Original Article

Snakebites mapping in municipalities of the Coffee Triangle Region in Colombia using Geographic Information Systems (GIS)

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Abstract
Objective: We sought to develop epidemiological maps using geographical information systems (GIS) for the incidence of reported venomous snakebites in the Coffee-Triangle region of Colombia, between 2007 and 2011.
Methods: Surveillance cases data (2007-2011) were used to estimate annual incidence rates of snakebites (cases/100,000 pop) to develop the first maps in the 53 municipalities of this region (departments Caldas, Quindío, Risaralda). The GIS software used was Kosmo Desktop 3.0RC1®. Thirty thematic maps were developed according to municipalities and years.
Results: A total of 617 cases were reported (56.08% from Caldas, 32.58% from Risaralda and 11.35% from Quindío), for a cumulated regional rate of 25. 25 cases/100,000 pop (35.43 for Caldas, 21.86 for Risaralda and 12.81% for Quindío). The highest cumulated rate was reported in the less developed and more rural municipality of one department (Pueblo Rico, Risaralda) with 265.64 cases/100,000 pop. Between 2007 and 2011, a considerable increase was seen in the rates. At Pueblo Rico, Risaralda, there was a change from 41.04 cases/100,000pop in 2007 up to 63.11 cases/100,000pop in 2011 (1.54 times higher). From Caldas, Samaná showed a high variation from 19.47 to 77.7 (3.99 times higher).
Conclusions: Morbidity of snakebites is highly concentrated in one department (Caldas). Use of GIS-based epidemiological maps allows guiding decisions-taking for prevention and control of public health problems that still represents a significant issue in the region and the country, such as snakebites.

Key words: envenomations; snakebites; Geographic information systems; Maps; Epidemiology; Colombia.

Introduction

Snakebites continue to be a significant health problem in developed and developing countries,[1-3] particularly in the tropical rural areas of countries in Asia, Africa and Latin America.[4-7] In Latin America, although a significant progress has been achieved in many aspects (e.g. study of snake venoms, venomics, and toxin action mechanism), there are still many challenges, including the insufficient supply of antivenoms in certain countries.[8]

In spite of considerable efforts in some countries in prevention, accessibility to treatment, and training of health staff in the management of envenomings, important improvements are still necessary for the geographic region as a whole, with the long term goal of reducing the social and personal impact of this injuries.[4, 7, 8]

In this setting, from the epidemiological point of view, technological tools, such as the use of geographical information systems (GIS) for mapping and analysis, are highly useful in planning, control and risk analyses particularly for public health, travel, wilderness and environmental medicine, as has been used until today for many other tropical diseases.

For example, in the past, French Geographer Charles Picquet made a map employing different tones depending on the percentage of cholera deaths per 1,000 habitants with the 48 districts of the city of Paris, France. This was one of the first mapping applications used in epidemiology, being the report on the progress and the

"Effects of Cholera-Morbus in Paris and Rural Communes of the Seine Department" (Rapport sur la Marche et les Effets du Choléra-Morbusdans Paris et les Communes Rurales du Departement de la Seine).[9] In addition, Doctor John Snow, father of modern epidemiology, supports their work on a map of 1854 to spatially identify cases of cholera in London, England.[10]

At present, these new implemented informatics tools have appeared as an essential and revolutionary component and control support of a wide range of works in public health and epidemiology, but also in wilderness and environmental medicine, including there, snakebites. Geographic information systems (GIS) are then, in this setting of utmost importance.[11-13] GIS are of the most important and functional tools for epidemiology. During the last decades them have shown great capacity to make geographic analysis, supports of the planning and take decisions and the development of mapping health conditions. Furthermore, visual analysis (evidence mapped) are a useful measure to strengthen decision making for epidemiological control in endemic areas. Recently, increasing use of GIS in snakebites surveillance programs is a promising look,[11-13] unfortunately its use has developed very slowly in Latin American countries.[11, 13-15]

The GIS are composed of hardware, software, human resources and geographic data, integrated components to capture, save, organize, control, monitoring and to provide geographically referenced data in order to carry out strategic planning and geographic management, which is derived from the understanding of these concepts, and which can greatly be useful in the study of snakebites at collective levels.

Although the use of GIS in various branches of medicine has been the subject of numerous publications worldwide, this is not the specific situation in Latin America, where few studies about it are available.[11] Even more in Colombia, where no previous studies have been published regard the use of geographic information systems (GIS) in snakebites.

