ORIGINAL ARTICLE

Ecological association between socioeconomic, occupational and sanitation factors and the occurrence of scorpionism in Brazil, 2007-2019*

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Abstract

Objective: To analyze ecological association between socioeconomic, occupational and sanitation characteristics and scorpionism in Brazil. **Methods:** This was an ecological study with data on scorpion sting accidents reported on the Notifiable Health Conditions Information System (2007-2019). Negative binomial regression was used to estimate incidence rate ratios (IRR) and confidence intervals (95%CI). **Results:** In the study period there were 1,079,333 scorpion sting accidents, with a cumulative incidence rate of 41.5/100,000 inhabitants. In the adjusted analysis, there was association with the municipal percentages of: women (IRR=1.65 – 95%CI 1.18;2.30) and men (IRR=0.90 – 95%CI 0.88;0.91) working in the construction industry, women (IRR=1.21 – 95%CI 1.18;1.25) and men (IRR=0.73 – 95%CI 0.69;0.77) working in domestic service, women (IRR=1.03 – 95%CI 1.02;1.04) and men (IRR=0.93 – 95%CI 0.92;0.93) working in farming, households with refuse collection (IRR=0.99 – 95%CI 0.98;0.99) and households with refuse left nearby (IRR=1.02 – 95%CI 1.01;1.02), expected years of schooling (IRR=0.88 – 95%CI 0.83;0.92), and unemployment rate (IRR=1.07 – 95%CI 1.05;1.09). **Conclusion:** Scorpionism was associated with precarious infrastructure/sanitation, job availability, education and female occupation.

Keywords: Scorpion Sting; Social Determinants of Health; Epidemiology; Ecological Studies; Occupational Health.

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Introduction

Scorpion poisoning, or scorpionism, is estimated to be responsible for 1.5 million new cases and 2,600 deaths worldwide every year.[1] In Latin America, mainly in Mexico, Brazil, Guyana and Venezuela, simultaneous high incidence and clinical severity is attributed to scorpions of the *Tityus* and *Centruroides* genera.[2] In Brazil, severe cases are related to four species of medical importance: *T. serrulatus*, *T. obscurus, T. bahiensis* and *T. stigmurus*.[3] The *T. serrulatus* species stands out for its toxicity and abundance in urban environments.[2]

> *Justifications put the blame on individuals for this health condition and do not explore the role of social determinants of health, such as socioeconomic, occupational and poor infrastructure/ sanitation aspects.*

In Brazil, in the decade between 2007 and 2017, there was a 234.4% increase in scorpion sting accidents, from 37,370 (2007) to 124,982 cases (2017).[4] Cases are usually more frequent among males aged 20 to 49 years, with 4 to 7 years of schooling, stung in the upper limbs, and living in urban areas, while deaths are more frequent among males aged up to 9 years, and among individuals stung in rural areas.[5]

Scorpions are small, cosmopolitan, carnivorous, nocturnal, synanthropic arthropods whose prey can be anything from other scorpions to insects, such as crickets, grasshoppers, termites and cockroaches.[2] During foraging, scorpions seek prey located in accumulated organic matter and debris; and in houses, where they can hide in dark places like crevices, between clothes and inside shoes.[2,6]

Because of these behavioral characteristics and feeding preferences of scorpions, scorpionism is also related to people's individual attitudes, which contribute to the occurrence and permanence of this arachnid in the environment, such as letting refuse accumulate and not performing prophylactic actions: i.e. failure to use personal protective equipment and inspect clothing.[6] However, these justifications put the blame on individuals for this health condition and do not explore the role of social determinants of health, such as socioeconomic, occupational and poor infrastructure/sanitation aspects, identified in the epidemiological profiles of scorpionism.[5,7-9]

Despite the accumulation of evidence about people's individual aspects that favor the occurrence of scorpion sting accidents, the role played by the jobs they do and other municipal descriptors capable of interfering in the occurrence of this health condition remain unexplored.

In view of this scenario, the objective of this study was to analyze ecological association between socioeconomic, occupational and infrastructure/ sanitation characteristics and occurrence of scorpionism in Brazil.

Methods

This is an ecological study on the occurrence of scorpionism, taking the Brazilian municipalities as its units of analysis.

