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ORIGINAL ARTICLE

Lonomia envenomation in Brazil: an epidemiological overview for the period 2007–2018

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Background: Among the Lepidoptera with medical importance in Brazil, larvae of *Lonomia* moth (Saturniidae: Hemileucinae) stand out by being the etiological agent of the lonomism, a form of erucism in which the most troubling symptoms include systemic hemorrhage that can lead to death.

Methods: This study provides an epidemiological overview of accident notifications with *Lonomia* registered by the Brazilian Reportable Disease Information System (SINAN) between 2007 and 2018. The categories of sociodemographic aspects of the victim, accident characteristics, and clinical data (6,636 records) were analysed by the chi-square test for goodness of fit (α=0.05). By the same test, accident frequencies by month, year, and state were also compared. To explore the spatial distribution of notifications and to identify significant space-time and purely spatial clusters, a spatial scan statistic (SaTScan) was used.

Results: The epidemiological profile of most of the victims had at least one of the following characteristics: male, >50 y of age, ethnically classified as white, and with a low level of education. Accidents in urban areas were as frequent as in rural areas. A higher frequency of non-work-related accidents was detected. Victims were mostly stung on the upper limbs. Most victims received medical care within the first 3 h after the accident. Most cases were classified as mild, although 12 deaths were reported. The south states of Brazil concentrate the highest frequencies of notifications. Summer was the season with the greatest number of cases, and the majority of the notifications occurred between 2017 and 2018.

Conclusions: These results provide an overall and current situation assessment of the lonomism in Brazil, and they should enable health authorities to improve the management of this envenomation in states/regions that share the high epidemiological risk of exposure to *Lonomia*.

Keywords: caterpillar, epidemiology, erucism, lonomism, public health, venomous animal

Introduction

Envenomation caused by larval forms of moths (also called 'stinging caterpillars') is known as erucism (eruca=caterpillar), a dermatological condition common in tropical areas. Regardless of the species, this type of envenomation was considered benign until the beginning of haemorrhagic accidents, which were attributed to larvae of the genus *Lonomia* (Saturniidae: Hemileucinae) in South America.[1] This genus is the aetiological agent of lonomism, a form of erucism responsible for numerous deaths in Brazil.[2]

At the present time, *Lonomia achelous* Cramer 1977 and *Lonomia obliqua* Walker 1885 are the only two species identified as responsible for lonomism in Brazil.[1] Their larvae are characterized by 'spines' (spicules) arranged symmetrically along the dorsum, presenting an arboreal aspect and a clearer base concerning the apex. During this larval stage, *Lonomia* spp. cluster on tree hosts, forming colonies that can contain from 10 to >1000 individuals.

Figure 1. Trunk of a tree with some larvae of the genus *Lonomia* Walker 1885. Photograph by Estela Wagner.

They mimic the host's trunk by homochromia, making them very difficult to see (Fig. 1). Usually accidents occur when the victim leans against the spicules, puncturing the subcutaneous tissue and allowing the release of toxins from the caterpillar's spicules into the skin.[2]

The clinical presentation of lonomism is initially characterized by intense pain at the site of contact, followed by headache and generalized aches. Between 8 and 72 h after 'stinging', systemic coagulation disorders (bleeding, gingivorrhagia, ecchymosis, haematoma, disseminated intravascular coagulation, petechiae) with consequent acute renal failure may occur. The severity of symptoms is variable, depending on the number of larvae that come into contact with the skin, the intensity of the contact and the victim's individual characteristics. Without adequate emergency treatment, victims may die.[3,4]

The first report of a haemorrhagic accident by moth larvae in Brazil was by Dr Zoroastro de Avarenga in 1912, in the state of Minas Gerais (MG).[2] According to the author, a farmer accidentally touched a colony of larvae on the trunk of a tree. Blood was found in the patient's saliva about 24 h after contact.[2] In 1986, Fraiha-Neto et al.[5] described accidents with *L. achelous* in the state of Amapá and Marajó Island between 1978 and 1982, involving workmen who were tapping rubber trees. In addition, accidents by *L. obliqua* were common in southern Brazil during the late 1980s, reaching epidemic proportions as the incidence of such accidents grew annually.[1] Due to these epidemic outbreaks, a specific antivenom was produced for effective treatment against *L. obliqua* venom and for re-establishing the coagulation parameters in envenomed patients.[6] Before the production of *Lonomia* antivenom, the calculated lethality was 1.7%, decreasing to about 0.3% in patients receiving the specific treatment.[7] To date, only the Butantan Institute in São Paulo, Brazil, manufactures *Lonomia* antivenom, which consists of purified F(ab′)2 fragments of immunoglobulin G obtained from the plasma of horses hyperimmunized with *L. obliqua* bristles extract.[8]

Since it is not only increasing in number annually, but also expanding to other areas of the country,[9] and due to its medical importance (the *Lonomia* caterpillar envenomation case fatality rate is six times higher than that observed for snake bites),[10] lonomism is an important public health problem in Brazil. Taking into consideration that continuous epidemiological monitoring is necessary to specifically address public health policy efforts, this study presents an epidemiological overview of accidents with *Lonomia* spp. recorded in this country between 2007 and 2018.

