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Injuries

Actual incidences of road casualties, and their injury severity, modelled from police and hospital data, France

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Background: Nation-wide road casualty figures usually come from police data. In France, as in many developed countries, the reporting of fatalities is almost complete but the reporting of non-fatal casualties is rather low. It is moreover strongly biased. Valid estimates are needed. **Methods:** Using the capture–recapture method on police data and on a road trauma registry covering a large county of 1.6 million inhabitants, we estimate police under-reporting correction factors that account for unregistered casualties. These correction factors are then applied to the nation-wide police data, with standardization on under-reporting bias factors. **Results:** In 2004, whereas the police report 108 727 non-fatally injured, the estimation yields 400 200. Over the 1996–2004 study period, the average annual estimated incidence is 871/100 000 for all injured (3.4 times the police incidence), 232/100 000 for hospitalized, 103/100 000 for seriously injured (2.2 times the police incidence) and 12.6/100 000 for casualties with long-term major impairment. The incidence of seriously injured (NISS 9+) is 11.3/100 000 for pedestrians, 9.5/100 000 for cyclists, 36.3/100 000 for motorized two-wheel users and 42.5/100 000 for car users. **Conclusions:** The estimated incidences are much higher than the police-based ones. This changes the scale of the road injuries issue. The risk of suffering a major impairment from a road crash is equal to the risk of being killed. Motorized two-wheel users experience a large burden of traffic casualties, much larger than that indicated by police data. The approach used can be reproduced in other countries, if an additional medical registration exists.

Keywords: capture–recapture, impairments, incidences, injuries, traffic accidents

Introduction

In most countries, data on road injuries are provided by the police. In the developed countries, the reporting rate of fatalities is usually rather high, but it is rather low for non-fatal casualties.[1] There is under-reporting, both to and from the police. It is strongly biased, mostly on injury severity, mode of transport and number of vehicles involved (single versus multiple).[1–4] Another source of registration, namely hospital records, can sometimes be used. When both hospital and police data are available, it is possible to obtain a good estimation of the actual number of non-fatal road casualties and of their injury pattern. This is needed to better define prevention programmes.[5]

In France, only the police data are available at the nation-wide level. A national hospital discharge file exists but external causes of injuries are often not recorded. In the Rhône county, a hospital-based road trauma registry provides a second source of data. At this county level, we confront the two registrations, model the probability of registration by accounting for those not reported at all and estimate police under-reporting correction factors. Applying these correction factors to the nation-wide police data, standardizing on the relevant covariates, we obtain a global picture of the health burden of road accidents at a national scale.

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Materials and methods

The projection covers all non-fatal road casualties (counts of fatalities are not corrected as they are almost complete). At the nation-wide level, only the police data is available, but at the Rhône county level, both the police data and the road trauma registry are available. This county has 1.6 million inhabitants, with a large city (Lyon), its suburbs and a rural area. Over the 1996–2004 study period, 83 447 non-fatally injured are reported by the registry, 36 329 by the Rhône police file and 1 353 600 by the nation-wide police file.

Police road crash data

The French police have to write a report for every road crash causing at least one casualty. A road crash is officially defined as a crash involving at least one vehicle (motorized ones and bicycles). The police report should describe everyone involved in the crash, and classify them as non-injured, slightly injured, seriously injured or killed. Slightly injured are out-patients and in-patients with a hospital stay of at the most 6 days. Seriously injured are those requiring a longer hospital stay. Killed are those who died within 6 days of the crash.

The Rhône road trauma registry

A road trauma registry has been in operation since 1995 and has been certified by the relevant French authority.[6] It covers all casualties from road crashes in the Rhône county, who seek medical care in health facilities. All health care facilities (from public and private hospitals) in the county and its surrounding area, which may receive crash victims participate: about 220 health units ranging from pre-hospital emergency care, emergency departments, intensive care units, surgery units, etc. to rehabilitation departments. Injury assessment is based on all diagnoses established in the different health services a casualty may have visited. Diagnoses are coded with

the Abbreviated Injury Scale (AIS),[7] which includes a severity score, ranging from 1 (minor) to 6 (beyond treatment).

