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Analysis of the spatial distribution of road accidents attended by the Mobile Emergency Service (SAMU-192) in a municipality of northeastern Brazil

Análisis de la distribución espacial de los accidentes de transporte terrestre atendidos por el Servicio Móvil de Urgencia (SAMU-192), en un municipio de la región nordeste de Brasil

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ABSTRACT This study describes the epidemiological characteristics of road accident victims attended by the Brazilian Mobile Emergency Service (SAMU-192) and located in the areas of highest accident density in the municipality of Olinda, (Pernambuco, Brazil). Kernel density estimation was used to detect spatial agglomerations of accidents. In 2015, 724 accidents occurred; of these, 73.48% of the victims were males aged 20-39 years. There was a predominance of accidents involving motorcycles (54.97%). Accident clusters were detected in the main traffic corridors, with run-over accidents located near bus terminals. Spatial analysis proved to be a relevant instrument for the identification of accident clusters and the application of effective prevention and traffic safety improvement measures.

KEYWORDS Traffic, Accidents; Emergency Medical Services; Spatial Analysis; Brazil.

RESUMEN Se describen las características epidemiológicas de las víctimas de accidentes de transporte terrestre atendidas por el Servicio Móvil de Urgencia (SAMU-192) y se localizan las áreas de mayor densidad de accidentes en el municipio de Olinda (Pernambuco, Brasil). Se empleó la estimación de densidad kernel para la detección de aglomerados espaciales de accidentes. En 2015 se registraron 724 accidentes. El 73,48% de las personas afectadas fueron del sexo masculino, y de entre 20 y 39 años de edad. Hubo un predominio de los accidentes con motocicletas (54,97%). Los aglomerados de accidentes se localizaron en las principales vías de tránsito y, los atropellamientos, cercanos a las terminales de ómnibus. El análisis espacial se mostró como un instrumento relevante para la identificación de los aglomerados de accidentes y una aplicación eficaz de las medidas de prevención y la mejora en la seguridad del tránsito vehicular.

PALABRAS CLAVES Accidentes de Tránsito; Servicios Médicos de Urgencia; Análisis Espacial; Brasil.

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INTRODUCTION

Road accidents have grown significantly, constituting one of the leading causes of death and disability in the world.[1] It is estimated that there are 1.2 million deaths annually due to injuries caused by these accidents. About 90% of these deaths occur in low and middle income countries, which account for only 54% of the global vehicle fleet.[2]

Economic and social conditions as well as public policy interventions[3] are among the explanatory factors of the concentration of traffic accidents in low and middle income countries. The rapid increase in the number of vehicles and exposure to risk factors, such as excessive speed and alcohol consumption, failure to use protective equipment, insufficient road safety regulations, and an inefficient public healthcare system are part of the causality of traffic accident-related injuries and deaths.[4]

In addition, non-fatal injuries resulting from traffic accidents imply high economic and human costs for society,[5] including emergency care, hospital admissions, social security expenses, physical sequelae and the impact on daily and functional activities.[6]

In Brazil, a rising trend in hospital admissions and mortality due to road traffic accidents[7,8,9] has been observed. Between 2000 and 2010, the mortality rate rose from 18 to 22.5 deaths per 100,000 inhabitants.[7] The analysis of hospital admissions due to external causes in the Unified Health System (SUS) [Sistema Único de Saúde], in the period 2002-2011, showed that traffic accidents are the second most frequent cause of hospitalizations, revealing a constant growth pattern of hospital admissions.[8] It is estimated that 50 billion Brazilian reales are spent annually in road accidents in Brazil.[9]

In 2003, through Resolution MS/GM 1863/2003 and Resolution MS/GM 1864/2003, the National Emergency Care Policy was set up. This policy incorporates the prehospital component with the implementation of the Mobile Emergency Service (SAMU-192) [*Serviço de Atendimento Móvel de Urgência*] in municipalities and regions of Brazil, with the purpose of providing qualified care at the scene of the accident, so that transport and arrival at the hospital are conducted rapidly and the victim may arrive alive.[10]