Located in South America, in 2020 Brazil covered an area of approximately 8,510,295.914 km^2, with 211,049,519 inhabitants, demographic density of 25.25 inhab./km^2 and 5,570 municipalities distributed over its five geographic macro-regions: Northeast, North, Midwest, Southeast, and South. The country borders 11 other countries and has a vast coastal area along the Atlantic Ocean. Most of the Brazilian population resides in urban areas (86.8%) and has a life expectancy of around 75.9 years.[10]

Only municipalities that had become independent before 2007 were eligible for the study, so that all municipalities covered by the study were in existence right from the first year of the study period. Six municipalities were not included in this research because they became independent after 2007.

The Notifiable Health Conditions Information System comprised the data source for reported scorpionism cases. The municipal variables were obtained from the 2010 Demographic Census, conducted by the Brazilian Institute of Geography and Statistics (IBGE), and the population estimates were also provided by IBGE (Box 1). All data sources were accessed electronically, on August 20, 2020.[11,12]

This study's outcome variable was the cumulative number of scorpionism cases registered between 2007 and 2019 in each Brazilian municipality. The cumulative number of records was used to increase case-by-case assessment and avoid distortions in case reporting due to turnover in the teams responsible for reporting them. Accidents that occurred before 2007 were not selected, due to changes made in 2006 to the Notification Form for Accidents Involving Venomous Animals, used on the Notifiable Health Conditions Information System.

Municipal independent variables or descriptors were selected so as to take into consideration structural determinant categories (municipal occupation and socioeconomic descriptors) and intermediate determinants (infrastructure/sanitation descriptors) of the Social Determinants of Health model adopted by Solar & Irwin.[13]

The independent variables were summarized according to measures of central tendency (average and median) and dispersion (standard deviation; minimum and maximum values). The factors associated with cumulative scorpionism cases occurring in Brazilian municipalities between 2007 and 2019 were analyzed using negative binomial regression, since the outcome variable presented overdispersed count data, identified by alpha>0 in the multivariate regression (alpha=2.33).[14] The geographic macro-region of occurrence (North, Northeast, Southeast, Midwest or South) was included as an adjustment variable in both the bivariate and the multivariate regression analysis.

Negative binomial regression assumes that $\mu_j=\exp(ß x_j+\text{offset}_j)$, where **μ** is the average occurrence of accidents, **ß** is the regression coefficient and **x** is the covariable. The estimated regression coefficients were transformed into incidence rate ratios (IRR), given that $IRR=\exp^{ßi}$. The cumulative population estimates for each municipality, between 2007 and 2019, were logarithmized and included as an offset variable, i.e., an offset factor of total cases that allows model counts such as IRR.[11,14]

Based on the "forward" selection method, the independent variables were included in the multivariate model when they had a 95% confidence interval (95%CI), statistical significance of 5% (p-value<0.05) and a reduction in the value of the Akaike information criterion (AIC) after including new variables, as well as theoretical consistency according to the scientific literature, so as to avoid spurious association.[15]

None of the variables selected for the final model were left out by the program used to perform the analysis, indicating that there was no multicollinearity. In addition, a correlation matrix with the multivariate regression coefficients was plotted to further check for multicollinearity. The factor used to identify multicollinearity was high correlation (≥0.9).[16]

The negative binomial regression model fit was checked using the Tukey-Pregibon goodness-of-link test, using linear squared predicted values (_hatsq), taken not to be statistically significant at a level of 5% (p-value>0.05).[14] All steps described in the analysis of associated factors were processed using the Stata version 16.0 statistical program.

The research project was approved by the Federal University of Bahia Institute of Public Health Research Ethics Committee: Opinion No. 1.370.415/2015, issued on December 16th 2015.

Results

According to the records held on the Notifiable Health Conditions Information System, between 2007 and 2019, there were 1,079,333 scorpion sting accidents in the 5,564 municipalities investigated, representing an average of 194.0 cases (standard deviation=1,017.9; minimum value=0 and maximum value=41,523) and cumulative incidence of 41.5/100,000 hab. per municipality. About 25%, 50% and 75% of the municipalities investigated recorded, respectively, a total of 5, 29 and 118 cases in this period, indicating a pattern of high scorpionism (outcome variable) case count dispersion.