Methods

Obtaining data

Data of lonomic accidents were provided by the Brazilian Ministry of Health (BMH), recorded by the 'Sistema Nacional de Agravo de Notificação' (SINAN; Brazilian Reportable Disease Information System). SINAN was created by the BMH and was implemented gradually from 1993 onwards. Since 1998, the use of SINAN has been regulated, making mandatory the regular updating of the national database by the municipalities, states and the Federal District. Currently the database is administered by the Secretariat of Health Surveillance.[11]

SINAN is based primarily on reports and investigations of pathological events and disease cases on the national list of mandatory notifiable diseases, but states and municipalities may include other major health problems in their region. The objective of the systematic use of SINAN is to allow all health professionals to have access to information and make it available to the community.[11]

Lonomism is a disease of compulsory notification in Brazil, i.e. in the case of clinically suspected lonomism, health professionals must fill in a specific SINAN form to start procedures to investigate the disease. Initially, data about the patient (such as home address, age, gender, schooling, occupation), date of the accident and clinical manifestations (signs and symptoms) are collected. Later, additional information, such as the use of antivenom for treatment and outcomes, must be added to the system.

In the present study, data from cases of lonomism recorded in Brazil between 2007 and 2018 were obtained from SINAN through the Electronic System of Citizen Information Service (e-SIC; https://esic.cgu.gov.br/sistema/site/index.aspx). The e-SIC allows anyone to send requests for access to information free of charge and receive the response to the request made to agencies and entities of the Federal Executive. Data were requested on 28 February 2019 and received a month later. They included details about sociodemographic aspects of the victim (sex, age group, ethnicity and education), accident characteristics (place, dates, time to medical care, whether the accident was work related and the part of the body that was stung) and clinical data (severity of envenomation, use of antivenom and evolution of the case).

Study area

Brazil is comprised of 26 federal states and the Federal District, representing a total of 5570 municipalities. It is divided into five regions; the Northeast has the greatest number of states and municipalities. The Southeast is the region with the highest Municipal Human Development Index (IDHM) followed by the Midwest, South, North and Northeast.[12] In relation to area, the North presents the largest territory when compared with the other regions (Table 1; Supplementary Material 1).

Table 1. Geopolitical division of Brazil

Geopolitical region	Number of states	Municipalities	IDH	Territory (km^2)	% of total area
Northeast	9	1794	0.660	1554 257	18.24
Southeast	4	1668	0.754	924 565	10.86
South	3	1191	0.756	576 737	6.78
Midwest	3+Federal	466	0.753	160 6317	18.87
North	7	450	0.684	3850 510	45.25

IDH: Human Development Index.

In 2006 the Brazilian population was estimated at 187 million, reaching 208.5 million in 2018.[13] Independent of the year, the Southeast has the largest population when compared with the other regions, with the North and Midwest regions having the smallest populations (Supplementary Material 2).

Regarding the climate, Brazil has three major zones and 12 types of climates, according to the Köppen classification (1936). The tropical climate zone has the largest area, representing 81.4% of the Brazilian territory, and occurring in all regions of the country except in the states of Rio Grande do Sul (RS) and Santa Catarina (SC) and a significant part of Paraná (PR) in the Southern region. The tropical zone can be divided into four subregions: without dry season, monsoon, with dry winter and with dry summer.[14]

The semi-arid climate zone is the typical climate of northeastern Brazil, representing 4.9% of the national territory and occurring in landscapes where annual rainfall is on average <800 mm. In Brazil, this zone has only a single subregion, called 'semi-arid with low latitude and altitude'.[14]

The humid subtropical climate covers 13.7% of the Brazilian territory, which is mainly in the southern region, in its plateaus and mountains. The subtropical climate is divided into four major subgroups: oceanic climate, without dry season, with dry winter and with dry summer.[14]

Statistical analysis

Data were analysed by variable category in as number and relative frequency (%). The frequencies of the categories were compared by the chi-square test for goodness of fit (α=0.05). The 'ignored' category was not included in the analyses. The adjusted residual post-hoc test was performed to classify the frequency of accidents by category of a variable.

To explore the spatial distribution of lonomic accidents and to identify significant space–time and purely spatial clusters, a spatial scan statistic (SaTScan) was used. This method has increasingly been used by epidemiologists to detect regions with significantly elevated disease rates (see https://www.satscan.org/references.html). In the space–time model, the analysis uses cylindrical windows in motion on a study region to identify clusters, testing a null hypothesis that the number of case notifications in each window is proportional to the expected number of notifications outside the window. The base and the height of the cylindrical window correspond to a geographical area and a period of time, respectively. SaTScan increases the size of the window until it covers a specific user-defined population limit. The windows move from one geographical centre to another until all the centres within the study region are included. Once this testing is done, the detected clusters are ordered in the results section according to the likelihood ratio, whose p-value is obtained through Monte Carlo testing. The cluster with the maximum likelihood ratio is the most likely cluster. The purely spatial analysis basically uses the same methods as the spatiotemporal analysis, with the difference that a circle corresponds to a geographical area.[15]