Matched casualties between the two registrations

At the Rhône level, casualties recorded in both the police and the registry were identified thanks to a semi-automated probabilistic record linkage.[8] Linking variables were date and time of the crash, crash location (town/village and possibly street/road), mode of transport, year of birth, month of birth and gender of the casualty.

Health outcomes

The outcomes of interest are all injured, hospitalized, seriously injured and injured with major impairment, based on medical classifications (except for the hospitalized). The casualty's injury severity is measured with the New Injury Severity Score (NISS).[9] It is defined as the sum of squares of the AIS severity scores of a casualty's three most severe injuries, regardless of body region. The NISS scores are grouped into three categories: NISS 1–3 (minor severity), NISS 4–8 (moderate) and NISS 9+ (serious). Casualties with long-term major impairment(s) are defined with the Injury Impairment Scale (IIS),[10] restricted to those with any injury of IIS 3+. These correspond mostly to serious head injuries (e.g. intraventricular haemorrhage of cerebrum), spine injuries (e.g. contusion, laceration) and lower extremities injuries (e.g. knee dislocation). Information on these health outcomes is available on registry casualties; for police-reported casualties they are estimated by prediction models (Step 1 subsequently).

The whole estimation procedure is presented for the NISS (here and in figure 1); it is repeated for: hospitalized, any IIS 3+ injury and any head, spine or lower extremities IIS 3+ injury separately.

Predicting the injury severity (NISS) of police-reported casualties (Step 1)

The police severity classification is not satisfactory but it is correlated with the NISS,[11] and hence useful for its prediction. The prediction model is constructed on non-fatal casualties identified in both the police and registry files, for which both the NISS and police severity are available (22 704 matched casualties). The three-level NISS variable is ordinal, and we model it with a cumulative logit model. The proportional odds assumption being rejected ($P < 0.01$) this corresponds to two binomial models, which are fitted with SAS software, logistic procedure. The variables retained in the predictive model are: interaction between police severity classification and type of police, road user type, interaction between road user type and third party (yes/no), road user type of third party, age, gender, road type, urban/rural and calendar year. For the prediction of the other health outcomes, which are binary (yes/no), we merely use a logistic regression, with the same covariates.

The three-level NISS prediction model is applied to the Rhône non-fatal casualties reported only by the police (figure 1), so that the under-reporting model (which must be based on all observations from the two registrations in the Rhône county) can include the NISS. The three-level NISS prediction model is applied to the nation-wide police data (figure 1), so that in Step 4 the under-reporting correction factors, which are defined according to NISS level (among others), can be applied to these data.

Improving the record linkage (Step 2)

Before modelling under-reporting, we need to have a highly reliable picture of how many non-fatal casualties are recorded by the police only, by the registry only and by both. As a result of the record-linkage, there might be false positives: linked

