ORIGINAL ARTICLE

Risk compensation theory and voluntary helmet use by cyclists in Spain

P Lardelli-Claret, J de Dios Luna-del-Castillo, J J Jiménez-Moleón, M García-Martín, A Bueno-Cavanillas, R Gálvez-Vargas

Injury Prevention 2003;**9**:128–132

See end of article for authors' affiliations

Correspondence to: Pablo Lardelli-Claret, Departamento de Medicina Preventiva y Salud Pública, Facultad de Farmacia, Campus de Cartuja s/n 18071-Granada, Spain; lardelli@ugr.es

Objective: To obtain empirical data that might support or refute the existence of a risk compensation mechanism in connection with voluntary helmet use by Spanish cyclists.
Design: A retrospective case series.
Setting: Spain, from 1990 to 1999.
Subjects: All 22 814 cyclists involved in traffic crashes with victims, recorded in the Spanish Register of Traffic Crashes with Victims, for whom information regarding helmet use was available.
Main outcome measures: Crude and adjusted odds ratios for the relation between committing a traffic violation and using a helmet.
Results: Fifty four percent of the cyclists committed a traffic violation other than a speeding infraction. Committing a traffic violation was associated with a lower frequency of helmet use (adjusted odds ratio (aOR) 0.63, 95% confidence interval (CI) 0.58 to 0.69). Cycling at excessive or dangerous speed, a violation observed in 4.5% of the sample, was not significantly associated with helmet use either alone (aOR 0.95, 95% CI 0.56 to 1.61) or in combination with any other violation (aOR 0.97, 95% CI 0.79 to 1.20).
Conclusions: The results suggest that the subgroup of cyclists with a higher risk of suffering a traffic crash are also those in which the health consequences of the crash will probably be higher. Although the findings do not support the existence of a strong risk compensation mechanism among helmeted cyclists, this possibility cannot be ruled out.

Hypotheses on risk homeostasis and compensation are based on assumptions that persons adapt their behavior toward greater or lesser risk taking on the basis of how they subjectively perceive risk.[1 2] In other words, when persons perceive themselves to be in a high risk situation, they will try to behave more cautiously than when they perceive themselves to be in a low risk situation. As a result of such adaptations, the objective level of risk may remain relatively constant. The overall behavior of the theoretical system is analogous to that of a thermostat, the underlying metaphor in the concept of risk homeostasis.[1]

Different authors have suggested that risk compensation by drivers may attenuate the potential benefits of measures aimed at improving traffic safety.[2–4] One of the situations in which the phenomenon can occur is in the decision by cyclists to wear a helmet. Cyclists who opt to use a helmet may feel safer (that is, they may perceive less risk of being injured as a result of a crash), and this may lead them to use more careless cycling behaviors.[5] Thus, the consequent increase in crash rates offsets the beneficial effects helmet use would have if a crash occurred (that is, a substantial reduction in the risk of head injury and death).[6 7] This argument has been used to question the effectiveness of mandatory helmet use for cyclists.[8 9]

The validity of the risk compensation hypothesis is hard to test for many reasons.[2 9 10] As a result, controversy remains intense regarding both conceptual viewpoints[11 12] and the merits of specific applications to real situations such as helmet use by cyclists.[9] Although in Spain helmet use has been required by law for cycling on interurban roads since 2000,[13] compulsory helmet use is still a highly controversial topic among cyclists,[14 15] and evidence in support of or against a policy of mandatory use would be useful to future policy making efforts. In fact, in spite of the law, helmet use has not yet become widespread in the Spanish population of cyclists.

The aim of the present study was therefore to search for empirical data that might support or refute the existence of a risk compensation mechanism in connection with voluntary helmet use by Spanish cyclists.

METHODS

Three hypotheses underlie the methodological basis for this study:

(1) If the risk compensation theory is true, cyclists who use a helmet should show more imprudent cycling behaviors than those who do not use a helmet.
(2) A cyclist committing a traffic infraction reflects imprudent cycling.
(3) A positive association between committing an infraction and a higher frequency of helmet use among cyclists would be an argument in favor of the risk compensation theory.