Of the total number of accidents in the country, in the selected period (2007-2019), 46% (495,252) occurred in the Brazilian Northeast, 43% (459,819) in the Southeast, 5% (53,391) in the Midwest, 4% (44,475) in the North, and 2% (26,396) in the South. In the same period, a 311% increase was seen in the number of reported cases, rising from 37,347 in 2007 to 153,641 in 2019 (Figure 1).

The measures of central tendency and dispersion of the 17 variables of the investigated municipalities are described in Table 1. In the bivariate negative binomial regression analysis, 15 of these variables had significant association with the outcome.

Box 1 – Municipal descriptors and variables selected for analysis of factors associated with total scorpion sting accidents in Brazilian municipalities

Municipal descriptor	Municipal variables	Description of municipal variables
Occupational	Men working in domestic service	Percentage of men working in domestic service
	Women working in domestic service	Percentage of women working in domestic service
	Men working in farming	Percentage of men working in farming
	Women working in farming	Percentage of women working in farming
	Men working in the construction industry	Percentage of men working in the construction industry
	Women working in the construction industry	Percentage of women working in the construction industry
Socioeconomic	Annual per capita income	Average income per person (currency: BRL)
	Poor population	Percentage of the population in a situation of poverty
	Human development index (HDI)	HDI expressed as a percentage
	Social vulnerability index (SVI)	SVI expressed as a percentage
	Illiteracy rate	Percentage of the illiterate population aged ≥18 years
	Expected number of years of schooling	Average number of years of schooling that a generation of children would have at 18 years
	Unemployment rate	Percentage of unemployed people of economically active age
Infrastructure/ Sanitation	Households with water supply	Percentage of households with water supply
	Households with refuse collection	Percentage of households with refuse collection
	Households with refuse left nearby	Percentage of households with refuse left nearby
	Households with sewage nearby	Percentage of households with sewage nearby

Source: Brazilian Institute of Geography and Statistics (IBGE), 2010 Demographic Census.

In the multivariate regression model, 10 independent variables remained strongly associated with the occurrence of scorpionism: (i) percentage of men working in the construction industry (IRR=0.90 – 95%CI 0.88;0.91); (ii) percentage of women working in the construction industry (IRR=1.65 – 95%CI 1.18;2.30); (iii) percentage of men working in domestic service (IRR=0.73 – 95%CI 0.69;0.77); (iv) percentage of women working in domestic service (IRR=1.21 – 95%CI 1.18;1.25); (v) percentage of men working in farming (IRR=0.93 – 95%CI 0.92;0.93); (vi) percentage of women working in farming (IRR=1.03 – 95%CI 1.02;1.04); (vii) percentage of households with refuse collection (IRR=0.99 – 95%CI 0.98;0.99); (viii) percentage of households with refuse left nearby (IRR=1.02 – 95%CI 1.01;1.02); (ix) expected number of years of schooling (IRR=0.88 – 95%CI 0.83;0.92); and (x) unemployment rate (IRR=1.07 – 95%CI 1.05;1.09) (Table 2).

According to the results of the matrix of correlation between the negative binomial regression coefficients (Table 3), no multicollinearity was identified between the variables of the adjusted model. The final model (AIC =58,766.11) showed a better data fit, compared to the bivariate model (AIC=59,978.13), formed by the outcome and the variable with the highest association in the bivariate analysis (percentage of women working in the construction industry). Additionally, the non-statistically significant result at the 5% level for the Tukey-Pregibon goodness-of-link test (hatsq=0.004 - p-value=0.707) indicated the good fit of the adjusted model to the negative binomial regression model.

Discussion

The results of this study demonstrate directly proportional association between scorpionism incidence in Brazil and the following municipal descriptors: percentage of households with refuse left nearby; unemployment rate; and percentage of women working in the construction industry, domestic service and farming. Inversely proportional association was

