Risk factors for road traffic accidents severity in the province of Milan, Italy

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Abstract
To identify the major risk factors for the severity of road accidents in the province of Milan the police reports of more than 120 thousand accidents occurred in 2004 and 2005 were analysed. Logistic model to evaluate the different risk factors was performed. The risk of being injured or of dying rather than of being unhurt was higher for riders of two-wheeled vehicles (bicycles, motorcycles and mopeds) than for car drivers (OR of being injured 35.42, 34.96 and 26.97 respectively; OR of dying 133.32, 72.79 and 26.18 respectively). Women have a higher risk of being injured (OR: 1.98) but a lower risk of dying (OR: 0.64). Accidents which occurred during the night and during the weekend are more serious. The most dangerous accidents are the single-vehicle ones (OR of injuries with respect to head-on or side accidents: 1.88; OR of death: 1.85). Accidents on extra-urban roads and accidents on a wet or slippery surface are more associated with the risk of sustaining injuries (OR: 1.07 and OR: 1.20 respectively). The risk of being killed when involved in a road accident is higher for older drivers (>=65 years) compared with people younger than 30 years of age (OR: 2.84) and on extra-urban road and on motorway (OR with respect to accident in the urban area: 5.17 and 2.05 respectively).

KEY WORDS: *accident, injury, mortality, prevention, risk factor, road safety.*

Introduction

In the member states of the European Union, every year about 43 000 people die following a road accident, and about 1.8 million are injured (1).
Among the 25 European Union member countries, Italy ranks twelfth in mortality from traffic accidents (96 deaths per million inhabitants) and it is over the European average (85 deaths per million inhabitants) (1).
In Italy, an average of 598 road accidents are registered every day; these are associated with the average daily death of 13 people and 849 injured people. In 2008, 218 963 road accidents were registered, in which 4731 people died, and a further 310 739 were injured. In comparison with previous years, the number of accidents and the number of deaths and injuries have both decreased: compared with 2007, a 5.2% decrease was registered for accidents, 7.8% for deaths, and 4.6% for injuries. With reference to the target set by the European Union in the White Book of 13th September 2001, which forecast that the mortality rate should reduce by 50% by 2010, Italy has reduced its mortality rate of 33.0% (2). Clearly these figures reveal that road accidents and the consequences of road accidents are improving. However, they do remain as a great problem in our society.
The province of Milan is situated in the Northwest of Italy. Along with Rome it is the most populated province in Italy (about 3.7 million inhabitants). As one of the largest Italian cities, a considerable percentage of the countries' road accidents (in 2008 about 11%) occurs in this area. Since this area is predominantly flat, bicycles are used as a common mode of urban transportation along with cars and motorcycles (3).

We have carried out an analysis of road accidents which occurred in the province of Milan in 2004 and 2005, using accident data recorded by police forces. Valent et al. (4), using the same type of data and methodology, analysed the risk factors associated with the injuries and fatalities of road accidents occurred in the period 1991-1996 in the province of Udine, a province situated in the Northeast of Italy (about 530 000 inhabitants). The objective of this current work is to identify the major risk factors associated with the risk of being injured (injuries or death) in a road accident, in order to suggest opportune primary and secondary prevention interventions.

Materials and methods

Data sources

In Italy, the National Institute of Statistics (Istituto Nazionale di Statistica, ISTAT) collects data relating to accidents occurring on a public road, in which at least one person has been injured (and has gone to casualty), or has died, and in which at least one moving vehicle has been involved. The data are collected by the police authorities (traffic police, carabinieri, provincial police, municipal police, according to the location) who are obliged to arrive to the site and to compile an official report, the module "road accidents" (or module ISTAT/CTT/INC), which is then sent to ISTAT. In the module, information to identify the location and dynamics of the accident are registered: date and place of the accident, the area and locality of the accident (if inside or outside an urban area), the type of road, the paving, the road surface conditions, sign posting, weather conditions, the dynamics of the accident (crash, off-road, etc.), the type of vehicles involved, the circumstances which caused the accident, the consequences to the people and vehicles involved, the names of the injured and deceased, and the hospital admission. The characteristics of the driver are registered, even when that driver remains uninjured.

Population

Using the ISTAT/CTT/INC modules as a source, all the drivers involved in an accident which occurred in the province of Milan in 2004 and 2005 were analysed. In these two years, 69 082 accidents took place, which involved 129 629 drivers. Only the drivers for whom the accident consequences were known, were included in the analyses (122 142; 94.2%).

Since the goal of the analysis is to identify factors influencing crash severity, we chose to use the driver as the unit of analysis rather than any subject involved in the accident. In fact, for drivers, but not for passengers, information is collected regardless of whether they are injured or not. In addition, the driver and, generally, not the passenger may hold some responsibility of the accident and should be the main target of prevention.

Variables and their role

The following independent variables were considered:

- gender of the driver (man – woman)
- age of the driver (less than 30 – 30 to 64 years – more than 65)
- area in which the accident took place (urban – extra urban – motorway)
- impact type (head-on/side– rear-end/multiple collision – single-vehicle accident, pedestrian knocked down)
- time of accident (from 6.00 a.m. to 11.59 a.m. – form 12.00 a.m. to 5.59 p.m. – from 6.00 p.m. to 12.59 p.m. – from 1.00 a.m. to 5.59 a.m.)
- day of accident (Monday – Friday, Saturday – Sunday)
- season (Summer: June, July, August – Autumn: September, October, November – Winter: December, January, February – Spring: March, April, May)
- road surface (dry – wet/slippery)
- paving (asphalted – non asphalted)
- reduction of points from driving license following the accident (no – yes)
- type of vehicle (car – heavy vehicle – motorcycle/moped – bicycle). Heavy vehicles were considered such with a total mass exceeding 3.5 tonnes and which are used for transporting objects: trailer trucks with tow, articulated vehicles, semitrailers, vehicles equipped with special instruments, no-farm tractors, and vehicles used for towing only. Vans and pickups were considered as cars. Two-wheeled vehicles with engine size more than 50 c.c. were considered motorcycles, whereas two-wheeled vehicles with engine size less than or equal to 50 c.c. were considered moped.

