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Review article

Epidemiological study in Brazil: Scorpion sting cases in Natal, Rio Grande do Norte

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ABSTRACT

Scorpion sting accidents are a public health problem in the state of Rio Grande do Norte, Brazil. The increasing and high incidence of cases in urban areas reveals the importance of studies to determine the epidemiological profile and the spatial distribution of these accidents. This is a retrospective study that describes and analyzes the cases of scorpion stings in the city of Natal, Rio Grande do Norte, Northeast Brazil, from 2007 to 2018. Data from the Information System database of Notifiable Diseases (SINAN) were obtained from the Secretary of Health of Rio Grande do Norte. 31,368 accidents due to scorpion stings were reported, more frequently in urban areas of Natal, whose Human Development Index is low. The cases occurred predominantly in hot and humid regions, mainly affecting women aged between 30 and 60 years. Most individuals sought medical attention within 3 h of the incident. The severity and mortality of the injured individuals varied according to the area of occurrence, age of the patient, and the local and systemic symptoms presented. Pain, numbness, and edema were the most frequent local symptoms, and systemic symptoms were frequently described as headache, hyperthermia and sweating. Therefore, scorpionism in the city of Natal is an environmental and public health problem, with a significant growth trend ($p < 0.05$). Through the data collected on the spatial distribution and risks, this approach allows the creation of effective control strategies to prevent accidents.

1. Introduction

Scorpionism is a neglected public health problem in Brazil and other tropical and subtropical countries [1]. In Brazil, the incidence

Abbreviations: HDI, Human Development Index; HDI-M, Human Development Index-Municipal; HDI-L, Human Development Index-Longevity; INMET, National Meteorological Institute; IBGE, Brazilian Institute of Geography and Statistics; INPE, National Institute for Space Research; MHDI, Municipal Human Development Index; NDVI, Normalized Difference Vegetation Index; SPSS, Statistical Package for Social Sciences; SINAN, Notifiable Diseases Information System.

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of accidents and deaths from scorpion envenomation has increased in all regions in recent years, especially in the Northeast [2–4]. Between 2007 and 2018, 430,332 cases and 439 deaths were reported in Northeastern Brazil. In the state of Rio Grande do Norte, from 2007 to 2018, 31,944 cases and 18 deaths were reported. In this state, the cases increased from 1726 in 2007 to 8842 in 2019, with an average of 18.2 serious cases per year [2].

The scorpionism shows similar frequencies between genders in some states in the Northeast, such as Rio Grande do Norte and Ceará, with variations in the proportions only in Pernambuco [5]. The cases of scorpion accidents commonly accompany the economically active age group [6]. The scorpion stings predominantly affect the extremities of the body (hands, feet, and fingers) which usually result in accidents of mild severity [1].

Despite the high incidence and morbidity, scorpion accidents are still neglected by public policies especially in tropical and subtropical countries in the world, making the correct management of the victims difficult [7,8]. In addition, the historical-sociocultural context, political management and environmental conditions strongly reflect on the incidence of scorpion stings in a region. Although the severity of scorpion accidents also depends on the pathophysiology of the victim, the incidence of scorpionism and clinical management demonstrate the precariousness of health and sanitary conditions in the region [9]. And due to the characteristics of opportunistic predatory arthropods, they use natural or man-made spaces and gaps to hide and survive. Studies on the spatial distribution of scorpionism are important to determine the region most affected by injury, allowing us to understand the influence of local conditions in the areas where accidents occur [1]. In addition, the epidemiological and demographic analysis of scorpionism allows establishing a space-time relationship that reveals the synanthropism of scorpions, providing relevant results that guide the development of accident control strategies [10].