SaTScan was carried out using a discrete Poisson model and was configured to detect clusters with high rates of lonomism case notifications (α=0.05). The centroid of each Brazilian state was used as a spatial reference for the clusters. The maximum window length limit was specified as the geographical size that includes 50% of the study.[15] For the spatiotemporal analysis, the number of notifications and estimated population per state and year were used. For the purely spatial analysis, the total number of notifications for the entire study period (11 y) and the population average were used. The estimated population per state was obtained through the 'Sistema IBGE de Recuperação Automática (SIDRA; IBGE Automatic Recovery System) in the statistics database.[13]

For graphical analysis, the incidence of lonomism was described per state for every 100 000 inhabitants (equation 1). For that, the number of notifications per state was divided by the estimated population, and the result multiplied by 100 000 (equation 1). For the space–time analysis, the incidence rate was calculated per year. In contrast, for the purely spatial analysis, the rate was obtained from the sum of lonomism notifications divided by the population average for the period of 11 y.

$$Incidence\ rate\ of\ lonomism/state = \left(\frac{Number\ of\ notifications}{Population\ size}\right) \times 100\,000 \qquad (1)$$

All analyses were performed using R software (R Foundation, Vienna, Austria)[16] and for spatial analyses the 'RSaTScan' package was used.[17]

Table 2. Sociodemographic profile of victims of lonomism

Variable	Category	n	%	χ^2	p-Value
Sex	Female	2575[b]	38.80	331.6	<0.001
	Male	4058[a]	61.15		
	Ignored	3*	0.05		
Age group (years)	0–10	1273[a]	19.18	648.54	<0.001
	10–<20	1029[b]	15.51		
	20–<30	796[b]	12.00		
	30–<40	835[b]	12.58		
	40–<50	908[b]	13.68		
	≥50	1795[a]	27.05		
Ethnicity	Black	235[b]	3.54	11 979	<0.001
	Brown	1245[b]	18.77		
	Indigenous	39[b]	0.59		
	White	4508[a]	67.96		
	Yellow	47[b]	0.71		
	Ignored	562*	8.47		
Education	Illiterate	79[b]	1.19	7124.5	<0.001
	Incomplete elementary school	2430[a]	36.64		
	Complete elementary school	386[b]	5.82		
	Incomplete high school	359[b]	5.41		
	Complete high school	607[b]	9.15		
	Incomplete higher education	70[b]	1.06		
	Complete higher education	178[b]	2.68		
	Not applied	882*	13.30		
	Ignored	1645*	24.80		

The superscripted letters 'a' and 'b' refer to the highest and lowest (respectively) classification of frequencies according to the adjusted residual test.
*These categories were not included in the analysis.

Results

Between 2007 and 2018, 6636 cases of envenomation by *Lonomia* spp. were reported in Brazil. The sociodemographics of the victims are shown in Table 2. Most of the accidents involved male victims. The age groups that included people >50 y and <10 y of age had the highest frequency of accidents. People classified ethnically as white included more than half of the notifications. Most of the patients also had a low level of formal education, without completion of elementary school (Table 2).

There were no statistically significant differences between occurrences of accidents in urban and rural areas, and accidents were mainly not related to work activities. Most patients were treated within the first 3 h after the accident. There was a higher frequency of accidents due to contact of larvae of *Lonomia* spp. with the victim's hand, arm and finger (Table 3).

Concerning clinical data, most of the cases were classified as mild, with evolution to cure. Of the total accidents reported herein, only 1484 (22.36%) patients received *Lonomia* antivenom, corresponding to the following severity levels: mild in 301 (4.54%) patients, moderate in 928 (13.98%) and severe in 216 (3.25%). The average number of antivenom vials used per patient was 5.18±2.36 (3.84±2.25 in mild cases, 5.07±1.63 in moderate cases and 7.75±3.06 in severe cases) (Table 4).

The states with the highest frequency of lonomism notifications are concentrated in the Southern and Southeastern regions (χ^2=10 709; p<0.001) (Fig. 2). The state of SC was the one that presented the highest percentage of notifications, followed by the states of MG, RS, São Paulo (SP) and PR. In the other Brazilian states, the frequency of notifications was low, varying between 10 and 155 over the sampled period (Fig. 2).

The highest number of cases occurred between December and April (Fig. 3). The number of accidents began to decline in May, reaching their lowest number in August (Fig. 3A). The years 2017 and 2018 had the highest frequency of notifications (Fig. 3B).

