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Man, road and vehicle: risk factors associated with the severity of traffic accidents

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ABSTRACT

OBJECTIVE: To describe the main characteristics of victims, roads and vehicles involved in traffic accidents and the risk factors involved in accidents resulting in death.

METHODS: A non-concurrent cohort study of traffic accidents in Fortaleza, CE, Northeastern Brazil, in the period from January 2004 to December 2008. Data from the Fortaleza Traffic Accidents Information System, the Mortality Information System, the Hospital Information System and the State Traffic Department Driving Licenses and Vehicle database. Deterministic and probabilistic relationship techniques were used to integrate the databases. First, descriptive analysis of data relating to people, roads, vehicles and weather was carried out. In the investigation of risk factors for death by traffic accident, generalized linear models were used. The fit of the model was verified by likelihood ratio and ROC analysis.

RESULTS: There were 118,830 accidents recorded in the period. The most common types of accidents were crashes/collisions (78.1%), running over pedestrians (11.9%), colliding with a fixed obstacle (3.9%), and with motorcycles (18.1%). Deaths occurred in 1.4% of accidents. The factors that were independently associated with death by traffic accident in the final model were bicycles (OR = 21.2, 95%CI 16.1;27.8), running over pedestrians OR = 5.9 (95%CI 3.7;9.2), collision with a fixed obstacle (OR = 5.7, 95%CI 3.1;10.5) and accidents involving motorcyclists (OR = 3.5, 95%CI 2.6;4.6). The main contributing factors were a single person being involved (OR = 6.6, 95%CI 4.1;10.73), presence of unskilled drivers (OR = 4.1, 95%CI 2.9;5.5) a single vehicle (OR = 3.9, 95%CI 2,3;6,4), male (OR = 2.5, 95%CI 1.9;3.3), traffic on roads under federal jurisdiction (OR = 2.4, 95%CI 1.8;3.7), early morning hours (OR = 2.4, 95%CI 1.8;3.0), and Sundays (OR = 1.7, 95%CI 1.3;2.2), adjusted according to the log-binomial model.

CONCLUSIONS: Activities promoting the prevention of traffic accidents should primarily focus on accidents involving two-wheeled vehicles that most often involves a single person, unskilled, male, at nighttime, on weekends and on roads where they travel at higher speeds.

DESCRIPTORS: Accidents, Traffic, mortality. Risk Factors. Hospital Information Systems. Mortality Registries. Urban Population.

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INTRODUCTION

Traffic accidents remain a significant public health problem in Brazil and preventative activities require different approaches. The dynamic of this multi-causal phenomenon affects victims to different degrees depending on the type of accident (run over pedestrian, motorbike accident or another type of accident involving a vehicle or motorbike)[1] and demographic characteristics (sex, age, skin color, marital status and schooling).[12,20] Monthly distribution is differentiated by day of the week and time of day.[5] Research using analysis techniques to understand these characteristics are relevant to redirecting activities aiming to reduce the severity of the accidents.

The factors involved, implicitly or explicitly, which can contribute to a greater or lesser extent to casuistry are: man; vehicle; road and environment; and factors referring to legislation and complying with it.[4] Separating these factors and studying their associations is necessary in order to better understand and intervene in the phenomenon of traffic accidents. This is because these factors combined may increase the likelihood of accidents in different ways in specific areas.[a,b]

A significant number of studies in Brazil have looked at fatalities due to traffic accidents. However, there are few studies that deal with survivors of these accidents, which has led some authors to emphasize the importance of research into non-fatal accidents.[9,10,14,18,c] In addition to being scarce, these studies make use of different methodologies different sources of data. A large part of this output refers to problems with the coverage and quality of the official information systems as limiting factors to understanding this phenomenon.[20]

For specialists, the lack of an integrated information system based on standardized police reports of traffic accidents makes it impossible to really know the situation of traffic accidents in the country and, therefore, makes it impossible to put in place appropriate measures to mitigate it.[7] As a way of overcoming this difficulty, techniques to relate databases were used in order to improve the quality of information on the number of variables investigated and the number of valid records, achieving more complete information.

This study aimed to describe characteristics of the victims, the roads and the vehicles involved in traffic accidents and risk factors for fatal accidents.

METHODS

A non-concurrent cohort study of traffic accidents that occurred within the geographical limits of Fortaleza, CE, Northeastern Brazil, between January 1st 2004 and December 31st 2008. The incidents covered those registered in Police Incident Reports (PI) recorded in the Fortaleza Traffic Accidents Information System (SIAT-FOR) and run by the Fortaleza Municipal Transit Authority (AMC). A traffic accident was deemed to be any incident that occurred on a public road, including not only crashes between vehicles but also collisions with fixed objects, collisions between pedestrians and cyclists, vehicles overturning, running over pedestrians and vehicles leaving the road.[17] Criteria for inclusion were the accident being recorded in a PI, with or without injuries or fatalities among the victims and accidents that were not recorded in a PI were excluded.