The consequences reported by the driver following the accident (unhurt – injured – death) were considered as outcome. An injured person is a subject who has sustained wounds to their body following the accident, and death corresponds to a person who dies at the scene, or within 30 days of the accident having occurred.

Statistical Analysis

For all drivers, the percentage of drivers unhurt, injured and killed in the different classes of risk factors considered was calculated. To evaluate the role of the various risk factors in the severity of the accident, the likelihood of being injured versus not injured, of being killed versus not injured and of being killed versus injured was calculated, for the drivers of all vehicle types collapsed, and separately for the drivers of each vehicle category (cars, heavy vehicles, motorized two-wheeled vehicles, bicycles). Using logistic regression, the adjusted odds ratios (OR), and 95% confidence intervals (95%CI), were calculated to estimate the likelihood of the more severe outcome as compared with the lesser one. Therefore, the ORs presented are estimates of the relative risks of drivers being killed or injured given that they have been involved in an accident. The aim of adjusted analyses is to allow for the effect of possible confounders so that the effect of a given exposure is not distorted. Since in our study each variable can be considered both as an exposure factor and as a confounder, an adjustment was obtained including several exposure factors in a single multivariate model. The statistical analysis has been carried out using the software SPSS, version 15.0.

Results

Characteristics of the database

Table 1 presents accident consequences according to characteristics of the driver: 122,142 drivers were analysed, most of which (64.7%) drove cars, followed by motorised two-wheeled vehicles (20.4%), then heavy vehicles (9.1%) and then bicycles (3.7%).

The majority of drivers involved are men (78.2%) and people aged 30-64 years (62.7%). Most drivers are involved in accidents (78.4%) that occurred during the week (between Monday to Friday); with regard to the time of day, 40.4% in accidents occurred between 12.00 p.m. and 5.59 p.m., 31.6% between 6.00 a.m. and 11.59 a.m., 21.5% between 6 p.m and 12 a.m, and 6.5% during the night between 1.00 a.m. and 5.59 a.m. Most drivers were involved in accidents in urban area (82.7%), and on a dry surface (82.7%). The most common type of accident is the head-on or side collision (55.0%), followed by rear-end or multiple collisions (22.7%). For 2.1% of drivers, points were deducted from their driving license following the accident.

Factors associated with the risk of consequences for drivers of all vehicles

Table 2 reports the OR of death and injuries following an accident versus receiving no injuries, and the OR of death versus sustaining injuries for the drivers of all vehicles, adjusted for the considered risk factors.

Most notably is the high risk for riders of two-wheeled vehicles compared to the risk for cars drivers. Specifically, compared to car drivers, the risk of being injured is 35.42 times greater for cyclists, 34.96 times greater for motorcycle riders and 26.97 times greater for moped riders (95%CI: 31.24, 40.15; 32.62, 37.47 and 25.06, 29.03 respectively). The risk of death is 133.32 times greater for cyclists, 72.79 times greater for motorcycle riders, and 26.18 times greater for moped riders (95%CI: 88.03, 201.90; 52.63, 100.65 and 16.54, 41.42 respectively), than for car drivers.

Women have a higher risk of being injured (OR: 1.98; 95%CI: 1.91, 2.05) and less of dying (OR: 0.64; 95%CI: 0.42, 0.99) with respect to men. The risk of being injured decreases as age increases, whereas drivers older than 65 are almost three times more likely (OR: 2.84; 95%CI: 1.84, 4.39) to die if involved in an accident than drivers younger than 30.

Accidents which take place in the evening (from 6.00 p.m. to 12.59 a.m.), at night (from 1.00 a.m. to 5.59 a.m.), and during the weekend are more serious, whilst significant differences among the seasons are not revealed.

As compared to crashes on urban roads, crashes on extra-urban roads are more likely to result in injuries (OR: 1.07; 95%CI: 1.01, 1.13) and death (OR: 5.17; 95%CI: 3.79, 7.06); instead, with regard to accidents on motorways only the risk of death is higher (OR: 2.05; 95%CI: 1.43, 2.95) than on an urban road, whilst that of being injured is less (OR: 0.44; 95%CI: 0.42, 0.46).

With regard to the type of accident, the most dangerous accidents are the single-vehicle ones (OR of being injured with respect to head-on and side ones: 1.83, 95%CI: 1.74, 1.93; OR of being killed: 1.82, 95%CI: 1.31, 2.52), whilst the least dangerous for the driver of the vehicle are those where the pedestrian is knocked down (OR of being injured with respect to frontal and lateral ones: 0.10, 95%CI: 0.09, 0.11; OR of being killed: 0.19, 95%IC: 0.09, 0.41).

Concerning the condition of the road surface, accidents on a wet or slippery surface are more associated with the risk of sustaining injuries (OR: 1.20; 95%CI: 1.16, 1.25).

