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Spatial variations in motorcycle registrations and the mortality of motorcycle users due to traffic injuries in Argentina

Variaciones espaciales en el patentamiento y la mortalidad de usuarios de motocicletas por lesiones de tránsito en Argentina

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ABSTRACT Although pedestrians, cyclists and motorcyclists account for nearly half of those killed in traffic accidents in the world, little is known about the geographical distribution patterns of these vulnerable roadway users. Using spatial scan statistics techniques, the spatiotemporal variations in the mortality of motorcycle users in Argentina were analyzed for the period 2001-2010, as well as the spatial variations in mortality and motorcycle registration from 2007-2010. Two space-time clusters with a high risk of death for motorcycle riders were identified during the second half of the study period. Overall, there was a spatial relationship between motorcycle registrations and the mortality of the users of these vehicles in the northern-central region of Argentina. The results of this study indicate the need to reinforce primary prevention policies focused on motorcycle users in this region of the country, especially in areas with high population density.
KEY WORDS Mortality; Accidents, Traffic; Motorcycles; Space-Time Clustering; Argentina.

RESUMEN A pesar de que los usuarios vulnerables de las vías de tránsito (peatones, ciclistas y motociclistas) representan casi la mitad de las víctimas mortales por lesiones de tránsito en el mundo, poco es lo que se sabe acerca de los patrones de distribución geográfica de este tipo de usuarios. Mediante técnicas de rastreo estadístico-espacial se analizaron las variaciones espacio-temporales en la mortalidad de usuarios de motocicletas por lesiones de tránsito en Argentina, durante el período 2001-2010, y las variaciones espaciales en esta variable y el patentamiento de motos durante el período 2007-2010. Se registraron dos conglomerados espacio-temporales de alto riesgo de mortalidad en usuarios de motocicletas durante la segunda mitad del período de estudio. En general, se observó una relación espacial entre el patentamiento de motocicletas y la mortalidad de los usuarios de estos vehículos en el centro-norte de la Argentina. Los resultados de este estudio indican la necesidad de reforzar las políticas de prevención primaria enfocadas en usuarios de motocicletas en esta zona del país, especialmente en áreas de mayor densidad poblacional.
PALABRAS CLAVES Mortalidad; Accidentes de Tránsito; Motocicletas; Agrupamiento Espacio-Temporal; Argentina.

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INTRODUCTION

Vulnerable roadway users (pedestrians, cyclists and motorcycle users) represent almost half of those killed due to traffic injuries in the world (1). While pedestrians register greater mortality in lower-income countries, motorcycle users present a greater relative distribution in middle-income countries, especially Southeastern Asian countries, in relation to high- and low-income countries (2).

In recent years, the deaths of motorcycle users derived from traffic injuries has become a serious public health problem in some countries, registering greater increases than users of other means of transport (3-5). Even in developed countries, like the US, where the mortality rate due to traffic injuries has decreased, the number of deaths of motorcycle users has increased during the last years (6). The increase in motorcycle sales and fuel costs are factors that have been related to this phenomenon (3,6,7).

Deaths due to traffic injuries are first among deaths produced by external causes in Argentina in the age group of 5 to 64 years (8). If different types of roadway users are considered, motorcycle users are the second group in terms of fatalities, with young people from 14 to 29 years most affected (8). In relation to this data, deaths due to traffic injuries are a primary public health concern in Argentina and, as a consequence, more specific studies that consider the particular characteristics of mortality according to users of different transport methods with the aim of improving the efficiency and effectiveness of public prevention policies are necessary.

Among the few precedents of quantitative spatial analysis of mortality and morbidity in vulnerable roadway users are studies specifically devoted to pedestrians carried out in developed countries (9-11), which focus solely on spatial variations without considering spatial and temporal dynamics. In the particular case of motorcycle users from developing countries, there are few studies which analyze spatial variations in mortality (12,13). Space-time analyses of the mortality of motorcycle users have not been carried out to date, nor has an analysis of the relation between their geographic distribution and the spatial distribution of the motorcycles sales.

The aims of this study are: a) to analyze the distribution of the space-time clusters of motorcycle user mortality due to traffic injuries in Argentina, for the period 2001-2010; b) to compare the distribution of the spatial clusters of motorcycle registrations and motorcycle user mortality in Argentina, for the period 2007-2010; and c) to describe the temporal evolution of motorcycle user mortality in areas with different population density, for the period 2001-2010.

