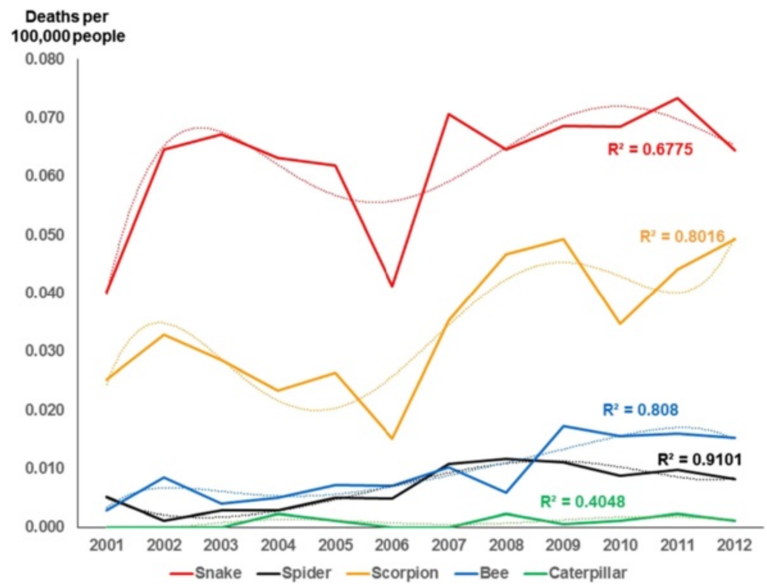

Fig. 3 Trends of annual mortality following envenomations per 100,000 people in Brazil, 2001–2012

Snakebites

Just over a quarter (28 %) of envenomations were attributable to snakebites, which resulted in more than half (54 %) of the deaths provoked by venomous terrestrial animals. There was no regional variation in the distribution of genera involved in snakebites, apart from *Lachesis* bites which were highest in North region (9 % versus less than 1 % in other regions). The genus *Bothrops* was responsible for over 70 % of envenomations, *Crotalus* genus for 7-11 % of cases according to the region, and *Micrurus* in less than 1 % of envenomations whatever the region. The snake was not identified in 15 % of cases.

The sex ratio was 3.4, very significantly skewed in favor of men considering a similar risk for both genders ($p = 4 \times 10^{-11}$). Male victims accounted for over 70 % of snakebites, regardless of the region. Only in Amapá, where over 84 % of bitten persons were males, the sex ratio differed by more than 2 standard deviations from the mean.

The specific incidence increased with age until 65 years old and then decreased. It showed the same characteristics in all regions, with the exception of the North, where young people from 10 to 60 years were the majority (Fig. 4).

The severity of envenomation was similar in all regions: 50–60 % of the cases were asymptomatic or mild, 35–40 % consisted of moderate envenomations, 6–9 % were severe envenomations and 0.2 to 1 % of the cases evolved to death, especially in the North of the country. Sequels, which severity was not specified, were mentioned in 3.5 % of snakebites between 2001 and 2006. In subsequent years, the information was no longer available.

The seasonal incidence of snakebites was higher from November to May in all regions. However, differences according to seasons were more pronounced in the southern region.

The time between the bite and arrival at hospital was very heterogeneous in all regions (Fig. 5). Nevertheless,

Table 5 Regional incidence and mortality (per 100,000 population) according to the zoological groups

Region	Population (2010)	Snake		Scorpion		Spider		Bee		Caterpillar	
		Inc.	Mort.	Inc.	Mort.	Inc.	Mort.	Inc.	Mort.	Inc.	Mort.
North	7,689,052	56.1	0.29	16.7	0.04	2.9	$5 \cdot 10^{-3}$	0.6	$4 \cdot 10^{-3}$	0.3	0
Norteast	18,601,238	14.3	0.09	46.9	0.07	1.2	$5 \cdot 10^{-3}$	2.8	0.01	0.3	10^{-3}
Southeast	49,004,779	7.9	0.02	23.3	0.04	5.3	0.01	10.1	0.03	4.2	10^{-3}
Central-West	6,106,153	21.3	0.11	15.4	0.03	2.3	$3 \cdot 10^{-3}$	10.1	$2 \cdot 10^{-3}$	0.3	0
South	10,003,683	10.2	0.02	4.2	10^{-3}	52.6	0.06	15.7	0.05	14.9	0.01

Table 6 Incidence of envenomations (per 100,000 population) according to the states and zoological groups, 2001–2012 (except for caterpillar, 2007–2012)

Regions	States	Snake	Scorpion	Spider	Bee	Caterpillar
North	Rondônia	29.06	5.68	3.17	1.43	0.84
	Acre	61.10	4.58	3.85	2.68	1.10
	Amazonas	40.36	3.69	2.27	0.26	0.95
	Roraima	69.54	6.10	2.81	9.17	0.75
	Pará	68.30	18.79	3.23	0.43	0.27
	Amapá	55.10	18.13	1.28	0.24	0.49
	Tocantins	61.74	16.20	2.78	5.57	6.81
Northeast	Maranhão	24.60	1.91	0.60	0.42	0.21
	Piauí	7.73	11.06	1.06	1.05	0.22
	Ceará	8.57	9.09	0.54	1.39	0.08
	Rio Grande do Norte	12.33	61.45	3.22	3.53	0.80
	Paraíba	12.55	17.44	0.89	1.61	0.43
	Pernambuco	8.89	54.73	0.73	4.06	0.26
	Alagoas	10.89	111.39	1.40	5.53	1.44
	Sergipe	9.83	3.55	1.03	1.48	0.59
	Bahia	20.42	51.31	1.75	1.72	0.41
Southeast	Minas Gerais	15.94	52.39	7.10	3.47	3.22
	Espírito Santo	28.07	24.23	6.41	3.39	3.71
	Rio de Janeiro	3.63	1.78	1.12	0.13	0.10
	São Paulo	3.93	12.79	5.79	3.44	1.01
South	Paraná	9.62	5.98	87.95	5.89	10.05
	Santa Catarina	13.16	2.64	65.65	10.47	9.19
	Rio Grande do Sul	8.98	0.54	13.73	2.48	3.48
Central-West	Mato Grosso do Sul	21.40	5.05	2.27	2.74	4.55
	Mato Grosso	41.68	10.00	2.95	0.72	0.32
	Goiás	17.43	16.08	2.52	1.34	0.50
	Distrito Federal	5.94	11.32	1.25	3.23	0.92
Brazil		14.73	21.51	10.35	2.84	1.94

the consultations were earlier in the South, showing an increasing gradient from South to North.

Scorpion stings

Scorpion stings were the most frequent accidents inflicted by venomous terrestrial animals in Brazil (41 %) and were responsible for 30 % of deaths.

At nationwide the sex ratio, close to 1.03, seemed balanced (p = 0.85), as highlighted by Reckziegel and Pinto [15]. However, it was observed a considerable disparity between regions and states. For example, men accounted for 66 % of scorpion stings in the North region against 46 % in the Northeast. In southern Brazil, the percentage of men stung by a scorpion was 57 % in Southeast and 54 % both in Central-West and South regions. However, despite a large apparent dispersion, no state showed a sex ratio outside 2 standard deviations.

The specific incidence increased with age and decreased after 65 years in all regions (Fig. 6).

The severity of the envenomation differed in North region where only 60 % of stings were asymptomatic or mild against 80–90 % in the other four regions. Moderate envenomations accounted for 35 % in North region while less than 15 % elsewhere. Severe envenomation were 4 % in the North region and less than 2.5 % in all other regions. Finally, case fatality rate was similar in most regions (0.2–0.3 %) except in the South region where it was nil.