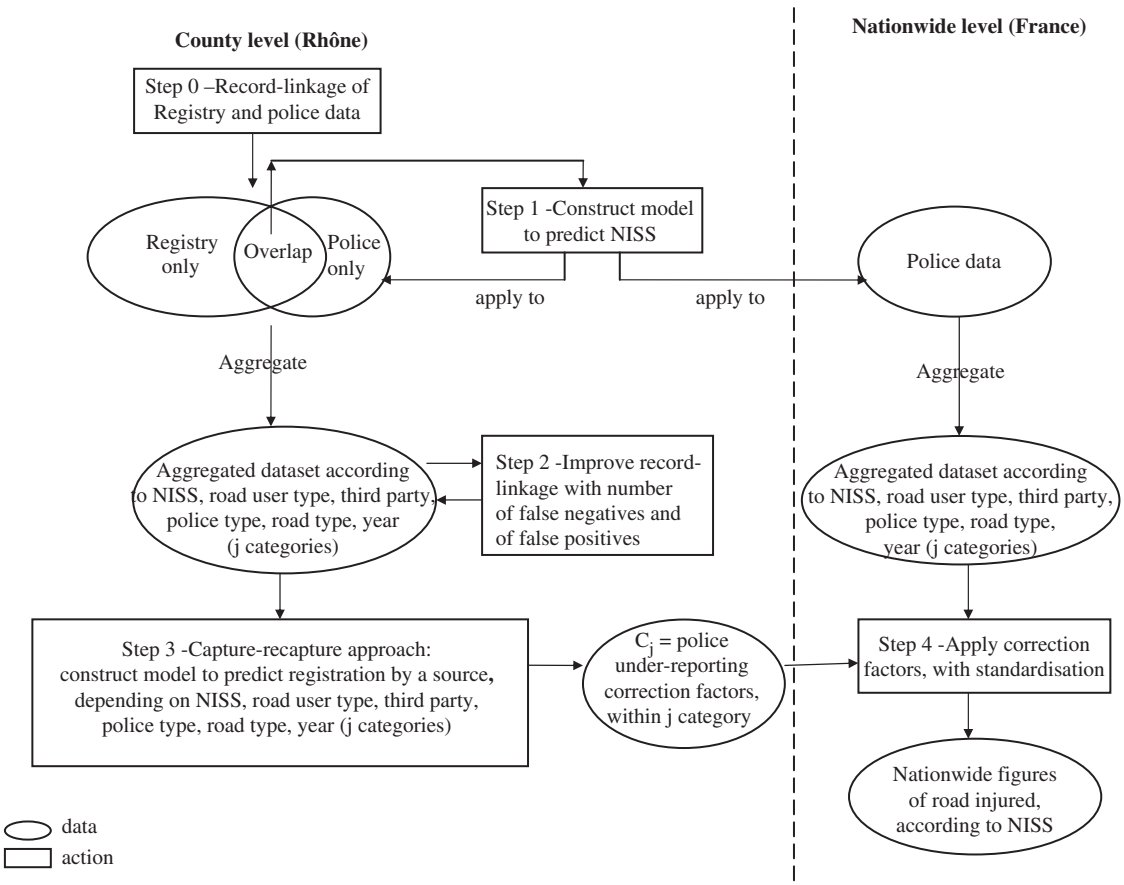

Figure 1 Flow chart of the whole estimation procedure

pairs corresponding to two distinct casualties, and false negatives: non-linked pairs corresponding to the same casualty. We estimate their numbers[12–14] and use them to improve the result of the record-linkage.

Estimating police under-reporting correction factors, with capture–recapture (Step 3)

The capture–recapture approach has been used in epidemiology,[15–18] including in road crash injuries.[19–24] The major feature of capture–recapture is to quantify those unobserved i.e. not recorded by any registration. The validity of the method is based on four key assumptions;[15,16] they are discussed later.

A capture–recapture model is fitted to the aggregated Rhône police and registry data (96 238 casualties). A standard result is the total number of road casualties in the Rhône county.[12] Here we aim to estimate under-reporting correction factors, and these can be directly obtained from the fitted model. The model formulates the probabilities of being reported by each source, conditional on the observed data. It enables the estimation of these probabilities, unconditional on the observed data. The inverse of these provides the under-reporting correction factors. The dependent variable is categorical nominal (police only, registry only, both), modelled by a generalized logit,[25] using SAS logistic procedure.

One assumption of capture–recapture is 'homogeneity of capture': all subjects should have the same probability of being recorded by a given source.[15,16] If this is true only within groups (e.g. by injury severity level) one should stratify on or include the corresponding covariate. The probability of being reported by the French police mostly depends on injury severity, road user type, third party (yes/no) and their interaction, road type, urban/rural area and type of police.[26] The probability of being reported by the registry mostly depends on injury severity.[12] In other words, the probability of being reported by a source is homogenous within every j category defined by the combination of these aforementioned characteristics. We hence include the corresponding covariates in the model,[25] except for urban/rural, not available in the registry. Year is also included (as a quantitative variable) to allow for a possible time trend in under-reporting. Under-reporting correction factors (Cj) are estimated within every j category.