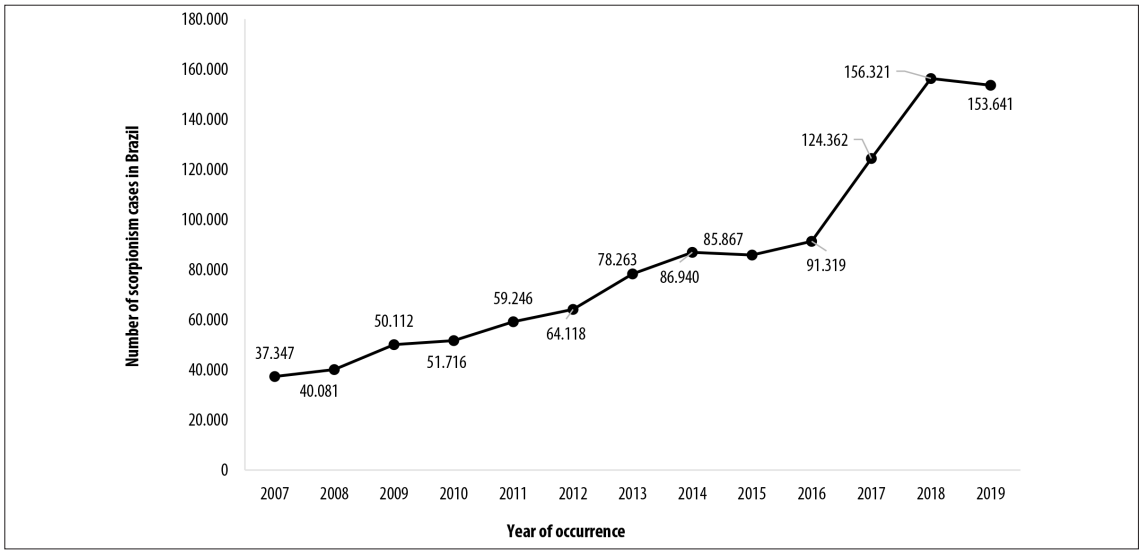

Figure 1 – Absolute frequencies of scorpionism cases reported in Brazil, 2007-2019

Table 1 – Socioeconomic, infrastructure/sanitation and occupational characteristics of 5,564 Brazilian municipalities, 2010

Municipal variables	Average percentage	Median percentage	Standard deviation	Minimum	Maximum
Occupational (%)					
Men working in the construction industry	6.22	5.81	2.90	0.11	24.22
Women working in the construction industry	0.13	0.08	0.16	0.00	1.57
Men working in domestic service	0.57	0.36	0.75	0.00	12.13
Women working in domestic service	5.53	5.39	2.26	0.00	19.85
Men working in farming	25.96	27.48	12.68	0.01	65.61
Women working in farming	10.13	8.66	7.34	0.00	37.73
Infrastructure/sanitation (%)					
Households with refuse collection	70.26	74.10	21.85	0.00	100.00
Households with water supply	69.10	72.60	19.93	0.00	100.00
Households with refuse left nearby	3.31	0.86	6.24	0.00	90.43
Households with sewage nearby	12.96	2.24	22.22	0.00	100.00
Socioeconomic					
Illiteracy rate (%)	17.40	14.11	10.70	0.97	47.64
Expected number of years of schooling (average)	9.46	9.47	1.10	4.34	12.83
Human development index (HDI) (%)	65.97	67.00	7.21	42.00	86.00
Social vulnerability index (SVI) (%)	35.16	33.40	13.01	9.00	78.40
Poor population (%)	23.20	18.12	17.92	0.00	78.59
Annual per capita income (currency: BRL)	493.65	467.74	243.27	96.25	2,043.74
Unemployment rate (%)	6.19	5.66	3.66	0.00	38.45

Table 2 – Bivariate and multivariate negative binomial[a] regression models, for factors associated with 1,079,333 scorpionism cases reported in 5,564 Brazilian municipalities, 2007-2019