In total, four spatiotemporal groups were identified by SaTScan (Table 5, Fig. 4). The first consisted of all Southern states between 2007 and 2012, the second corresponded to MG between 2013 and 2018, the third to Tocantins (TO) in 2018 and the fourth to Rondônia (RO) between 2013 and 2014. Cluster 3 represented the spatio–time window with the highest relative risk (RR) of lonomism notifications, 5.43 times greater than the expected number. Interestingly, the state of TO had its

Table 3. Characteristics of lonomic accidents

Variable	Category	n	%	χ^2	p-Value
Zone of occurrence	Urban	3102[a]	46.75	5480	<0.001
	Rural	3229[a]	48.66		
	Interurban	102[b]	1.54		
	Ignored	203*	3.06		
Work-related accident	Yes	1262[b]	19.02	4881.4	<0.001
	No	4860[a]	73.24		
	Ignored	514*	7.75		
Time to medical care (hours)	0–1	2907[a]	43.81	6331.9	<0.001
	1–<3	1710[a]	25.77		
	3–<6	544[b]	8.20		
	6–<12	219[b]	3.30		
	12–<24	266[b]	4.01		
	≥24h	579[b]	8.73		
	Ignored	411*	6.19		
Part of the body stung	Head	210[b]	3.16	8079.1	<0.001
	Arm	843[a]	12.70		
	Forearm	639	9.63		
	Hand	2542[a]	38.31		
	Finger	812[a]	12.24		
	Trunk	336[b]	5.06		
	Thigh	155[b]	2.34		
	Leg	315[b]	4.75		
	Foot	577[b]	8.69		
	Toe	68[b]	1.02		
	Ignored	139*	2.09		

The superscripted letters ‘a’ and ‘b’ refer to the highest and lowest (respectively) classification of frequencies according to the adjusted residual test.
*These categories were not included in the analysis.

peak for lonomism in 2018, with 2.70 notifications per 100 000 inhabitants.

The result of the purely spatial cluster analysis indicated a non-random distribution of four clusters (Table 5, Fig. 5). The first cluster consisted of the states of RS and SC, the second of MG, the third of Mato Grosso del Sul and PR and the fourth of TO (RR=2.81). Cluster 1 represented the area with the highest risk of lonomism notifications, 4.48 times greater than the expected value. The state of SC had the highest number of notifications, with approximately 24.75 per 100 000 inhabitants, while RS had approximately 9.31 cases per 100 000 inhabitants. TO, the state that comprised cluster 4, also had a value of approximately 9.31 cases per 100 000 inhabitants.

Discussion

The envenomation caused by contact with *Lonomia* caterpillars has become an important health problem in Brazil. These accidents have been reported for the Northern region since the 1970s, but an alarming increase in cases was registered in the late 1980s in the South.[1] Lorini[18] attributed this sudden increase in the number of accidents with *Lonomia* to the anthropic impact of the use and occupation of land, which probably resulted in a decrease in its arboreal hosts, culminating in its adaptation and migration to new hosts in orchards surrounding urban areas.

Epidemiological studies regarding accidents with *Lonomia* have been conducted mainly for the South region of Brazil.[19–21] For the whole country, only Azevedo[9] showed the distribution of lonomism cases by state between 2000 and 2007, but without providing any additional epidemiological information. The present work aimed to update and expand on knowledge about the epidemiological situation of lonomic accidents in Brazil, taking into consideration the cases registered by SINAN between 2007 and 2018.

Following a pattern that has long been seen in accidents with venomous animals, including those caused by *Lonomia* spp.,[22,23] the results of the current study indicate that lonomism is more frequent in men (almost 1.6 times greater than in women). At first this could be thought of as related to rural work, a predominantly male activity in Brazil.[24] However, the number of accidents in urban and rural areas did not present statistically significant differences in this study, which is in accordance with Garcia.[25] In fact, accidents involving *Lonomia* spp. have been documented in plazas and parks of different Brazilian cities,[26,27] which could also explain the frequency of non-work-related accidents. In addition,

Table 4. Clinical aspects of victims of lonomic accidents

Variable	Category	n	%	χ^2	p-Value
Severity of envenomation	Mild	4841[a]	72.95	8668.1	<0.001
	Moderate	1364[b]	20.55		
	Severe	236[b]	3.56		
	Ignored	195*	2.94		
Evolution of the case	Cure	6178[a]	93.10	10709	<0.001
	Death	12[b]	0.18		
	Ignored	446*	6.72		
Use of *Lonomia* antivenom	Yes	1484[b]	22.36	5188.3	<0.001
	No	4887[a]	73.64		
	Ignored	265*	3.99		

The superscripted letters ‘a’ and ‘b’ refer to the highest and lowest (respectively) classification of frequencies according to the adjusted residual test.
*These categories were not included in the analysis.