Projection to the nation-wide level (Step 4)

It is a projection of county-level estimates to the nation-wide level, standardizing on the relevant covariates. It is similar to the indirect standardization of rates,[27] usually over age and sex. The nation-wide estimated number of non-fatal casualties is obtained as $E = \sum_{J=1}^{J} Cj \times O_j$, where j indexes the categories defined by the combination of the under-reporting bias factors, instead of the age and sex categories; Cj are the j-specific reference correction factors, instead of the age- and sex-specific reference incidence rates and O_j are the observed police counts of non-fatal casualties nation-wide, instead of the size or person-years of the study population.

Study outcomes

Counts and incidences per 100 000 inhabitants are displayed. Population figures are provided by INSEE, the French National Institute for Statistics and Economics Studies. Police-based figures, including fatalities, are provided for comparison. Trends are the proportion of change between 1996 and 2004. Confidence intervals (95%) are 2.5 and 97.5 percentiles from a non-parametric bootstrap[28] over the whole projection process, with 2000 iterations.

Results

Over the study period 1996–2004, for the whole country, the police-based average annual incidence for all injured is 255/100 000; whereas the estimated incidence is 871/100 000 (95% CI: 828–894), i.e. 3.4 times higher. The police-based incidence of seriously injured is 47/100 000 (those requiring more than 6 days of hospital stay) whereas the estimated incidence of NISS 9+ casualties is 103/100 000 (97–106), i.e. 2.2 times higher. As for the hospitalized, the police-based estimated incidence is 104/100 000 (101–107) and the projected one is 232/100 000 (221–239). Table 1 displays annual incidences. The estimated incidences display a lesser decrease than the police-based incidences, especially for seriously injured casualties: a decrease by less than a third instead of by half.

The average annual incidence of all injured is 69/100 000 (66–71) for pedestrians, 94/100 000 (78–112) for cyclists, 203/100 000 (192–210) for motorized two-wheel users and 469/100 000 (450–479) for car occupants. The number of injured cyclists is slightly higher than the number of injured pedestrians. The average annual incidence of seriously injured is 11.3/100 000 (10.5–12.0) for pedestrians, 9.5/100 000 (7.2–11.8) for cyclists, 36.3/100 000 (33.5–38.1) for motorized two-wheel users and 42.5/100 000 (39.8–44.4) for car occupants. The number of seriously injured is in the same order of magnitude for cyclists and pedestrians on the one hand, and for motorized two-wheel users and car occupants on the other hand. Table 2 displays annual estimates. Regarding time trends, motorized two-wheel users experience a much smaller decrease of their number of casualties than the other road users.

Casualties with major impairments (IIS 3+) are quantified in table 3. The IIS 3+ injured body region is principally the head (53.3%), followed by the lower extremities (24.3%) and the spine (15.8%). Cyclists and pedestrians are particularly prone to head IIS 3+ injuries. Motorized two-wheel users have a high frequency of spine and lower extremities IIS 3+ injuries.

Incidences by age group indicate that the 20- to 29-year olds and especially the 15- to 19-year olds have very high incidences, up to 2164/100 000 for all injured, 277/100 000 for the seriously injured and 31.8/100 000 for the ones with major impairment. The ratio of incidences between the 15- to 19-year olds and the 0- to 4-year olds (who have the lowest incidences) is 10 for all injured, 18 for the seriously injured and 16 for the ones with major impairment.

The ratio between the male and female average incidences is 2.0 for all injured, 3.1 for the seriously injured and 4.0 for the ones with major impairment. The male average incidence reaches 1162/100 000 for all injured, 158/100 000 for the seriously injured and 20.6/100 000 for the ones with major impairment.

Discussion

Limitations and strengths of the method

Capture–recapture is based on four key assumptions.[15,16] The 'homogeneity of capture' has been dealt with: covariates that are correlated with the registration probabilities are included in the model. A second assumption is the perfect identification of subjects common to the different registrations: the record-linkage is based on many informative linking variables and it has furthermore been corrected for false positives and false negatives. A third assumption is a closed population i.e. no entries or losses between two recordings. Most casualties injured in crashes in the Rhône county live in this county (89.8%) or a county next to it (6.7%)[29] so that even if slightly injured, most casualties will go to a hospital in the Rhône county or its close surroundings i.e. covered by the registry.