Fortaleza is a metropolitan agglomeration in the Northeast of Brazil and is classed as the fifth largest city in the country. The urban area is crisscrossed by a 3,700 km network of roads. Of this total, around 35 km are under state jurisdiction and 25 km under federal jurisdiction.[d] The road layout follows a radio-centric pattern and constituted the main connections between the urban area and neighboring municipalities. The roads are narrow as they originate in a layout defined when the city was founded and due to their use not being managed and a lack of control in occupation of the terrain, this makes it unviable to extend them and the system has become insufficient.[e]

Data were collected from the SIAT-FOR system, which includes ten bodies involved in dealing with traffic accidents in the municipality.

Data from the *Habilitação e Veículos do Departamento Estadual de Trânsito* (DETRAN-CE – State Traffic Department Driving Licenses and Vehicle) database were also used, as were data from the *Informações de Mortalidade* (SIM – Mortality Information System), which contains death certificates and data from the *Sistema de Informações Hospitalares* (SIH – Hospital Information System), with the aim of obtaining complementing the data. Databases on hospitalization and deaths (SIH and SIM) were accessed through the Ceará State Department of Health (SESA). The data from the SIM refer to all deaths that occurred in Ceará between

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[d] Departamento Nacional de Trânsito (BR). Anuário estatístico de acidentes de trânsito de Fortaleza - 2008. Ceará; 2009.
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January 2004 and March 2009, as accidents occurring in December may have led to death in 2009. Data on hospitalization in the Brazilian Unified Health System (SUS) network in Fortaleza are for between January 2004 and July 2009, as requests for payment can be presented up to six months after being authorized.

Data on vehicles and driving licenses were obtained from DETRAN-CE and refer to all vehicles and licenses in the state of Ceará up to December 31st, 2008.The variables investigated were categorized in four groups: characteristics of the victim, subdivided into socio-demographic characteristics, length of time driving and state of vehicle at the time of the accident; variables related to the time (year, time and week); jurisdiction of the road, location of the accident and illumination; type of accident, type and age of vehicle.

The databases were linked using relationship techniques to create one single database containing information on the vehicle, the road, the driver and the individuals involved.

Two methods were used in this process: deterministic and probabilistic relationship techniques.[6,13]

Data on the accidents collected by the SIAT-FOR system were complemented according to the two types of relationship, involving two different stages. In the first, deterministic, stage the SIAT-FOR database, provided by the AMC, regarding vehicles which had been involved in traffic accidents, was linked to the DETRAN-CE database using vehicle license plates to obtain information on the year and type of vehicle. Data on the driver: type and year of driving license, sex, marital status, level of schooling, date of birth and mother's name were obtained from the database provided by DETRAN-CE based on the driving license number, registered in the SIAT-FOR system database of individuals involved in traffic accidents.

Complementing the data concerning pedestrians and passengers involved in traffic accidents was achieved by using probabilistic relationship technique, together with the SIM and SIH systems. The key variables were: name and age of victim and date of the accident when the individual died or was hospitalized in the SUS network.

In order to analyze the traffic accidents, a set of co-variables was created based on the variables described: type and number of vehicles involved, type and number of individuals, age of the vehicles, sex of the driver, status of the drivers' licenses, length of time drivers had been driving and their age, marital status and schooling.

Descriptive data were presented according to the variables in question. Pearson's Chi-squared test, Fisher's exact test and the Student t-test were used in the comparative analysis. Estimated risk of a fatal accident was verified with bivariate analysis using the odds ratio, with a 95% confidence interval. Variables which had an association with a fatal accident of $p < 0.20$ according to the Chi-squared test were selected to be included in the multinomial analysis.[11]

The multinomial analysis was carried out using the Generalized Linear Model (GLM) with binomial distribution and the logistic link function. The choice of this distribution was justified as the measurement of the outcome was dichotomous.

The modelling followed the strategy recommended by Hosmer & Lemeshow[11] and each variable was withdrawn after comparison of the models' likelihood ratio (-2logL) with and without the variable in question. Variables remained in the model according to theoretical justifications and statistical significance.

The final model was assessed for sensitivity, specificity accuracy and based on the percentage improvement of the model in relation to the initial *deviance* (likelihood ratio). The value of the area above the ROC curve was 0.86, indicating high discriminatory power.

The research was approved by the Ethics Committee of the *Universidade Federal do Ceará* (Process No. 90/2008).

RESULTS

There were 118,830 traffic accidents in Fortaleza between January 2004 and December 2008, 1.4% were fatal and 46.6% involved serious or minor injuries. Of the incidents, 78.1% were categorized as a cash/collision and 11.9% were pedestrians run down, 3.9% were collisions with a fixed obstacle, 0.5% involved the vehicle overturning and 5.6% involved the vehicle falling/leaving the road and other types of accidents on public roads (Table 1).

The annual mean number of accidents in the period was 23,767 accidents/year, and the highest number of incidents was recorded in 2008 (20.8%; $p < 0.001$). The monthly mean for the period was 1,981 accidents/month. The quarter from October to December stands out as having the highest number of accidents (mean of 6,382 accidents), while the January to March quarter had the lowest number of accidents (mean of 5,421 accidents; $p < 0.001$) (Table 1).

Around 43.7% of the accidents occurred between cars and/or trucks, 26.5% involved motorcyclists and 8.5% were between motorcyclists. Accidents involving more than two vehicles were in the minority throughout the study, especially in 2005 (4.7%; $p < 0.001$) (Table 1).