The seasonal incidence showed no variation in northern Brazil and a very small decrease in the South, especially in the Southeast region from April to August.

The time before arrival at hospital was short in all regions, although the consultations were later in North region. About half of the patients were seen during the

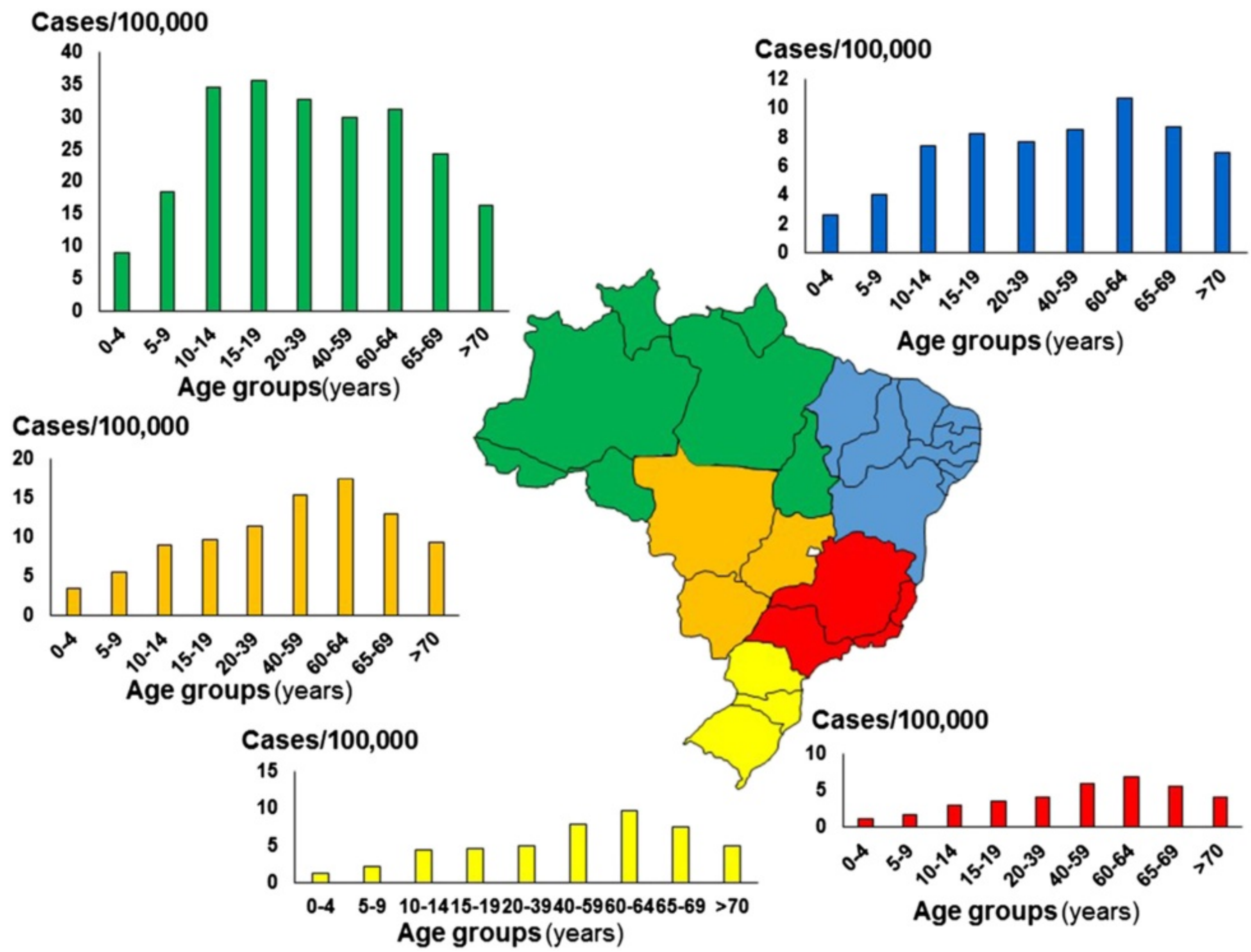

Fig. 4 Age-specific snakebite incidence (per 100,000 people) in Brazil according to age group and region

first hour (35 % in North region) and more than three-quarters arrived at the hospital before the third hour, including in northern Brazil, where consultations spread regularly during the first three hours after the sting.

Spider bites

Spider bites consisted of 21 % of attacks and 6 % of deaths by terrestrial venomous animals, with a strong variation according to the regions and even states (Table 6). The species responsible for the bite was not identified in 32 % of envenomations. *Loxosceles* were involved in 56 % of cases in which the species has been recognized, *Phoneutria* in 21 %, *Latrodectus* in 0.6 % and other species in about 22 %. However, the proportion of *Loxosceles* bites was 65 % in the South region, while it was 25–30 % in all other regions. For other species, the incidence was similar in all regions.

The sex ratio was balanced (1.01; p = 0.94) in the entire Brazil with a significant disparity between regions but relative homogeneity within it. In five states, the sex ratio was outside 2 standard deviations from the mean, particularly in the North region (Amazonas, Roraima and Pará). In the South, 46 % of spider bites victims were men, while in Northeast they were 58 % and in the North up to 64 %.

The specific incidence by age group was similar in all regions except in Central-West region, where it was very low before age 20. It showed a peak between 20 and 40 years and then lowered regularly in older persons (Fig. 7).

The severity of envenomation by spider bites was consistent across all regions. Asymptomatic or mild bites accounted for 70 to 85 % of the cases; moderate envenomations, 10–25 %; and severe envenomations, 0.5–2 %. The case fatality rate was between 0.1 in the South and Southeast regions, and 0.3–0.4 % in the others.

The seasonal incidence was steady during the year in all regions except in the South region, where the incidence significantly decreased by two thirds in winter (Fig. 8).

The presentation at the hospital was usually early in all regions. However, in the South region, more than