Emergency medical services seek to reduce the number of deaths and improve the quality of care. For this purpose, the focus has often been placed on the reduction of prehospital care times.[11] Time is considered an essential determinant in the initial care of trauma patients.[12,13] The *golden hour* is a fundamental principle of trauma care, being the time immediately following an injury, when resuscitation, stabilization and rapid transport are perceived to be most beneficial for the patient.[11,14,15] Recently, the focus of prehospital care has been placed on the *platinum five minutes*, a concept that requires the rapid treatment of life-threatening complications immediately after a severe injury.[16]

In the last decades, there has been an increase in the use of Geographic Information Systems (GIS) and spatial analysis techniques in the field of public health, which provide new tools for epidemiology.[17,18,19,20] These tools are fundamental for the identification of epidemiological risks and the planning of health care actions.[21,22]

Several studies have used spatial analysis techniques to detect the areas of risk for road transport accidents.[9,23,24,25,26,27,28,29] One of the most widely used methods is kernel density estimation, which is used to analyze the point distribution of an event and has been broadly applied to identify areas of accident concentration.[10,23,27,29,30]

The localization of the critical points of accident occurrence is essential for the allocation of resources and improvements in road safety.[23,29] From this perspective, the objective of this work is to describe the epidemiological characteristics of the victims of road accidents attended by the SAMU-192 and to estimate the areas of greater density of accidents in the municipality of Olinda, state of Pernambuco, Brazil.

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METHODS

This is a descriptive cross-sectional study, including data from the prehospital care component of SAMU-192 in the municipality of Olinda. This municipality is located in the metropolitan area of Recife, state of Pernambuco, in the northeast of Brazil. It has a territorial extension of 41,681 km² (98% of which is urban) and an estimated population of 389,494 people, distributed in 31 neighborhoods. The population density rate is 9,360,236 inhabitants/km², the highest in the state of Pernambuco and the fifth highest in Brazil. The human development index (HDI) was 0.735 in 2010.

All road traffic accidents attended between January 1 and December 31, 2015 were analyzed. SAMU-192 was implemented in this municipality in the year 2006 and is part of the network of the Recife Metropolitan Area. The service consists of four basic support ambulances, one advanced support unit and one motorcycle ambulance. The team includes seven doctors, 13 nurses, 49 nursing technicians and 22 ambulance drivers. On average, it attends 392 accidents per month and its coverage scope accounts for approximately 15% of road traffic accidents.

All accidents attended by Olinda SAMU-192 units are georeferenced through the Global Positioning System (GPS). The prehospital care ambulances of the municipality are equipped with GPS and the drivers have been duly trained in its use.[10] The medical care forms are completed in a database, which is consolidated by the Geoprocessing Nucleus of the Health Secretariat of the municipality. In addition to the spatial information, the database includes variables related to the victim, the accident occurrence and the care received.

The following variables were selected for this study: demographic (sex and age group), accident-related (type of accident, day of the week, time of occurrence) and support vehicle. A high percentage (80.3%) of the *trauma mechanism* variable was missing information and therefore could not be assessed. The analysis was carried out in the Epi Info version 7 software. Descriptive statistics were employed through the distribution of absolute and relative frequencies for the categorical variables and measures of central tendency and dispersion for the quantitative variables.

For the mapping and detection of spatial agglomerates, the Quantum GIS (QGIS) version 2.18 software was used with kernel density estimation, a non-parametric method used to identify spatial patterns. This method calculates the density of events around each point, weighted by the distance from the point of each event.[31,32,33] Thus, the peaks represent the presence of clusters or "hot spots" in the distribution of events, while the low values represent events that occur less frequently in the area.[34]

Kernel density estimation is defined by the following equation:

$$\lambda(s) = \sum_{i=1}^{n} (1/r)\, k(d_{is}/r)$$

Where:

$\lambda(s)$ is the density in locality s.

r is the scope radius of the kernel density estimation; only specific points within that radius are used to estimate $\lambda(s)$.

$k(d_{is}/r)$ is the weight of the distance between i and s (d_{is}).

k is a function of the radius between r and d_{is}; therefore, the smoothing effect of the distance is taken into account for its estimation.