Table 1 Counts and incidences of road casualties per 100 000 inhabitants, police-based and estimated, France

Year	All (non-fatally) injured					Seriously injured					Hospitalized					Killed	
	Police-based		Estimated			Police-based[a]		Estimated[b]			Police-based[c]		Estimated			Police-based	
	Count	Incidence	Count	Incidence	95% CI	Count	Incidence	Count	Incidence	95% CI	Count	Incidence	Count	Incidence	95% CI	Count	Incidence
1996	170 117	293.2	554 700	955.9	905.2–993.1	36 204	62.4	64 500	111.1	104.0–116.6	70 878	122.1	151 400	261.0	247.5–270.8	8080	13.9
1997	169 577	291.3	561 600	964.8	915.9–997.8	35 716	61.4	67 000	115.2	108.3–119.9	71 055	122.1	154 400	265.3	252.3–274.2	7990	13.7
1998	168 535	288.6	566 300	969.8	923.2–1000.4	33 977	58.2	66 400	113.6	107.5–117.7	69 613	119.2	152 100	260.5	248.7–268.1	8437	14.4
1999	167 572	285.7	562 900	959.6	917.0–985.8	31 851	54.3	65 200	111.2	105.7–114.5	68 216	116.3	148 900	253.9	243.0–260.1	8029	13.7
2000	162 117	274.7	548 900	930.1	891.7–950.5	27 407	46.4	61 900	104.9	99.8–107.8	64 723	109.7	141 800	240.3	230.4–245.6	7643	13.0
2001	153 945	259.2	524 000	882.3	846.4–900.3	26 192	44.1	61 100	102.9	97.8–105.7	61 719	103.9	136 900	230.4	220.8–235.5	7720	13.0
2002	137 839	230.6	484 900	811.1	774.5–829.5	24 091	40.3	59 000	98.7	93.3–101.9	56 066	93.8	129 000	215.8	205.5–221.4	7242	12.1
2003	115 170	191.5	425 400	707.2	671.6–725.6	19 110	31.8	53 000	88.1	82.2–91.4	46 804	77.8	113 600	188.8	178.8–194.5	5724	9.5
2004	108 727	179.7	400 200	661.3	627.7–677.5	17 435	28.8	49 500	81.7	76.2–85.3	43 779	72.3	104 600	172.8	163.3–178.4	5232	8.6
Trend (%)		−38.7		−30.8			−53.8		−26.5			−40.8		−33.8			−37.9

a: Based also on police definition (requiring more than 6 days of hospital stay)
b: Defined as NISS 9+
c: Estimated. It corresponds to Step 1 in figure 1 applied to the nation-wide police data

The fourth assumption is independence between the two registrations. We think there is some positive dependence for the serious casualties[12] (the police alerting the emergency care and reciprocally). In such a case, it has been established[18] that the capture–recapture estimator (of the total number of subjects of interest) is biased downwards. The projected counts and incidences must hence be interpreted as lower limits.

There have been attempts in other places to estimate the actual number of road casualties. This can be done when additional registration of road casualties is available (hospital, insurance companies or self-reporting). Some have used the capture–recapture method to account for road casualties missed by all two or three registrations, but they have focused on sub-populations (children,[23,30] young adults,[31] pedestrians and cyclists,[20] heavy vehicles,[21] a large town[22,24] or an island).[19] Other attempts[3,4,32] have estimated under-reporting correction factors and sometimes nation-wide incidences by further projection, but they have not considered casualties missed by all registrations, which can be far from negligible. The approach presented here, which combines the two, can be reproduced in other countries, if some additional registration exists, preferably a medical one to obtain injury severity, and provided that some conditions are fulfilled.

The underlying assumption of the projection is the homogeneity of police practices across France, within defined groups. These are defined by the police under-reporting and severity classification bias factors. In other words, the police practices of casualty reporting and severity classification are the same across France for any given group (e.g. seriously injured cyclists in a crash with a third party, on a county road, rural police area). This assumption is supported by the centralized structure and management of each French police type (three of them in France).

The bootstrap confidence intervals of the incidences are very narrow. The problem is that they are based on observed data, even though re-sampled (by the use of the non-parametric bootstrap method), while the capture–recapture approach is based on the existence of unobserved[25] i.e. non-reported casualties.