Scorpion accidents occur in higher numbers in metropolitan regions, at night and during rainy months [11,12]. Increased rainfall can result in scorpions leaving their habitats, which increases the risk of contact with people [13]. Metropolitan regions have conditions that favor synanthropism, in which scorpions proliferate and the natural habitat is modified. Therefore, the high incidence of these synanthropic animals in urban environments can be the effect of the number of favelas, population increase, lack of basic sanitation, and removal of vegetation for the implementation of new subdivisions [14,15]. However, the highest severity of accidents is reported in rural areas [5]. Despite the medical importance and the increasing incidence of scorpion accidents in the municipality of Natal and the metropolitan region, the epidemiological profile and the social and spatial distribution of cases in this area have not been studied yet. In this sense, the present study aimed to determine the clinical-epidemiological profile and the spatial distribution of cases of accidents due to scorpion stings in the city of Natal, from the period of 2007–2018.

2. Materials and methods

2.1. Study area

Natal is the capital of the state of Rio Grande do Norte, located on the Brazilian coast (latitude 5° 47 ’42″S and longitude 35° 12′ 32″W). This municipality has 36 neighborhoods, with an area of 170 km^2 and an estimated population of 884,122 inhabitants. About 52.94 % of the inhabitants are female, and 69.22 % of the municipality’s population is economically active [16]. In 2010, the demographic census carried out in Natal showed that the Municipal Human Development Index (MHDI) is 0.763 [17]. The Human Development Index-Longevity (HDI-L) is 0.773, one of the highest in the metropolitan region [17]. The average temperature of the region is 26.58 °C, with fluctuations through the year [18]. In Natal, the humid coastal tropical climate is predominant, with an average rainfall of 1200 mm/year, and vegetation coverage of 18.01 % [16].

2.2. Data acquisition

All cases of accidents due to scorpion stings reported in Natal from 2007 to 2018 were included in this study. Epidemiological information was collected from the database of the Notifiable Diseases Information System (SINAN). Demographic and population data were collected at the Brazilian Institute of Geography and Statistics (IBGE) Index obtained by the Municipality of Natal [16]. Humidity and temperature data were obtained by the National Meteorological Institute (INMET), in Sentinel and Landsat 2 satellites (INPE - National Institute for Space Research).

2.3. Spatial distribution

The spatial analysis was obtained by ArcMap 10.5 software (ESRI, New York, United States of America), with estimates of the average incidence per district, using the SIRGAS 2000 datum. The incidence rate was calculated for 100,000 inhabitants and the interpolation of the incidence of cases of scorpion accidents performed by beta-Spline method. For this analysis, the size of the output cell was set to 0.33, and a power value of two was used. The search neighborhood was set to smooth circular (smoothing factor of 0.2), with a radius of 30.15 and absence of barriers [19]. The MHDI map was produced from data from the Municipality of Natal, using geoprocessing tools. The Normalized Difference Vegetation Index (NDVI) and humidity map were obtained using images from Sentinel 2 [20].

2.4. Statistical analysis

In the study, the trend of the annual increase and existence of the growth of the number of accidents per year with scorpions were

obtained by linear regression. The epidemiological variables analyzed were year, month, and area of occurrence (urban, peri-urban, and rural); body part stung, sex, occupation and age of the victim; and time elapsed between the bite and medical care, clinical manifestations, severity, and evolution of the case. Statistical analyses were performed using the Chi-square (Likelihood Ratio Chi-Square) and Odds Ratio tests (OR) [21].

For correlation between the number of scorpion accident cases and the climatological variables, the following were considered: relative humidity (%) and average temperature (°C). The data covered the first month of 2007 to the last month of the year 2018. Using the number of cases of scorpion accidents in the city of Natal and the average of the climatological variables obtained by INMET, a univariate regression analysis was first performed on each outcome variable (number of cases) to know the variance in the absence of dependent effect (climatological). Then, a multiple linear regression was performed using the retrograde elimination model [22,23] with the climatological variables (predictors). The predictors below 60 % were eliminated from the analysis. The level of significance was $p < 0.05$. All statistical analyses were performed using SPSS® (IBM, Chicago, Illinois, United States of America) software version 22.0 for Windows, and the figures were generated using GraphPad Prism 7.04 (San Diego, California, United States of America).