In 75.1% of the accidents, only one driver of a motorized vehicle was involved. Accidents involving passengers in

Table 1. Absolute and relative frequency of traffic accidents according to the variables studied and the year in which they occurred. Fortaleza, CE, Northeastern Brazil, 2004 to 2008.

Variable	2004		2005		2006		2007		2008		Accidents	
	n	%	n	%	n	%	n	%	n	%	n	%
Type of accident												
Crash/collision	17,381	76.1	18,074	74.8	18,093	77.2	18,912	79.8	20,387	82.7	92,847	78.1
Running over pedestrian	3,027	13.2	3,160	13.1	2,784	11.9	2,746	11.6	2,366	9.6	14,083	11.9
Fall/leaving road and other	1,441	6.3	1,784	7.4	1,494	6.4	981	4.1	925	3.8	6,625	5.6
Collision with a fixed object	878	3.8	999	4.1	952	4.1	953	4.0	870	3.5	4,652	3.9
Vehicle overturned	126	0.6	155	0.6	120	0.5	108	0.5	114	0.5	623	0.5
Total	22,853	100.0	24,172	100.0	23,443	100.0	23,700	100.0	24,662	100.0	118,830	100.0
Vehicles involved												
Only car/truck	9,622	42.1	10,761	44.5	10,267	43.8	10,430	44.0	10,857	44.0	51,937	43.7
Only motorcycles	1,941	8.5	2,238	9.3	2,161	9.2	1,966	8.3	1,852	7.5	10,158	8.5
With motorcycles	3,857	16.9	4,149	17.2	4,299	18.3	4,360	18.4	4,788	19.4	21,453	18.1
Heavy goods vehicles	3,568	15.6	3,396	14.0	3,534	15.1	3,888	16.4	4,678	19.0	19,064	16.0
With bicycles	2,226	9.7	2,328	9.6	2,051	8.7	1,599	6.7	1,552	6.3	9,756	8.2
Various vehicles	1,639	7.2	1,300	5.4	1,131	4.8	1,457	6.1	935	3.8	6,462	5.4
Total		100.0		100.0		100.0		100.0		100.0		100.0
Number of vehicles involved												
One vehicle	5,383	23.6	6,013	24.9	5,289	22.6	4,713	19.9	4,177	16.9	25,575	21.5
Two vehicles	16,375	71.7	17,019	70.4	16,984	72.4	17,659	74.5	19,091	77.4	87,128	73.3
More than two vehicles	1,095	4.8	1,140	4.7	1,170	5.0	1,328	5.6	1,394	5.7	6,127	5.2
Total		100.0		100.0		100.0		100.0		100.0		100.0
Type of individual involved												
Only driver	16,332	71.5	17,571	72.7	17,442	74.4	18,182	76.7	19,728	80.0	89,255	75.1
Passenger	1,352	5.9	1,211	5.0	1,246	5.3	1,251	5.3	1,113	4.5	6,173	5.2
Pedestrian and/or cyclist	5,169	22.6	5,390	22.3	4,755	20.3	4,267	18.0	3,821	15.5	23,402	19.7
Total		100.0		100.0		100.0		100.0		100.0		100.0
Number of individuals involved												
One	2,130	9.3	2,615	10.8	2,269	9.7	1,781	7.5	1,701	6.9	10,496	8.8
Two	18,448	80.7	19,338	80.0	18,860	80.5	19,397	81.8	20,600	83.5	96,643	81.3
More than two	2,275	10.0	2,219	9.2	2,314	9.9	2,522	10.6	2,361	9.6	11,691	9.8
Total		100.0		100.0		100.0		100.0		100.0		100.0

Continue

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Type of intersection												
Crossing	7,121	31.2	7,205	29.8	7,186	30.7	7,170	30.3	7,006	28.4	35,688	30.0
T and double T, Y, roundabout and other	829	3.6	1,002	4.1	1,179	5.0	1,219	5.1	1,233	5.0	5,462	4.6
Level crossing	60	0.3	54	0.2	59	0.3	61	0.3	30	0.1	264	0.2
Mid-block	14,843	64.9	15,911	65.8	15,019	64.1	15,250	64.3	16,393	66.5	77,416	65.1
Total		100.0		100.0		100.0		100.0		100.0		100.0
Jurisdiction												
Municipal	21,331	93.3	22,627	93.6	21,907	93.4	21,811	92.0	22,385	90.8	110,065	92.6
State	1,048	4.6	994	4.1	991	4.2	1,122	4.7	1,199	4.9	5,354	4.5
Federal	474	2.1	551	2.3	545	2.3	767	3.2	1,078	4.4	3,415	2.9
Total		100.0		100.0		100.0		100.0		100.0		100.0
Type of road surface												
Not asphalt	8,881	38.9	9,336	38.6	8,839	37.2	8,805	37.2	8,489	34.4	44,350	37.3
Asphalt	13,972	61.1	14,836	61.4	14,895	62.8	14,895	62.8	16,173	65.6	74,480	62.7
Total		100.0		100.0		100.0		100.0		100.0		100.0
Light												
Daylight	12,481	67.5	13,145	67.0	12,785	66.8	13,246	67.6	14,357	68.9	66,014	67.6
Dawn	767	4.1	857	4.4	822	4.3	839	4.3	648	3.1	3,933	4.0
Dusk	2,213	12.0	2,359	12.0	2,293	12.0	2,218	11.3	2,245	10.8	11,328	11.6
Street lighting	2,224	12.0	2,481	12.7	2,531	13.2	2,629	13.4	2,933	14.1	12,798	13.1
Poor/no illumination	802	4.3	763	3.9	705	3.7	669	3.4	667	3.2	3,606	3.7
Total		100.0		100.0		100.0		100.0		100.0		100.0
Type of signs												
Traffic lights	3,491	17.3	4,166	18.6	4,297	19.5	4,291	19.3	4,557	19.4	20,802	18.9
Overhead	3,168	15.7	3,752	16.8	4,212	19.1	4,096	18.4	4,770	20.3	19,998	18.1
Lateral	13,540	67.0	14,452	64.6	13,487	61.3	13,895	62.4	14,170	60.3	69,544	63.0
Total		100.0		100.0		100.0		100.0		100.0		100.0