In addition, there have been a relatively limited number of surveillance studies on snakebites in the country.[16-18] In this country, we found a relatively high incidence of snakebites in of one its regions, called the coffee triangle region. This is located at the western area of Colombia (South America), where no previous studies published related to snakebites. This region is constituted administratively by three departments, Caldas, Quindío and Risaralda, including 53 municipalities.

As part of efforts to improve and integrate tools in surveillance of certain tropical diseases of the region[19], including snakebites, the Universidad Tecnológica de Pereira (through the Research Group Public Health and Infection) the regional information system, the Health Secretary of Risaralda are working together in the academic analysis of the epidemiological information, specifically also in snakebites. In this setting, this study aims to develop GIS based epidemiological maps for snakebites in the Coffee Triangle region of Colombia. That is a family (e.g. *Elapidae* (*micrurus*), *Viperidae* (bothrops and Lachesis)). Current analyses cover the period 2007 to 2011.

Neither in this region have other studies mapping conditions of specific interest in wilderness and environmental medicine till now, and there are no previous studies on the epidemiology of snakebites.

Methods

Colombia is a South American country constituted by 32 departments (main administrative level) (Figure 1). These departments are grouped by regions, one of them, located in the Andean area, is the Coffee Triangle (Figure 1). This is a geographic region including three departments (Caldas, Quindío and Risaralda) with 53 municipalities and a total population of 2,463,507 for the year 2011. Among these municipalities, located in three departments, there is high variation regard development and poverty. For reference, Bogota, the country's capital city had in 2011 an index of unsatisfied basic needs (proportion of homes living with at least one unsatisfied basic need) of 9.2% (optimum value is 0%), however department of Risaralda obtained 17.5%, Caldas 17.8% and Quindío 17.6%. Among the municipalities, the rural area of Pueblo Rico obtained 62%. The largest urban municipalities in the region are Pereira (Risaralda), Manizales (Caldas) and Armenia (Quindío), the capital cities of the three departments, but in every municipality of the region. The capital is not part of rural area, and then all municipalities are considered to have rural and urban areas.

The region is bounded by the basins of the Campoalegre, Otún and La Vieja Rivers. Weather conditions vary widely by the diversity of the area, but range from -8 °C in the Nevados up to 29 °C in the valleys and the Andean rainforests. The vast abundance of hydrological conditions, rich soil, altitude and climate, have allowed their great aptitude for the production of coffee which has based much of their economic, social and political history as well as its potential for development. This area has a rich water births made up

of water on the eastern slope of the Western Cordillera and both slopes of the Central being the Cauca and Magdalena rivers clear providers such abundance. In addition, the soil quality is high aptitude agrological which is enhanced by the wide variety of terrain and climate. Additionally, it has a vast diversity of fauna and flora in the various departments located in different natural ecosystems are the Natural Park of the Nevados, moors, wetlands and forests in watersheds that allow water regulation. As for the economy and regional culture is derived from the roots of their colonial culture as well as the tradition of coffee production in Colombia making the culture associated with the product, plus one, is an essential symbol in the national identity and one of the most important in the world (Figure 1).

Figure 1. Study area, Coffee Triangle Region of Colombia and relative position of the country.

For this study, the epidemiological data was collected from the surveillance system, obtaining the number of cases for each municipality by year (2007-2011). Data was obtained with agreement from the Colombia Ministry of Health through the Protection Information System (SISPRO), through a Client Access server which allowed retrieving cases from the SISPRO server to a local computer. The SISPRO surveillance data used for this study are constituted from confirmed cases, which have been revised in terms of data quality, initially from data from the National Institute of Health of Colombia and later by the program SISPRO and its Data Cubes system. The information for this study from 53 primary notification units, one per municipality, later consolidated in three secondary notification units, at department levels, and finally centralized in Bogotá with the SISPRO system. Quickly revised and consolidated information is available for the years 2007 to 2011.

In Colombia snakebites are under specific surveillance. This ensures that data from each of the municipalities of the country are generated each week.

Using official reference population data from the National Administrative Department of Statistics (DANE) 265 estimates of annual incidence rates for all the municipalities during the study period were calculated (53 municipalities, for 5 years) (cases/100,000 pop) to develop the first maps of snakebites in the study region constituted by the departments of Caldas, Quindío and Risaralda. Five thematic maps were developed according to municipalities and years.