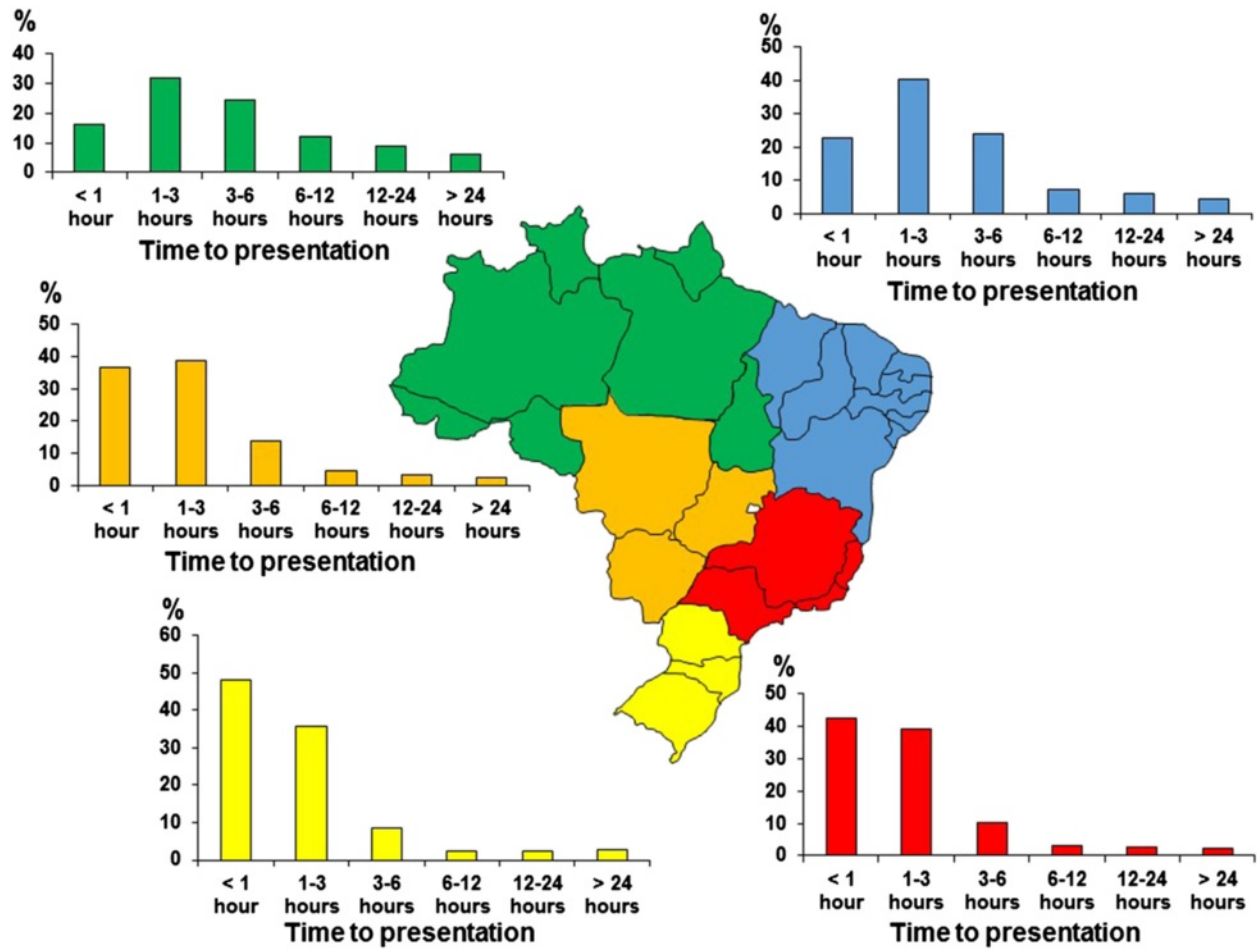

Fig. 5 Time elapsed between snakebite and medical care according to the region in Brazil

30 % of consultations occurred after 24 h (Fig. 9). They also accounted for a significant proportion (15 %) in the North region.

Bee stings

Accounting for 6 % of envenomation cases and 9 % of deaths, bees were weakly represented, but showed high severity. The sex ratio was 1.74 ($p = 0.02$). Between 60 and 68 % of the bee stings involved males with a fair homogeneity according to the regions and within them.

The specific incidence by age group was similar in all regions, which was relatively low in people under 20 years and peaked in persons between 20 and 40 years, corresponding to 35 and 40 % of all bites and a rapid decrease in older persons.

The severity of bee stings was consistent across all regions. Asymptomatic and mild stings accounted for 80 to 90 % of patients; moderate envenomations, 10 to 18 %; and severe envenomations, 0.8 to 1.3 %. Case fatality rate was 0.3 to 0.4 % in all regions.

The seasonal incidence decreased in winter, more accentuated in southern than in northern Brazil (Fig. 10). The time before arrival at the hospital was brief in all regions. Between 60 and 75 % of the patients arrived within three hours after the accident.

Caterpillar envenomations

Caterpillars, especially those belonging to the genus *Lonomia*, were responsible for 4 % of envenomation and 1 % of deaths provoked by venomous terrestrial animals. The distinction between *Lonomia* and other genera of caterpillars was no longer specified after 2006.

The sex ratio was 1.37 ($p = 0.15$), 58 % regarding males, showing a good homogeneity between the regions. There was no variation in incidence as a function of age.

The severity of envenomation by caterpillar was consistent across all regions showing mild envenomations in 88–95 % of patients, moderate envenomations in 5–11 % and severe envenomations in 0–1 %. Case fatality rate was nil in Central-West and North regions, by 0.1 in South and Southeast regions and up to 0.3 % in Northeast region.

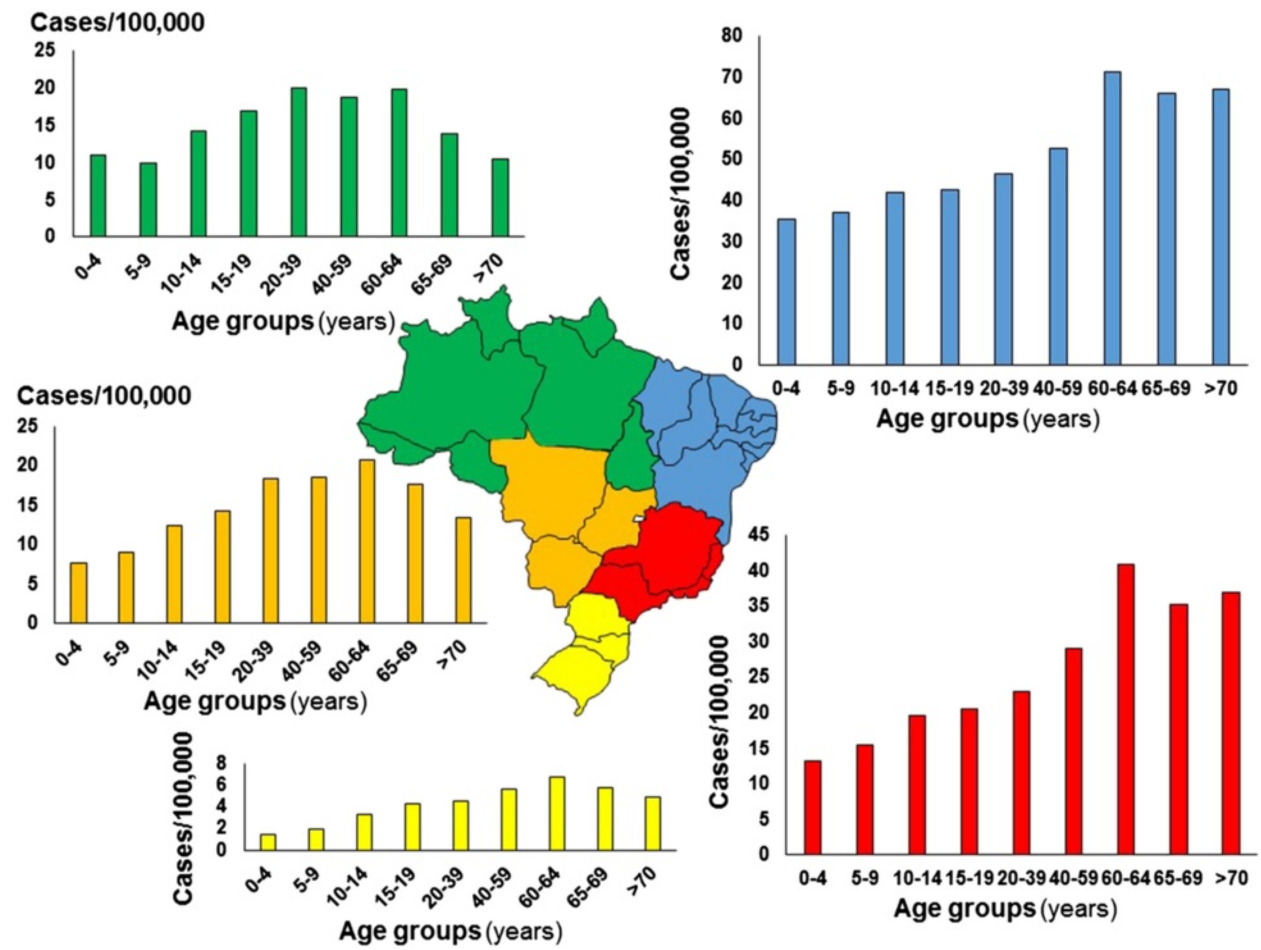

Fig. 6 Age-specific scorpion sting incidence (per 100,000 people) in Brazil according to age and region

The seasonal incidence was steady during all the year in North and Northeast regions. However, in Central-West, Southeast and South regions, it showed a dramatic reduction between May and October.

