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## Powered two-wheelers riders' crash injury risk on urban arterial streets

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► **To cite this version:**

Nicolas Clabaux, Jean-Yves Fournier, Jean-Emmanuel Michel. Powered two-wheelers riders' crash injury risk on urban arterial streets. RSS2013 - Road Safety and Simulation International Conference, Oct 2013, Italy. 7p. hal-00903844

**HAL Id: hal-00903844**

**<https://hal.science/hal-00903844>**

Submitted on 13 Nov 2013

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1 **Road Safety and Simulation**  
2 **International Conference**  
3 **RSS2013**

4  
5 **October 23-25, 2013**  
6 **Rome, Italy**  
7

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9 **Powered two-wheelers riders' crash injury risk on urban arterial**  
10 **streets**  
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**46 ABSTRACT**

47 *Context:* In recent years, the use of powered two-wheelers has experienced extraordinary growth  
48 in Europe, notably in densely population areas (CARE, 2012). Nevertheless, the powered two-  
49 wheelers' crash risk is still very poorly documented. It is mainly due to a lack of available  
50 accurate exposure data about this road user category and its subcategories. Thus, powered two-  
51 wheelers' accident risk is generally overall and roughly studied.

52 *Method:* Based on data held by the Police, a case-control study was conducted. The cases  
53 comprised 110 powered two-wheelers riders and 157 motorists involved in injury crashes  
54 occurred on nine arterial streets in the Marseille metropolitan area (France) from 1<sup>st</sup> January  
55 2011 to 31<sup>st</sup> December 2011. The controls were powered two-wheelers riders and motorists who  
56 passed the crash sites at the same time of day and same day of week as when the crashes  
57 occurred. These controls were collected during periodic roadside surveys.

58 *Results:* Per kilometer travelled, powered two-wheelers have significantly greater chance of  
59 being involved in a crash than motorists (odds ratio 3.81, 95% confidence interval 2.97 to 4.89).  
60 Concerning the risk of being injured, powered two-wheelers riders are 22.3 times (95%  
61 confidence interval 13.7 to 36.3) more likely to be injured compared to motorists. Significant  
62 differences are found in these risks between mopeds, light motorcycles and heavy motorcycles  
63 riders.

64 *Conclusion:* This study quantifies both the crash risk and risk of injury for different categories of  
65 powered two-wheelers (mopeds, light motorcycles and heavy motorcycles) and confirms that the  
66 over-representation of powered two-wheelers in accidents statistics in large metropolitan areas  
67 seems more due to their extreme vulnerability rather than their over-implication in collisions.  
68

69 **Keywords:** crash risk, powered two-wheeler, moped, motorcycle, case-control study  
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71

**72 INTRODUCTION**

73 In France, powered two-wheelers contribute disproportionately to the burden of road traffic  
74 casualties. In 2011, it was estimated that powered two-wheelers accounted for about 2% of  
75 kilometers driven on public roads (CGDD, 2012), but during this year, they accounted for 25 %  
76 of road traffic deaths and 32 % of injured road users reported (ONISR, 2012). Thus, per  
77 kilometer traveled, motorcyclists and moped users have respectively a 15 and 13 times higher  
78 risk of death in a crash than car occupants. The risk of being injured is greater by a factor of 18  
79 and 37 respectively for motorcycle and moped users compared to car occupants. Concerning the  
80 risk of being involved in a crash<sup>1</sup>, it is respectively 10 and 19 times higher for motorcyclists and  
81 moped users than for car occupants (same reference). However, the main limitation of these  
82 indicators is that they use as the denominator the total number of powered two-wheelers  
83 registered in the whole country multiplied by the average annual distance traveled estimated by  
84 national postal or telephone survey. Thus, they assume a constant level of risk of being killed or  
85 injured per kilometer over the entire distance of travel (Lin and Kraus, 2008). Nevertheless, the  
86 crash risk for a given kilometer for light motorcycles users who accumulate their mileage on  
87 congested city streets for commuting purpose is for example probably different compared with  
88 riders of heavy motorcycle who accumulate their mileage on rural roads for leisure purpose.

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<sup>1</sup> In this paper, the term « crash » refers to injury accident, that is to say resulting in at least one injured or killed person.