Independent municipal variables	Bivariate			Multivariate		
	IRR[b]	Standard error	95%CI[c]	IRR[b]	Standard error	95%CI[c]
Occupational (%)						
Men working in the construction industry	1.16	0.01	1.14;1.19	0.90	0.01	0.88;0.91
Women working in the construction industry	31.44	5.55	22.24;44.45	1.65	0.28	1.18;2.30
Men working in domestic service	0.84	0.02	0.79;0.89	0.73	0.02	0.69;0.77
Women working in domestic service	1.39	0.02	1.35;1.42	1.21	0.02	1.18;1.25
Men working in farming	0.95	0.00	0.94;0.95	0.93	0.00	0.92;0.93
Women working in farming	0.92	0.00	0.92;0.93	1.03	0.01	1.02;1.04
Infrastructure/sanitation (%)						
Households with refuse collection	1.03	0.00	1.02;1.03	0.99	0.00	0.98;0.99
Households with water supply	1.03	0.00	1.03;1.03			
Households with refuse left nearby	1.07	0.01	1.05;1.08	1.02	0.00	1.01;1.02
Households with sewage nearby	1.00	0.00	0.99;1.00			
Socioeconomic						
Illiteracy rate (%)	0.93	0.00	0.93;0.94			
Expected number of years of schooling (years)	1.27	0.03	1.20;1.34	0.88	0.02	0.83;0.92
Human development index (HDI) (%)	1.11	0.00	1.10;1.11			
Social vulnerability index (SVI) (%)	0.96	0.00	0.96;0.97			
Poor population (%)	0.96	0.00	0.96;0.96			
Annual per capita income (currency: BRL)	1.00	0.00	1.00;1.00			
Unemployment rate (%)	1.20	0.01	1.18;1.22	1.07	0.01	1.05;1.09

a) Estimated associations were adjusted by the geographic macro-region in which the accident occurred; b) Incidence rate ratio (IRR); c) 95%CI: 95% confidence interval.
Note: All the multivariate regression variables were statistically significant ($p<0.05$).

observed between scorpionism incidence and the following municipal descriptors: expected number of years of schooling; percentage of households with refuse collection; and percentage of men working in the construction industry, in domestic service and in farming.

In Brazil, scorpion poisoning is reported with greater frequency in the home environment and the environment immediately surrounding the home, thus predisposing women working in domestic services to this health condition.[17] Due to historical and social influences, the role of women in society is still linked to doing domestic activities,[18] which have been related to scorpionism for more than 50 years in Brazil.[17,19] However, this is the only study which has measured in an aggregated manner association between domestic service and scorpion poisoning.

The study showed that women were more vulnerable to scorpionism in all the Brazilian municipalities surveyed: an increase of 1% in the number of women working in domestic service was associated with a 21% increase in the incidence of scorpionism cases. The vulnerability of these workers has already been discussed in a study carried out in the city of Salvador, BA, based on scorpionism cases that occurred between 1982 and 2000.[17] Despite its frequently benign outcome in adults, this health condition leads to suffering, such as intense pain at the site of the sting, and can lead to clinical severity, especially in older adults or those with comorbidities, such as diabetes mellitus and hypertension.[20,21]

In the environment outside the household, other occupations related to scorpionism have been identified, such as the construction industry and rural work.[22,23] In this study, the 'percentage of

Table 3 – Matrix of correlation between the coefficients of the negative binomial multivariate regression model, for factors associated with 1,079,333 scorpionism cases reported in 5.564 Brazilian municipalities, 2007-2019

Variable	Working in the construction industry (%)		Working in domestic service (%)		Working in farming (%)		Households with refuse collection (%)	Households with refuse left nearby (%)	Expected number of years of schooling	Unemployment rate (%)
	Men	Women	Men	Women	Men	Women				
Men working in the construction industry (%)	1.00									
Women working in the construction industry (%)	-0.12	1.00								
Men working in domestic service (%)	0.09	-0.20	1.00							
Women working in domestic service (%)	0.08	0.03	-0.12	1.00						
Men working in farming (%)	0.04	0.07	0.29	0.10	1.00					
Women working in farming (%)	0.26	0.27	0.07	0.04	-0.33	1.00				
Households with refuse collection (%)	0.03	0.19	-0.02	0.12	0.30	0.51	1.00			
Households with refuse left nearby (%)	-0.05	0.01	-0.03	-0.06	-0.03	0.14	0.11	1.00		
Expected number of years of schooling	-0.01	0.06	0.02	0.03	-0.04	0.15	-0.14	0.07	1.00	
Unemployment rate (%)	0.01	-0.12	-0.04	0.00	0.18	0.00	-0.04	-0.09	0.11	1.00

women working in the construction industry' variable showed direct association with cumulative incidence of scorpionism cases in the Brazilian municipalities. The same was not found for the 'percentage of men working in the construction industry', which showed an inverse relationship.

Presence of rubble on building sites is constant, and workers in this sector are susceptible to the presence of scorpions that use this waste material for shelter.[24] Historically, the construction industry labor market has been dominated by men, preserving the socially inherited influence of the ways of working destined to each gender. Despite women entering the construction industry, they tend to do jobs such as cleaning and catering, when they do not have the qualifications necessary for more prestigious professions such as engineering and architecture.[25] It is to be expected that women will be closer to piles of building waste, which scorpions use as shelter.