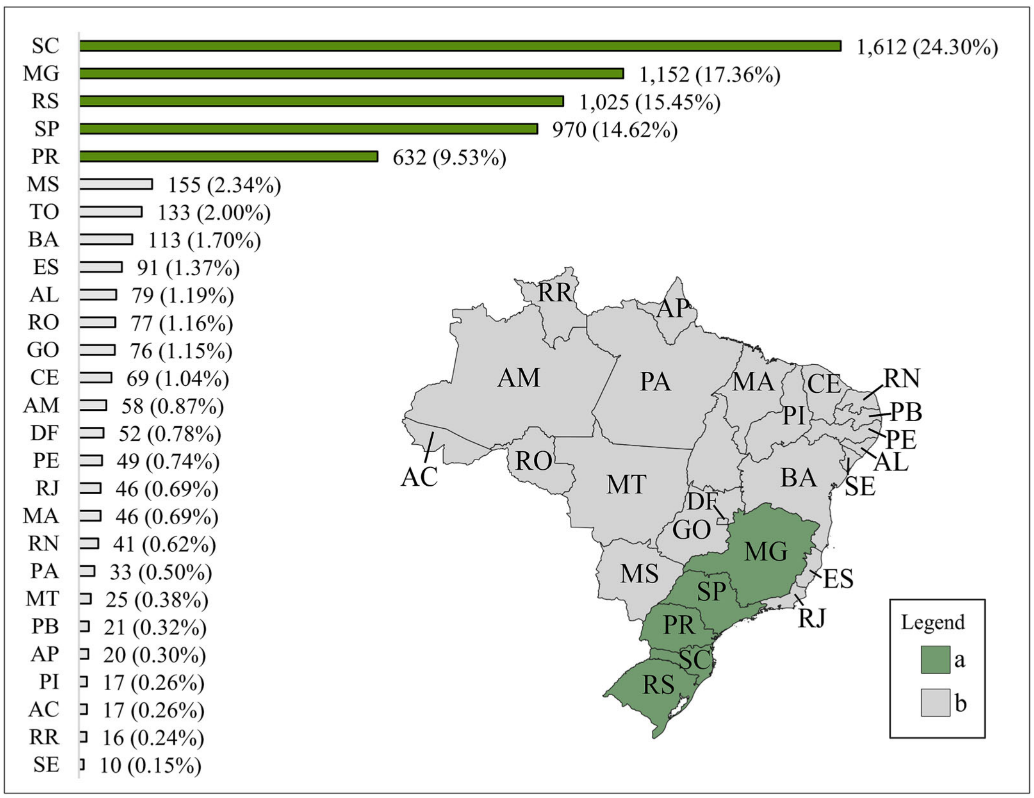

Figure 2. Total number (%) of lonomism notifications per Brazilian state between 2007 and 2018. The letters ‘a’ and ‘b’ refer to the highest and lowest (respectively) classification of frequencies according to the adjusted residual test.

a higher incidence of cases was seen in both older (>50 y) and younger (<10 y) people, which is probably related to the low level of education predominating in victims of lonomism in this study.

Another point related to sociodemographic patterns is the predominance of the white ethnic group among victims of lonomism. This is due to the fact that white ethnicities are dominant in South and Southeast Brazil as a result of the European