If the first two hypotheses are accepted as valid, testing the third hypothesis in a representative sample of cyclists would constitute a test of the risk compensation theory. The problem is the lack of a representative sample. In Spain, however, the Dirección General de Tráfico (DGT) has continuously compiled a computerized database that contains information recorded by the traffic police at the scene of each crash with victims occurred throughout the country since 1990. For every cyclist involved in a crash, information is recorded regarding helmet use and any traffic infractions committed (among other variables). This information makes it possible to test the third hypothesis for the population of cyclists involved in a crash,

Abbreviations: aOR, adjusted odds ratio; cOR, crude odds ratio; CI, confidence interval; DGT, Dirección General de Tráfico

Table 1 Distribution of cyclists according to infraction (excluding speed related infractions) recorded by the Dirección General de Tráfico in Spain

Infraction	No	%
Distracted or inattentive	2094	9.18
Incorrect use of vehicle lights	136	0.60
Driving in the wrong lane or in the wrong direction	759	3.33
Partially invading opposite lane	512	2.24
Incorrect turn	1367	5.99
Illegal passing	299	1.31
Zig-zagging	92	0.40
Violating the minimum safety distance between vehicles	479	2.10
Unjustified braking	15	0.07
Failure to grant right-of-way	900	3.94
Disobeying a traffic light	742	3.25
Disobeying a stop sign	933	4.09
Disobeying a yield sign	467	2.05
Invading a pedestrian crossing	125	0.55
Disobeying any other traffic sign or a police instruction	95	0.42
Failure to correctly signal intention	105	0.46
Entering traffic flow carelessly	565	2.48
Stopping in an illegal or dangerous place	7	0.03
Cycling two or more abreast in the same lane	194	0.85
Cycling outside cycle lane or shoulder	784	3.44
Other infraction	2528	11.09
No infraction	9616	42.15

although this population does not represent all cyclists on the road. Therefore the question that needs to be asked is whether the magnitude of association between helmet use and the commission of infractions is similar in the two populations. In other words, does the restriction of our study population to cyclists involved in a traffic crash introduce a selection bias in the association between helmet use and the commission of infractions in the overall population of cyclists? Because committing an infraction is clearly related with the risk of being involved in a crash (regardless of helmet use),[16 17] the proportion of infractors among the group of cyclists involved in traffic crashes should be higher than for the whole population of cyclists. However, according to our two previous hypotheses, helmet use would not be expected to be directly related with the risk of being involved in a traffic crash independently of the commission of infractions. In other words, in a sample of non-infractor cyclists, helmeted and non-helmeted cyclists would have the same risk of being involved in a crash. Therefore, our selection criteria (based on involvement in a crash) does not modify the association between helmet use and the commission of infractions. However, helmet use may also be associated with other factors which, independently of the tendency to commit an infraction, may be related with the risk of being involved in a crash. Such factors might be personal (for example, older age, impaired vision, or foreign nationality) or environmental (for example, inadequate light conditions or poor condition of the road). However, because these variables are also recorded in the DGT database, their potential confounding effect on our analysis can be controlled for.

Under the former assumption we studied 22 883 cyclists involved in traffic crashes in Spain during the 10 year period from 1990 to 1999, for whom information was available in the DGT database regarding helmet use. For each cyclist we recorded information from the database on the following variables (the categories of each variable used in the analysis are shown in parentheses):

(1) Cyclist related variables

Any infraction except speed related infractions (see list of infractions recorded by the DGT, table 1), speed related infraction (none, excessive speed for existing conditions, going over the speed limit, excessively slow cycling), age (in five year strata except for cyclists older than 64 years), sex, seriousness of injury (death, serious injury, slight injury, no injury, unknown), helmet use (yes, no), psychophysical circumstances (apparently normal, under the influence of alcohol or other drugs, other circumstances: sudden illness, sleepiness, drowsiness, worried, other, unknown), administrative infraction (yes, no), reason for travelling (during the working day, to or from work, other), physical disability (vision, hearing, both, neither, unknown), and nationality (Spanish, foreign).