Table 1. Consequences of accident by risk factors among drivers in the province of Milan, Italy, 2004-2005

	N	%	Unhurt (%)	Injured (%)	Killed (%)
Type of vehicle					
Car	79 020	64.7	70.0	29.8	0.1
Heavy vehicle	11 107	9.1	86.6	13.3	0.2
Motorised two-wheeled vehicles	24 868	20.4	20.9	78.0	1.1
Motorcycle	13 531	11.1	9.9	89.2	0.8
Moped	11 337	9.3	10.9	88.8	0.3
Bicycle	4474	3.7	8.6	90.2	1.3
Other	2673	2.2	82.0	17.8	0.3
Total	*122 142*	*100.0*	*57.4*	*42.3*	*0.3*
Gender					
Man	95 083	78.2	59.1	40.6	0.3
Woman	26 573	21.8	51.1	48.8	0.1
Total	*121 656*	*100.0*	*57.3*	*42.4*	*0.3*
Age					
< 30 years	37 475	30.9	48.5	51.2	0.3
30-64 years	76 130	62.7	60.7	39.0	0.2
65+ years	7720	6.4	66.0	33.3	0.6
Total	*121 325*	*100.0*	*57.3*	*42.4*	*0.3*
Time of day					
6.00 a.m. – 11.59 a.m.	37681	31.6	58.9	40.8	0.3
12.00 p.m. – 5.59 p.m.	48 088	40.4	59.0	40.8	0.2
6.00 p.m. – 12.59 a.m.	25 639	21.5	56.3	43.4	0.3
1.00 a.m. – 5.59 a.m.	7732	6.5	47.0	52.3	0.7
Total	*119 140*	*100.0*	*57.6*	*42.1*	*0.3*
Day of week					
Monday-Friday	95 794	78.4	57.8	41.9	0.2
Saturday-Sunday	26 348	21.6	55.9	43.7	0.4
Total	*122 142*	*100.0*	*57.4*	*42.3*	*0.3*
Season					
Summer	27 824	22.8	55.6	44.1	0.3
Autumn	32 225	26.4	58.0	41.7	0.3
Winter	27 562	22.6	59.4	40.3	0.3
Spring	34 531	28.3	56.7	43.0	0.3
Total	*122 142*	*100.0*	*57.4*	*42.3*	*0.3*
Area					
Urban	100 273	82.7	54.4	45.3	0.2
Extra-urban	8260	6.8	58.6	40.5	0.9
Motorways	12 724	10.5	79.3	20.3	0.4
Total	*121 257*	*100.0*	*57.3*	*42.4*	*0.3*
Accident type					
Head on/side	63 530	55.0	56.2	43.5	0.3
Rear-end/multiple collisions	26 197	22.7	62.5	37.3	0.2
Single	12 754	11.0	39.7	59.8	0.6
Pedestrian knocking down	4440	3.8	85.3	14.5	0.2
Other	8670	7.5	50.8	49.0	0.2
Total	*115 591*	*100.0*	*56.5*	*43.2*	*0.3*
Surface					
Dry	95 569	82.7	56.6	43.1	0.3
Wet/slippery	20 004	17.3	56.2	43.5	0.2
Total	*115 573*	*100.0*	*56.5*	*43.2*	*0.3*
Reduction of points from driving license					
No	114	893	97.9	59.1	40.9
Yes	2491	2.1	75.6	24.4	
Total	*117 384*	*100.0*	*59.4*	*40.6*	

Table 2. Odds ratios (and 95% confidence intervals) of being personally non-fatally injured versus unhurt, of being personally killed versus unhurt, and of being personally killed versus non-fatally injured among drivers in the province of Milan, Italy, 2004-2005

Independent variable	Drivers involved in accidents				Injured vs. unhurt			Killed vs. unhurt			Killed vs. injured		
	Total	Unhurt	Injured	Killed	OR	95% CI		OR	95% CI		OR	95% CI	
Total	110 382	56.4%	43.3%	0.3%									
Gender													
Man	85 999	58.2%	41.4%	0.3%	1.00			1.00			1.00		
Woman	24 383	50.1%	49.8%	0.1%	1.98	1.91	2.05	0.64	0.42	0.99	0.37	0.25	0.56
Age													
< 30 years	33 790	47.4%	52.3%	0.3%	1.00			1.00			1.00		
30-64 years	69 541	59.9%	39.8%	0.3%	0.82	0.80	0.85	1.06	0.81	1.39	1.08	0.84	1.40
65+ years	7051	65.4%	34.0%	0.6%	0.72	0.67	0.77	2.84	1.84	4.39	2.98	1.96	4.51
Type of vehicle													
Car	70 963	69.3%	30.5%	0.1%	1.00			1.00			1.00		
Heavy vehicle	10 060	85.9%	13.9%	0.2%	0.49	0.47	0.53	1.03	0.61	1.72	2.18	1.29	3.67
Motorcycle	12 534	9.2%	90.0%	0.9%	34.96	32.62	37.47	72.79	52.63	100.65	2.76	2.01	3.79
Moped	10 331	9.6%	90.1%	0.3%	26.97	25.06	29.03	26.18	16.54	41.42	1.18	0.75	1.84
Bicycle	4002	7.2%	91.5%	1.3%	35.42	31.24	40.15	133.32	88.03	201.90	4.28	2.88	6.35
Other	2492	81.7%	18.0%	0.3%	0.72	0.65	0.80	1.87	0.86	4.08	3.96	1.80	8.72
Time of day													
6.00 a.m. – 11.59 a.m.	34 574	57.6%	42.2%	0.3%	1.00			1.00			1.00		
12.00 p.m. – 5.59 p.m.	44 298	57.8%	41.9%	0.2%	0.97	0.93	1.00	0.78	0.58	1.05	0.84	0.63	1.12
6.00 p.m. – 12.59 a.m.	24 098	55.5%	44.3%	0.3%	1.11	1.07	1.16	1.03	0.73	1.44	1.02	0.74	1.41
1.00 a.m. – 5.59 a.m.	7412	46.0%	53.3%	0.7%	2.62	2.47	2.78	5.42	3.60	8.16	2.59	1.76	3.80
Day of week													
Monday-Friday	86 915	56.8%	43.0%	0.3%	1.00			1.00			1.00		
Saturday-Sunday	23 467	55.1%	44.5%	0.4%	1.08	1.04	1.12	1.22	0.93	1.61	1.32	1.02	1.70
Season													
Summer	24 956	54.6%	45.1%	0.3%	1.00			1.00			1.00		
Autumn	29 154	57.2%	42.6%	0.3%	0.97	0.93	1.01	0.85	0.60	1.20	0.88	0.64	1.23
Winter	25 202	58.4%	41.4%	0.3%	1.03	0.99	1.08	1.09	0.78	1.54	1.04	0.75	1.45
Spring	31 070	55.6%	44.0%	0.3%	0.94	0.90	0.98	0.93	0.67	1.29	1.03	0.75	1.40
Area													
Urban	90 261	53.2%	46.6%	0.2%	1.00			1.00			1.00		
Extra-urban	7807	58.3%	40.7%	0.9%	1.07	1.01	1.13	5.17	3.79	7.06	6.44	4.84	8.57
Motorways	12 314	79.3%	20.3%	0.4%	0.44	0.42	0.46	2.05	1.43	2.95	7.03	4.93	10.02
Accident type													
Head on/side	60 740	56.1%	43.6%	0.3%	1.00			1.00			1.00		
Rear-end/multiple collisions	25 073	62.4%	37.4%	0.2%	1.57	1.51	1.63	0.59	0.41	0.86	0.48	0.33	0.69
Single	11 972	39.1%	60.3%	0.6%	1.83	1.74	1.93	1.82	1.31	2.52	1.04	0.78	1.40
Pedestrian knocking down	4311	85.3%	14.6%	0.2%	0.10	0.09	0.11	0.19	0.09	0.41	1.68	0.78	3.63
Other	8286	50.7%	49.1%	0.2%	1.25	1.17	1.32	0.55	0.32	0.93	0.57	0.34	0.94
Surface													
Dry	91 381	56.5%	43.2%	0.3%	1.00			1.00			1.00		
Wet/slippery	19 001	56.1%	43.6%	0.2%	1.20	1.16	1.25	0.93	0.66	1.31	0.82	0.59	1.14