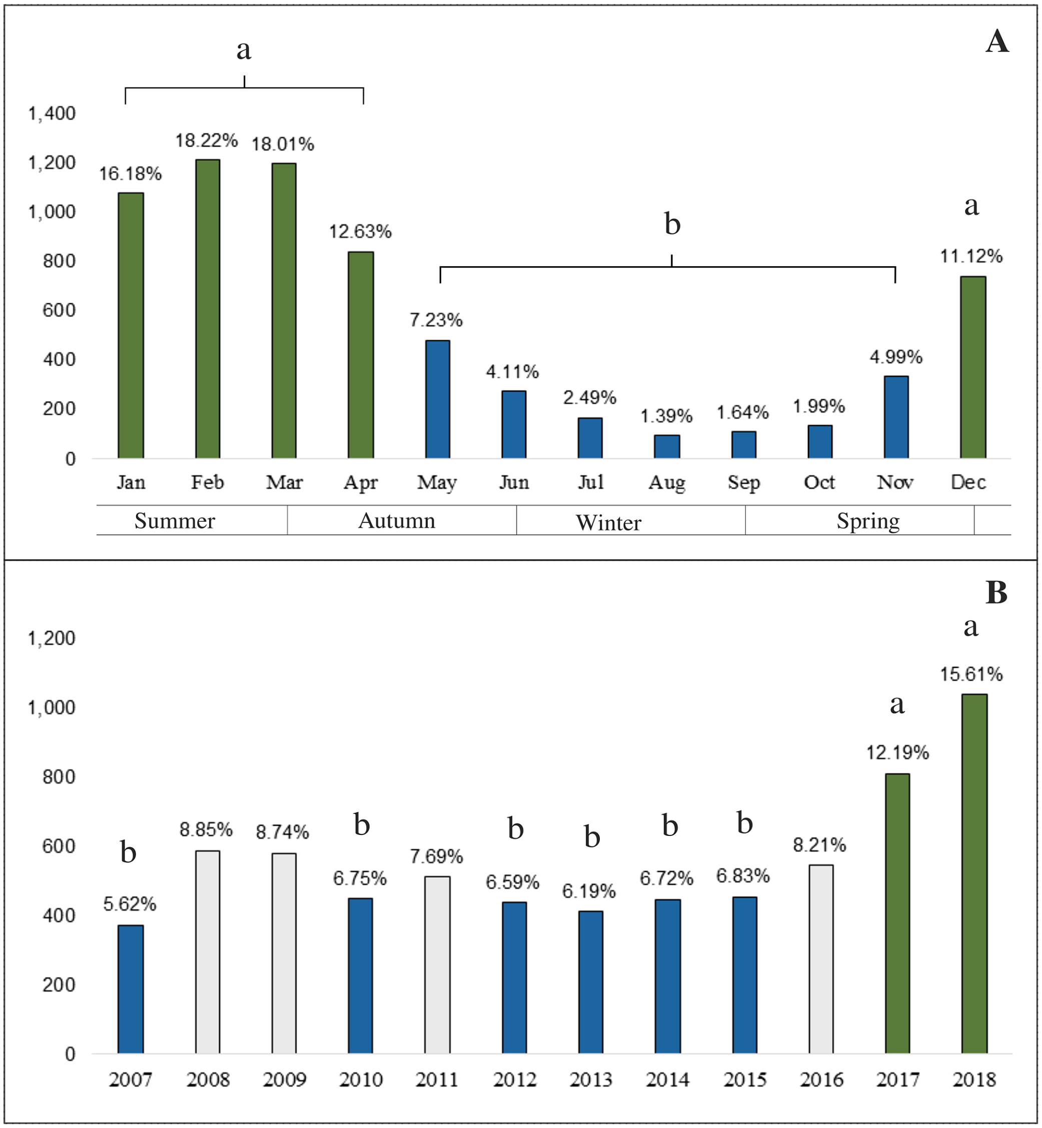

Figure 3. (A) Frequency of lonomism cases among months. (B) Frequency of notifications among years. The letters 'a' and 'b' refer to the highest and lowest (respectively) classification of frequencies according to the adjusted residual test.

migratory wave,[28] and these regions presented the highest number of case reports.

The larvae of *Lonomia* spp. exhibit colours that range from light brownish to light greenish-brown and cluster in colonies on the trunks of host plant species. When walking in parks, orchards or forests, humans can inadvertently touch them, resulting in accidents.[18] These accidents occur most frequently on the upper limbs of children and rural workers.[29] Accordingly, in this study we found that hands, arms and fingers were the main anatomical regions involved in lonomic cases, which is related with the fact that these are the usual primary points of contact with the host plants of *Lonomia*.

We found that the majority of cases were classified as mild, which may be related to the fact that most victims received medical care in the first 3 h after touching *Lonomia* larvae, i.e. they were evaluated during the onset of the clinical presentation. It is generally known that earlier diagnosis results in a better prognosis.[27,30] Since the 1990s, the BMH has advised people to seek immediate medical attention after contact with *Lonomia* spp. Considering that the haematological changes occur 8–72 h after contact with these larvae, prolonged delay in seeking medical care can become fatal.[31]

Depending on the severity of the condition, accidents by *Lonomia* are classified by SINAN as mild, moderate or severe.[32] Mild accidents are characterized by the manifestation of local symptoms such as pain, oedema, erythema and regional lymphadenomegaly. These symptoms are indistinguishable from those caused by other stinging caterpillars.[32] Taking into account that it is not always possible or easy to confirm the diagnosis of lonomism by identifying the aetiological agent, and that the symptoms of mild accidents caused by different types of stinging caterpillars are very similar, we suspect that accidents

Table 5. Significant clusters (space–time and purely spatial) with discrete Poisson distribution for higher rates of lonomism notifications in Brazilian states

Type	Cluster	State ID	Coordinates	Radius (km)	Time frame	Expected cases	Observed/ expected	RR	Log likelihood ratio	p-Value
Space–time	1	RS, SC, PR	29.737839 S, 53.316837 W	591.01	2007–2012	423.15	4.10	5.19	1284.09	<0.001
	2	MG	18.457986 S, 44.657703 W	0	2013–2018	376.33	1.98	2.10	151.18	<0.001
	3	TO	10.150184 S, 48.330001 W	0	2018	7.73	5.43	5.46	36.91	<0.001
	4	RO	10.898565 S, 62.856550 W	0	2013–2014	7.36	4.35	4.36	22.43	<0.001
Purely space	1	RS, SC	29.737839 S, 53.316837 W	454.94	–	588.00	4.48	6.78	2303.03	<0.001
	2	MG	18.457986 S, 44.657703 W	0	–	681.47	1.69	1.84	153.38	<0.001
	3	MS, PR	20.325898 S, 54.845470 W	582.10	–	449.23	1.75	1.85	112.89	<0.001
	4	TO	10.150184 S, 48.330001 W	0	–	47.95	2.77	2.81	51.19	<0.001