The network analysis to establish the relationship between the symptoms and the clinical condition of scorpionism victims was performed using the Gephi 0.9.2 software (Paris, France). This program allows the analysis of complex data and its visualization with intuitive clusters [24]. The pairs of relationships (severity and symptoms) are represented by us and the edges are the strength of the relationship. The final visualization was obtained by Yifan Hu Multilevel layout algorithm [24]. This research used secondary data available on the website of the Ministry of Health of Brazil (https://datasus.saude.gov.br), without identifying the individuals; therefore, it does not present any potential risk for the participants. Thus, it is exempted from approval by a research ethics committee (Resolution 466/2012 of the National Health Council).

3. Results

In the municipality of Natal, 31,368 cases of scorpion accidents were reported between 2007 and 2018, with an average annual incidence of 309.35 during this period. The scorpion sting cases increased from 1286 in 2007 to 3600 in 2018, revealing an upward trend ($F = 107.3$; $r = 0.9148$; $p < 0.001$) (Fig. 1).

Scorpion accidents in Natal occurred in all months of the years studied, most frequently in September ($n = 1858$; 9.04 %), May ($n = 1825$; 9.48 %), and March ($n = 1841$; 8.33 %). The least frequent months were February ($n = 1551$; 7.55 %) and November ($n = 1536$; 7.47 %). Fifteen deaths were reported during the investigated period, being 2017 the year with the highest lethality rate (0.46 %, n = 4), followed by 2012 (0.37 % n = 3). The humidity was correlated with the increase in the number of cases between 2007 and 2018 ($R = 0.7$; $p < 0.04$) (Fig. 2) and the temperature showed a low ratio with the increase in annual cases ($R = 0.46$; $p < 0.04$).

The spatial analysis revealed a great dispersion of the distribution of hotspots in the municipality of Natal. The relationship between scorpion accidents and humidity and less urbanized regions showed no statistical significance (Fig. 3A and C). The regions with the lowest HDI revealed a high rate of scorpionism (Fig. 3B). The main hotspots were in the following neighborhoods: Quintas (2027.39 by 100,000 inhabitants), Alecrim (1780.18 by 100,000 inhabitants), Dix-sept Rosado (1446.87 by 100,000 inhabitants), Rocas (1320.32 by 100,000 inhabitants), and Bom Pastor (1316.94 by 100,000 inhabitants) (Fig. 3D). It was observed that in the analysis of excess risk between incidence and HDI, for the Quintas and Alecrim neighborhoods this value was high (OR: 2 %–4 %).

Most cases of scorpion stings involved women ($n = 19,657$; 62.67 %). Despite the non-statistical significance, the risk of dying was 1.5 times higher in men (*CI*: 0.5326–4.0526). The age group most affected were those 20–29 years old ($n = 5817$; 18.54 %), followed by those 30–39 years old ($n = 4992$; 15.91 %). The age group from 50 to 59 years old were 1.9 times more likely to die than the others, however these data did not show statistical relevance (*CI*: 0,2588–14,9744). The majority of scorpion stings reached the finger ($n = 8283$; 26.4 %) and foot ($n = 8281$; 26.4 %), although the toe bite exhibited a higher risk of causing the individual to die but with no statistical significance (1.124; *CI*: 0.2535–4.9821). The cases occurred mainly in the urban area ($n = 30,461$; 97.11 %). However, the

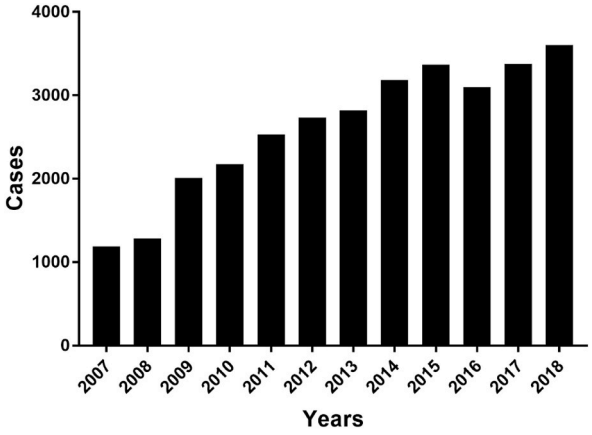

Fig. 1. Annual distribution of scorpion accidents between 2007 and 2018.