MATERIALS AND METHODS

This study was carried out using three different data sources. The cases of death of motorcycle users were obtained through the mortality database provided by the National Ministry of Health of Argentina, through the Health Statistics and Information Department; the database includes the whole country and is codified using the Tenth Revision of the International Statistical Classification of Diseases (ICD-10). The codes V20-V28 [3-5, 9] and V29 [4-6, 9] were used, taking into account the *department* [administrative geographic unit] where the fatality took place, for the period 2001-2010. The population density (inhabitants per km2) was obtained through the data provided by the National Institute of Statistics and Censuses of Argentina from the National Census of Population and Housing of Argentina [*Censo Nacional de Población, Hogar y Viviendas*] for the year 2010 (14). Based on this data, departments were classified by quartiles of population density (quartile 1: <2.68 inhabitants per km^2, quartile 2: 2.68-7.57; quartile 3: 7.58-24.73; quartile 4: >24.73). Annual motorcycle registration data were provided by the Statistical Bulletins (15) of the National Registry of Motor Vehicles and Pledge Loans [*Dirección Nacional de los Registros Nacionales de la Propiedad del Automotor y Créditos Prendarios*], which are only available from 2007 onward. The data on motorcycle registrations is available by locality, therefore this data was aggregated at a department level so as to compare it with the mortality data of motorcycle users.

The spatial units were the minimum territorial subdivisions (known as *counties* in the Province

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of Buenos Aires and *departments* in the rest of the provinces) with available data on deaths. As there is no disaggregated data available for the 21 schools districts of the autonomous City of Buenos Aires, a global number of cases was assigned for all the districts that constitute the city.

A space-time scan statistic for all the cases of mortality of motorcycle users for the period 2001-2010 was carried out as well as a spatial scan statistic for these same cases and the motorcycle registrations for the period 2007-2010. This type of analysis is defined as a cylindrical window, with a geographic base and a temporal height (the latter only in the case of space-time analysis) (16). This cylindrical window moves along different geographic points adopting different sizes. In this way, an infinite number of cylindrical windows (each of them reflecting a possible cluster) which are overlapped and cover the entire geographic space is created. The analysis assumes that the mortality cases of motorcycle users and the motorcycle registrations have a Poisson distribution, in which each geographic area (in this case, each department) presents the same risk of a fatal event. By using the discrete Poisson model, the number of deaths due to traffic injuries in motorcycle users and motorcycle registrations expected are proportional to the population of each geographic area. Annual population estimates at a departmental level for the period 2001-2010 were therefore also used (17). Thus, the null hypothesis states that the same risk level exists through the space and time considered in the analysis, while the alternative hypothesis is that at least one cylinder (one cluster) has a different risk level in relation to the rest of the analyzed space and time. The cylinder with more observed cases than expected cases is considered the most likely cluster (16) that, in this study, was named "cluster 1." The spatial scan statistic or space-time scan statistic can detect other clusters with these characteristics, known as secondary clusters, which in this study were named "cluster 2" and so forth. In the case of the space-time scan statistic, the cluster size was limited to half of the study period and 50% of the population at risk. The statistical significance of these clusters was calculated through Monte Carlo simulations at the level $p < 0.05$.

The software used to perform this space-time scan statistic was SaTScan version 9.1.1, developed by Martin Kulldorff of Harvard Medical School (Boston, USA) and Information Management Services Inc. (Maryland, USA).

RESULTS

Space-time analysis

Two space-time clusters with high risk of mortality in motorcycle users were registered. Cluster 1 (the most likely cluster) was located in the northern central region of Argentina for the period 2006-2010 (Figure 1, Table 1). Cluster 2 was located in a large part of the province of La Pampa, the southwest of the province of Buenos Aires, the eastern half of the province of Rio Negro and in the department of Confluenza (province of Neuquén) between 2008 and 2010 (Figure 1, Table 1). A temporal adjustment for an annual increase of 6.35% in the mortality rate on a national scale for the period 2001-2010 was made, and the same results were produced.

Spatial analysis

The spatial scan carried out for the cases of mortality of motorcycle users for the period 2007-2010 resulted in two statistically significant clusters. Cluster 1 (the most likely) spanned the north and center of Argentina (Figure 2, Table 2) while cluster 2 (secondary cluster) was located throughout almost all of La Pampa, half of Río Negro and two departments of the provinces of Buenos Aires and Neuquén (Figure 2, Table 2).