89 The second limitation of these indicators is that they are based on old exposure data. Indeed, the  
90 last French extensive survey on powered two-wheelers ownership and their utilization dates back  
91 to 2001. However, in recent years, in France like in the rest of Europe, the use of powered two-  
92 wheelers has experienced important growth and changing patterns, notably in densely population  
93 areas (CARE, 2012). For example, in Paris, the use of this means of transport, as examined on  
94 some boulevards, has risen by 64 % between 1997 and 2009 (Maestracci et al., 2012). In,  
95 Marseille, which - with more 1.5 million inhabitants - is the second French urban zone (INSEE,  
96 2011), the number of journeys using motorcycle has risen from around 80 % between 1997 and  
97 2009 (Marseille's Urbanism Agency, 2011). These increase and recent changing in the use of  
98 powered two-wheelers probably have had an impact on casualty crash risk of this road user  
99 category.

100 The aims of this study were to determine the risk per kilometer travelled of being involved in a  
101 crash and the risk of being injured for riders of different categories of powered two-wheelers  
102 (moped, light motorcycle and heavy motorcycle) relying on recent exposure data collected on  
103 arterial streets of a French large metropolitan and to compare these risks with those of motorists.  
104

## 105 METHOD

106 A case-control study was conducted on nine arterial streets (see figure 1) of the Marseille  
107 metropolitan area. Marseille is located on the Mediterranean coast in a warm climate region  
108 where mopeds and motorcycles are a relatively common means of transportation. The study  
109 population was drawn from all motorists and powered two-wheelers riders travelling on nine  
110 urban arterial streets located in the Marseille downtown over a one year period from the 1<sup>st</sup>  
111 January 2011 to the 31<sup>st</sup> December 2011, Sundays and legal holidays excluded, between 6h00  
112 and 22h00<sup>2</sup>. Powered two-wheelers riders and motorists travelling Sundays, legal holidays and  
113 between 22h00 and 6h00, were excluded because of low traffic volumes in these situations.

114 The cases were, with the exclusions described above, all powered two-wheelers riders and all  
115 motorists injured and/or involved in an injury accidents occurred in 2011 on the nine arterial  
116 streets studied. The identification of cases was based on the exploitation of national data from the  
117 French police for the year 2011; i.e. Bulletins d'Analyse des Accidents Corporels de la  
118 Circulation (BAAC). The BAACs are the computerized version of the police reports which the  
119 police have the obligation to draw up for all injury accidents occurring on public roads. Each  
120 BAAC provides information on time, location of the accident and some characteristics on  
121 vehicles and on the users involved.

122 Controls were all non-accident-involved powered two-wheelers riders and motorists traveling in  
123 2011 (with the exclusions described above) on the nine sites studied. Concerning the exposure of  
124 motorists, was made use of hourly traffic volume collected by magnetic loop detectors.  
125 Concerning the exposure of powered two-wheelers riders, we conducted periodic roadside  
126 surveys to obtain the mean proportion of powered two-wheelers (and the proportion of each  
127 category of powered two-wheelers<sup>3</sup>) in traffic. 52 hours of observations were conducted on the  
128 nine arterial streets studied. For these surveys, the day, the hour, the site and the side of the street  
129 were randomly allocated. Once the total number of vehicles traveling in 2011 on the sites studied

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<sup>2</sup> Let's note that all of nine streets studied contain bus lanes.

<sup>3</sup> In France, three main official powered two-wheelers categories are distinguished: the mopeds, which with an engine displacement less than 50 cm<sup>3</sup>, can be driven after a short formation by any person over 14 years old ; light motorcycles which with an engine displacement between 50cm<sup>3</sup> and 125 cm<sup>3</sup>, can be driven with a car license under certain conditions; heavy motorcycles, which with engine size over 125cm<sup>3</sup>, need a motorcycle license.

130 and the proportion of powered two-wheelers among these vehicles<sup>4</sup> were known and once the  
 131 number of injury accidents and casualties for each road user category were known, odds ratios  
 132 (ORs) with 95 % confidence intervals, were calculated for each site. Injury accident being rare  
 133 event, we use a Poisson distribution. Then, was calculated a synthetic odds ratio using meta-  
 134 analysis techniques. Meta-analysis is a statistical technique used to systematically summarize the  
 135 results of a group of individual studies. The method has been largely used to summarize the  
 136 effects of various road safety interventions (Elvik and Vaa, 2004).