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Continuation

Time												
Morning	6,084	27.2	6,466	27.3	6,223	27.2	6,519	28.0	7,375	30.4	32,667	28.1
Afternoon	7,755	34.6	8,202	34.7	8,100	35.4	8,192	35.2	8,646	35.7	40,895	35.1
Night	6,637	29.6	6,834	28.9	6,525	28.5	6,460	27.8	6,474	26.7	32,930	28.3
Early morning	1,912	8.5	2,143	9.1	2,053	9.0	2,098	9.0	1,741	7.2	9,947	8.5
Total		100.0		100.0		100.0		100.0		100.0		100.0
Week												
Monday - Friday	15,334	67.1	15,898	65.8	15,684	66.9	16,314	68.8	17,820	72.3	81,054	68.2
Saturday and Sunday	7,519	32.9	8,274	34.2	7,759	33.1	7,386	31.2	6,842	27.7	37,780	31.8
Total		100.0		100.0		100.0		100.0		100.0		100.0
Day of the week												
Wednesday	2,806	12.3	3,015	12.5	2,952	12.6	3,100	13.1	3,482	14.1	15,355	12.9
Thursday	3,110	13.6	3,076	12.7	3,177	13.6	3,141	13.3	3,397	13.8	15,901	13.4
Friday	3,780	16.5	3,711	15.4	3,572	15.2	3,778	15.9	3,996	16.2	18,837	15.9
Saturday	4,085	17.9	4,443	18.4	4,121	17.6	4,093	17.3	3,818	15.5	20,560	17.3
Sunday	3,434	15.0	3,831	15.8	3,638	15.5	3,293	13.9	3,024	12.3	17,220	14.5
Monday	2,912	12.7	3,122	12.9	3,097	13.2	3,270	13.8	3,495	14.2	15,896	13.4
Tuesday	2,726	11.9	2,974	12.3	2,886	12.3	3,025	12.8	3,450	14.0	15,061	12.7
Total		100.0		100.0		100.0		100.0		100.0		100.0
Quarter												
January to March	5,042	22.1	5,377	22.2	5,573	23.8	5,351	22.6	5,761	23.4	27,104	22.8
April to June	5,915	25.9	5,982	24.7	5,940	25.3	5,857	24.7	6,305	25.6	29,999	25.2
July to September	5,686	24.9	6,330	26.2	5,844	24.9	5,963	25.2	5,993	24.3	29,816	25.1
October to December	6,210	27.2	6,483	26.8	6,086	26.0	6,529	27.5	6,603	26.8	31,911	26.9
Total		100.0		100.0		100.0		100.0		100.0		100.0

any type of vehicle were in the minority throughout the period (5.2%). The mean number of individuals involved in accidents was 2.03 individuals/accident.

Almost two thirds (65.1%) of incidents occurred in moving traffic, categorized as mid-block, followed by at intersections (30.0%); 67.6% occurred in daylight, 13.1% during the night on illuminated roads and 11.6% at dusk. Unlit or poorly lit streets accounted for 3.7% and 4.0% occurred at dawn; 63.2% of accidents occurred during the day. The afternoon, between 12.00 and 18.00, was the period in which the highest number of incidents were recorded (35.1%) (Table 1).

Almost all incidents (92.6%) occurred under municipal jurisdiction, followed by state jurisdiction (4.5%), due to the distribution of jurisdiction in the city's road network. Saturday was the day on which most accident occurred (17.3%), followed by Friday (15.9%) and Sunday (14.5%). Tuesdays and Wednesdays are the days on which fewest accidents occurred (12.7% and 12.9%, respectively) (Table 1).

In the bivariate analysis, accidents involving bicycles had the highest gross risk (OR = 3.95; 95%CI 3.44;5.17) of being fatal, based on accidents with automobiles or trucks. Accidents between motorcycles had the second highest gross risk of being fatal (OR = 2.88; 95%CI 2.48;3.34). Accidents involving one vehicle had a higher risk of fatalities (OR = 4.15; 95%CI 3.77;4.57) than accidents with two vehicles (Table 2).

Running over pedestrians (OR = 6.32; 95%CI 5.71;6.98) had a higher gross risk of being fatal, followed by accidents involving the vehicle overturning (OR = 4.90; 95%CI 3.32;7.24) and colliding with a fixed obstacle (OR = 3.57; 95%CI 2.98;4.28), compared with crashes or collisions (Table 2).