Results were validated whenever estimates from other sources were available. For traumatic spine injuries, 2000 cases per year are estimated in France,[33] some 70% from traffic accidents, hence an incidence of 2.4/100 000. This is very close to our estimate of 1.9/100 000. For severe traumatic brain injuries, a registry in the French Aquitaine region reported[34,35] 642 cases in 1996, with a head injury of AIS 4 or 5, all causes. Restricted to traffic accidents (50% of all injured) and excluding early deaths (at least 18%), it goes down to 265. Our projection restricted to Aquitaine yields 244 cases (annual average over 1996–2004). These two figures are very similar.

Interpretation of findings

The estimated incidences obtained by projection are much higher than the police-based incidences. This changes the scale of the road injuries issue. These much higher figures are not so surprising since the French police under-reporting rate is 37.7%.[26] This rate is well within the average of other countries,[1] implying that it is not only a French issue but one that concerns many countries.

The estimated incidences decrease less than the police-based ones, and the difference in decreases is larger for serious casualties. These decreases are coherent with the decrease in the number of road fatalities observed in France, which has been especially large since 2002, when numerous speed control cameras were announced and installed.

Estimated incidences according to age and gender give the same ranking of age and gender groups as those based on police data (data not shown) since these two characteristics are

Table 2 Estimated incidences of road casualties per 100 000 inhabitants, according to road user type, France

Year	All injured (NISS 1+)				Seriously injured (NISS 9+)			
	Pedestrians	Cyclists	M2W users[a]	Car occupants	Pedestrians	Cyclists	M2W users[a]	Car occupants
1996	76.3	113.7	196.4	528.5	12.8	11.8	34.9	47.7
1997	73.9	118.4	207.6	525.0	12.6	12.4	38.1	48.1
1998	72.2	108.9	210.2	537.0	12.3	10.6	37.8	48.9
1999	73.3	101.4	215.4	527.3	12.2	9.8	37.6	47.6
2000	73.3	91.8	217.5	512.1	11.6	8.5	37.3	44.2
2001	70.6	78.4	211.2	489.2	11.2	7.5	37.2	43.9
2002	65.9	81.3	194.3	438.4	10.6	8.6	35.8	40.7
2003	59.0	83.9	189.5	346.1	9.4	9.5	34.0	32.0
2004	58.6	70.5	189.3	317.8	9.3	6.7	33.9	29.4
Trend (%)	−32.8	−37.6	−17.3	−47.1	−27.3	−43.2	−2.9	−38.4

a: Motorized two-wheel users: include moped and motorbike users

Table 3 Road fatalities and casualties with major impairment (IIS 3+ injury), average annual estimated incidences per 100 000 inhabitants, counts and proportions, 1996–2004, France

	All road users		Pedestrians	Cyclists	M2W users[a]	Car occupants
	Incidence	Count	Count (row %)	Count (row %)	Count (row %)	Count (row %)
Killed (police based)	12.4	7344	811 (11)	256 (4)	1291 (18)	4722 (64)
Casualties						
With any IIS3+ injury	12.6	7479	726 (10)	857 (12)	2249 (30)	3393 (45)
At body region:						
Head	6.8	3993	474 (12)	561 (14)	946 (24)	1846 (46)
Spine	1.9	1145	60 (5)	126 (11)	497 (44)	461 (40)
Lower extremities	3.1	1821	156 (9)	41 (2)	694 (38)	884 (48)

a: Motorized two-wheel users: include moped and motorbike users

not major bias factors in police reporting practices. Results confirm the higher incidence of road injuries among young people and among men.[36]

The number of motorized two-wheel casualties hardly decreases; this confirms what is seen in the police-based statistics.[37] Some likely explanations are the ineffectiveness of speed cameras for motorized two-wheel users (because of difficulties in identifying them) and the rather large increase in the fleet of motorbikes.[37]

The number of seriously injured (NISS 9+) motorized two-wheel users has reached the same level as seriously injured car users (whereas the number of killed motorized two-wheel users is three times lower than that of car users, and their share in the traffic is highly different). Cyclists roughly undergo the same number of injured (NISS 1+ and NISS 9+) as pedestrians. These two patterns are new. They cannot be seen in the police-based figures because of the biases associated with police reporting.[26]

The risk of suffering a major impairment is equal to the risk of being killed. For cyclists and motorized two-wheel users, this risk is in fact higher than the risk of being killed. These criteria should be used for prevention campaigns; the number of fatalities must not be the only criteria.