Patients arrived early at the hospital in all regions. Consultations occurred in less than one hour in 40–60 % of patients, and for 80 % of all patients in less than three hours.

Discussion

The incidence of envenomations is the consequence, on the one hand, of the biology and behavior of the animal responsible for the envenomation which explain its presence and abundance in a particular place and, on the other hand, human activities that put victim in contact with the animal. Mortality results from both the toxicity of the venom, associated with the amount of inoculated venom, and precocity and effectiveness of treatments. This does not exclude the role of either cultural (perception of the animal by the victim and his entourage) or circumstantial (accessibility of health centers) factors which influence the healthcare seeking behavior, use of hospital treatment, the efficiency of which depends on the available means.

The description of the epidemiology of the envenomations involves two major problems. The first concerns the source of the data as highlighted by Bochner [14]. Data based on focal studies often lack representativeness and reliability at state and regional levels due to high variability of environmental and economic conditions impacting on risks of animal encounter. However, in many cases, as until recently in Brazil, they are the only ones that are directly accessible. As a result, their analysis requires the use of statistical models to produce useful information. This was never done in Brazil, to my knowledge, but was tested in Africa and Europe [5, 6]. Case reporting, now available online in Brazil, brings an elegant and reliable solution. The second problem regards the scale of analysis that would allow health authorities to organize the prevention and management of envenomation. The main objective of this study was to provide baseline data useful for the validation of methods capable

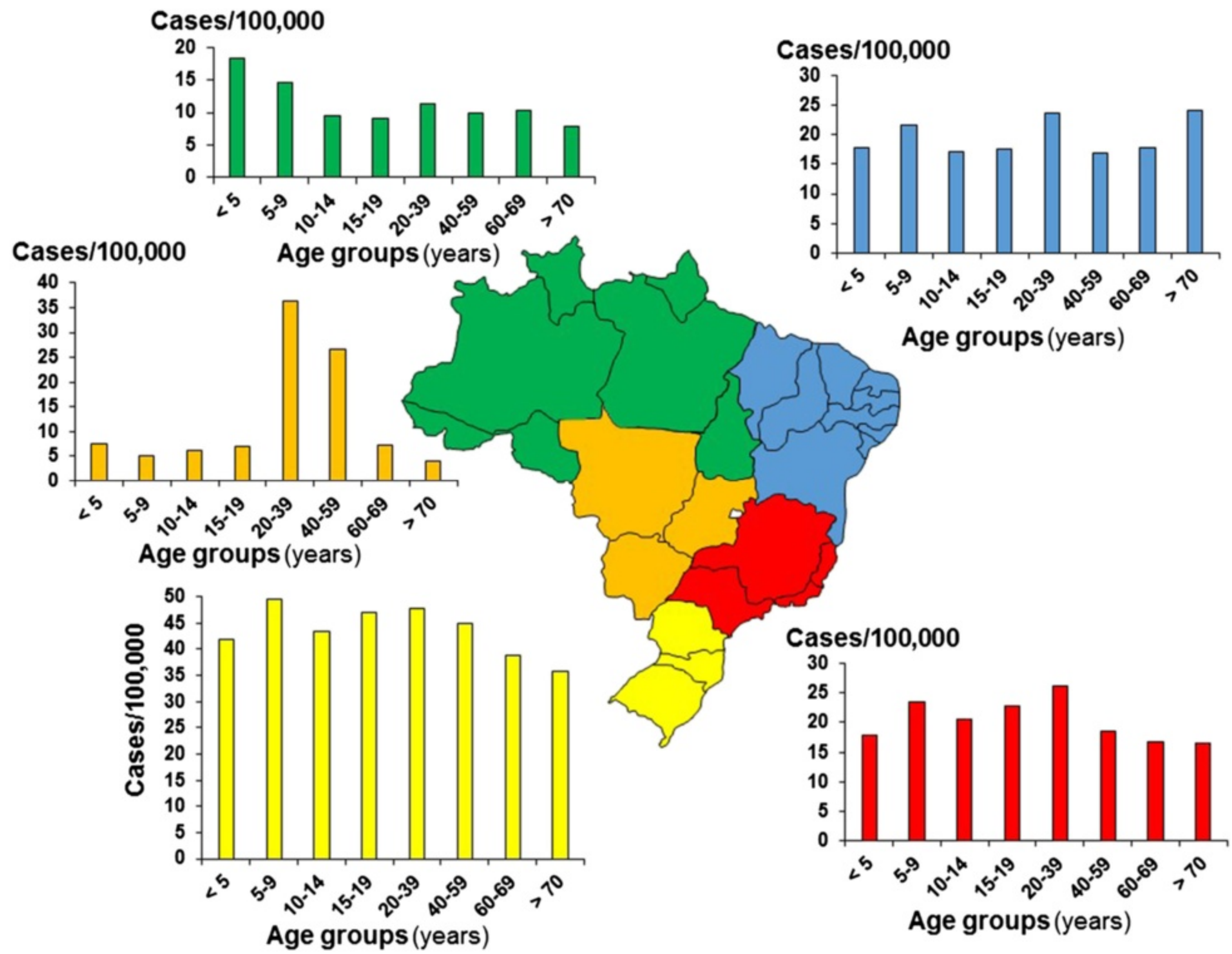

Fig. 7 Age-specific spider bite incidence (per 100,000 people) in Brazil according to age group and region

of assessing incidence and severity of envenomation in the absence of reporting of cases. In addition, it could serve to explore epidemiological methods to define a relevant scale for further analysis.

The data from the Brazilian Notifiable Diseases Information System (SINAN) are available online only since the early 2000s [11, 12, 14]. Previously, they were accessible through the administration or CD-ROM, which did not allow foreign investigators to use them and led to very poor assessments [14]. However, this did not avoid a certain inconsistency of information characterized by high irregularity and obvious underestimations (Fig. 11) limiting the ability to produce a reasonable estimate of the incidence of envenomation. Thus, the comparison of the annual incidence of snakebites before 1999 (incidence between 8.32 and 10.74 per 100,000) showed a wide disparity with those recorded after 2001 (14.04/100,000). The difference in incidence between 2001–2006 (14.32) and 2007–2012 (14.93) was not significant ($p = 0.13$), whereas the difference in mortality (0.056 and 0.068 respectively) was highly significant ($p = 0.005$). The difference was even more marked for scorpion stings with an annual incidence between 0.42 and 3.08 per 100,000 inhabitants until 1999 versus 15.7–26.2 per 100,000 people after 2001. The difference of incidences between 2001–2006 and 2007–2012 was highly significant ($p = 0.004$), like the difference of mortalities ($p = 0.002$) in the periods 2001–2006 (0.025) and 2007–2012 (0.043).

In addition, the updated data is permanent and some states provide records with a lag, sometimes after one or two years. Accordingly, the presentation of data may differ depending on the online interrogation date of the database. This may explain low variations – which do not affect the analysis and interpretation – according to reports or publications [14, 15].