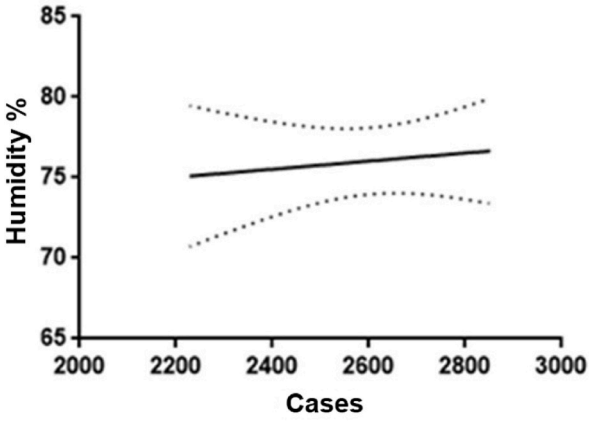

Fig. 2. Analysis of the correlation of the humidity of bites by scorpions between 2007 and 2018. The dashed points represent the confidence interval of the relationship between the variation in humidity and the number of accidents caused by scorpions.

rural area showed a risk of 1969 times higher of death but showed no statistical significance (0.458–8.458). Regarding occupation, most of the victims were housewives ($n = 4646$; 14.81 %), students ($n = 4005$; 12.77 %) and retirees ($n = 2295$; 7.32 %), and most accidents were not related to work ($n = 20{,}736$; 66.11 %). With regard to education, 18.12 % had completed high school ($n = 5685$) and 18.12 % had completed elementary school ($n = 3746$) (Table 1).

Victims of scorpionism arrive at the place of medical care predominantly in the first 3 h after the incident ($n = 12244$; 39 %). The time between the sting and the first medical visit was more associated with mild and moderate clinical conditions ($X^2 = 50.445$; $p < 0.05$). Most patients revealed mild symptoms of poisoning ($n = 30{,}232$; 96.38 %), with a predominant clinical progression towards cure ($n = 30{,}232$; 96.38 %). During the period from 2007 to 2018, 15 deaths were reported, resulting in a lethality rate of 0.1 %. Anti-scorpion serum was administered to 346 patients (1.1 %), with 2–4 ampoules applied in most patients ($n = 115$; 33.24 %) and most classified as the moderate clinical picture. An average of 33 ampoules was used per year (Table 2).

Local symptoms were observed in 30,013 scorpion sting victims (95.7 %), with the most frequent local symptoms being pain ($n = 34{,}000$; 96.25 %), numbness ($n = 12{,}977$; 36.74 %) and edema ($n = 11{,}320$; 32.05 %). Patients who manifested numbness were more associated with severe clinical conditions and their risk of dying was 11.04 times higher than that for the others (1.481–82.269, $p < 0.05$). In addition, the risk of a patient with numbness evolving to a severe clinical condition was 3.14 times higher (1.412–6.981, $p < 0.05$). Patients who exhibited pain were 4.6 times more likely to die (1.350–15.760, $p < 0.05$). As can be seen in Fig. 4, local symptoms most associated with mild clinical conditions were pain, heat, burning, hyperemia, paresthesia, and edema. The network analysis confirms that numbness was the local symptom most associated with severe clinical conditions, being the edema ($n = 7$; 63.64 %) the most common local complication.