There were six statistically significant clusters regarding motorcycle registration for the period 2007-2010 (Table 3). Cluster 1 (the most likely) was located in the north and center of Argentina, except for the province of Misiones (Figure 3). Cluster 2 was located in the eastern-central region of the Province of Buenos Aires (Figure 3) while the remaining four clusters were distributed in the urban conglomerate of Buenos Aires, La Plata, and nearby areas (Table 3).

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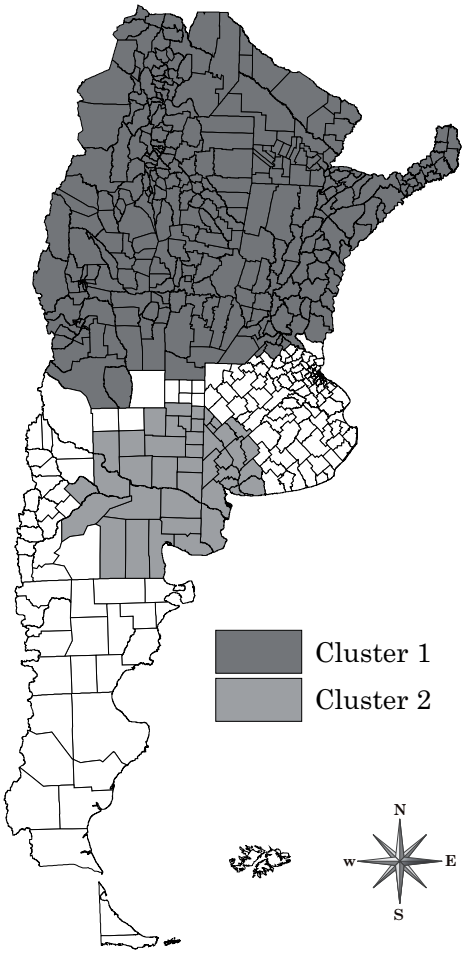

Figure 1. Statistically significant space-time clusters with high mortality due to traffic injuries in motorcycle users. Argentina, 2001-2010.

Source: Own elaboration based on mortality data from the Secretary of Health Statistics and Information, Ministry of Health of Argentina and population data from the National Institute of Statistics and Censuses.

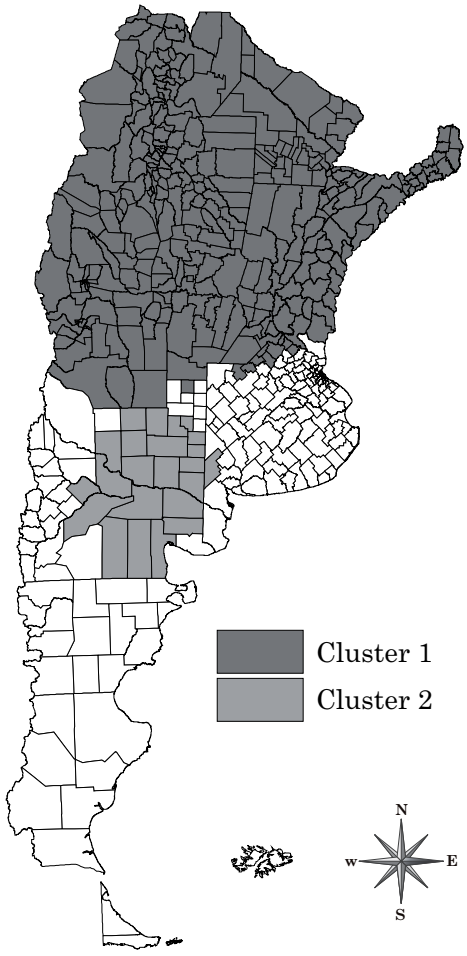

Figure 2. Statistically significant spatial clusters with high mortality due to traffic injuries in motorcycle users. Argentina, 2007-2010

Source: Own elaboration based on mortality data from the Secretary of Health Statistics and Information, Ministry of Health of Argentina and population data from the National Institute of Statistics and Censuses.

Table1. Characteristics of the space-time clusters with high mortality due to traffic injuries in motorcycle users. Argentina 2001-2010.