One of the simplest assumption is that the increase in the number of cases follows the growth of the population, which should not modify the incidence. Consequently, the significant increase in the incidence and mortality over time indicates that other factors might be

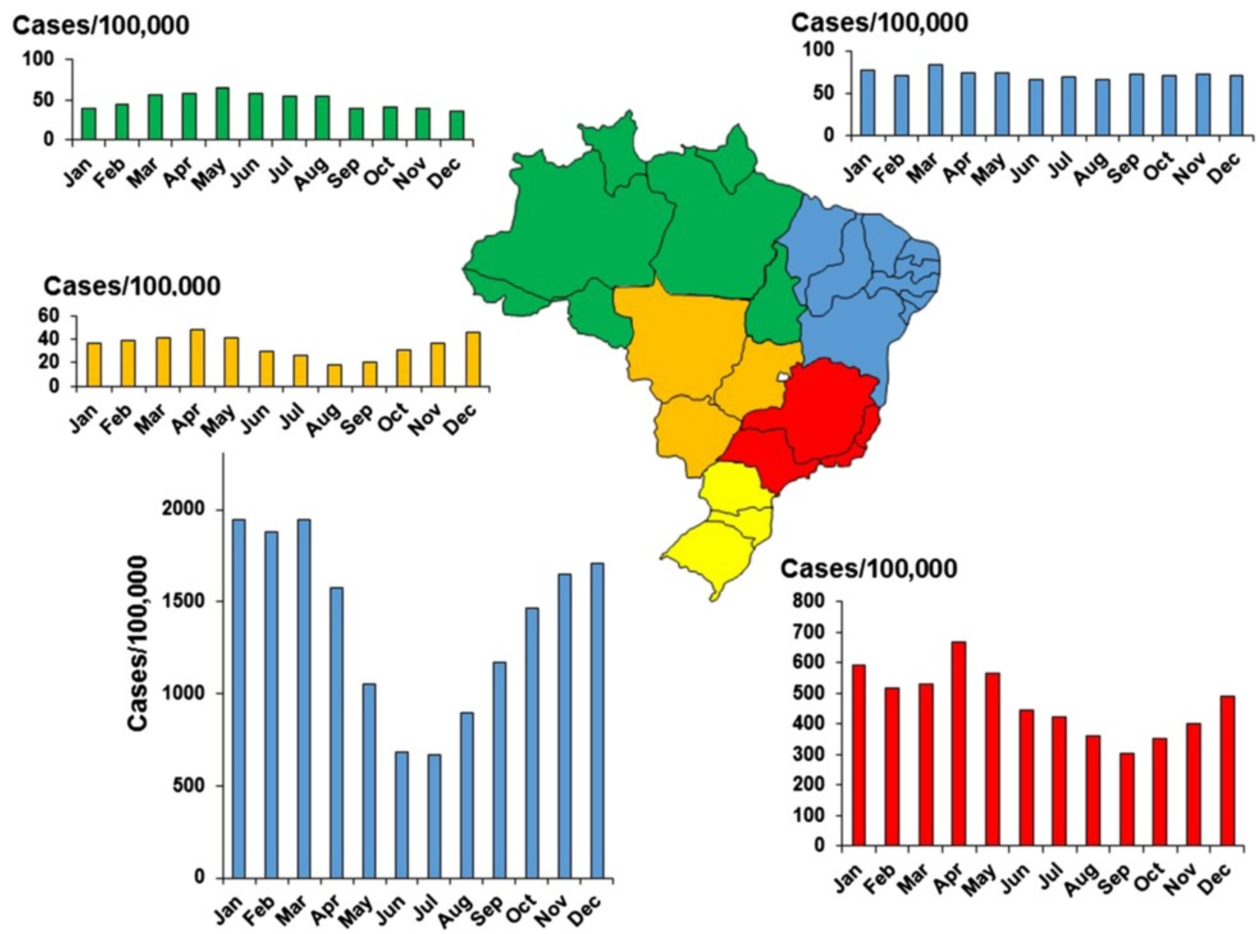

Fig. 8 Seasonal incidence of spider bites according to the region

involved since 2001 (Figs. 2–3). The improvement of case reporting system was probably a valid reason, which suggests that data collection was more precise – especially in some states – but maybe that healthcare seeking behavior of the patients evolved and that they came in higher number to the hospital.

Certainly, changes in the behavior of animals and human activities affect morbidity at various levels. Some studies showed the impact of the environmental factors or ecology of venomous animals on the incidence of envenomation. A well-established example is the growth of arachnid populations – and the change in species composition – in the suburbs of big cities [16–19]. However, the ecology, biology and behavior of venomous animals require further studies to better understand the risk factors attributable to them.

Bochner and Struchiner [20] showed the significant influence of socioeconomic factors, such as illiteracy or agricultural activities, on snakebite incidence. The inverse correlation between the Gross Domestic Product (GDP) and the incidence of snakebites is at the limit of significance ($r = -0.36$; $p = 0.06$). However, there is no correlation between GDP and the incidence of accidents with other terrestrial venomous animals. The Human Development Index (HDI) is negatively correlated with the incidence of scorpion stings ($r = -0.43$; $p = 0.03$) but positively with spider bites ($r = 0.38$; $p = 0.05$) and envenomation per caterpillars ($r = 0.42$; $p = 0.03$). Finally, literacy is inversely correlated with the incidence of scorpion stings ($r = -0.57$; $p = 0.002$) but not with other accidents by venomous land animals. However, it is likely that each factor does not apply in the same manner to every situation and the impact of some of them could be different in various places or circumstances. Discrepancies of correlations between the economic indicators and incidences could be explained by the circumstances of the accidents which socioeconomic characteristics and environmental factors differ depending on the animals.

The population density may appear as a relevant synthetic indicator, especially regarding snakebite. The inverse correlation between population density and the incidence of snakebites in each of the 27 Brazilian states is highly significant ($r = 0.66$; $p < 1.6 \times 10^{-4}$; Fig. 12). The relationship is consistent with other findings, particularly