Individuals holding a license for fewer than five years (OR = 1.78; 95%CI 1.52;2.08) had a higher gross risk of being involved in a fatal accident compared with drivers with more than five years' experience. Drivers without an appropriate license (OR = 1.95; 95%CI 1.74;2.18) had the highest risk of being involved in a fatal accident, compared with licensed drivers (Table 3).

Accidents in moving traffic or mid-block (OR = 2.02; 95%CI 1.79;2.19) had the highest gross risk of involving fatalities and occurred with higher frequency, in contrast to accidents at level crossings (OR = 8.50; 95%CI 5.44;13.30), which carry a higher risk of fatality but occur with less frequency. Around 18.9% of incidents occurred at traffic lights and do not carry a risk of fatalities compared with overhead road signs. Accidents involving lateral road signs (OR = 2.26; 95%CI 1.92;2.66) represented 63% of the total and had a gross risk of fatal accidents compared with overhead road signs (Table 1, Table 2).

The severity of the accidents proved to be more accentuated at a federal level federal (OR = 4.30; 95%CI 3.70;4.99), followed by a state level, compared with municipal. The gross risk of fatal accidents was higher at dusk (OR = 2.78; 95%CI 2.32;3.34) compared with daylight. Sunday (OR = 2.11; 95%CI 1.76;2.53) was the day with the highest gross risk of fatal accidents compared with Wednesday. The gross risk of a fatal accident was higher in the early hours of the morning (OR = 2.42; 95%CI 2.07;2.82), followed by during the night (OR = 1.48; 95%CI 1.30;1.68) compared with in the morning (Table 2).

Table 2. Bivariate analysis to investigate factors related to roads, vehicles and time associated with fatal traffic accidents. Fortaleza, CE, Northeastern Brazil, 2004 to 2008.

Variable	Traffic accident						OR	95%CI	χ^2	p
	Total		Fatal		No fatality					
	n	%	n	%	n	%				
Type of accident										
Crash/collision	92,847	78.1	760	0.8	92,087	99.2				
Running over pedestrian	14,083	11.9	728	5.2	13,355	94.8	6.32	5.71;6.98	1530.95	0.0000
Fall/leaving road and other	6,625	5.6	49	0.7	6,576	99.3	0.90	0.68;1.20	1.92	0.4895
Collision with a fixed object	4,652	3.9	136	2.9	4,516	97.1	3.57	2.98;4.28	182.41	0.0000
Vehicle overturned	623	0.5	25	4.0	598	96.0	4.90	3.32;7.24	24.37	0.0000
Type of vehicles										
Only car/truck	51,937	43.7	462	0.9	51,475	99.1				
Only motorcycles	10,158	8.5	260	2.6	9,898	97.4	2.88	2.48;3.34	387.77	0.0000
With motorcycles	21,453	18.1	203	0.9	21,250	99.1	1.06	0.90;1.25	136.96	0.0000
Heavy goods vehicles	19,064	16.0	269	1.4	18,795	98.6	1.59	1.37;1.84	1771.98	0.0000
With bicycles	9,756	8.2	343	3.5	9,413	96.5	3.95	3.44;4.17	117.54	0.0000
Various vehicles	6,462	5.4	161	2.5	6,301	97.5	2.80	2.35;3.34		0.0000