The software Microsoft Access® was the platform to design the spatial database used, to import incidence rates by municipalities, years, etiology and clinical forms to the GIS software. The Client GIS software Open source used was Kosmo Desktop 3.0 RC1®. For the access to geographic data required and sharing results with institutions support was provided by the spatial data infrastructure for the Coffee Triangle region by the Regional Information System. The shapefiles of municipalities (.shp) were linked to data table database through spatial join operation, in order to produce digital maps.

Finally, seasonal (monthly) variations during the study period were also assessed in order to describe the months with higher number of snakebite cases.

Results

During the study period 617 cases were reported (56.08% from Caldas, 32.58% from Risaralda and 11.35% from Quindío), for a cumulated regional rate of 25. 25 cases/100,000 pop (35.43 for Caldas, 21.86 for Risaralda and 12.81% for Quindío). The highest cumulated rate was reported in the less developed and more rural municipality of one department (Pueblo Rico, Risaralda) with 265.64 cases/100,000 pop.

Figure 2 shows geographical and temporal variation in snakebite incidence rates expressed as cases/100,000 pop). Between 2007 and 2011, a considerable increase was seen in the rates. At Pueblo Rico, Risaralda, there was a change from 41.04 cases/100,000pop in 2007 up to 63.11 cases/100,000pop in 2011 (1.54 times higher) (Figure 2). At Risaralda, rural areas of Pereira municipality contributed with 47.8% of cases of the department, with a considerable change from 1.34 cases/100,000pop in 2007 up to 4.79 cases/100,000pop in 2011 (3.58 times higher) (Figure 2). From Caldas, Aranzazu shown a high variation from 2007 with 7.97 cases/100,000pop up to 16.71 cases/100,000pop in 2011 (2.10 times higher) (Figure 2). Similar situation was seen in Marquetalia, from 6.73 up to 13.39 (1.99 times higher) (Figure 2) and for Samaná, with the highest variation, from 19.47 to 77.7 (3.99 times higher) (Figure 2).

**Figure 2**. Snakebites incidence rates geographical distribution, Coffee Triangle Region, Colombia, 2007-2011.
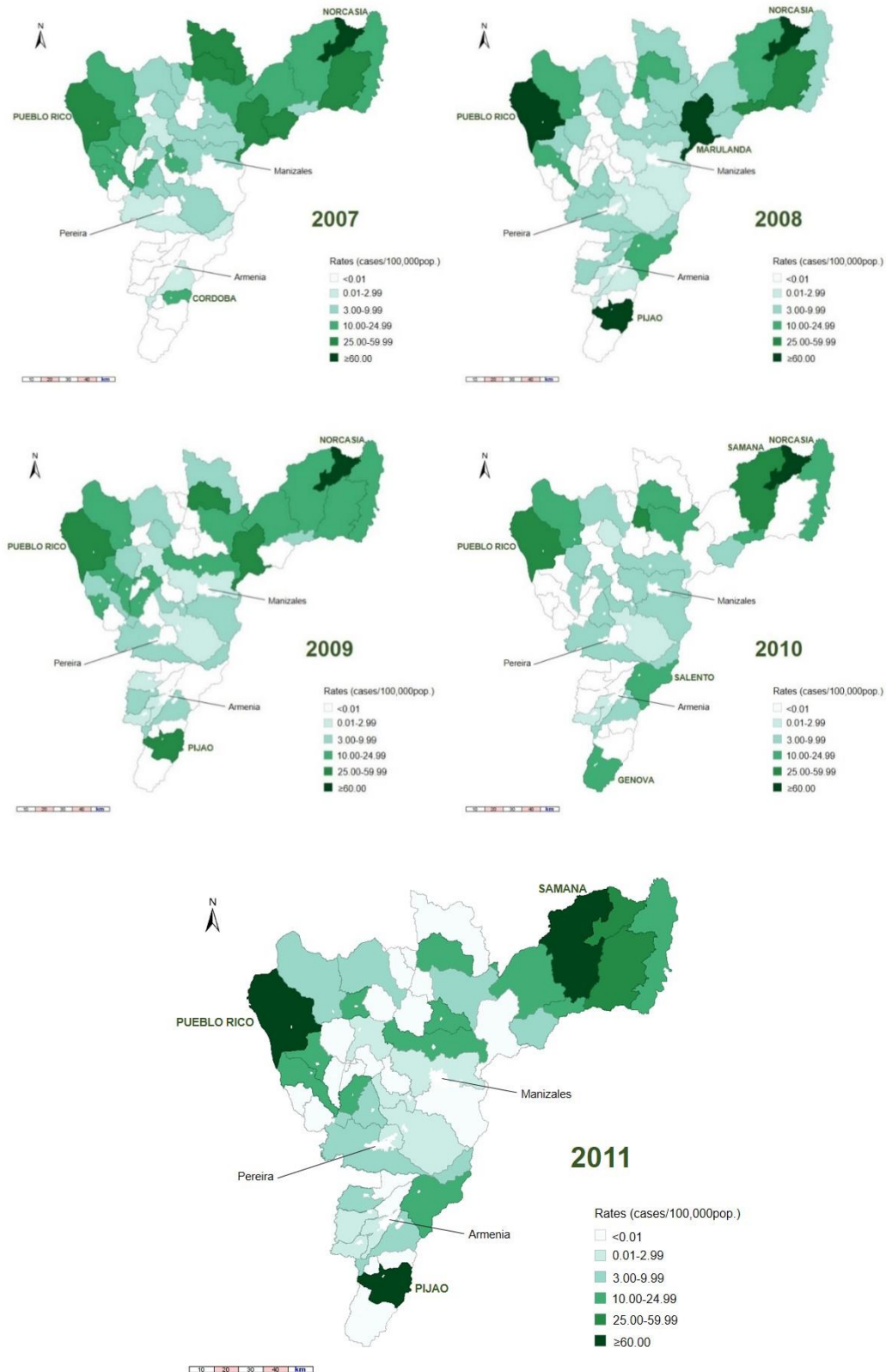
For Quindío department, also a considerable increase was seen in its rates, with a change from 0.56 cases/100,000pop in 2007 up to 2.71 cases/100,000pop in 2011 (4.89 times higher) (Figure 2). In this department, the municipality Calarcá shown a change from 2.69 to 5.26 (1.96 times higher) (Figure 2). Pijao increased from 0.0 cases/100,000pop in 2007 up to 62.9 cases/100,000pop in 2011 (Figure 2).