OR = odds ratio; 95% CI = 95% confidence interval

Table 3. Odds ratios (and 95% confidence intervals) of being personally non-fatally injured versus unhurt, of being personally killed versus unhurt, and of being personally killed versus non-fatally injured among car drivers in the province of Milan, Italy, 2004-2005

Independent variable	Drivers involved in accidents				Injured vs. unhurt			Killed vs. unhurt			Killed vs. injured		
	Total	Unhurt	Injured	Killed	OR	95% CI		OR	95% CI		OR	95% CI	
Total	70 963	69.3%	30.5%	0.1%									
Gender													
Man	51 341	72.8%	27.0%	0.2%	1.00			1.00			1.00		
Woman	19 622	60.1%	39.9%	0.1%	1.96	1.89	2.03	0.58	0.32	1.08	0.33	0.18	0.60
Age													
< 30 years	20 153	63.4%	36.4%	0.2%	1.00			1.00			1.00		
30-64 years	45 357	70.9%	28.9%	0.1%	0.79	0.76	0.82	1.08	0.69	1.68	1.30	0.84	2.02
65+ years	5453	77.5%	22.3%	0.2%	0.67	0.62	0.72	2.12	1.03	4.39	2.87	1.39	5.92
Time of day													
6.00 a.m. – 11.59 a.m.	20 670	71.5%	28.4%	0.1%	1.00			1.00			1.00		
12.00 p.m. – 5.59 p.m.	27 903	71.7%	28.2%	0.1%	0.97	0.93	1.01	1.00	0.56	1.80	0.97	0.54	1.74
6.00 p.m. – 12.59 a.m.	16 312	69.9%	30.0%	0.1%	1.11	1.06	1.17	1.17	0.62	2.20	0.96	0.50	1.81
1.00 a.m. – 5.59 a.m.	6078	49.4%	50.0%	0.6%	2.57	2.40	2.74	5.55	3.03	10.17	2.32	1.29	4.18
Day of week													
Monday-Friday	53 439	70.5%	29.4%	0.1%	1.00			1.00			1.00		
Saturday-Sunday	17 524	65.8%	33.9%	0.3%	1.08	1.04	1.13	1.36	0.89	2.08	1.31	0.87	1.98
Season													
Summer	15 287	70.0%	29.9%	0.1%	1.00			1.00			1.00		
Autumn	19 350	68.7%	31.1%	0.2%	0.96	0.92	1.01	0.61	0.34	1.09	0.61	0.34	1.09
Winter	16 984	68.2%	31.6%	0.2%	1.05	1.00	1.10	0.82	0.50	1.36	0.79	0.48	1.31
Spring	19 342	70.4%	29.5%	0.1%	0.94	0.90	0.99	0.69	0.40	1.19	0.70	0.41	1.21
Area													
Urban	56 760	68.8%	31.1%	0.1%	1.00			1.00			1.00		
Extra-urban	5547	61.9%	37.6%	0.5%	1.15	1.08	1.22	5.28 a	3.21	8.70	5.24	3.24	8.46
Motorways	8656	77.4%	22.3%	0.3%	0.47	0.44	0.49	1.75	1.00	3.07	4.63	2.71	7.91
Accident type													
Head on/side	38 049	71.3%	28.5%	0.1%	1.00			1.00			1.00		
Rear-end/multiple collisions	19 262	64.4%	35.5%	0.1%	1.62	1.56	1.69	0.39 a	0.20	0.76	0.27	0.13	0.52
Single	6168	60.0%	39.4%	0.6%	1.74	1.64	1.85	2.44 a	1.46	4.09	1.60	0.99	2.58
Pedestrian knocking down	2862	97.7%	2.2%	0.1%	0.06	0.05	0.07	0.77	0.24	2.49	5.22	1.45	18.80
Other	4622	67.8%	32.1%	0.0%	1.26	1.18	1.35	0.36	0.09	1.47	0.32	0.08	1.31
Surface													
Dry	57 538	70.4%	29.5%	0.1%	1.00			1.00			1.00		
Wet/slippery	13 425	64.8%	35.0%	0.2%	1.19	1.14	1.24	1.05	0.66	1.65	1.04	0.66	1.63
Reduction of points from driving license													
No	69 029	69.1%	30.9%		1.00								
Yes	1831	79.4%	20.6%		0.58	0.52	0.65						