Continue

Continuation

Number of vehicles involved										
One vehicle	87,128	73.3	745	0.9	86,383	99.1				
Two vehicles	25,575	21.5	907	3.5	24,668	96.5	4.15	3.77;4.57	991.56	0.0000
More than two vehicles	6,127	5.2	46	0.8	6,081	99.2	0.88	0.65;1.18	0.74	0.0000
Age of vehicles										
Over ten years	32,944	27.7	133	0.4	32,811	99.6				
Between six and ten years	23,986	20.2	501	2.1	23,485	97.9	5.17	4.28;6.26	357.85	0.0000
Only vehicles under 5 years	25,810	21.7	452	1.8	25,358	98.2	4.34	3.58;5.26	266.58	0.0000
Location										
Crossing	35,688	30.0	302	0.8	35,386	99.2				
T, Duplo T, Y, roundabout and other	5,462	4.6	51	0.9	5,411	99.1	1.10	0.82;1.48	1.66	0.5137
Level crossing	264	0.2	19	7.2	245	92.8	8.50	5.44;13.30	7.60	0.0000
Mid-block	77,416	65.1	1.326	1.7	76,090	98.3	2.02	1.79;2.19	128.22	0.0000
Jurisdiction										
Municipal	110,061	92.6	1.402	1.3	108,659	98.7				
State	5,354	4.5	109	2.0	5,245	98.0	1.60	1.32;1.94	22.95	0.0000
Federal	3,415	2.9	187	5.5	3,228	94.5	4.30	3.70;4.99	423.58	0.0000
Road surface										
Not asphalted	44,350	37.3	495	1.1	43,855	98.9				
Asphalt	74,880	63.0	1.203	1.6	73,677	98.4	1.44	1.30;1.60	47.72	0.0000
Light										
Daylight	65,337	55.0	725	1.1	64,612	98.9				
Dawn	4,402	3.7	136	3.1	4,266	96.9	2.78	2.32;3.34	97.97	0.0000
Dusk	11,323	9.5	211	1.9	11,112	98.1	1.68	1.44;1.96	42.24	0.0000
Street lighting	12,759	10.7	217	1.7	12,542	98.3	1.53	1.32;1.78	28.22	0.0000
Poor/no illumination	22,898	19.3	406	1.8	22,492	98.2	1.60	1.42;1.80	36.15	0.0000
Type of signs										
Traffic lights	19,998	16.8	160	0.8	19,838	99.2				
Overhead	20,802	17.5	185	0.9	20,617	99.1	1.11	0.90;1.37	0.97	0.3249
Lateral	69,544	58.5	1.256	1.8	68,288	98.2	2.26	1.92;2.66	100.99	0.0000
Time										
Morning	32,667	27.5	372	1.1	32,295	98.9				
Afternoon	40,895	34.4	498	1.2	40,397	98.8	1.07	0.94;1.22	0.97	0.3248
Night	32,930	27.7	554	1.7	32,376	98.3	1.48	1.30;1.68	34.82	0.0000
Early morning	9,951	8.4	274	2.8	9,677	97.2	2.42	2.07;2.82	127.57	0.0000
Week										
Monday - Friday	81,054	68.2	956	1.2	80,098	98.8				
Saturday and Sunday	37,780	31.8	742	2.0	37,038	98.0	1.67	1.51;1.83	112.59	0.0000
Day of the week										
Wednesday	15,355	12.9	165	1.1	15,190	98.9				
Thursday	15,901	13.4	186	1.2	15,715	98.8	1.15	0.93;1.41	1.69	0.1931
Friday	18,837	15.9	240	1.3	18,597	98.7	1.19	0.97;1.44	2.88	0.0899
Saturday	20,560	17.3	351	1.7	20,209	98.3	1.59	1.32;1.91	24.84	0.0001
Sunday	17,220	14.5	391	2.3	16,829	97.7	2.11	1.76;2.53	69.21	0.0000
Monday	15,896	13.4	198	1.2	15,698	98.8	1.16	0.94;1.42	1.99	0.1584
Tuesday	15,061	12.7	167	1.1	14,894	98.9	1.03	0.83;1.28	0.08	0.7738
Quarter										
October to December	31,911	26.9	432	1.4	31,479	98.6				
January to March	27,104	22.8	387	1.4	26,717	98.6	1.05	0.92;1.21	0.59	0.4434
April to June	29,999	25.2	451	1.5	29,548	98.5	1.11	0.97;1.27	2.46	0.1160
July to September	29,816	25.1	428	1.4	29,388	98.6	1.06	0.93;1.21	0.75	0.3867

In the multinomial analysis, the presence of drivers who do not have a license (OR = 4.1; 95%CI 2.9;5.5) or do not have a license appropriate for the vehicle (OR = 1.6; 95%CI 1.2;1.9), using roads that are under federal jurisdiction (OR = 2.4; 95%CI 1.8;3.1), early hours of the morning (OR = 2.4; 95%CI 1.8;3.0) and Sundays (OR = 1.7; 95%CI 1.3;2.2) all stand out as contributing factors to fatal accidents (Table 3).

Accidents involving motorcyclists (OR = 3.5; 95%CI 2.6;4.5) were potentially fatal. The traffic accidents with the highest risk of fatality were those involving bicycles (OR = 21.2; 95%CI 16.1;27.8), running over pedestrians OR = 5.9 (95%CI 3.7;9.2) and collisions with fixed obstacles OR = 5.7 (95%CI 3.1;10.4).

DISCUSSION

Brazil is moving onto the world stage due to its promising economic growth, however, morbidity and mortality due to traffic accidents is recognized as a large-scale and highly complex phenomenon. It represents the relationship between investments in road safety, economic development policies centered around the automotive industry and traffic education.

Analyzing the factors which affect the occurrence of traffic accidents is a complex procedure as they are numerous and they are not independent.[8] The results of this study provide a broader view of the phenomenon of traffic accidents based on its analysis of characteristics of the road, the individuals and the vehicles involved.

Table 3. Bivariate analysis to investigate factors related to the roads, the vehicles and the time linked to fatal traffic accidents. Fortaleza, CE, Northeastern Brazil, 2004 to 2008.