In certain regions, such as in the state of Amazonas, scorpionism is more frequently reported in rural areas.[26] The rural environment is also favorable to the proliferation of scorpions when there are places for them to shelter (e.g., piles of organic matter, debris, garbage, warehouses and stores) and food (e.g., cockroaches, termites, crickets, insect larvae and spiders).[6] Closeness to these places and failure to use personal protective equipment can result in rural workers being at risk of accidents involving scorpions. In the case of female rural workers, risk of these accidents is expected to be greater, given their increased exposure resulting from doing both agricultural and domestic activities.[27]

Socioeconomic and infrastructure/sanitation factors also need to be considered and incorporated into scorpion poisoning protection strategies in Brazilian municipalities. According to the findings of this investigation, adding one year to the 'expected number of years of schooling' of the municipal

population was associated with a 12% reduction in the incidence of scorpion stings.

The relationship between scorpion poisoning and educational aspects has been mentioned in other studies, according to which scorpionism was directly related to illiteracy – in the accidents that occurred in Brazil between 2001 and 2012 – or was more frequent in individuals with less education – also in the cases that occurred in Brazil between 2001 and 2012.[5,7]

Education is a social determinant of health that contributes to the improvement of living conditions because, indirectly, it facilitates having better paid jobs, thus ensuring access to quality health services and housing with good infrastructure/sanitation.[13]

Supporting the findings for education, the incidence of scorpion accidents in Brazilian municipalities was shown to be directly associated with the municipal unemployment rate. Being employed is an important source of income, implies access to the minimum necessities for survival, and can impact health and nutrition conditions.[13] Difficulty in obtaining consumer goods and services is often related to housing with precarious infrastructure/sanitation services, this being a favorable scenario for scorpions.[13,28] It is well known that parental unemployment can influence child malnutrition and increased incidence of low weight for age, this being one of the determinants of the occurrence of severe scorpionism symptoms and mortality among children.[28,29]

Disposal of household refuse in the municipal environment was related to the occurrence of scorpionism. Accumulation of refuse favors the appearance of scorpions, as it provides food and shelter.[2] Cockroaches and other small insects are part of the main diet of scorpions, and are found in abundance in places with periodic accumulation of organic waste, as usually occurs in areas with poor infrastructure/sanitation.[2,6] Establishing environments with good bio-sanitary conditions, free from food and water sources for insects, can be an important strategy for reducing the proliferation of the medically important species *T. serrulatus*, which also figures as an urban pest in Brazil.[2,30]

This research was conducted using secondary data from the Notifiable Health Conditions Information System, which is known to be prone to data completion errors, as well as reporting problems. However, there are advantages in using secondary data, such as lower cost and studies being conducted more quickly. The ecological study design, adopted in this investigation, prevents causal inferences from being made in relation to the associated factors identified. However, its exploratory nature allows the formulation of hypotheses to be investigated. Furthermore, because this is an ecological study that used existing data, lack of availability of relevant information from secondary sources limited the analysis, making it impossible to explore other factors, such as the spatial distribution, richness, and abundance of scorpion species, which could influence scorpionism being recorded.

We conclude that addressing the occurrence of scorpion sting accidents – which have been increasing in recent years – demands improvements in infrastructure/sanitation conditions, in education indicators, and in the availability of jobs that indirectly facilitate access to good bio-sanitary conditions in households. This study also brings evidence that scorpion sting accidents could be related to the type of work/occupation that women do.

This set of information should be used in municipal service management, as a demand in relation to health, as well as in agendas related to education and economic development, because it appears to be intrinsically linked to the occurrence of scorpion poisoning.

Author contributions

Almeida ACC and Mise YF contributed to the concept and design of the study, data analysis and interpretation, drafting and critically reviewing the content of the manuscript. Carvalho FM contributed to the design of the study, data analysis and interpretation, drafting and critically reviewing the content of the manuscript. Lira-da-Silva RM contributed to the design of the study, data interpretation, drafting and critically reviewing the content of the manuscript. All the authors have approved the final version of the manuscript and are responsible for all aspects thereof, including the guarantee of its accuracy and integrity.

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