The radius of influence defines the proximity of the point to be interpolated and controls the smoothing of the generated surface. A very small radius generates a very discontinuous surface, while a very large radius generates a surface that tends to appear flat and smooth. In this study, a radius of 600 meters was selected. On the map, low density areas were represented in green and high density areas in red.

The research project was approved by the Research Ethics Committee of the University Hospital Oswaldo Cruz and Pronto-Socorro Cardiológico Universitario of Pernambuco "Prof. Luiz Tavares", under code 1,778,389.

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Table 1. Characterization of road traffic victims attended by SAMU-192 (N=724), in the municipality of Olinda, state of Pernambuco, Brazil, 2015

Variables	n	%
Sex		
Female	167	23.07
Male	532	73.48
Unknown	25	3.45
Age group (in years)		
1 to 9	8	1.10
10 to 19	71	9.81
20 to 39	394	54.42
40 to 59	147	20.30
60 years and more	39	5.39
Unknown	65	8.98
Time of the day		
Morning	187	25.83
Afternoon	200	27.62
Night	265	36.60
Dawn	57	7.87
Unknown	15	2.07
Day of the week		
Sunday	135	18.65
Monday	92	12.71
Tuesday	65	8.98
Wednesday	84	11.60
Thursday	101	13.95
Friday	131	18.09
Saturday	116	16.02
Type of ambulance		
Basic support unit	329	45.44
Advanced support unit	378	52.21
Unknown	17	2.35
Destination health care unit		
Attention at the scene of the accident	16	2.21
Hospital	215	29.70
Emergency Unit	361	49.86
Polyclinic	25	3.45
Patient rejection of transfer	33	4.56
Others	21	2.90
Unknown	53	7.32
Road traffic victims		
Pedestrian	124	17.13
Motorcyclist	398	54.97
Cyclist	16	2.21
Car occupant	154	21.27
Bus occupant	27	3.73
Heavy transport vehicle occupant	5	0.69

Source: Own elaboration from data provided by the Olinda Health Secretariat, Pernambuco, Brazil.

RESULTS

In 2015, 4704 accidents were attended, of which 724 (15.40%) accounted for road traffic accidents. Male individuals accounted for the highest proportion of attended victims (73.48%). The average age of the victims was 30 years (standard deviation =14.40 years), with a minimum age of 2 and a maximum age of 96 years. The age group from 20 to 39 years was the most frequent (54.42%) (Table 1).

Case distribution according to the time and days of the week showed highest accident occurrence at night (36.60%) and during the weekend, accounting for 52.76% (382) of the total. The advanced support unit provided care in most of the events (52.21%) and the emergency care centers were the main destination (49.86%). Motorcycle accidents (54.97%) ranked first among the vehicles involved (Table 1).

Ten 10 deaths were recorded, four of which were due to motorcycle accidents and three to run-over accidents. Six of the fatal victims were male, with an average age of 33.5 years (ranging from 17 to 68 years). The accidents occurred on the weekend, in the morning.

Figure 1 shows, on the one hand, the point distribution of care for road traffic accidents attended by SAMU-192, and, on the other, the kernel density analysis that allows to visualize two significant clusters located along Route PE-015, in the Fragoso and Ouro Preto neighborhoods, located north of the municipality.

Kernel density analysis was conducted for all types of accidents and separately for run-over, car and motorcycle accidents.

Run-over accidents (Figure 2) are distributed in five clusters located in Rio Doce, Fragoso, Ouro Preto and Aguazinha neighborhoods. The first cluster is located at the intersection of Tiradentes Avenue with Napolis Avenue, close to the bus terminal. The second one is located in Route PE-015 near the bus terminal; the third one is on the same route, at the intersection with Chico Science Avenue. The fourth and fifth are on