From geographic analysis is evidenced that the municipalities with highest incidence rates for 2011 were Pueblo Rico in Risaralda, Samaná in Caldas and Pijao in Quindío.

Finally, the highest median number of cases per month in the region was in April (17 snakebites), however the peak for the quartile 3 distribution was on May (28 cases) (Figure 3). The lowest median number of cases per month was in December (7 cases), with the lowest quartile 1 distribution on June (0 cases) (Figure 3).

Figure 3. Seasonal variation in the number of snakebites Coffee Triangle Region, Colombia, 2007-2011 (Q1=Quartile 1; Q3=Quartile 3; for the month during the study period).
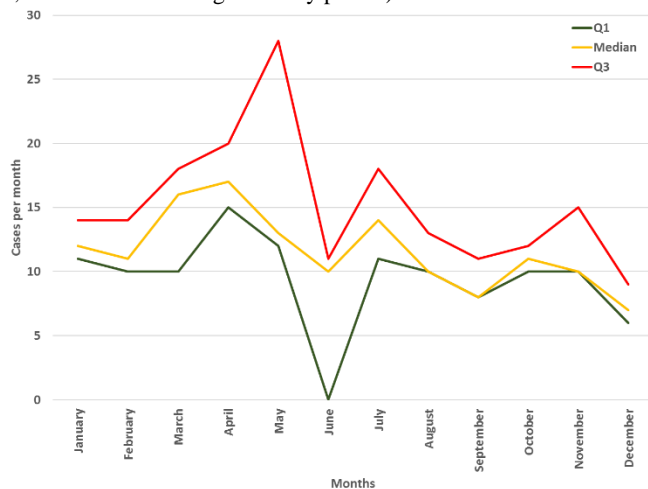
Discussion

The true global incidence of snake envenomations and their severity remain largely misunderstood, except for a few countries where these accidents are rare or correctly reported. According to the World Health Organization (WHO) estimates, up to five million people suffer each year from snakebites.[20] The venomous snakes can cause enormous morbidity and mortality, as well also disability.[5, 6, 16-18, 20] In countries such as India, national representative studies have found a high number of deaths (123,000, in 2001-2003) for an annual age-standardized rate of 4.1/100,000 pop.[21] The

annual global burden of snake envenomations and deaths is estimated to be, respectively, 421,000–1,841,000 and 20,000–94,000.[22, 23] The WHO incorporated snakebite envenomation in its list of neglected diseases in 2009.[24]

Previous studies have proposed, and it confirmed that snake envenoming is a disease of the poor. The negative association between snakebite deaths and government expenditure on health have confirmed that the burden of mortality is highest in those countries least able to deal with the considerable financial cost of snakebite.[25] This would probably explain the high morbidity found in the poorest municipalities of the coffee triangle region of Colombia, such as Pueblo Rico in Risaralda department. However, needing further studies to statistically confirm that relationship.