Motorized two-wheel users experience a large burden of traffic casualties, and much larger than what was known. These casualties are mostly teenagers and young adults.[38] It is crucial that prevention campaigns target these users.

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Key points

- We provide the first French nation-wide estimations of non-fatal road casualties that are corrected for under-reporting and its biases (and defined with medical classifications: NISS and IIS).
- The incidence is 871/100 000 for all injured (NISS 1+) and 103/100 000 for seriously injured (NISS 9+), respectively 3.4 and 2.2 times higher than the police-based incidences.
- The number of seriously injured (NISS 9+) motorized two-wheel users is now equal to the number of seriously injured car users (while their share in traffic are highly different).
- The risk of suffering a long-term major impairment (IIS 3+) is equal to the risk of being killed, on average. For cyclists and motorized two-wheel users, the risk of major impairment is higher.
- In terms of morbidity, injury prevention in France should focus on motorized two-wheel users.

References

1 Elvik R, Mysen AB. Incomplete accident reporting; meta-analysis of studies made in 13 countries. *Transp Res Rec* 1999;1665:133–40.

2 Hauer E, Hakkert A. Extent and some implications of incomplete accident reporting. *Transp Res Rec* 1988;1185:1–10.

3 Hvoslef H. *Under-reporting of road traffic accidents recorded by the police at the international level*. IRTAD special report. Norway: Public Roads Administration, 1994.

4 James HF. Under-reporting of road traffic accidents. *Traffic Eng Control* 1991;32:573–83.

5 Krug EG, Sharma GK, Lozano R. The global burden of injuries. *Am J Public Health* 2000;90:523–6.

6 Laumon B, Martin JL, Collet P, et al. A French road accident trauma registry: first results. *41st annual conference of the Association for the Advancement of Automotive Medecine*; 10–11 November 1997; Orlando, Florida, 1997:127–37.

7 AAAM. Association for the Advancement of Automotive Medicine. The Abbreviated Injury Scale (1990 revision). Des Plaines, IL, 1990.

8 Clark DE. Practical introduction to record linkage for injury research. *Inj Prev* 2004;10:186–91.

9 Osler T, Baker S, Long W. A modification of the Injury Severity Score that both improves accuracy and simplifies scoring. *J Trauma* 1997;43:922–6.

10 AAAM. Association for the Advancement of Automotive Medicine. Injury Impairment Scale. Des Plaines, IL, 1994.

11 Amoros E, Martin JL, Laumon B, Chiron M. Road crash casualties: characteristics of police injury severity mis-classification. *J Trauma* 2007;62:482–90.

12 Amoros E, Martin J-L, Laumon B. Estimating non-fatal road casualties in a large French county, using the capture-recapture method. *Accid Anal Prev* 2007;39:483–90.

13 Brenner H. Application of capture-recapture methods for disease monitoring: potential effects of imperfect record linkage. *Methods Inf Med* 1994;33:502–6.

14 Brenner H, Schmidtmann I. Determinants of homonym and synonym rates of record linkage in disease registration. *Methods Inf Med* 1996;35:19–24.

15 Gallay A, Nardone A, Vaillant V, Desenclos JC. La méthode capture-recapture appliquée à l'épidémiologie: principes, limites et applications [the capture-recapture method applied to epidemiology: principles, limitations and application]. *Rev Epidemiol Sante Publique* 2002;50:219–32.

16 Hook EB, Regal RR. Capture-recapture methods in epidemiology: methods and limitations. *Epidemiol Rev* 1995;17:243–64.

17 International Working Group for Disease Monitoring and Forecasting. Capture-recapture and multiple-record systems estimation II: applications in human diseases. *Am J Epidemiol* 1995;142:1059–68.