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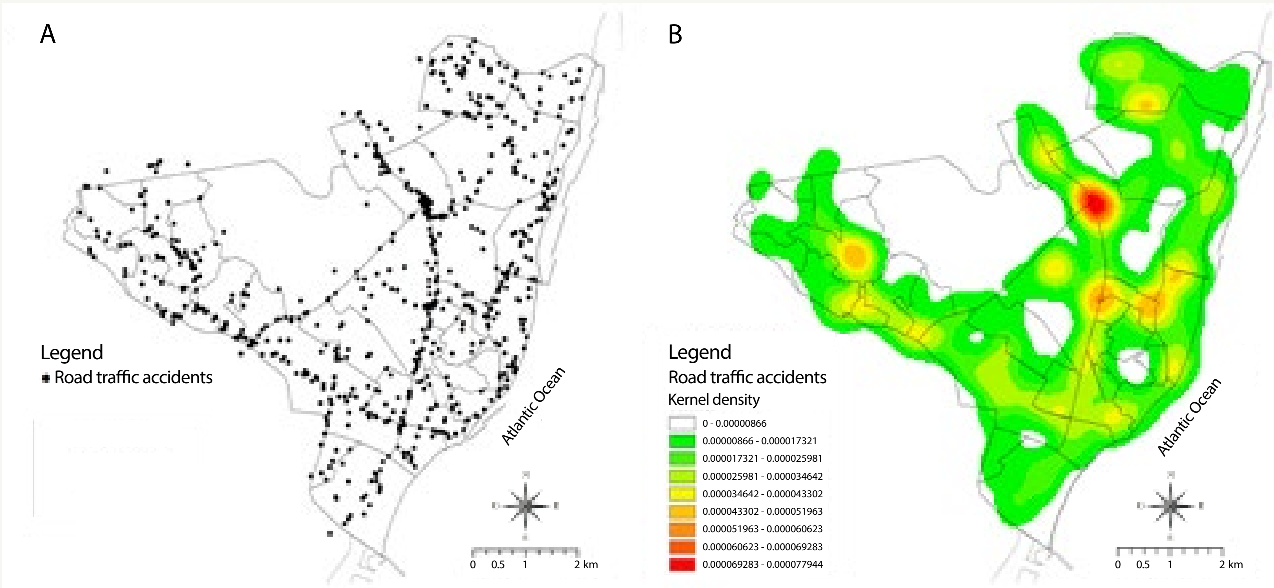

Figure 1. Road traffic accidents attended by SAMU-192. (A) point distribution; (B) kernel density. Olinda, Pernambuco, Brazil, 2015.

Source: Own elaboration from data provided by the Olinda Health Secretariat, Pernambuco, Brazil.

Presidente Kennedy Avenue. Car accident agglomerates are distributed in four clusters (Figure 3). The first one is located in Jardim Atlântico neighborhood; the second one near the bus terminal on Route PE-015: the third one in the Fragoso neighborhood and the last one in the Aguas Compridas neighborhood, near the Xambá integrated bus terminal.

In motorcycle accidents, two areas with greater concentration were identified: the first one is located in Fragoso and Ouro Preto neighborhoods, near the bus terminal of Route PE-015 and the second in the same route at the intersection with the Chico Science Avenue (Figure 4).