Then, this baseline study including the snakebites maps developed with geographic information systems (GIS), open the future for other studies relating other social variables with geographical and environmental variables with the occurrence of snakebites in the region. As has been proposed for other tropical diseases, for snakebites is also important to recognize that basic knowledge with epidemiological tools should be highly distributed in order to make better surveillance and control of this condition. Nonetheless, implementation of GIS in epidemiology and particularly in epidemiological snakebite studies is still lacking in Latin America but particularly in Colombia. Then, current research offers a confident geographical approach to the extension of snakebites all over a region in Western Colombia including 3 departments and 53 municipalities with interesting implications for advice on the occurrence in this region.

In this region the spatial distribution of municipality-level snakebite largely followed the expected pattern. Incidence was higher in rural, humid lowlands, notably in the three corners of the region (northwestern, southern and northeastern part of the region).

Geographical accessibility to antivenom treatment, however, has been generally good. However, in some areas there is a need of improved treatment accessibility. These are areas where hospitals and clinics are located relatively far from some of the areas with a likely high snakebite incidence, but there are not municipalities far than four hours by car.

Our study demonstrates that using GIS facilitates rational decision-making on localization of treatment allocation against snakebite. GIS is a promising tool for devising cost-effective interventions aimed at reducing

the public health impact of snakebite envenoming, as has been also proposed.[11]

Researches in public health and epidemiology have been using GIS and remote sensing (RS) like an innovative and important component used for monitoring, surveillance and spatial modelling of diseases.[26-28] These systems offer new and expanding opportunities for epidemiology because they allow an informed user choose between options based in geographic distributions.[26] These tools provide also examples of how Earth observation satellites can be used in studies of ecology and prediction of snakebites, as has been used in other tropical conditions.[28]

The ideal objective would be to have and routinely use of GIS to support public health surveillance and epidemiological investigations in all the health authorities related to surveillance programs of snakebites. In this setting, getting snakebite maps for the territory in the Coffee triangle region would be convenient for local health authorities, for researchers for developing new research works about the topic, as well for physicians assessing imported cases from this zone of Colombia when investigate the epidemiological risk according to the geographical destination, which is also part of the post-travel medical consultation, but fundamentally also advice before travel for enhancing preventive measures in high risk areas. Snakebites are an infrequent but real risk for travelers.[29] Even more, because findings from some studies have provided evidences supporting the use of bed nets in the prevention of snakebites.[29, 30]

This group of maps (categorized by municipalities and years) will be included in the spatial data infrastructure for Coffee Triangle region supported by the Regional Information System, which would provide maps through standardized web services OGC (Open Geospatial Consortium). This information will be helpful quickly for the scientific and biomedical community in the country and in the world, as well for the education in epidemiology of snakebites. The web services are accessible online and make available the access, visualization, interchange the analysis and the decision making by the government institutions and monitoring this by people.

Even more, based on this approach with GIS tools, other studies, joining the impact of social and ecological variables (e.g. climatic) for the region, will be expected; not just talking about the distribution pattern by year, but also analyzing the influences of such variables on snakebites incidence. For example, the higher number of cases during April-May would related to the beginning of summer, then leading to more reproduction of the involved species, more exposure for people and then more snakebites. Other demographic variables, such as age and ethnic groups, in countries such as Colombia, would be also useful in the geographical assessment of snakebites epidemiology.

In this tropical epidemiological scenario, for a lot of clinical studies addressing that topic would be also helpful to have this information. Few studies in the country are about the epidemiology of snakebites, while in other countries in the South American continent, like Venezuela and Brazil, as well in Asia, have been largely documented and reported its morbidity and mortality in many studies and research works.[5, 14, 17, 18, 29]

This preliminary investigation describes a GIS approach to mapping snakebite incidence rates in a five-year period in a region of Colombia. Detailed and extensive further studies will enable the more reliable estimation of snakebite incidence at a local level across not only the region, but also the country, also including the potential for planning and development of trials with antivenom therapies.

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