The systemic symptoms were observed in 4333 scorpion sting victims (13.81 %), being frequently described headache ($n = 1306$; 28.89 %), hyperthermia ($n = 861$; 19.05 %) and sweating ($n = 683$; 15.11 %). The symptoms most associated with severe clinical conditions were acute lung edema ($X^2 = 811.760$; $p < 0.05$) and drowsiness ($X^2 = 60.628$; $p < 0.05$). According to the network analysis (Fig. 4), it is possible to observe that symptoms such as dyspnea ($X^2 = 14.899$; $p < 0.05$), hypoesthesia ($X^2 = 5.052$; $p < 0.05$) and agitation ($X^2 = 8.554$; $p < 0.05$) were most associated with moderate and severe clinical conditions. The main systemic complications were anaphylactic shock ($n = 4$; 36.36 %), renal failure ($n = 4$; 36.64 %) and septicemia ($n = 1$; 9.09 %) (Fig. 4).

4. Discussion

Scorpionism is a public health problem in Brazil, and epidemiological research is an essential approach to identify the factors involved in scorpion stings, allowing direct effective public policies to prevent and control scorpion accidents [2]. This study reports a progressive increase in the number of notifications involving scorpion animals between 2007 and 2018 in Natal, revealing an average annual incidence of 309.35 cases per 100 thousand inhabitants and a mean annual mortality rate of 0.4 %.

In Ponta Grossa [25] and Belo Horizonte [26], municipalities of the state of Minas Gerais in the southeastern region of Brazil [27], the annual incidence of scorpion accidents was 309.35 and 114.7/100 thousand inhabitants (2005–2009), respectively, showing a lower incidence when compared to Natal. The results obtained in this study showed that Natal has endemic characteristics, revealing a tendency to increase in the number of cases of scorpion stings. This growth of accidents in Natal may be related to the existence of conditions that facilitate the proliferation of scorpions, such as the presence of rubble, garbage, high population density, abundant food, absence of natural predators, lack of basic sanitation, among others [12], which are still characteristic features in the region. Therefore, it is necessary to develop health actions using constructive health monitoring and management tools to reduce the number of cases of scorpion stings [28].

Our results showed a moderate correlation between humidity and the number of cases of accidents by scorpions (Fig. 1) in the years 2007, 2009, and 2013, and no correlation with temperature variation, indicating that high temperatures with low variations