OR = odds ratio; 95% CI = 95% confidence interval

Factors associated with the risk of consequences for car drivers

Cars represent almost 65% of the vehicles analysed. The results that emerge from the analyses of the data of these vehicles (Table 3) therefore overlap the results obtained by the analyses performed on the data of all vehicles.

For car drivers we also associated injury risk with deduction of points from the driving license following the accident. Drivers who had points deducted from their license, had a lower risk of sustaining injuries (OR: 0.58; 95%CI: 0.52, 0.65).

Factors associated with the risk of consequences for heavy vehicle drivers

As can be seen in Table 4, similar patterns to those found across all vehicles were indicated for heavy vehicles.

Factors associated with the risk of consequences for motorised two-wheeled vehicle riders

With regard to motorised two-wheeled vehicles (Table 5), mopeds are less dangerous than motorcycles: the risk of being injured is 0.79 (95% CI: 0.71, 0.87), the risk of being killed is 0.30 (95%CI: 0.19, 0.49), the risk of death with respect to non-fatal injuries is 0.41 (95%CI: 0.26, 0.64). A greater risk of injury for women is confirmed (OR: 2.31; 95%CI: 1.92, 2.78); furthermore, for women the risk of death is less than that of injury (OR: 0.15; 95%CI: 0.04, 0.60). Instead, the age effect disappears.

A greater risk during the night is confirmed, while there is no evidence of higher risk during the weekend. On extra urban roads and motorways the risk of injury is less (OR for extra urban roads: 0.69, 95%CI: 0.56, 0.85; OR for motorways: 0.21, 95% CI: 0.17, 0.27) whilst that of dying is greater.

The most dangerous accidents seem to be the single-vehicle ones (OR of being injured: 2.14, 95% CI: 1.80, 2.55; OR of death: 2.46, 95% CI: 1.50, 4.03) followed by head-on or side accidents, and rear-end collisions or multiple collisions (OR of being injured: 0.66, 95%CI: 0.57, 0.77; OR of death: 0.38, 95%CI: 0.18, 0.81). As can be expected, knocking down the pedestrian is the least dangerous type of accident for the driver (OR of being injured: 0.10, 95%CI: 0.08, 0.11; OR of death: 0.10, 95% CI: 0.03, 0.34).

Factors associated with the risk of consequences for bicycle riders

In accidents involving bicycles (Table 6), women are 1.45 (95% CI: 1.10, 1.91) times more likely than men to be injured and the severity of the consequences for the rider increases with age. Specifically, individuals between 35-64 years old and individuals over 65 years old are respectively 1.66 (95% IC: 1.25, 2.21) and 1.57 (95% IC: 1.11, 2.24) times more likely to be injured than individuals younger than 30. People aged 35-64 years are at risk of dying 4.13 times higher (95%CI: 1.16, 14.68), those over 65 years 14.70 times higher (95%CI: 4.13-52.32); furthermore, bicycle riders over 65 years are at risk of dying with respect to sustaining injury 7.56 (95%CI: 2.57-2.22) times higher than people under 30 years.

Riding at night (from 1.00 a.m. to 5.59 a.m.) is confirmed as a risk factor for the fatality of the accident for the rider as compared to morning accidents (6.00 a.m. to 11.59 a.m.): the risk of death is 17.86 times higher (95% CI: 1.36, 234.59) with respect to being not injured, and 5.52 times higher (95% CI: 1.46, 20.88) with respect to sustaining injury.

The risk of death is higher in the accidents which occur on extra urban roads (OR with respect to being not injured: 25.04, 95% CI: 4.94, 126.96; OR with respect to sustaining injury: 4.86; 95%CI: 2.19, 10.80); the risk of being injured is greater in the accidents occurred on wet or slippery surfaces (OR: 1.92; 95% CI: 1.08, 3.43).

Discussion

The results obtained allow us to make some considerations about the phenomenon of road accidents, based on a consistent survey, relating to 94% of all the accidents that occurred in province of Milan in the two years of 2004 and 2005. The most important findings of this study can be summarized as follow. The risk of being injured when involved in a road accident is higher:

- for two-wheeled vehicles riders compared to car drivers and decrease from bicycles to motorcycles to mopeds
- for women compared to men
- during the night and during the week-end
- on extra-urban road
- for single-vehicle accident
- on wet or slippery road surface.