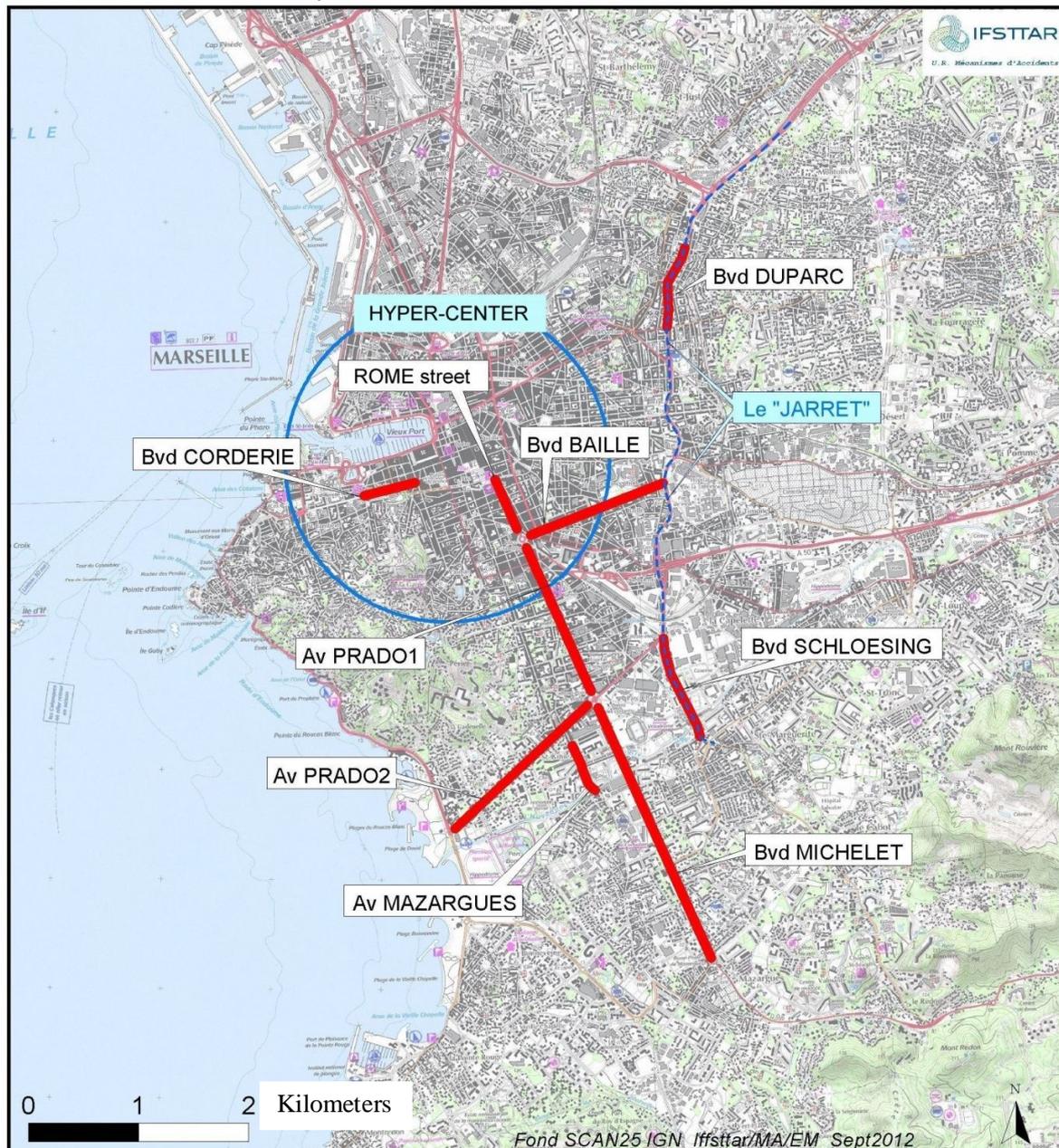


Figure 1. Location of streets on which the study was conducted

<sup>4</sup> Let's note that the automated vehicles detection systems used in Marseille count powered two-wheelers but don't distinguish them from others vehicles (Clabaux, Michel and Fournier, 2012).