18 International Working Group for Disease Monitoring and Forecasting. Capture-recapture and multiple-record systems estimation I: history and theoretical development. *Am J Epidemiol* 1995;142:1047–58.

19 Aptel I, Salmi LR, Masson F, et al. Road accident statistics: discrepancies between police and hospital data in a French island. *Accid Anal Prev* 1999;31:101–8.

20 Dhillon PK, Lightstone AS, Peek-Asa C, Kraus JF. Assessment of hospital and police ascertainment of automobile versus childhood pedestrian and bicyclist collisions. *Accid Anal Prev* 2001;33:529–37.

21 Meuleners LB, Lee AH, Cercarelli LR, Legge M. Estimating crashes involving heavy vehicles in Western Australia, 1999–2000: a capture-recapture method. *Accid Anal Prev* 2006;38:170–4.

22 Razzak JA, Luby SP. Estimating deaths and injuries due to road traffic accidents in Karachi, Pakistan, through the capture-recapture method. *Int J Epidemiol* 1998;27:866–70.

23 Roberts I, Scragg R. Application of capture-recapture methodology to estimate the completeness of child injury surveillance. *J Paediatr Child Health* 1994;30:513–4.

24 Tercero F, Andersson R. Measuring transport injuries in a developing country: an application of the capture-recapture method. *Accid Anal Prev* 2004; 36:13–20.

25 Tilling K, Sterne JA. Capture-recapture models including covariate effects. *Am J Epidemiol* 1999;149:392–400.

26 Amoros E, Martin JL, Laumon B. Under-reporting of road crash casualties in France. *Accid Anal Prev* 2006;38:627–35.

27 Esteve J, Benhamou E, Raymond L. *Descriptive epidemiology*. Lyon: International Agency for Research on Cancer, 1994.

28 Diciccio TJ, Efron B. Bootstrap confidence intervals. *Stat Sci.* 1996;11:189–228.

29 Laumon B, editor. Recherches coordonnées sur les traumatismes consécutifs à un accident de la circulation routière, et sur leurs causes et conséquences. [Coordinated research studies on injuries from road crashes and on their causes and consequences.] UMRETTE report. Bron: INRETS, 2002. Report No.: 0205.

30 Jarvis SN, Lowe PJ, Avery A, et al. Children are not goldfish – mark/recapture techniques and their application to injury data. *Inj Prev* 2000;6:46–50.

31 Morrison A, Stone DH. Capture-recapture: a useful methodological tool for counting traffic related injuries? *Inj Prev* 2000;6:299–304.

32 Broughton J, Yannis G, Evgenikos P, et al. Deliverable 1.6. Estimation of the real number of road accident casualties. SafetyNet project, intermediate progress report on Task 1.5; 2005.

33 Saillant G, Pascal-Moussellard H, Langeron O, Lazennec J. Les lésions traumatiques de la moelle épinière: épidémiologie et prise en charge hospitalière [spinal cord trauma: epidemiology and pre-hospital management]. *Bull Acad Natl Med* 2005;189:1095–106.

34 Masson F, Thicoipe M, Aye P, et al. Epidemiology of severe brain injuries: a prospective population-based study. *J Trauma* 2001;51:481–9.

35 Masson F, Thicoipe M, Aye P, Mokni T, Senjean P. Epidémiologie des traumatisés crâniens graves (Aquitaine 1996) [résumé] [Epidemiology of serious brain injuries, Aquitaine 1996, abstract]. *An Fr Anesth Reanim* 1998;17:921(R218).

36 Robertson LS, editor. *Injury epidemiology*, 2nd edn. USA: Oxford University Press, 1992.

37 ONISR. Exposition au risque [Exposure to crash risk]. In: ONISR, editor. *La sécurité routière en France, bilan de l'année 2004 [Traffic safety in France, 2004 results]*. Paris: La Documentation Française, 2005, 211–6.

38 Martin JL, van Kampen B, Perez K. Deliverable D9 WP3 (Hospital data) data analysis: Pan-European Co-ordinated Accident and Injury Databases (PENDANT); 2006.

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