(2) Crash related variables

Type of road (open road, through-street, urban area), light conditions (daylight, twilight, night with good lighting, night with poor lighting, night with no lighting), shoulder (none or impracticable, less than 1.5 m wide, 1.5 to 2.49 m wide, 2.50 m wide or more), place of the crash (straightaway or wide curve, tight curve with poor signage, tight curve with good signage but with no indication of speed limit, tight curve with good signage and indication of speed limit, highway intersection, street intersection), condition of the road surface (normal, altered), visibility restricted by buildings (yes, no), visibility restricted by terrain (yes, no), other danger (yes, no), type of crash (collision with moving vehicle, collision with stationary vehicle, collision with pedestrian, fall from bicycle in the road, collision with object in the road, running off the road without subsequent collision, running off the road with subsequent collision, other), seriousness of the crash considering only persons other than the cyclist (no victims, slightly injured, at least one seriously injured but no deaths, at least one death).

Analysis

Because this study was intrinsically cross sectional, data analysis consisted of estimation of the odds ratio for the strength of association between commission of an infraction and helmet use. From the information provided by the DGT register, a new variable—commission of an infraction—was

Table 2 Frequency of helmet use and commission of infractions by cyclists involved in traffic accidents with victims

	Helmet use					
	Yes		No		Total	
Type of infraction	No	%*	No	%*	No	%†
None	1764	18.54	7748	81.46	9512	41.69
Infractions not accompanied by speed related infractions	1111	9.04	11174	90.96	12285	53.85
Excessive or dangerous speed	19	18.27	85	81.73	104	0.46
Both	162	17.74	751	82.26	913	4.00
Total	3056	13.40	19758	86.60	22814	100

*Percentage by rows; †percentage by columns.

Table 3 Crude (cOR) and adjusted odds ratios (aOR)* for the relationship between committing an infraction and helmet use

	Crude estimates		Adjusted estimates	
Infractions	cOR	95% CI	aOR	95% CI
None (reference category)	1		1	
Infractions not accompanied by speed related infractions	0.44	0.40 to 0.47	0.63	0.58 to 0.69
Excessive or dangerous speed	0.98	0.60 to 1.62	0.95	0.56 to 1.61
Both	0.95	0.79 to 1.13	0.97	0.79 to 1.20

*Other variables included in the model: age, sex, seriousness of injury to cyclist, psychophysical circumstances, administrative infraction, reason for travelling, physical disabilities, nationality, type of road, light conditions, shoulder, place of the accident, condition of the road surface, visibility restricted by buildings, visibility restricted by terrain, other danger, type of accident, seriousness of injuries to persons other than the cyclist.

created, with four categories: none, commission of any except those related with speed, commission of speed infractions (excessive or dangerous speed), and commission of both infractions (speed related plus any other infraction). Unconditional logistic regression analysis was used to obtain crude and adjusted odds ratios (cOR and aOR, respectively) and their respective 95% confidence interval (CI)[18] for each category of this variable (taking the first category as the reference) related to helmet use, which was used as the dependent variable. (We used helmet use as the dependent variable because conventional logistic regression only deals with dichotomous dependent variables and our actual dependent variable—the commission of infractions—was categorized in four strata.) Regarding speeding infractions, we did not consider it appropriate to combine excessively low speed cycling with the other two clearly different types of speed infractions. We therefore excluded from the analysis those 69 cyclists who committed the former infraction (cycling at excessively low speed). The final study sample therefore comprised a total of 22 814 cyclists. To estimate the aOR, all remaining cyclist and crash related variables were included in a multivariate model. Because values were missing for some variables, this analysis included only 21 804 cyclists (95.6% of the initial sample). These analyses were initially performed for the whole study population. In a second step, they were stratified according to severity of the crash and location of the injuries. All analyses were performed with the Stata software statistical package (version 7.0).[19]

RESULTS

Table 2 shows how the two main variables of interest (helmet use and the commission of infractions) were distributed for cyclists involved in crashes. Of this group, 42% did not commit any infraction. The most frequent circumstance was commission of an infraction not accompanied by excessive or dangerous speed (that is, incorrect turn, failure to grant right-of-way or cycling outside the cycle lane or shoulder) (54%). The global frequency of helmet use was 13%; the lowest percentage was found for cyclists who committed only infractions not related with speed (9%), and the highest figure was found for those who committed no infraction (19%).