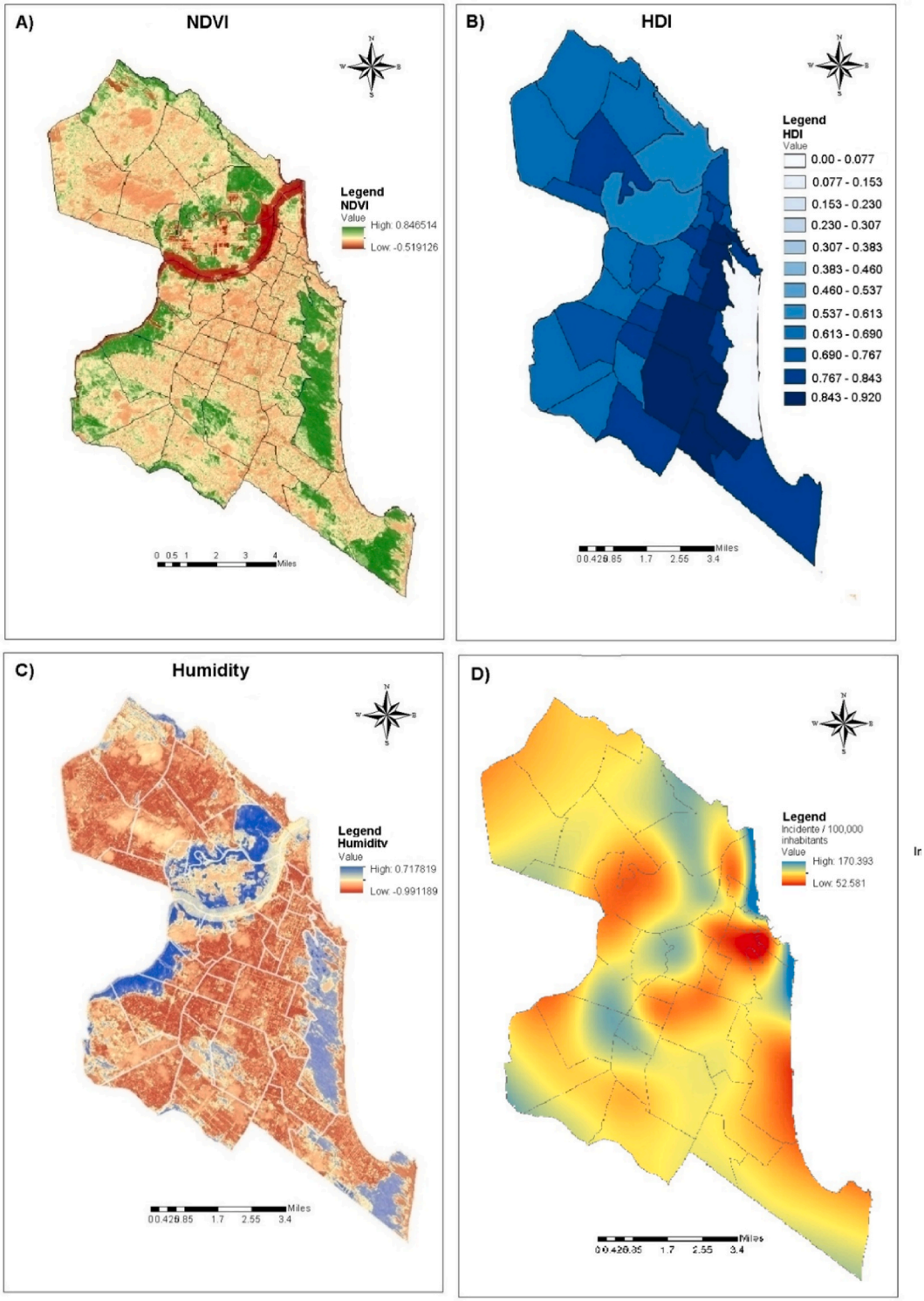

Fig. 3. Normalized Difference Vegetation Index (NDVI) (**A**), Human Development Index-Longevity (HDI-L) (**B**), Humidity (**C**) and spatial distribution of scorpion accidents in the municipality of Natal between 2007 and 2018 (**D**).

throughout the year and the presence of humidity are favorable conditions for the survival of scorpions. These data corroborate with the research carried out by Taj et al. [29], which showed that scorpions become more active in the warmer months, and consequently increase the number of accidents [28]. However, in contrast when comparing our results, a relation to humidity in the Northwest of

Table 1
Sociodemographic characteristics of scorpion accidents in the municipality of Natal, from 2007 to 2018.

Sex	*(n)*	*(%)*
Female	19,657	62.67
Male	11,710	37.33
Unknown	1	0
Age (years)		
0 ├ 9	3371	10.75
10 ├ 19	4177	13.32
20 ├ 29	5817	18.54
30 ├ 39	4992	15.91
40 ├ 49	4707	15.01
50 ├ 59	3866	12.32
60 ├ 69	2529	8.06
<70	1909	6.09
Area of occurrence		
Urban	30,461	97.11
Rural	533	1.7
Periurban	43	0.14
Unknown	331	1.06
Occupation		0
Housewife	4646	14.81
Student	4005	12.77
Retiree/Pensioner	2295	7.32
Merchant	988	3.15
General services	391	1.25
Bricklayer	476	1.52
Dressmaker	288	0.92
Other workers	5720	18.24
Work-related accident		
Yes	545	1.74
No	20,736	66.11
Ignored	10,087	32.16
Anatomical site		
Head	434	1.38
Arm	845	2.69
Forearm	598	1.91
Hand	3112	9.92
Finger	8283	26.41
Stem	1305	4.16
Thigh	1049	3.34
Leg	1035	3.3
Foot	8281	26.4
Toe	4624	14.74
Ignored	1802	5.74

Table 2
Victims of scorpion sting treated with serotherapy and the number of ampoules administered in Natal, from 2007 to 2018.