Variable	Traffic accidents: Total n	Total %	Fatal n	Fatal %	No fatalities n	No fatalities %	OR	95%CI	χ^2	p
Sex of drivers										
Only female	10,696	9.0	106	1.0	10,590	99.0				
Only male	73,955	62.2	1,249	1.7	72,706	98.3	1.70	1.40;2.08	28.89	0.0000
Both	26,919	22.7	338	1.3	26,581	98.7	1.27	1.02;1.57	4.59	0.0302
Age of drivers										
From 25 to 64	63,369	53.3	972	1.5	62,397	98.5				
Under 25	27,407	23.1	503	1.8	26,904	98.2	1.20	1.08;1.33	10.87	0.0000
Presence of a driver aged over 65	5,513	4.6	223	4.0	5,290	96.0	2.64	2.29;3.04	187.60	0.0000
Marital status of driver										
Married	26,998	22.7	253	0.9	26,745	99.1				
Single	23,469	19.8	435	1.9	23,034	98.1	1.98	1.70;2.31	78.41	0.0000
Married and single	41,835	35.2	586	1.4	41,249	98.6	1.49	1.29;1.73	29.29	0.0000
Drivers' schooling										
Only further education	18,665	15.7	107	0.6	18,558	99.4				
High school and further education	36,490	30.7	347	1.0	36,143	99.0	1.66	1.34;2.06	50.91	0.0000
Primary education	42,837	36.0	1,166	2.7	41,671	97.3	4.75	3.90;5.78	549.99	0.0000
Type of individual involved										
Driver	89,255	75.1	395	0.4	88,860	99.6				
Passenger	6,173	5.2	241	3.9	5,932	96.1	8.82	7.53;10.33	1046.09	0.0000
Pedestrian or cyclist	23,402	19.7	1,062	4.5	22,340	95.5	10.25	9.41;11.50	2457.98	0.0000
Number of individuals involved										
Two	96,643	81.3	1,206	1.2	95,439	98.8				
More than three	11,691	9.8	350	3.0	11,340	97.0	2.40	2.13;2.70	224.61	0.0000
One	10,496	8.8	142	1.4	10,353	98.6	1.08	0.91;1.29	0.84	0.3586
Driving license										
Correct license	52,557	44.2	578	1.1	51,979	98.9				
Incorrect license	27,902	23.5	598	2.1	27,304	97.9	1.95	1.74;2.18	1.21	0.0000
No license	27,219	22.9	522	1.9	26,697	98.1	1.74	1.55;1.96	19.80	0.0000
Length of time driver has held license										
Drivers holding licenses for more than 5 years	53,027	44.6	546	1.0	52,481	99.0				
Drivers holding licenses for fewer than 5 years	11,998	10.1	220	1.8	11,778	98.2	1.78	1.52;2.08	54.33	0.0000

This aspect highlights the importance of inter-sector practices to better deal with the problem, in view of its complexity and the multiplicity of factors related to diverse areas of human knowledge.

Road structure, signs and illumination, the day of the week and time of day of the occurrence are connected to the severity of traffic accidents. Researchers have found similar results and attribute higher fatality rates to weekends and the early hours, to drinking and driving and speeding.[2] On the other hand, it is important to bear in mind the role of poor quality of lighting and adequate signage as a parameter of safety.[16]

Severity of the accident is related to the type of jurisdiction of the road, with higher risks at a federal level, followed by state, compared to municipal. The speed limit on each type of road and the flow of traffic differs and lead to congestion on municipal roads, leading to less serious accidents without injuries.

Drivers who have held a license for fewer than five years have the highest risk of being involved in a fatal accident, in contrast with the findings of other studies, which highlight older motorists as significantly more likely to be involved in serious and fatal accidents, when figures are adjusted for differences in exposure.[22] This information places the Brazilian process of issuing driving licenses under discussion. Lack of experience on the part of new drivers is an implicit criticism of the rigidity of the traffic code which stipulates that a learner's permit for up to a year is not sufficient to make them fit to drive vehicles.

Traffic, the condition of the road and the greater flow of individuals commuting increase exposure to the problem. Added to this is the culture of punishment at the expense of education around this phenomenon. These obstacles impede an improvement in the indicators, despite the implementation of public policies which attempt to mitigate the phenomenon. The more vulnerable population groups (pedestrians, cyclists and motorcyclists) become victims of the conditions of the road, the vehicles and the road users.

There are differences in the seriousness of traffic accidents according to type. Running over pedestrians and accidents involving cyclists and motorcyclists are described as more serious.[1] This fact is explained by the kinematics of trauma, and will continue to be a problem until equality exists in traffic.

The individual's position in the traffic is a determinant of the seriousness of the injury. The risk of death is higher among cyclists and pedestrians. This fact has also been presented in other studies, in which pedestrians and cyclists are the most vulnerable road users and make up the highest percentage of victims.[19] Whereas cyclists lack proper cycle lanes and need to struggle with the vehicles for space amid the oppression and the fumes, pedestrians are faced with narrow poorly maintained sidewalks. This occurs despite Fortaleza being a flat city where these methods of transport should, for diverse reasons, be prioritized: health, environment and economy.

Congestion in the large cities, inefficient public transport, tele-deliveries and mototaxis have led to the rapid spread of motorcycle use, representing an increase of 700% in fatalities between 1998 and 2008.[3] Their low cost and facilitated financing are responsible for the significant increase in motorcycles. The problem of the severity of this type of accident, as evidenced in this and other studies, raises the need to think about the safety of these road users.

Accidents in which only one vehicle was involved had a higher risk of fatality compared with accidents with two vehicles. Conflicts in traffic with more susceptible vehicles such as motorbikes and bicycles can lead to the driver falling. According to the kinematics of trauma, the injury is more severe where there is a greater transference of kinetic energy. This was proved in this study, in which the main type of accidents involving fatalities were those involving collisions with fixed objects and running down pedestrians. Speed is the most significant producer of this energy.

Both severity and incidence of accidents increase during the night and at the weekends, due to lack of congestion and drinking and driving, in view of the devastating effect of combining drink driving and speeding.