Table 3 shows the cOR and aOR for commission of infractions in relation to helmet use. Committing one infraction not related with speed was significantly associated with a lower frequency of helmet use in both the crude (cOR 0.44, 95% CI 0.40 to 0.47) and the adjusted analysis (aOR 0.63, 95% CI 0.58 to 0.69). Committing a speed related infraction alone or in combination with other infractions was not associated with frequency of helmet use.

As table 4 shows, the inverse relationship between helmet use and the commission of infractions not related with speed remained practically unchanged across all strata defined according to severity of the crash and location of the lesions, with an aOR ranging from 0.60 to 0.65. Neither of the other two categories of infractions was associated with helmet use for any strata, with an important exception: a strong and significant inverse relationship (aOR 0.17, 95% CI 0.39 to 0.70) was observed between helmet use and the commission of a speed related plus another infraction in the subgroup of cyclists involved in more severe crashes (those resulting in at least one death).

DISCUSSION

The only clear association our data yielded was between committing an infraction not accompanied by a speeding infraction and the lower frequency of helmet use. This association remained unchanged across all strata according to

Table 4 Adjusted odds ratios (aOR)* for the relationship between committing an infraction and helmet use stratified by severity of the crash and location of the injuries

		Infractions not accompanied by speed related infractions		Excessive or dangerous speed		Both	
Variable of stratification	Categories	aOR	95% CI	aOR	95% CI	aOR	95% CI
Severity of the crash	Only minor injuries	0.60	0.54 to 0.68	0.98	0.50 to 1.91	0.97	0.73 to 1.28
	Severe injuries without any deaths	0.61	0.52 to 0.71	1.08	0.46 to 2.57	0.97	0.69 to 1.37
	At least one death	0.61	0.39 to 0.94	–†		0.17	0.39 to 0.70
Location of the injury	Head/face/neck	0.65	0.54 to 0.78	1.12	0.47 to 2.67	0.93	0.63 to 1.38
	Other parts of the body	0.62	0.55 to 0.69	0.94	0.45 to 1.97	1.10	0.82 to 1.47
	None/unknown	0.65	0.51 to 0.81	0.84	0.17 to 4.10	1.03	0.58 to 1.85

*Reference category: no infractions. Other variables included in the model: age, sex, psychophysical circumstances, administrative infraction, reason for travelling, physical disabilities, nationality, type of road, light conditions, shoulder, place of the accident, condition of the road surface, visibility restricted by buildings, visibility restricted by terrain, other danger, type of accident.
†aOR estimate could not be obtained for this category because of small sample size.

severity of the crash and location of the lesions. Perhaps the most plausible interpretation of this association is that the two factors involved reflect imprudent cycling behavior. In other words, the perception of an intrinsically low risk of being involved in a crash or becoming injured may be manifested both as a decision not to use a helmet and as a propensity to commit traffic violations; this entails a higher risk of being involved in road crashes in comparison to helmeted cyclists. In agreement with this hypothesis, Spaite *et al* showed that non-helmeted cyclists tended to be in higher impact collisions than helmeted cyclists.[20] Furthermore, Farris *et al* observed increased compliance with two traffic laws (making legal stops and using hand signals) in helmeted cyclists compared to non-helmeted cyclists.[21]

On the other hand, with the exception of the subgroup of more severe crashes (those resulting in at least one death), committing speed related infractions does not appear to be associated with a higher or lower frequency of helmet use. Unfortunately, with the information available in the DGT register we cannot support or refute any particular hypothesis to explain this fact. In any case, the association between speed and helmet use can be considered a matter of minor concern: in our sample of cyclists involved in traffic crashes, only 4.5% committed speed related infractions.

There are several methodological concerns which should be taken into account in order to interpret the results of our study correctly. They can be grouped into three main categories:

(1) Study population

We studied only cyclists involved in traffic crashes. In the methods section we have provided a theoretical argument in support of the generalizability of our findings to the whole population of cyclists on the road. Another fact which supports this possibility is that the association between helmet use and infractions not related with speed did not seem to be influenced by the severity of the crash: if there are no differences between more severe and less severe crashes, there are fewer reasons to think that there may exist differences between less severe crashes and no crashes. However, we have to accept that none of these are definitive arguments in favor of the generalizability of our findings to all Spanish cyclists. Therefore, strictly speaking, our results are applicable only to the population of cyclists involved in road crashes.