Serotherapy	*(n)*	*%*
Yes	346	1.1
No	29,586	94.32
Ignored	1436	4.6
Total	31,368	100.0
Number of ampoules per number of patients		
Total used ampoules	**(*n*)**	**Total**
1	42	42
2	120	240
3	41	123
4	47	188
5	2	10
6	2	12
8	5	40
Total		1102

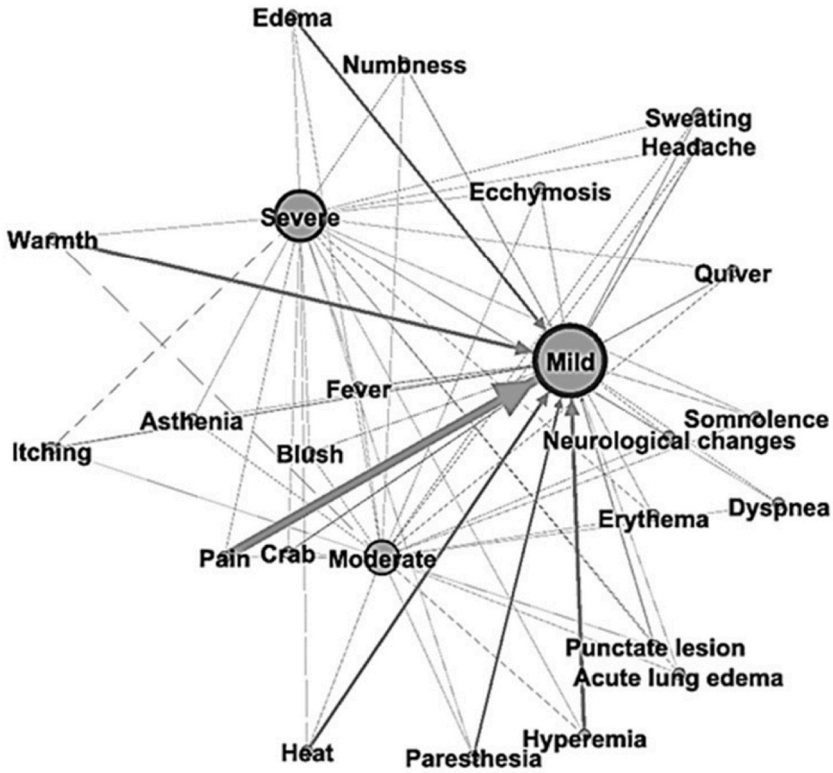

Fig. 4. Correspondence complementary network analysis between local and systemic symptoms and severity of clinical conditions.

Belo Horizonte (Minas Gerais) and in regions of Atlantic Forest that in the warmer months there is an increase in accidents [26,30].

Santos [31] described that the geographic space is the set of intertwined relationships between functions and forms, corroborating with Max Sorre's theory of the pathogenic complex, describing the relationships between an external environment that varies and an internal environment that needs to adapt to maintain its physiological constants. In this context, the spatialization of accidents can be affected by type of environment, food resources, and the marked difference in climate and predominant species [32]. The spatial distribution of cases in Natal was heterogeneous, with a predominance of scorpion stings in neighborhoods with low HDI when compared to the other regions evaluated in this approach. This showed characteristics conducive to the highest risk of accidents, such as the disorderly occupation of the space with poor health, inadequate environmental sanitation, and low levels of development of basic education [17]. On the other hand, the spatial distribution of accidents was not similar to that found in Salvador, Bahia, which had a wide distribution of cases across the municipality [33]. Also, the scorpion's behavior, economic and educational conditions can be risk factors for the accident, corroborating with data from other studies already carried out, as in the states of Ceará [12], Minas Gerais [34], Pará [35], and in other countries as Turkey [36], Arab countries [37] and Mexico [38]. In this approach, no relationship was found between the distribution of scorpion sting cases and the regions with the greatest presence of afforestation or closed forest, which may be associated with a lower population occupation rate in these areas. In the literature, it is reported that seasonality can influence the spatial distribution of accidents with venomous animals; an example is the Brazilian Atlantic Forest, in which rainfall can promote the growth or flooding of regions by modifying the distribution of scorpions. A similar effect occurs in the Caatinga, since in the rainy season there is an increase in the movement of insects restricted to wet locations during the dry season [30].