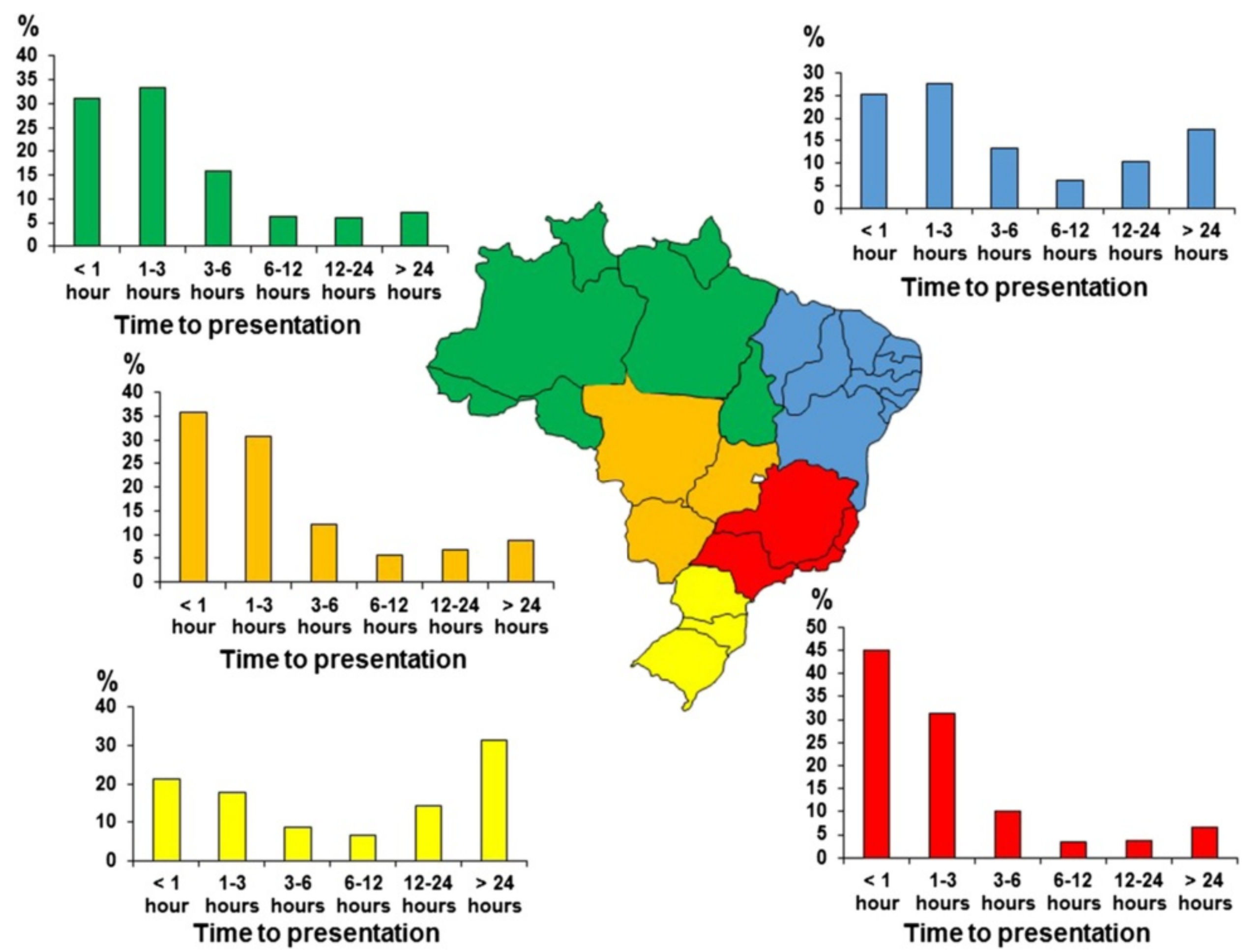

Fig. 9 Time to presentation at the hospital after spider bites according to the region

in Africa [5]. It is therefore possible to consider that, firstly the poor urbanization and human densities, and lower economic development of northern Brazil promote the growth of snake populations, and secondly agricultural activities increase the risk of snake-man encounters. In contrast, the population density is not correlated with the incidence of snakebites in Europe where agriculture reached a homogeneous level of industrialization [6, 7], or in Bolivia where variations in elevation mask the effect of demographics [21]. The important imbalance of sex ratio of snakebites, while it is weak or absent for other venomous land animals, probably reflects the difference of risks, with regard to the distribution of animals and/or human activities. This could confirm that snakebites rather result from agricultural activities, assuming that they involve men more than women.

The situation is different regarding other venomous animals. It was not observed a significant correlation between the population density and incidence of envenomation by scorpion, spider, bee or caterpillar. In addition to the environmental factors certainly important, it is likely that arthropods are more adaptable to suburban or urban conditions than vertebrates [17, 18, 22]. Thus, if scorpion stings seem fairly widely distributed throughout Brazil (with the notable exception of few northern states and those of the South region), spider bites, bee stings and caterpillar attacks were predominant in southern Brazil, especially spider envenomations, which incidence is more than ten times higher in the South region than in the others (Table 5). Accidents caused by arthropods are less related to professional activities and occur more often at home and sometimes even at night [17–19, 22, 23]. It could also explain a more homogeneous incidence according to the gender and age.

In addition, a higher case fatality rate in northern Brazil, could be related to case management, possibly less efficient than in southern Brazil where the availability of treatment resources is better. Other indicators could be proposed: the urbanization rate or frequency of family farms might be more accurate, but they were not obtained for all Brazilian states.

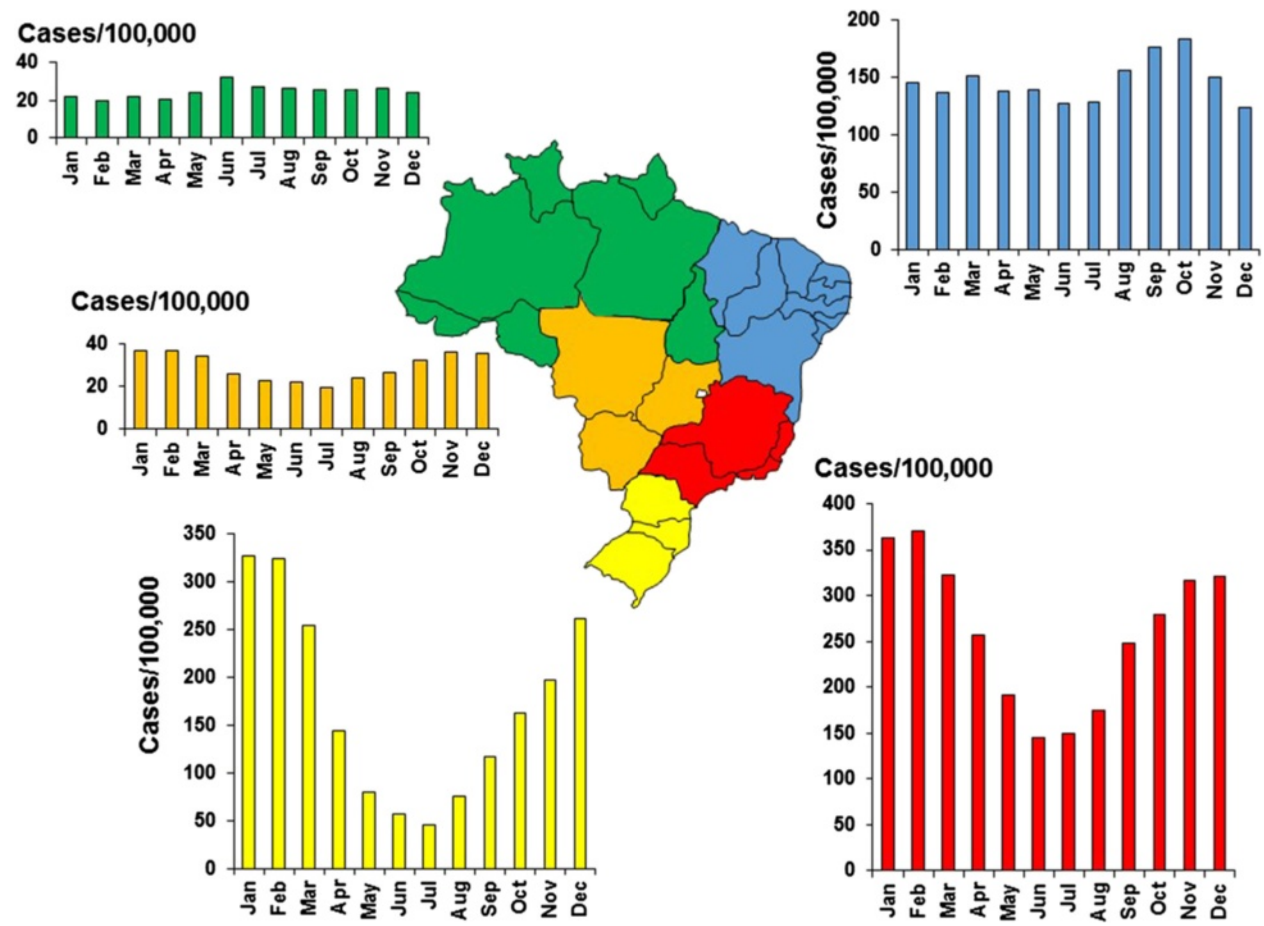

Fig. 10 Seasonal incidence of bee stings according to the region

An analysis at a more focal scale, as it was recently tested in the state of Rio de Janeiro, covering all factors would certainly be very informative and more accurate [20].