The risk of being killed when involved in a road accident is higher:

- for two-wheeled vehicles riders compared to car drivers and decrease from bicycles to motorcycles to mopeds

Table 4. Odds ratios (and 95% confidence intervals) of being personally non-fatally injured versus unhurt, of being personally killed versus unhurt, and of being personally killed versus non-fatally injured among heavy vehicles drivers in the province of Milan, Italy, 2004-2005

Independent variable	Drivers involved in accidents				Injured vs. unhurt			Killed vs. unhurt			Killed vs. injured		
	Total	Unhurt	Injured	Killed	OR	95% CI		OR	95% CI		OR	95% CI	
Total	10 060	85.9%	13.9%	0.2%									
Gender													
Man	9830	86.4%	13.4%	0.2%	1.00								
Woman	230	66.1%	33.9%	0.0%	3.26	2.44	4.37	.	.	.	.	.	.
Age													
< 30 years	2140	83.6%	16.4%	0.0%	1.00			1.00			1.00		
30-64 years	7609	86.6%	13.1%	0.2%	0.83	0.72	0.95	3.61	0.47	27.50	4.79	0.58	39.57
65+ years	311	83.9%	15.8%	0.3%	1.05	0.75	1.47	6.82	0.41	111.98	7.96	0.39	161.48
Time of day													
6.00 a.m. – 11.59 a.m.	4082	86.8%	13.0%	0.2%	1.00			1.00			1.00		
12.00 p.m. – 5.59 p.m.	4294	87.0%	12.8%	0.2%	0.96	0.84	1.10	1.19	0.42	3.33	0.89	0.28	2.87
6.00 p.m. – 12.59 a.m.	1232	87.1%	12.8%	0.1%	1.03	0.85	1.26	0.34	0.04	2.78	0.32	0.03	3.61
1.00 a.m. – 5.59 a.m.	452	63.9%	35.6%	0.4%	3.45	2.75	4.33	1.94	0.36	10.41	0.39	0.06	2.58
Day of week													
Monday-Friday	9128	86.8%	13.0%	0.2%	1.00			1.00			1.00		
Saturday-Sunday	932	77.5%	22.3%	0.2%	1.51	1.26	1.80	1.35	0.27	6.65	1.11	0.17	7.03
Season													
Summer	2231	85.3%	14.4%	0.3%	1.00			1.00			1.00		
Autumn	2623	85.2%	14.6%	0.2%	1.01	0.85	1.19	2.10	0.60	7.35	1.17	0.28	4.83
Winter	2486	86.4%	13.4%	0.2%	0.94	0.79	1.10	1.25	0.33	4.74	1.11	0.26	4.78
Spring	2720	86.6%	13.3%	0.1%	0.96	0.81	1.12	0.47	0.08	2.61	0.31	0.05	1.90
Area													
Urban	6347	84.3%	15.7%	0.0%	1.00			1.00			1.00		
Extra-urban	1036	85.0%	14.8%	0.2%	0.83	0.69	1.01	12.42	1.12	138.22	22.83	1.93	270.18
Motorways	2677	90.2%	9.3%	0.6%	0.44	0.37	0.51	32.49	4.22	250.22	131.21	15.53	1108.68
Accident type													
Head on/side	5135	88.2%	11.7%	0.1%	1.00			1.00			1.00		
Rear-end/multiple collisions	3057	82.6%	17.1%	0.3%	1.87	1.64	2.14	1.47	0.50	4.28	0.26	0.07	0.94
Single	833	79.5%	20.5%	0.0%	2.10	1.72	2.56	.	.	.	.	.	.
Pedestrian knocking down	283	99.3%	0.7%	0.0%	0.05	0.01	0.20	.	.	.	.	.	.
Other	752	85.8%	13.7%	0.5%	1.20	0.95	1.51	4.01	1.09	14.70	2.90	0.56	14.98
Surface													
Dry	8336	86.6%	13.2%	0.2%	1.00			1.00			1.00		
Wet/slippery	1724	82.5%	17.4%	0.1%	1.24	1.07	1.44	0.76	0.17	3.42	0.45	0.09	2.31
Reduction of points from driving license													
No	9784	85.9%	14.1%		1.00								
Yes	258	90.7%	9.3%		0.58	0.38	0.90						

OR = odds ratio; 95% CI = 95% confidence interval

Table 5. Odds ratios (and 95% confidence intervals) of being personally non-fatally injured versus unhurt, of being personally killed versus unhurt, and of being personally killed versus non-fatally injured among two-wheeled vehicles riders in the province of Milan, Italy, 2004-2005