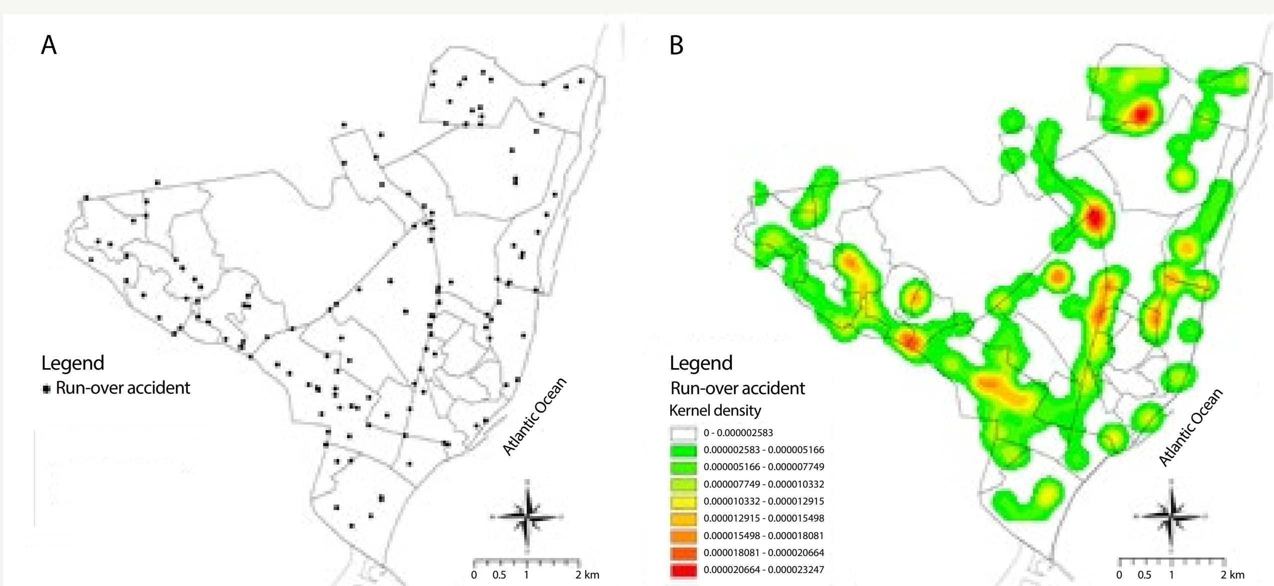

Figure 2. Run-over accidents attended by SAMU-192. (A) point distribution; (B) kernel density. Olinda, Pernambuco, Brazil, 2015.

Source: Own elaboration from data provided by the Olinda Health Secretariat, Pernambuco, Brazil.

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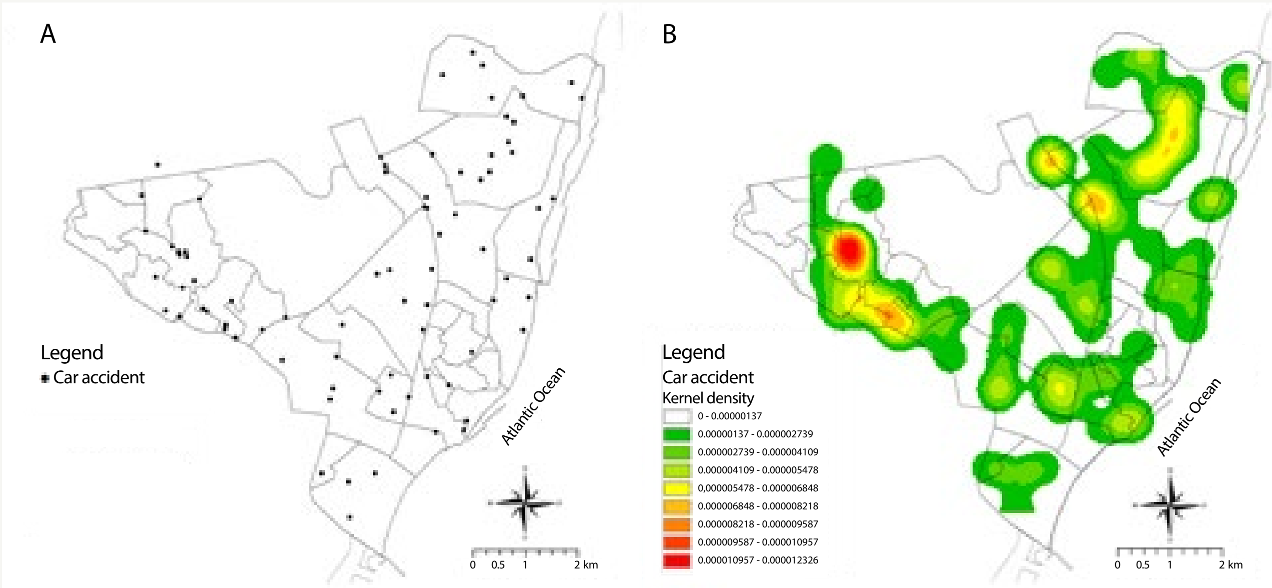

Figure 3. Car accidents attended by the SAMU-192. (A) point distribution; (B) kernel density. Olinda, Pernambuco, Brazil, 2015.

Source: Own elaboration from data provided by Olinda Health Secretariat, Pernambuco, Brazil.