The incidence of snakebites is lower, even in northern Brazil, than that expected in comparison with Africa and Asia [2, 3, 5]. An explanation is indirectly suggested by Padoch et al. [24] who observed that Amazonian peoples divided their time between the city and the forest according to the seasons and agricultural activities. Thus, their presence in rural areas, i.e. the period at risk because most snakebites occur outside cities, is reduced over time decreasing the expected incidence.

The proportion of envenomation in children younger than 10 years – which represent 20 % of the Brazilian population – is about 20 % with respect to the caterpillars and bees, 12–14 % for arachnids (spiders and scorpions), but only 8 % for snakes. This suggests that exposure to snakebite is higher in people between 10 and 70 years, probably related to agricultural activities (Fig. 13), which concern mostly adults. However, especially for accidents caused by arthropods, one cannot exclude a reporting bias – especially in adult patients with mild symptoms that may not consult in health centers – related to the severity of envenomation and behavior, especially in urban populations. This would explain the greater severity of scorpion envenomation in the North region (about 40 %, while it did not exceed 15–20 % in the others).

In Argentina, de Roodt et al. [17], using a similar methodology, showed a decrease of scorpion stings with age and a high prevalence in children and teenagers. This can be explained by more systematic consultations in case of stings in young than in adults, in whom the severity of envenomation appear milder. Between 2001 and 2012, the number of consultations for scorpion stings was multiplied by five, while the number of moderate scorpion envenomations doubled and those of severe envenomations or deaths remained stable (Fig. 14). While it is possible that the management improved [23], it seems that the difference is explained rather by a dramatic increase in mild bites, i.e. a higher hospital attendance.

The severity of envenomation according to age varies according to the animal species as shown by the case

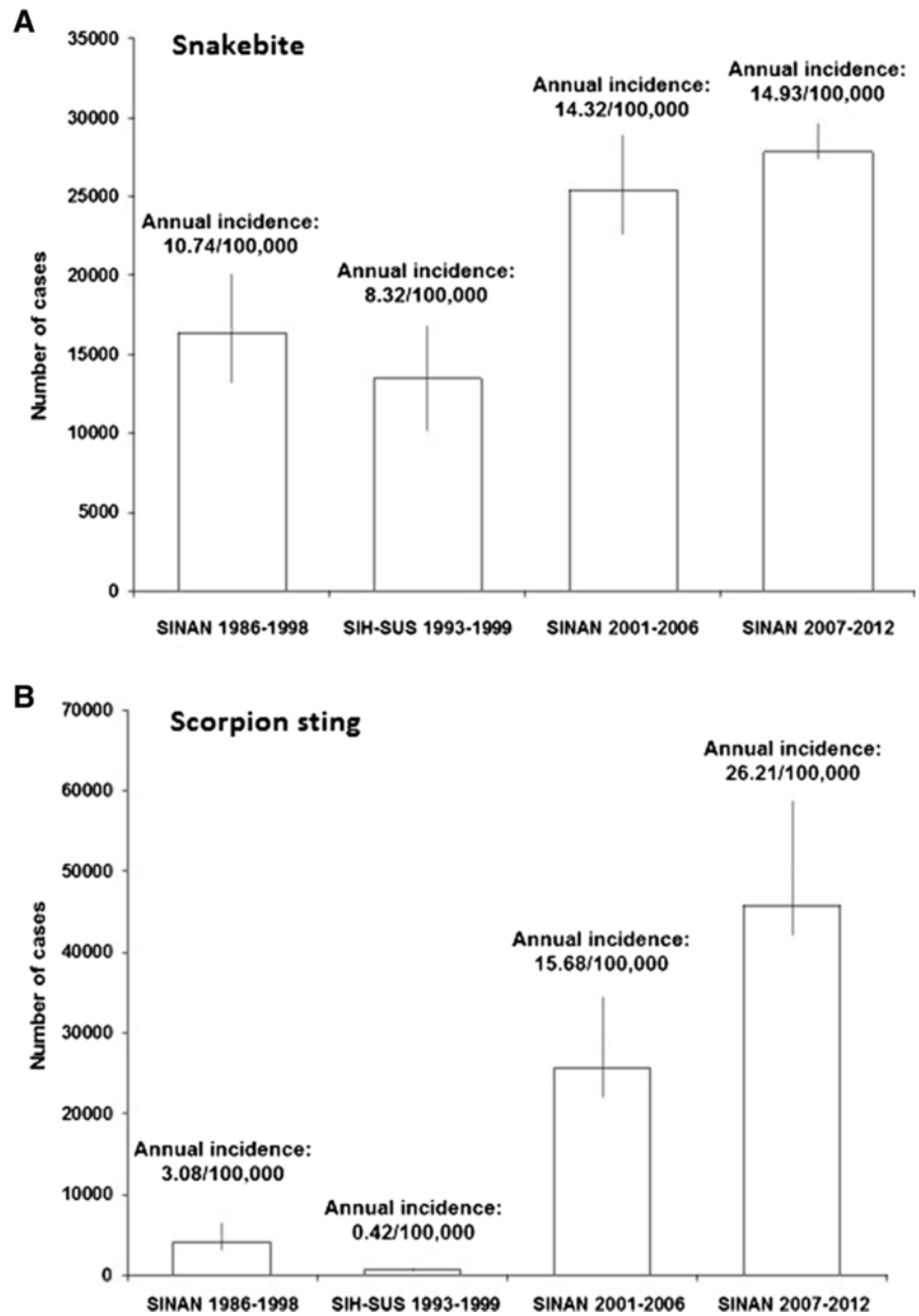

Fig. 11 Notifications of snakebite and scorpion stings in Brazil at various periods according to the Brazilian Notifiable Diseases Information System (SINAN). (**A**) Snakebite notification. (**B**) Scorpion sting notification. SUS: Brazil's Unified Health System. SIH: Hospital Information System

fatality rate (Fig. 15). Regarding snakes and bees, case fatality rate is higher in children and the elderly. Children, in particular between 5 and 10 years, seem more vulnerable to scorpion stings, which corroborates previous observations [15, 23]. Case fatality rate is constant throughout life regarding spider bites. The severity of bee stings can be due either to envenomation by a large amount of venom inoculated after multiple stings, or anaphylactic shock and allergy [25]. In children whose body volume is smaller and who generally have not been yet sensitized, envenomation is likely to be the commonest way for severity, while in adults the two etiologies should be considered.