	Cluster period	Observed cases	Expected cases	Relative risk	*p*-vale
Cluster 1[a]	2006-2010	2,520	1,064.67	4.37	<0.001
Cluster 2[b]	2008-2010	135	55.13	2.50	<0.001

Source: Own elaboration based on data from the Secretary of Health Statistics and Information, Ministry of Health of Argentina and the National Institute of Statistics and Censuses.

[a]Buenos Aires (Colón, Pergamino, Ramallo and San Nicolás); Catamarca; Chaco; Córdoba; Corrientes; Entre Ríos (except for Islas de Ibicuy); Formosa; Jujuy; La Rioja; Mendoza (except Malargüe); Misiones; Salta; Santa Fe; Santiago del Estero; San Juan; San Luis (except Gobernador Dupuy) and Tucumán.

[b]Buenos Aires (Adolfo Alsina, Bahía Blanca, Coronel de Marina L. Rosales, Coronel Dorrego, Coronel Pringles, Coronel Suárez, Daireaux, General La Madrid, Guaminí, Monte Hermoso, Patagones, Pellegrini, Puán, Saavedra, Salliqueló, Tornquist, Tres Lomas and Villarino); La Pampa (except Chalileo, Chapaleufú, Chical Co, Maracó, Rancul, Realicó and Trenel); Neuquén (only Confluencia); Río Negro (except Bariloche, Ñorquincó, Pilcaniyeu and 25 de Mayo).

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Table 2. Characteristics of spatial clusters with high mortality due to traffic injuries in motorcycle users, according to relative risk. Argentina 2007-2010.

	Observed cases	Expected cases	Relative risk	*p*-vale
Cluster 1[a]	2,196	1,222.5	8.20	<0.001
Cluster 2[b]	138	59.5	2.40	<0.001

Source: Own elaboration based on data from the Secretary of Health Statistics and Information, Ministry of Health of Argentina and the National Institute of Statistics and Censuses.

[a]Buenos Aires (Colón, General Arenales, General Pinto, Leandro N. Alem, Pergamino, Ramallo, Rojas, San Nicolás, San Pedro); Catamarca; Chaco; Córdoba; Corrientes; Entre Ríos (except Islas de Ibicuy); Formosa; Jujuy; La Pampa (only Realicó); La Rioja; Mendoza (except Malargüe); Misiones; Salta; Santa Fe; Santiago del Estero; San Juan; San Luis and Tucumán.
bBuenos Aires (only Puán); La Pampa (except Catriló, Chapaleufú, Chical Co, Conhelo, Maracó, Quemú Quemú, Rancul, Realicó and Trenel); Neuquén (only Confluencia); Río Negro (except Adolfo Alsina, Bariloche, Ñorquincó, Pilcaniyeu and 25 de Mayo).

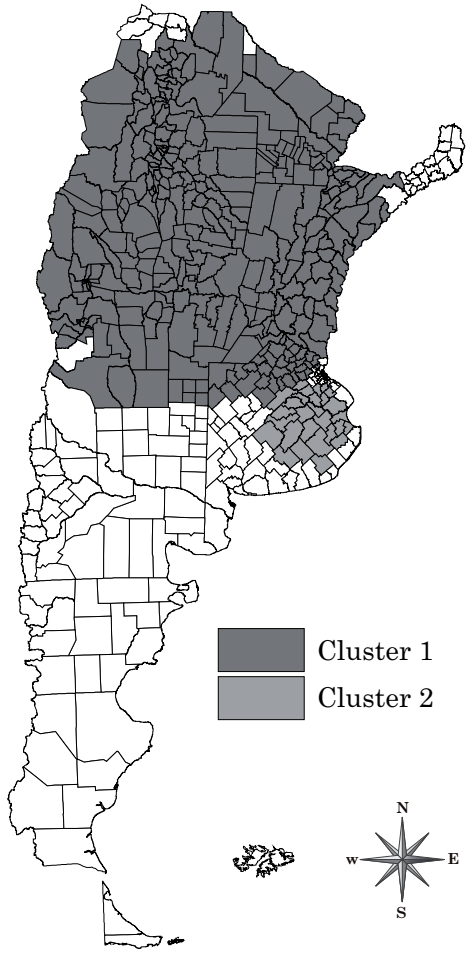

Figure 3. Statistically significant spatial clusters with high registration of motorcycles. Argentina 2007-2010.