Independent variable	Drivers involved in accidents				Injured vs. unhurt			Killed vs. unhurt			Killed vs. injured		
	Total	Unhurt	Injured	Killed	OR	95% CI		OR	95% CI		OR	95% CI	
Total	22 865	9.4%	90.0%	0.6%									
Gender													
Man	19 817	10.1%	89.2%	0.7%	1.00			1.00					
Woman	3048	4.6%	95.3%	0.1%	2.31	1.92	2.78	0.36	0.08	1.52	0.15	0.04	0.60
Age													
< 30 years	9969	9.8%	89.6%	0.6%	1.00			1.00					
30-64 years	12 587	9.0%	90.4%	0.6%	1.04	0.94	1.15	0.82	0.55	1.22	0.83	0.58	1.19
65+ years	309	9.4%	90.6%	0.0%	1.16	0.77	1.75	.	.	.	.	.	.
Type of vehicle													
Motorcycle	12 534	9.2%	90.0%	0.9%	1.00			1.00					
Moped	10 331	9.6%	90.1%	0.3%	0.79	0.71	0.87	0.30	0.19	0.49	0.41	0.26	0.64
Time of day													
6.00 a.m. – 11.59 a.m.	7403	9.3%	90.2%	0.5%	1.00			1.00					
12.00 p.m. – 5.59 p.m.	9335	10.0%	89.5%	0.5%	0.94	0.84	1.05	0.80	0.50	1.26	0.88	0.57	1.35
6.00 p.m. – 12.59 a.m.	5405	9.0%	90.2%	0.7%	1.06	0.93	1.20	1.19	0.73	1.95	1.27	0.81	1.99
1.00 a.m. – 5.59 a.m.	722	4.0%	94.5%	1.5%	1.98	1.34	2.92	5.52	2.19	13.95	2.68	1.31	5.47
Day of week													
Monday-Friday	18 880	9.3%	90.1%	0.5%	1.00			1.00					
Saturday-Sunday	3985	9.5%	89.6%	1.0%	0.91	0.80	1.03	1.20	0.78	1.86	1.45	0.98	2.15
Season													
Summer	5792	8.9%	90.5%	0.6%	1.00			1.00					
Autumn	5573	9.3%	90.2%	0.4%	1.03	0.90	1.18	1.04	0.59	1.85	0.99	0.58	1.67
Winter	4407	9.6%	89.8%	0.6%	1.00	0.87	1.15	1.39	0.76	2.56	1.28	0.73	2.24
Spring	7093	9.6%	89.7%	0.7%	0.96	0.85	1.10	1.36	0.80	2.30	1.36	0.84	2.21
Area													
Urban	21 525	9.0%	90.6%	0.4%	1.00			1.00					
Extra-urban	934	11.1%	85.7%	3.2%	0.69	0.56	0.85	4.20	2.55	6.92	6.28	4.09	9.63
Motorways	406	26.1%	71.4%	2.5%	0.21	0.17	0.27	1.01	0.48	2.12	5.80	2.90	11.58
Accident type													
Head on/side	13 644	8.3%	91.1%	0.6%	1.00			1.00					
Rear-end/multiple collisions	1952	13.3%	86.3%	0.4%	0.66	0.57	0.77	0.38	0.18	0.81	0.48	0.23	1.01
Single	4176	3.8%	95.4%	0.8%	2.14	1.80	2.55	2.46	1.50	4.03	1.21	0.80	1.83
Pedestrian knocking down	939	46.8%	52.9%	0.3%	0.10	0.08	0.11	0.10	0.03	0.34	1.09	0.34	3.50
Other	2154	7.3%	92.4%	0.2%	1.20	1.00	1.43	0.34	0.13	0.88	0.34	0.13	0.84
Surface													
Dry	19 750	9.7%	89.6%	0.7%	1.00			1.00					
Wet/slippery	3115	7.2%	92.6%	0.2%	1.25	1.07	1.46	0.36	0.15	0.86	0.33	0.14	0.75

OR = odds ratio; 95% CI = 95% confidence interval

- older drivers
- during the night
- on extra-urban road and on motorway
- for single-vehicle accident.

Furthermore, the coherence of the results obtained with the principal evidence of existing research using the same methodology (sources, etc.) gives our conclusions a greater consistency and scientific validity.

The vehicles

The findings of this study indicate that the risk of sustaining injury or death in an accident is inversely proportional to the weight and solidity of the vehicle: the odds decrease from two-wheeled vehicles, to cars, to heavy vehicles. These results are consistent with previous findings (5-8). These results are therefore also supportive of recommendations to prioritise plans for protective interventions for bicycle riders, such as guaranteeing the possibility of circulating in reserved bicycle lanes (9). The fact that between the two-wheeled vehicles the trend decreases from motorcycles to mopeds, with significant differences above all for lethality, also confirms the significant role played by speed.

Gender and age

Our findings indicate that female drivers (irrespective of the kind of vehicle) are at a greater risk than male drivers of being hurt following an accident, but of less severity, in line with the general patterns indicated in the literature (5, 10, 11, 4). While Valent et al. (4) and Laapotti and Keskinen (12) suggested that these differences between men and women reflect less attentiveness and driving expertise amongst women, but more prudence (reduced speed, less competitive, less aggressive, less driving at night, less use of alcohol and drugs, etc.), amongst women than men, our data does not allow any such conclusions to be made.

With regard to age, older drivers (65 years and over) are more at risk of dying if involved in an accident, according to the literature (13, 5, 14, 11, 4). Certainly this is due to the lower capacity of reaction and the higher risk of complications and comorbidities.

Time, day, season, and road surface

The night time (from 12.00 a.m. to 6.59 a.m.) and the weekend seem to be associated with a greater risk of sustaining injuries and above all of dying following the accident for drivers of all types of vehicles. This results are in accordance with Valent et al. (4), Cirera et al. (7) and Gray et al. (15). Season does not seem to have an influence, at least not in direct form, however a wet or slippery road surface does result as a risk factor, for all types of vehicles.

Zone and type of collision

The most dangerous roads are extra urban, followed by motorways, above all for the most serious consequences, and the type of crash that causes the worst consequences is the single vehicle accident, meaning accidents which occur without the intervention of other vehicles, but which are attributable to distractions, illness, falling asleep, often brought on by excess of food, alcohol, pharmaceuticals, and drugs. This findings are in accordance with Valent et al. (4).

Responsibility in the accident

The fact of having committed an infraction, which has then caused an accident, exposes the driver to a lesser risk of bearing consequences, evidently for a greater awareness of what is happening, for which the drivers of other vehicles are not prepared. This result is in accordance with Kockelman and Kweon (16) who found that prior citation history is associated with decreased injury levels.

Limitations of the study

The main limitation of the study is that, as we used an already existing database, the choice of which variables to include in the analyses was guided by what was available and by whether the information was registered in a consistent and accurate way. For this reason, some important variables were not included in the models. Regarding safety apparatus, information about seat belt and helmet use was not available for 43% of the examined subjects and neither information on airbags nor on use of child restraint systems are collected by the police. We could not include weight of vehicle in our analyses, since the Police reported this information for less than 1% of vehicles. Other important variables about the accident dynamic, for example the impact speed are not observed by the Police.