DISCUSSION

The results of this study showed a higher occurrence of road traffic accidents in male individuals between 20 and 39 years of age. These characteristics are similar to those found in other research studies.(35,36,37) The analysis of differences in mortality rates by sex and age in relation to exposure revealed a higher mortality among younger male drivers.(38) Safety awareness campaigns

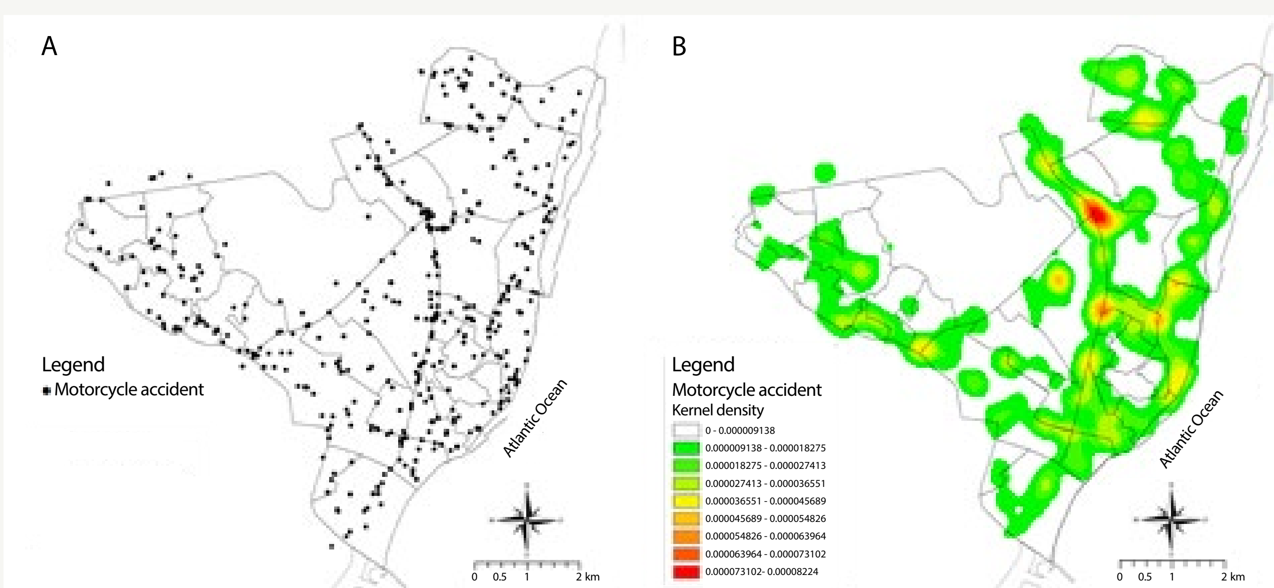

Figure 4. Motorcycle accidents attended by the SAMU-192. (A) point distribution; (B) kernel density. Olinda, Pernambuco, Brazil, 2015.

Source: Own elaboration from data provided by Olinda Health Secretariat, Pernambuco, Brazil.

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should be planned and organized by age and sex, considering the differences and characteristics of the groups of drivers.[39]

Studies on potential years of life lost due to road traffic accidents, developed by different authors, showed that the 20-39 year-old-group was the most affected and, specifically in the state of Pernambuco, the age group coincides with that found in this study.[40,41,42]

Weekends are the most critical days for accident occurrence. The literature shows that almost half of the accidents occur on weekends.[25,41,42,43,44] This fact can be explained by the amount of leisure time that people spend and, by inference, the increase in alcohol consumption, which can result in a greater vulnerability of car and motorcycle drivers.

The consumption of alcoholic beverages is a determinant factor for accident occurrence. A study that analyzed the prevalence of alcohol in the blood of individuals involved in accidents during five years showed differences related to the day of the week (week or weekend days), age and sex.[44]

With regard to the time of the accidents, a greater frequency was observed at night, differing from the results observed in Almeida's work,[42] which found the highest incidence at dawn. The constant presence of controls at dawn implementing repressive and punitive policies aimed at prohibiting drivers who have consumed alcohol from driving pursuant to Law 12760/2012[45] caused a significant reduction in the frequency of drunk adult drivers in the Brazilian capitals after these laws were enforced.[46] In addition, poor lighting and the precarious conditions of public roads may be factors that contribute to the occurrence of nighttime accidents.