Source: Own elaboration based on data from the Secretary of Health Statistics and Information, Ministry of Health of Argentina and the National Institute of Statistics and Censuses.

Table 3. Characteristics of spatial clusters with high numbers of motorcycle registrations.* Argentina 2001-2010.

	Observed cases	Expected cases	*p*-vale
Cluster 1[a]	1,243,277	929,402.9	<0.001
Cluster 2[b]	59,551	39,622.4	<0.001
Cluster 3[c]	20,878	15,302.6	<0.001
Cluster 4[d]	37,444	30,734.7	<0.001
Cluster 5[e]	4,228	3,825.8	<0.001
Cluster 6[f]	2,866	2,634.8	<0.05

Source: Own elaboration based on data from the Secretary of Health Statistics and Information, Ministry of Health of Argentina and the National Institute of Statistics and Censuses.

* Taking as the "population at risk" the number of residents in each spatial unit.
[a]Buenos Aires (Alberti, Arrecifes, Baradero, Bragado, Campana, Capitán Sarmiento, Carlos Tejedor, Carmen de Areco, Chacabuco, Chivilcoy, Colón, Escobar, Exaltación de la Cruz, Florentino Ameghino, General Arenales, General Pinto, General Viamonte, General Villegas, Junín, Leandro N. Alem, Lincoln, Luján, Mercedes, 9 de Julio, Pergamino, Ramallo, Rivadavia, Rojas, Salto, San Andrés de Giles, San Antonio de Areco, San Nicolás, San Pedro, Suipacha and Zarate); Catamarca; Chaco; Córdoba; Corrientes (except Santo Tomé); Entre Ríos; Formosa (except Ramón Lista); Jujuy (except Cochinoca, Rinconada, Santa Catalina and Yavi); La Pampa (Chapaleufú, Maracó, Rancul, Realicó and Trenel); La Rioja; Mendoza (except Malargüe and San Carlos); Salta (except Iruya and Santa Victoria); Santa Fe, Santiago del Estero, San Juan, San Luis and Tucumán
[b]Buenos Aires (Ayacucho, Azul, Balcarce, Benito Juárez, Brandsen, Cañuelas, Castelli, Chascomús, Dolores, General Alvear, General Belgrano, General Guido, General Paz, Las Flores, Lobos, Maipú, Monte, Navarro, Olavarría, Pila, Rauch, Roque Pérez, Saladillo, San Vicente, Tandil, Tapalqué, Tordillo and 25 de Mayo.
[c]Buenos Aires (Morón).
[d]Buenos Aires (La Plata).
[e]Buenos Aires (General Rodríguez).
[f]Buenos Aires (Ensenada).

Mortality and population density

Differences in the mortality of motorcycle users according to the levels of population density were registered, both inside and outside of the space-time clusters. Inside the space-time clusters 1 and 2, although a general increasing trend in the mortality rates of motorcycle users in the period 2001-2010 is observed, the highest rates are generally registered in departments with a higher population density (Figure 4). In contrast, no general pattern of increasing death rates in motorcycle users is registered in the remainder of the country, and the departments with greater population density registered the lowest mortality rates (Figure 5).

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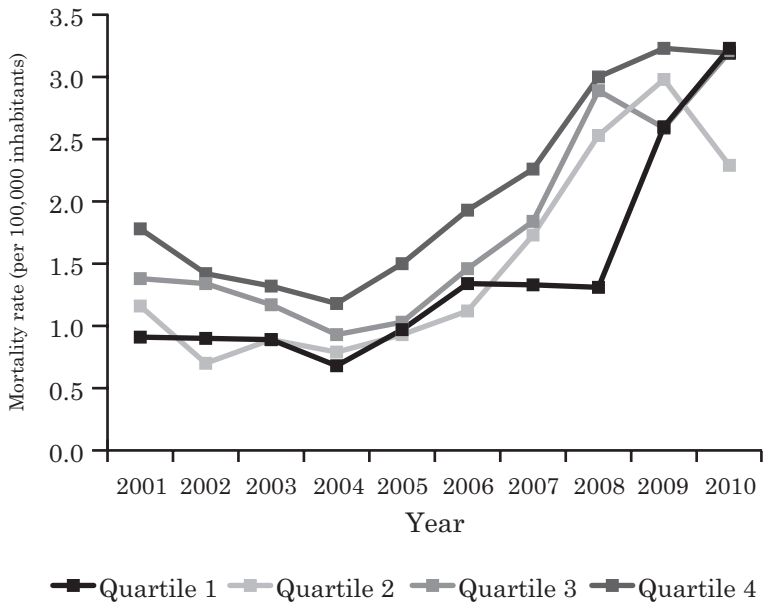

Figure 4. Mortality rate (per 100,000 inhabitants) due to traffic injuries in motorcycle users, by quartile of population density. Geographic areas that make up space-time clusters 1 and 2. Argentina, 2001-2010.