139 **RESULTS**

140 7032 powered two-wheelers were recorded on the nine sites studied during the 52 hours of  
 141 observations conducted. These powered two-wheelers represent 16,3 % of traffic. This  
 142 proportion is close to the one recorded by Kopp (2011) on some boulevards of Paris. Among  
 143 these 7032 powered two-wheelers, light motorcycles which are dedicated to be used in urban  
 144 areas, are the most numerous: they represent 48 % of the powered two-wheelers recorded. Most  
 145 of them are scooters. Then, heavy motorcycles represent 32 % of powered two-wheelers  
 146 observed. Concerning mopeds, they represent about 20 % of powered two-wheelers in traffic..

147 110 powered two-wheelers'riders (31 mopeds'riders, 33 light motorcycles'riders and 46  
 148 motorcyclists) and 157 motorists were involved during 2011 in an injury accident on the nine  
 149 streets studied. 89 powered two-wheelers'riders (22 mopeds'riders, 29 light motorcycles'riders  
 150 and 38 motorcyclists) and 19 motorists were injured.

151 Concerning the risk per kilometer traveled of being involved in a crash for powered two-  
 152 wheelers, Table 1 gives the numbers of powered two-wheelers' riders and motorists exposed and  
 153 involved in a crash, the odds ratios and their 95 % confidence intervals, for each street and for  
 154 the year 2011.

155

156 Table 1. Numbers of powered two-wheelers' riders and motorists exposed and involved in an  
 157 injury accident in 2011 for each street, relative risk and 95 % confidence interval

Streets	Riders exposed*	Motorists exposed*	Riders involved in an injury accident	Motorists involved in an injury accident	Relative risk	CI 95 %	
Bld. Baille	1524144	7728124	15	20	3.80	1.95	7.43
Bld. Corderie	397401	2014303	2	2	5.07	0.71	35.98
Bld. F. Duparc	1892313	9638034	19	30	3.23	1.82	5.73
Av. Mazargues	579354	2933875	3	4	3.80	0.85	16.97
Bld. Michelet	3534359	17837188	8	12	3.36	1.37	8.23
Av. Prado 1	1950733	9877126	27	32	4.27	2.56	7.13
Av. Prado 2	1516459	7679217	9	16	2.85	1.26	6.45
Rome street	473035	2400185	23	21	5.56	3.08	10.04
Bld. Schloesing	2084719	10568511	4	10	2.03	0.64	6.47

158 \*Expressed in driver-kilometers traveled

159

160 The results obtained show a risk of being involved in a crash for powered two-wheelers'riders, in  
 161 comparison with motorists, comprised between 2,03 and 5,56. This difference is statistically  
 162 significant for six of the nine streets studied. The results of each individual study listed in Table 1  
 163 are then combined by means of meta-analysis method. The meta-analysis of the nine individual  
 164 estimates of relative risk gave a mean relative risk of being involved in crash for powered two-  
 165 wheelers riders of 3,81, with 95 % confidence that the relative risk is between 2,97 and 4,89.  
 166 Statistical tests indicated the absence of heterogeneity in the data set ( $Q=3.86$  ;  $p\text{-value}=0,87$ ).  
 167 Same analysis were performed for each category of powered two-wheelers. The results indicate  
 168 a relative risk of 5,84 (confidence interval: [3,96 ; 8,59]) for mopeds' riders, 2,58 (confidence  
 169 interval: [1,76 ; 3,77]) for light motorcycles' users and 5,45 (confidence interval: [3,90 ; 7,60])  
 170 for motorcyclists. For each category of powered two-wheelers, statistical tests showed the  
 171 absence of heterogeneity in the data sets.

172 Concerning the risk per kilometer traveled of being injured for powered two-wheelers riders,  
 173 Table 2 gives the numbers of riders and motorists exposed and injured, the odds ratios and their  
 174 95 % confidence interval for the nine streets and for the year 2011.

175 Table2. Numbers of powered two-wheelers' riders and motorists injured in 2011 for each street,  
176 relative risk and 95 % confidence interval

Streets	Riders exposed*	Motorists exposed*	Riders injured	Motorists injured	Relative risk	CI 95 %	
Blvd. Baille	1524144	7728124	13	3	21.98	6.26	77.11
Blvd. Corderie	397401	2014303	2	0	25.34	1.22	527.92
Blvd. F. Duparc	1892313	9638034	16	5	16.30	5.97	44.49
Av. Mazargues	579354	2933875	3	0	35.45	1.83	686.30
Blvd. Michelet	3534359	17837188	8	2	20.19	4.29	95.06
Av. Prado 1	1950733	9877126	18	4	22.78	7.71	67.32
Av. Prado 2	1516459	7679217	9	1	45.58	5.77	359.74
Rome street	473035	2400185	16	3	27.06	7.88	92.87
Blvd. Schloesing	2084719	10568511	4	1	20.28	2.27	181.43