Conclusion

Every year in Brazil, there are about 100,000 envenomations following bites or stings by venomous terrestrial animals, resulting in 220 deaths. Over a quarter of the

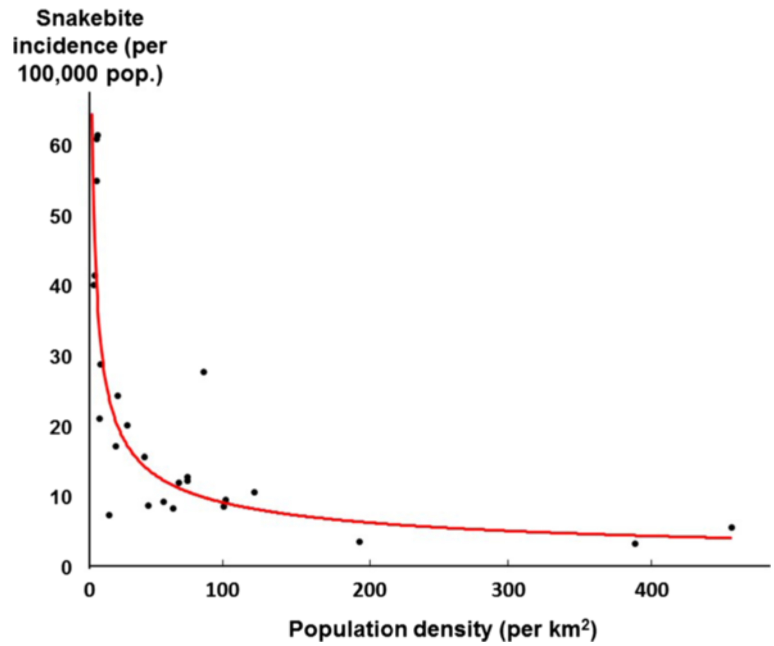

Fig. 12 Relationship between snakebite incidence and human population density

accidents – but half the deaths – result from a snakebite, while more than a third of cases and a quarter of deaths are the consequence of scorpion stings. In addition, each year nearly 1,000 patients suffer from sequels, the severity of which was not detailed, following a snakebite.

Snakebites are three times more common in men, whereas for other venomous land animals, the sex ratio is generally more balanced even if there are some regional differences. The incidence of envenomation increases with age until 65 years and then decreases. The results are consistent with higher risks in rural areas, especially for snakebites, and/or peri-urban areas for arthropod attacks.

Less than 10 % of envenomations are described as severe, and case fatality rate, constant over time, remains below 0.8 %. It increases at both ends of life – in children under 10 years and people aged 60 and over – especially with regard to scorpion stings.

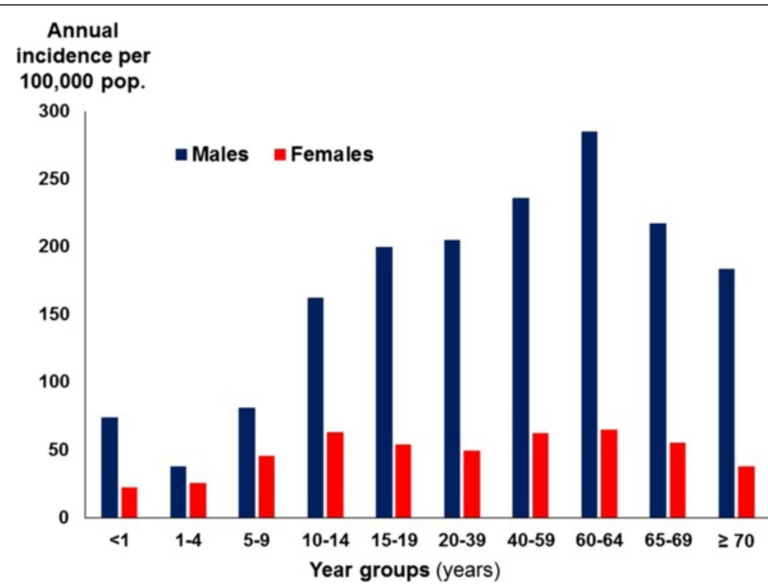

Fig. 13 Specific snakebite incidence according to age group and gender

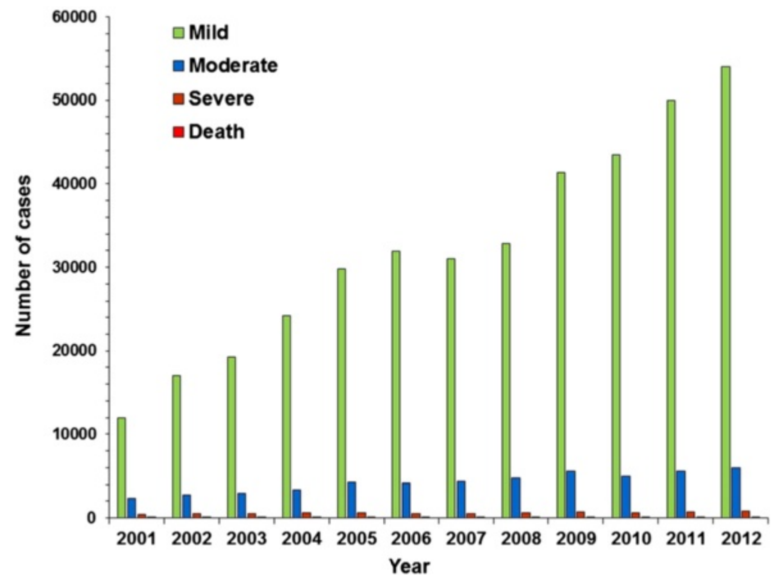

Fig. 14 Classification of scorpion stings from 2001 to 2012 in Brazil

The change in the seasonal incidence is not marked in northern Brazil while in south, incidence decreases between April and May, and from September to October.

Overall, the time between the accident and the medical care is brief – less than three hours – for the most cases of envenomation, which explains the favorable clinical evolution in numerous cases.

Mandatory reporting of cases, if functional and in routine, produces important indicators to improve the prevention and management of envenomations. It leads especially to provide relevant epidemiological data for health authorities in order to adjust the therapeutic offer, including antivenoms, in respect to the quantitative, qualitative and geographical actual demands.

This approach, highly useful, does not exclude the importance of more focused studies that specify many parameters, such as the clinical presentation, evolution and consequences of envenomation, treatment customs, geographic and cultural specificities, and other factors that can affect the treatment of envenomation.

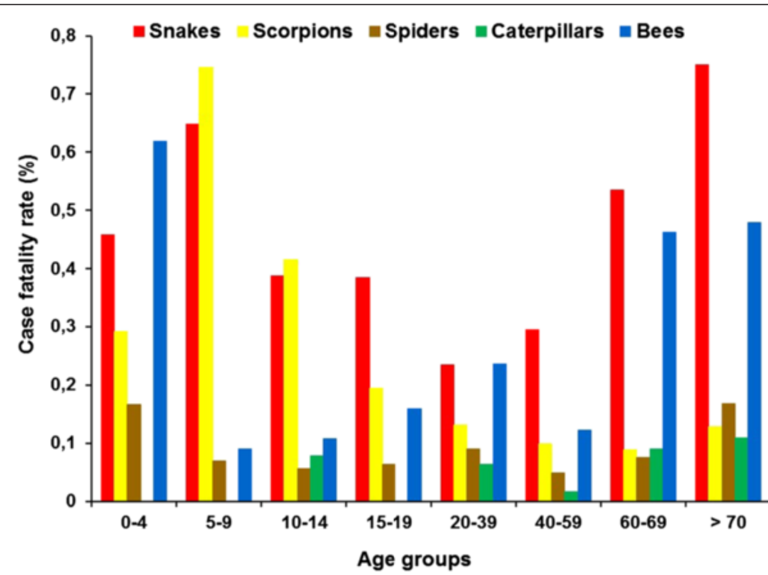

Fig. 15 Case fatality rate according to venomous animals and age groups

Competing interests
The author declares that he has no competing interests.

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