An epidemiological survey on road traffic accidents and driver-related factors found an association between type of accident, sex, education level, type of license, time of the accident, ultimate cause of the accident, driver's error, as well as the time elapsed between obtaining the driver's license and the accident (all $p < 0{,}001$).[47]

In our study, when characterizing the place where victims were referred, the Emergency Unit (UPA) was the place with the highest number of referrals, followed by hospitals of reference. In another study, the UPA was not mentioned, only the hospitals.[25] It is considered that in Pernambuco, the centralized regulation of hospital beds works properly, and guides the referral of patients within the State health care network, depending on the complexity needed, referring the most severely injured patients to the hospitals. In our study, the number of patients that were referred to hospitals accounted for 29.70% of all cases.[48] The type of ambulance most frequently used in the transport of victims was the Advanced Support Unit, accounting for 52.21%, differing from the study by Soares *et al.*,[25] in which more than 90% of care was provided by Basic Support Units.

In this work, spatial analysis methods were used to identify accident occurrences in the municipality of Olinda, Pernambuco, in order to "understand the impact of the place on health as a key element of epidemiological research."[20] In this sense, spatial agglomerates were identified through kernel density estimation in the main traffic corridors of the municipality. A concentration was observed along Route PE-015 and on Presidente Kennedy Avenue. The distribution of road traffic accidents in cities is relevant information for health surveillance actions. A previous investigation conducted in the municipality also evidenced accident foci on those roads, which shows the need to carry out actions integrating the different public administration bodies.[28]

Run-over accidents occurred near the local bus terminals, which have an intense flow of people and vehicles, as well as deficient signaling and lighting conditions, all factors that can potentiate the occurrence of pedestrian accidents. Two critical clusters were identified on Presidente Kennedy Avenue: the first cluster close to the street market fair, which is commercially active every day and requires pedestrians circulate on the street and not on the sidewalks. The second cluster is located in an area that is characterized by poor lighting and accentuated high speeds, causing difficult pedestrian circulation. A study that

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analyzed the factors associated with run-over accidents found that pedestrian fragility, slow movement and lack of proper lighting constitute the specific high risk feature of these events.[49] Improvements in street conditions, adequate lighting, road safety campaigns and educational programs are crucial measures for reducing pedestrian accidents.[49] Maps indicating the exact location of run-over accidents provide the necessary information for preventive measures.[50]

The four main spatial agglomerates involving cars were located in roads with the greatest flow of individuals and vehicles. The principal spatial agglomerate is located on Águas Compridas Avenue in the neighborhood bearing the same name. It is a narrow, two-way street lined with highly frequented stores. The areas close to the bus terminals (Route PE-015 and Xambá) remained critical points. Governador Carlos de Lima Cavalcanti Avenue, in Jardim Atlântico neighborhood, was a significant cluster, probably in terms of vehicle circulation towards the beach. The identification of areas with accident densities through kernel mapping has been shown to be efficient in guiding more effective prevention and safety measures.[34]

Motorcycles were involved in most accidents, with two critical areas located along Route PE-015. The first one is located near the bus terminal and the second one is at the intersection with Chico Science Avenue, a road with intense vehicle flow circulating at high speed. In Brazil, there has been an increase in the motorcycle fleet as a result of federal policies that promoted *baixo custo* [low cost] in manufacturing as well as loan opportunities for the purchase of this type of vehicles.[51] Motorcycles are mostly used for delivery of goods, due to their speed and their ability to avoid traffic congestion in the urban centers, which is directly related to the increase in accidents.[52]

Kernel density estimation has been widely used for the detection of traffic accidents; the identification of hot spots has proved to be useful in the analysis of the spatial distribution of fatal and non-fatal accidents.[34,52,53,54,55] The maps including the spatial agglomerates developed in this study show relevant information for health surveillance and for the planning and management of strategies aimed at improving traffic conditions, prevention and accident reduction.

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