177 \*Expressed in driver-kilometers traveled  
178

179 The results obtained show a risk of being injured for powered two-wheelers' riders, in case of a  
180 crash in comparison with motorists, comprise between 16 and 45. The result is statistically  
181 significant on all the streets studied. The meta-analysis of the nine individual estimates of  
182 relative risk gave a mean relative risk of being injured for powered two-wheelers riders of 22.3  
183 with 95 % confidence that the relative risk is between 13.7 and 36.3. Statistical tests indicated  
184 the absence of heterogeneity in the data set ( $Q=1.05$  ;  $p\text{-value}=0,99$ ). Same analysis were  
185 performed for each category of powered two-wheelers. The results indicate a relative risk of 28.6  
186 (confidence interval: [15.4 ; 53.2]) for mopeds' riders, 15.9 (confidence interval: [8.9 ; 28.5]) for  
187 light motorcycles' users and 31.8 (confidence interval: [18.4 ; 55.0]) for motorcyclists. For each  
188 category of powered two-wheeler, statistical tests showed the absence of heterogeneity in the  
189 data sets.  
190

## 191 DISCUSSION AND CONCLUSIONS

192 This work gives an estimation of the crash risk and risk of injury for different categories of  
193 powered two-wheelers (mopeds, light motorcycles and heavy motorcycles) in comparison with  
194 motorists who used the same roads at the same time. For this work, were collected relatively  
195 robust exposure data. In that respect, this work brings an original contribution because of the  
196 current lack of exposure data concerning the use of powered two-wheelers and their  
197 subcategories (mopeds, light motorcycles, heavy motorcycles), notably in urban areas (Lin and  
198 Kraus, 2008 ; Vlahogianni, Yannis and Golias, 2012). On another hand, this research work  
199 shows that in large metropolitan areas, despite the important growth of the use of powered two-  
200 wheelers in recent years, the risk of being injured for powered two-wheelers riders is still  
201 considerably higher than the risk for motorists (about 22 times higher risk of being injured in a  
202 crash than motorists). This excess risk has to be considered as a minimum because of the police  
203 under-reporting of non-fatal road accident casualties, which is often more important for powered  
204 two-wheelers than for motorists (Amoros, Martin and Laumon, 2006 ; Elvik and Vaa, 2004).  
205 Furthermore, results show that, in urban areas, the risk of being involved in a crash and the risk  
206 of injured are similar for mopeds riders and heavy motorcycles riders (respectively about 5 times  
207 for accident involvement and 30 times for risk of injury greater than for motorists) whereas these  
208 risks are about two times lower for light motorcycle users (relative risks respectively about 2,5  
209 times for accident involvement and 16 times for risk of injury greater than motorists). These  
210 differences probably reflect differences in usage patterns and rider-dependent factors among the  
211 different categories of powered two-wheelers.

212 Despite the limits of this investigation due in particular to the small number of sites studied, the  
 213 results presented suggest that transport policy in large metropolitan areas should more consider  
 214 their implications on the use of powered two-wheelers due to the very high casualty rate of this  
 215 means of transport. Any transport policy which would lead to an increase in the use of powered  
 216 two-wheelers probably would have a harmful effect on the safety of the transport system.  
 217 Furthermore, this work suggests that the over-representation of powered two-wheelers in  
 218 accidents statistics in large metropolitan areas<sup>5</sup>, seems more due to their extreme vulnerability  
 219 rather than their over-implication in collisions (Elvik, 2009).

220

## 221 ACKNOWLEDGEMENTS

222 The authors are very gratefully to Marc Jouvenne and Franck Lavergne from the “Direction  
 223 Gestion des Equipements de Trafic de Marseille Provence Métropole”, without which this work  
 224 wouldn’t have been possible.

225

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<sup>5</sup> For example, in 2009, within Paris, powered two-wheelers’riders were involved in 62,7 % of injury accidents and represent 43 % of fatalities (Maestracci et al., 2012). In Barcelona, according to Albalate and Fernández-Villadangos (2010), they represent 42 % of fatalities.