Source: Own elaboration based on data from the Secretary of Health, Statistics and Information, Ministry of Health of Argentina and the National Institute of Statistics and Censuses.

Note: Quartile 1: <2.68 inhabitants/km2; Quartile 2: 2.68-7.57; Quartile 3: 7.58-24.73; Quartile 4: >24.73).

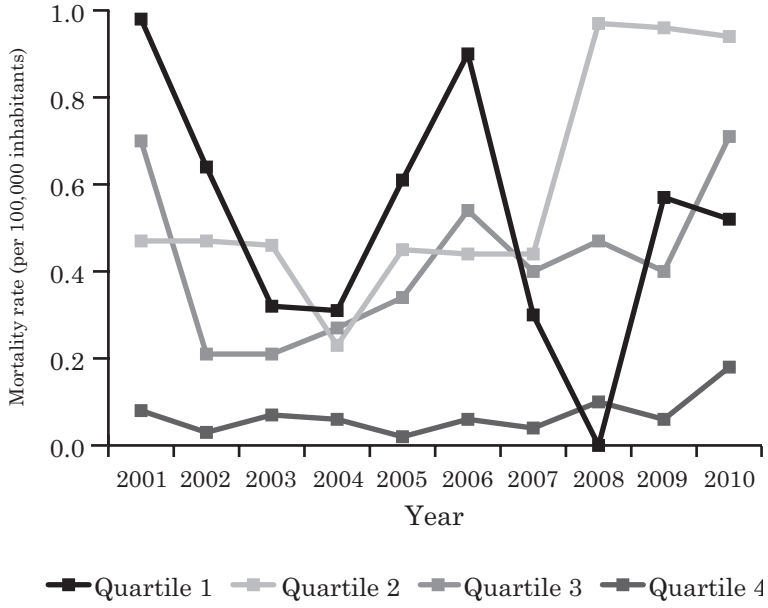

Figure 5: Mortality rate (per 100.000 inhabitants) due to traffic injuries in motorcycle users by quartile of population density. Geographic areas which do not make up space-time clusters 1 and 2. Argentina, 2001-2010.

Source: Own elaboration based on data from the Secretary of Health, Statistics and Information, Ministry of Health of Argentina and the National Institute of Statistics and Censuses.

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DISCUSSION

The mortality of motorcycle users showed a significant increase during the second half of the 2001-2010 period in the central and in the northern-central regions of the country. Although no annual data on motorcycle registrations was available until the year 2007, it was possible to confirm through other sources that at least from the year 2004 a constant increase in the sales of these vehicles occurred. While in 2004 sales were calculated at 64,000 motorcycles, in 2005 this number had almost tripled (189,000), and for the year 2007 motorcycles sales were calculated at 600,000 vehicles (18). This increase was favored by the relatively affordable prices of low displacement motorcycles, currently selling for around ARS $5,000-6,000 (equivalent to USD $856-1027), in addition to easy financing options provided by the banks (showing a guarantee of property ownership or proof of six months of employment in a registered job). This data supports the idea that the deaths of motorcycle users are related to the increase in the sales of these vehicles (6). During the last years, Brazil has also shown a significant increase in the mortality of motorcycle users which coincides with an important increase in the number of motorcycles in circulation (5). In that study, greater mortality rates were observed in the central-western region of Brazil, however researchers did not determine if this region also registered a higher increase in motorcycle sales in relation to other regions of the country.

The spatial analysis seems to show a geographic relation between these variables. The sales of new motorcycles generated a spatial cluster in the central-northern region of the country, in accordance with a cluster of similar size and geographic location for the death of motorcycle users. However, a second spatial cluster of motorcycle registrations was located in the interior of the province of Buenos Aires, without showing a spatial relation with the mortality of motorcycle users. The opposite happened in a high mortality cluster located primarily in the provinces of La Pampa and Río Negro.