Also, we did not include alcohol consumption in the model because we have this information only for a low percentage of drivers (during the study period only less than 0.01% of all drivers were found to be driving under the influence of alcohol) coming from the information about the violation of road rules and not from blood alcohol concentration levels performed by a formal test.

Table 6. Odds ratios (and 95% confidence intervals) of being personally non-fatally injured versus unhurt, of being personally killed versus unhurt, and of being personally killed versus non-fatally injured among bicycle drivers in the province of Milan, Italy, 2004-2005

Independent variable	Drivers involved in accidents				Injured vs. unhurt			Killed vs. unhurt			Killed vs. injured		
	Total	Unhurt	Injured	Killed	OR	95% CI		OR	95% CI		OR	95% CI	
Total	4042	7.2%	91.5%	1.3%									
Gender													
Man	2594	8.1%	90.4%	1.5%	1.00			1.00			1.00		
Woman	1408	5.7%	93.5%	0.9%	1.45	1.10	1.91	1.03	0.45	2.39	0.75	0.38	1.48
Age													
< 30 years	1071	10.5%	89.2%	0.4%	1.00			1.00			1.00		
30-64 years	2001	6.0%	93.1%	0.9%	1.66	1.25	2.21	4.13	1.16	14.68	2.21	0.74	6.60
65+ years	930	6.1%	90.8%	3.1%	1.57	1.11	2.24	14.70	4.13	52.32	7.56	2.57	22.22
Type of vehicle													
Motorcycle	12 534	9.2%	90.0%	0.9%	1.00			1.00					
Moped	10 331	9.6%	90.1%	0.3%	0.79	0.71	0.87	0.30	0.19	0.49	0.41	0.26	0.64
Time of day													
6.00 a.m. – 11.59 a.m.	1478	6.4%	91.8%	1.8%	1.00			1.00			1.00		
12.00 p.m. – 5.59 p.m.	1777	8.0%	91.1%	1.0%	0.81	0.61	1.08	0.47	0.21	1.03	0.69	0.37	1.29
6.00 p.m. – 12.59 a.m.	698	7.3%	92.0%	0.7%	0.88	0.60	1.28	0.53	0.15	1.84	0.63	0.23	1.69
1.00 a.m. – 5.59 a.m.	49	2.0%	91.8%	6.1%	2.81	0.38	20.81	17.86	1.36	234.59	5.52	1.46	20.88
Day of week													
Monday-Friday	3300	7.0%	91.7%	1.3%	1.00			1.00			1.00		
Saturday-Sunday	702	8.1%	90.6%	1.3%	0.86	0.63	1.18	0.60	0.20	1.83	1.02	0.48	2.14
Season													
Summer	1136	7.7%	91.0%	1.2%	1.00			1.00			1.00		
Autumn	913	5.9%	92.9%	1.2%	0.82	0.57	1.18	0.78	0.29	2.15	0.98	0.43	2.23
Winter	702	6.1%	92.3%	1.6%	1.01	0.66	1.55	1.31	0.44	3.93	1.32	0.56	3.14
Spring	1251	8.3%	90.5%	1.2%	0.76	0.53	1.08	0.73	0.26	2.06	1.11	0.50	2.50
Road type													
Urban	3862	7.3%	91.6%	1.1%	1.00			1.00			1.00		
Extra-urban	137	4.4%	89.1%	6.6%	1.72	0.74	4.02	25.04	4.94	126.96	4.86	2.19	10.80
Motorways	3	33.3%	66.7%	0.0%	0.12	0.01	1.47	1.08	-	-	-	-	-
Accident type													
Head on/side	2528	7.0%	91.7%	1.3%	1.00			1.00			1.00		
Rear-end/multiple collisions	303	6.9%	89.8%	3.3%	0.99	0.61	1.60	1.76	0.62	4.99	2.18	1.03	4.63
Single	619	4.5%	95.5%	0.0%	1.59	1.05	2.39	-	-	-	-	-	-
Pedestrian knocking down	76	52.6%	46.1%	1.3%	0.07	0.04	0.11	0.17	0.02	1.43	2.72	0.35	21.07
Other	476	5.0%	93.7%	1.3%	1.38	0.89	2.14	1.01	0.30	3.34	1.08	0.44	2.62
Surface													
Dry	3650	7.5%	91.2%	1.3%	1.00			1.00			1.00		
Wet/slippery	352	4.0%	94.9%	1.1%	1.92	1.08	3.43	3.40	0.83	13.85	0.88	0.30	2.60

OR = odds ratio; 95% CI = 95% confidence interval

Regarding the outcome variable, deaths occurring from the second to the 30th day could be underestimated because it is difficult for the Police to follow an injured subject through his hospital movements after 24 h (17). For this reason, the risk of fatality could be slightly underestimated and consequently the risk of being injured (not dead) slightly overestimated (Tab. 6).

Conclusions

We suggest that, despite limited available good quality data, the analysed database offers a consistent image of accident levels in a broad metropolitan area, and supplies many elements of scientific evidence useful to plan preventive interventions.

Different measure of risk provide different prospective. Two-wheeled vehicles riders' elevated risk of being injured or dying suggests that, with regard to infrastructure, more attention must be paid to make the most vulnerable road users (above all cyclists) safer. Older drivers' elevated risk of dying suggests the needs for measures to reduce older drivers' risk of dying when involved in a crash, such as improved vehicle occupant protection system. As far as the other factors are concerned, educational intervention appears as a priority, not only in the driving schools for giving the license but also other opportunities for road education are needed.

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