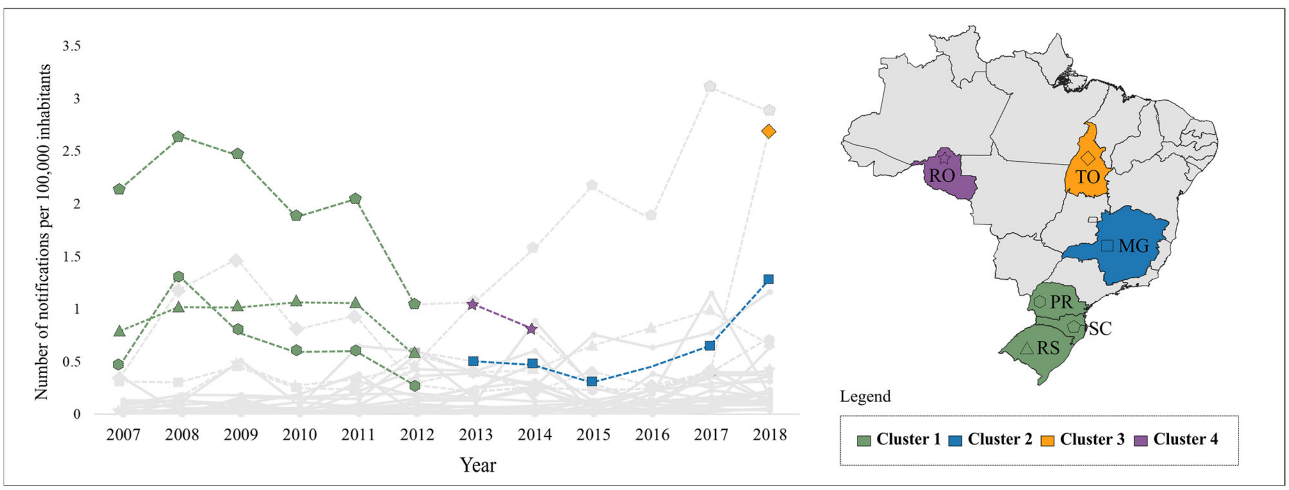

Figure 4. The annual incidence of lonomism for each Brazilian state from 2007 to 2018, with the representation of each cluster resulting from the space–time analysis of SaTScan.

with other genera of caterpillars may also have been included as responsible for mild lonomism. On the other hand, moderate and severe accidents are characterized by systemic haemorrhagic syndrome, with the presentation of symptoms that are more specific and related to lonomism.[32] Fortunately, the frequency of severe accidents and the number of fatalities (n=12 [0.18%]) registered in the analysed period were low. Four of the 12 cases that resulted in death were classified as mild and antivenom was not administered. Although the cause of death was not registered, deaths may have occurred due to failure to properly classify the severity of these cases. On the other hand, most severe cases that resulted in death had a delay in seeking medical attention after the accident (>24 h).

The use of *Lonomia* antivenom and the dose administered is determined by the clinical symptoms of the patient.[32] In this study, the fact that some mild cases (for which not only *Lonomia* but also other genera of caterpillars may have been included, because identification of the correct aetiological agent is not an easy task) were treated with antivenom caught our attention, since the recommendation for these cases is palliative

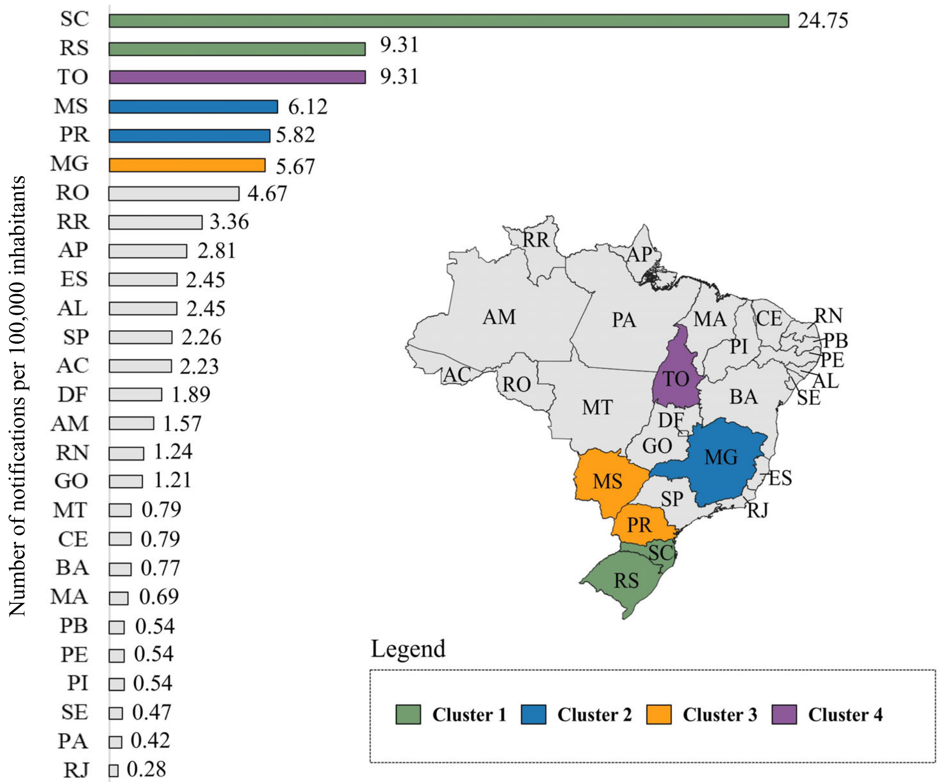

Figure 5. The incidence of lonomism for each Brazilian state, with the representation of each cluster resulting from the purely spatial analysis of SaTScan.

treatment for the relief of local symptoms.[31] It is important to mention that the production of *Lonomia* antivenom is challenging because these caterpillars are difficult to rear in lab conditions, so it depends on caterpillar donations in order to obtain bristle extracts for use in the immunization process.[33] Although most severe cases were treated with *Lonomia* antivenom, the mean number of vials used for these cases was around 8 per patient, which is lower than the recommended number of vials for severe lonomism (10 vials).[31] Furthermore, only 5 vials of antivenom were given to two of the severe cases that resulted in death, and none was given to two other such cases. Therefore the importance of administering the antivenom in accordance with the recommendations of the country's health agency is highlighted.