This important increase of motorcycle sales was likely accompanied by a lack of helmet use by the riders of these vehicles, generating a greater amount of fatalities. In accordance with the results of the National Survey of Risk Factors carried out during 2005, the provinces of Buenos Aires, Chaco, Entre Ríos, Jujuy, La Pampa, Salta and Santiago del Estero had a greater proportion of bicycle and motorcycle users that expressed never having used a helmet (19). These provinces, located in the center and north of Argentina, match the space-time clusters with high mortality registered during the second half of the period 2001-2010.

A study carried out in the city of Santa Fe, which is located in space-time cluster 1 and in spatial cluster 1, registered a low rate in helmet use (12%) and a decrease in helmet use during the period 1999-2006 (20). The decrease in compliance with this transit law was accompanied by an increase in the use of motorcycles during this same period (20). In the city of Mar del Plata, located outside of the high mortality clusters, 40% of motorcycle users wear helmets (21). This data reflects the low helmet usage of motorcyclists in Argentina. Given this troubling scenario, two prevention policies are possible. Firstly, the State and motorcycle manufacturers and importers should agree that these vehicles must obligatorily be sold with a helmet, as was recently implemented in Colombia (22). Secondly, controls and fines pursuant to the Transit Act No. 24449 have to be reinforced, especially in the main cities of the central and central-northern regions of Argentina.

In another study carried out in the US based on data from 62,840 adult motorcycle users involved in traffic accidents, black motorcycle users had a significantly greater probability of death in relation to users of European descent, despite the fact that black motorcyclists had greater helmet use (23). The authors of the study suggested limited access to and low quality of health services as one cause of this difference. Such a hypothesis may also be valid in the present study: even with similar levels of helmet use, territorial disparities in relation to access to health services may explain differences in mortality rates.

Improvements in population welfare, indirectly measured through annual motorcycle registrations, may also have caused the spread of "welfare illnesses" by increasing the number of deaths in motorcycle users. It seems that there is a relation between the adoption of a new motor

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vehicle – that is, a person who buys and registers a motorcycle likely for the first time – and the cases of mortality in users of this type of vehicles.

By taking the increase in motorcycle registrations as an indicator of economic growth, this study provides more evidence regarding the relation between economic prosperity and the increase in the general mortality of the population. Specifically, Ruhm (24,25) and Tapia Granados (26) have reported a decrease in death due to traffic injuries given the increase of unemployment rates in the US.

Future studies should determine if the deaths of motorcycle users, specifically in the center and north of Argentina, are related to an increase in employment (workers who use motorcycles as an inexpensive means of traveling to their workplace) or to new consumption patterns and improvements in the quality of life in certain sociodemographic groups (young people who use motorcycles as a means of transportation and recreation, adopting risky behaviors such as driving under the influence of alcohol or not wearing a helmet).

Generally, there is a negative relation between mortality rates due to traffic injuries and population density (27-29) and, specifically, between this variable and the mortality of motorcycle users (30). In this study, the areas with greater increases than expected in mortality rates of motorcycle users registered higher mortality rates in departments with high population density for the period 2001-2010. In contrast, outside these areas, mortality rates in the departments with low population density were greater.

These results demonstrate the need to formulate distinct prevention policies for each of these areas. Moreover, further studies should test the existence of different motorcycle user profiles between the central and northern-central areas as compared to the rest of Argentina, taking into account areas with different population density.

This study has some limitations. First, motorcycle registrations in a particular department may have increased as a result of the demand of neighboring departments. Second, due to the absence of annual population estimates by age group, the mortality of motorcycle users could not be adjusted to consider spatial variations in the age structure of the population. Finally, the lack of secondary data related to the use of motorcycles for work purposes (such as the increase in working hours, productivity, young workers and outsourcing for fast delivery of products and documents) prevented us from testing the effects of these variables in the mortality rate of motorcycle users.

CONCLUSIONS

This study shows that the mortality of motorcycle users has space-time distribution patterns in Argentina with clusters of high mortality in the second half of the 2001-2010 period in the central and northern-central regions of the country. Within these areas, the highest rates were registered in departments with higher population density. Lastly, there is a spatial relation between the deaths of motorcycle users and the sale of these vehicles in the northern-central area of the country.

Specific prevention policies for motorcycle users (control enhancement and penalties for lack of helmet use) should be applied, especially in these areas of the country.

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