The accidents by scorpions predominantly involved women in the municipality of Natal, but the greatest risk of complications occurs in men. In the literature, the fact that women are more affected by scorpion stings has been reported in the Northeast of Brazil, such as the states of Ceará [12] and Piauí [39,40], corroborating with our data. In the state of Pará, located in the Northern region of Brazil, it was found that there is a difference in the sex most affected by scorpionism and that men are more subject to the accident [27]. In addition, the high severity found among the elderly victims of scorpion accidents can be attributed to the sensitivity to toxins due to immunosenescence, as well as the reduction of enzymes and endocrine functions, which make the elderly more vulnerable to scorpion toxins [41].

The high ecological plasticity and parthenogenetic reproduction of scorpions combined with the abundant presence of food and the lack of predators in the urban environment are characteristics that explain the higher occurrence of accidents in urban areas of the municipality of Natal [32]. On the other hand, it was observed that individuals living in rural areas presented a higher risk of progression to death. This fact may be related to the distance between the place where the accident occurred and the hospital specialized in care (Giselda Trigueiro Hospital, Natal, Rio Grande do Norte, Brazil) as well as the centralization of the distribution of anti-scorpion serum [5]. In the municipality of Natal, the victims stung by scorpions who sought specialized medical care exhibited a more severe

clinical picture and a higher propensity to die. These findings reaffirm the importance that rapid medical care is important to reduce patient lethality [12]. In Natal, the anatomical regions of the body most affected by scorpion stings were the feet and fingers. However, scorpion stings on the toes had a higher risk of evolving to death, in contrast to the study by Araújo et al. (2017) [5], which reported a higher risk of death when the sting reached regions close to organs.

The most affected individuals by scorpion stings in Natal manifested pain, numbness, and edema, symptoms associated with mild clinical conditions. Similar results were observed in the Southern Region of Amazonas [42] and the state of Ceará in Northeastern Brazil [12]. In the scientific approach, it is reported that scorpion venoms have the ability to stimulate the neuroendocrine immunological axes, mobilizing leukocytes and releasing catecholamines, corticosteroids, bradykinin, and prostaglandins that result in the occurrence of these local symptoms [43]. Symptoms such as numbness have been more associated with the development of moderate to severe clinical conditions, with the risk of dying 11.04 times higher. Bearing in mind that numbness is one of the first symptoms to be exhibited by scorpion sting victims [43], this study suggests that it is an early symptom for the classification of moderate and severe clinical conditions.

5. Conclusion

Accidents due to scorpion stings in Natal are more frequent in urban areas with a low Human Development Index, higher humidity, and little vegetation, suggesting that the HDI may be a suitable predictor of areas at risk of accidents by scorpions in Natal. The data reveal an epidemiological profile prevalent in women in the economically active age group, in which the majority of victims seek medical care within 3 h after the accident. The temporal analysis revealed a significant increase over the years, indicating the need for more effective public measures for the prevention and control of scorpionism, especially in the areas of greater risk. More epidemiological studies in other regions of the city of Natal are necessary in order to characterize the panorama of scorpionism in the Rio Grande do Norte state.

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Data availability statement

Data will be made available on request.

CRediT authorship contribution statement

Kaliany Adja Medeiros de Araújo: Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Manoela Torres-Rêgo:** Writing – original draft, Conceptualization. **Thaynara Gurgel-Medeiros:** Writing – original draft, Conceptualization. **Arnóbio Antônio da Silva-Júnior:** Writing – original draft, Conceptualization. **Renner de Souza Leite:** Writing – review & editing, Formal analysis, Conceptualization. **Alessandra Daniele-Silva:** Writing – original draft, Conceptualization. **Matheus de Freitas Fernandes-Pedrosa:** Writing – review & editing, Supervision, Resources, Project administration, Funding acquisition, Formal analysis, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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