Matching Azevedo's[9] results, we found that SC is the Brazilian state with the highest number of lonomism notifications, comprising almost 25% of the total accidents during the analysed period, followed by the states of the South and Southeast regions: MG, RS, SP and PR. It is important to highlight that, in the South and Southeast of Brazil, except SP (because of its large population), places with the highest absolute number of cases present likewise the highest rate per 100000 inhabitants. Recently Favalesso et al.[34] demonstrated that the states mentioned above contain the largest area predicted for the presence of *L. obliqua*, and there is a large area of mosaic between native vegetation and agricultural areas that could favour the contact of humans with larvae. Similarly, Garcia and Danni-Oliveira[19] suggest that fieldwork and plant extractivism (mainly of native trees) put *L. obliqua* in contact with humans, increasing the risk of accidental contact. After the Northeast, the South and Southeast are the regions that presented the greatest amount of area planted with avocado, guava, pear and peach during the study period.[35] It is important to highlight that *L. obliqua* has been sampled in all these cultivars.[26] The Southern and Southeastern regions also include extensive areas of forestry, and *L. obliqua* has been found in *Eucalyptus* spp.[36]

When analysing the time course of lonomism, this study revealed that the formation of a cluster for the states of southern Brazil only continues until 2012. After that period, there is the formation of other clusters outside that region. This leads to two hypotheses: the expansion of lonomism cases outside of Southern Brazil from 2012 onwards and the establishment of local actions and public policies that mitigate the number of cases in Southern Brazil from 2012 onwards. From the spatial analysis carried out in this study, two clusters outside the Southern Brazil (TO and RO) were highlighted, which constitutes evidence that corroborates the hypothesis of the spread of lonomism beyond that region. Also supporting this hypothesis is that MS stood out when the incidence per 100 000 inhabitants was calculated, but only when the SatSCan purely spatial analysis was performed. The spread of notifications has relevance not only to Brazil, but also to other neighbouring countries such as Paraguay and Bolivia, where there have been no official reports of lonomic accidents yet, but some *Lonomia* specimens have been sampled in localities of both countries.[37,38]

The lonomism cases predominately occurred during the warm and rainy months (summer season). The accident pattern by the month of the year is related to biological aspects of *Lonomia*, as climate variations determine its life stages.[34] It is known that the larval phase occurs in the warmer and wetter months of the year, while the pupal phase occurs in colder periods.[34] The high frequency of notifications in 2017 and 2018 may be related to climatic or anthropic changes that favour the larval phase. It may also be related to an improvement in the sampling of information by SINAN. However, both hypotheses need further confirmation.

Various deficiencies were identified on the notification files, such as the high incidence of missing data, which has also been observed with reports of other mandatory notifiable diseases.[39,40] Such deficiencies may be related to the high demands at the health centres, the lack of available time for members of the health team, the small number of workers at the health centre or failure to record and transcribe data to the SINAN system, resulting in information deemed incomplete or unavailable in the system.[41] These situations should be emphasized since they all contribute to incomplete patient records and constitute important limitations of this study. Although the records considered here were not suitably complete, it is important to highlight that they provided useful data to draw epidemiological inferences about accidents with *Lonomia* in Brazil. The improvement of data collection, fulfilled by local health agencies, is of remarkable importance in order to provide reliable information sources, which in turn will lead to a better understanding of reportable diseases.

The results of the current study provide an overall and updated assessment of lonomism in Brazil and certainly will contribute to improve our understanding of the epidemiology of envenomation in this country. Furthermore, this study will help guide the appropriate allocation of resources and the implementation of lonomism prevention strategies and define priority criteria for epidemiological research, including its location, taking into account the known range of *Lonomia* accidents in the country. Finally, neighbouring countries where lonomism appears to be an emerging public health issue, such as Argentina,[42] will benefit from the availability of epidemiological data for Brazil, which is the South American country with the greatest experience with *Lonomia* envenomation. The information provided here may help to guide the healthcare system of other countries to develop cost-effective management approaches for this public health problem.

Supplementary data

Supplementary data are available at *Transactions* online.

Authors' contributions: M.M.F. and M.E.P. conceived the study and wrote the article. A.T.B.G., M.M.F. and P.F.C. analysed the data. All authors discussed the results and contributed to the revision of the manuscript. All authors read and approved the final version submitted.

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