A difference was observed in the distribution of occurrence according to month, day of the week and time.[5] Socio-demographic factors such as sex, age and schooling are related to the occurrence and the severity of accidents.[12,20]

Individuals who are single are at greater risk than married individuals of suffering a serious or fatal traffic accident, even after adjusting for sex, age and alcohol,[21] which may be due to the fact that singles expose themselves more to risk factors, as confirmed in this study. The times and roads on which fatal accidents occur suggest less congested driving conditions and travelling connected to leisure activities, characterized by imprudence. This indicates the need for investment in preventing accidents and promoting safe driving through educational strategies, creating a culture of peace in the traffic.

Activities promoting the prevention of traffic accidents should prioritize and focus on accidents involving two wheeled vehicles, which often involve only one victim, on unqualified drivers, males, night time, weekends and on roads where higher speeds are reached.

Table 4. Final model of the multivariate analysis for factors associated with fatal traffic accidents. Fortaleza, CE, Northeastern Brazil, 2004 to 2008.

Factors		Error			
	OR	Standard	z	p	95%CI
Type of accident					
Crash/collision	1				
Running over pedestrian	6.31	1.33	8.72	0.0000	4.17;9.55
Fall/leaving road and other	1.27	0.71	0.43	0.6690	0.42;3.83
Collision with a fixed object	5.87	1.69	6.15	0.0000	3.34;10.31
Vehicle overturned	2.38	1.17	1.76	0.0780	0.91;6.23
Day of the week					
Wednesday	1				
Thursday	1.06	0.16	0.40	0.6910	0.79;1.43
Friday	1.29	0.18	1.78	0.0750	0.98;1.70
Saturday	1.42	0.19	2.60	0.0090	1.09;1.86
Sunday	1.73	0.24	3.98	0.0000	1.32;2.26
Monday	1.11	0.17	0.70	0.4840	0.83;1.49
Tuesday	1.08	0.17	0.51	0.6100	0.80;1.46
Time					
Morning	1				
Afternoon	1.04	0.10	0.45	0.6510	0.87;1.26
Night	1.33	0.13	2.96	0.0030	1.10;1.61
Early morning	2.36	0.30	6.73	0.0000	1.84;3.03
Jurisdiction					
Municipal	1				
State	1.45	0.21	2.62	0.0090	1.10;1.92
Federal	2.56	0.34	7.04	0.0000	1.97;3.32
Location					
Crossing	1				
T, Duplo T, Y, roundabout and other	0.93	0.18	-0.39	0.6970	0.641.35
Level crossing	2.99	1.44	2.26	0.0240	1.16;7.71
Mid-block	1.09	0.09	0.96	0.3350	0.92;1.29
Number of vehicles involved					
More than two	1				
Two	2.28	0.42	4.41	0.0000	1.58;3.28
One	8.44	2.59	6.95	0.0000	4.62;15.40
Type of vehicles					
Only car/truck	1				
Only motorcycles	1.77	0.24	4.30	0.0000	1.37;2.30
With motorcycles	3.39	0.46	8.97	0.0000	2.60;4.43
Heavy goods vehicles	2.14	0.33	4.90	0.0000	1.58;2.90
With bicycles	20.89	2.86	22.20	0.0000	15.97;27.32
Various vehicles	1.40	1.01	0.47	0.6420	0.34;5.73
Age of vehicles					
Over ten years	1				
Between six and ten years	1.63	0.19	4.10	0.0000	1.29;2.06
Only vehicles under five years	1.52	0.18	3.46	0.0010	1.20;1.92
Driving license					
Correct license	1				
Incorrect license	1.55	0.19	3.63	0.0000	1.22;1.96
No license	0.40	0.07	-5.01	0.0000	0.28;0.57

Continue

Continuation

Length of time drivers have held license					
More than five years	1				
Fewer than five years	1.09	0.11	0.84	0.3980	0.89;1.33
No license	3.87	0.60	8.68	0.0000	2.85;5.25
Number of individuals involved					
Two	1				
More than three	2.45	0.58	3.79	0.0000	1.54;3.90
One	6.79	1.65	7.89	0.0000	4.22;10.92
Drivers' schooling					
Only further education	1				
High school and further education	1.01	0.13	0.07	0.9420	0.79;1.29
Primary education	2.10	0.25	6.11	0.0000	1.65;2.66
Sex of drivers					
Only female	1				
Only male	1.48	0.30	1.94	0.0520	1.00;2.20
Both	0.62	0.15	-1.98	0.0480	0.39;1.00
Marital status of driver					
Married	1				
Single	1.07	0.10	0.76	0.4480	0.90;1.28
Married and single	1.34	0.14	2.79	0.0050	1.09;1.65

It is possible to unify various sources of data from different sectors in order to improve understanding of traffic accidents so as to produce inter-sector public policies which aim to reduce deaths from this problem. This study's analysis of the characteristics of risk in the accident, considering the individuals and the roads where the vehicles drive was an important contribution for increasing the number of factors related to this phenomenon.

A possible limitation of this study was using secondary data. However, we believe that the techniques used to link the databases are an innovation in dealing with factors which affect the severity of traffic accidents. The effort in integrating the different databases used and the results achieved go some way to substituting the need for establishing a unified information system which includes the variables necessary for analyzing the traffic situation in Brazil.

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