On the other hand, the Spanish DGT register covers only those crashes in which at least one person is injured. Assuming that helmet use prevents some head or neck injuries, the number of helmeted and infractor cyclists may be underrepresented in our study population. This in turn would lead to underestimation of the association between helmet use and infractions. However, the magnitude of this association hardly differed between strata for different locations of the injury (head, face, and neck—where the magnitude of the bias would theoretically be higher—versus others). This fact suggests that the magnitude of this bias may be small.

(2) Validity and reliability of the data

The second main problem refers to uncertainty about the validity and reliability of the data. Unfortunately, the quality and completeness of the DGT traffic crash database have yet to be assessed. We must therefore assume that these data are affected by the same problems as have been described previously for similar databases in other countries, that is, under-representation of less severe accidents[22 23] and an undetermined degree of inaccuracy for individual related variables.[24] Regarding the commission of an infraction, differential classification bias could arise if police erroneously tended to ascribe infractions more frequently to cyclists without a helmet. This in turn could partially explain the association between non-helmet use and the commission of infractions. However, although this bias cannot be entirely ruled out, we believe that its magnitude is small: first, it would be expected to appear in all types of infraction, but this is not the case, as non-helmet use does not seem to be associated with speed related infractions. Second, helmet use was not compulsory in the study period, and the frequency of helmet use was quite low among cyclists. Therefore, non-helmet use could not be considered by police officers as an infraction or even as an indication of a high risk cycling pattern.

(3) Confounding bias

Finally, another problem is confounding bias. In accordance with the interpretation of our results given at the beginning of the discussion, the *a priori* perception of risk held by each cyclist might act as a confounder of the relationship between helmet use and the commission of infractions. In other words, a true risk compensation mechanism operating in helmeted riders towards an increase in their rate of infractions would be masked in our study if their *a priori* risk of committing infractions were intrinsically much lower than that of non-helmeted cyclists. According to this view, only a strong risk compensation mechanism would be able to compensate for this difference, making the rate of infractions for helmeted cyclists higher or equal to that of non-helmeted cyclists. Because our results show that the frequency of infractions is in fact higher among non-helmeted cyclists, there are two possible explanations in relation to risk compensation mechanisms:

- A risk compensation mechanism does not operate among helmeted cyclists.
- A risk compensation mechanism operates among helmeted cyclists, but its magnitude is not high enough to compensate for their *a priori* lower risk of committing infractions in comparison to non-helmeted cyclists.

What are the implications of our findings regarding risk compensation theory? Clearly, their usefulness in clarifying this question is limited. Strictly speaking, this theory could only be verified in longitudinal studies in which the perceived level of risk of a representative sample of all the cyclists in Spain were compared before and after the introduction of a law making helmet use compulsory. This is not an easy task, and lies beyond the scope of the present study:

(A) As we have stated, we cannot be completely sure that the findings we obtained for cyclists involved in traffic crashes can be extrapolated to the entire population of Spanish cyclists.

(B) We aimed here to specifically study voluntary helmet use (compulsory helmet use in Spain was introduced in 2000). However, according to the risk compensation theory, change in risk perception can occur only if cyclists perceive that their subjective risk is lower as a result of the introduction of the safety measure. This, evidently, is the motivation that underlies voluntary helmet use, and in theory, a compensatory mechanism may operate in those cyclists who chose to wear a helmet. However, in many cyclists who use a helmet only because it is compulsory but who do not believe it to be effective, no such compensatory mechanism may operate. In fact, several cyclist's associations have claimed that helmets do not offer effective protection against most fatal road crashes, and this is one of their arguments for rejecting compulsory use.[14 15] It would be informative to replicate the present analysis in countries such as New Zealand, Australia, the USA and Canada, where helmet use has been compulsory for a number of years.[25–27]

(C) We did not directly measure risk perception, but a surrogate measure of risk perception (the commission of infractions).

(D) We did not use a longitudinal design, but a cross sectional one. This means that we are unable to detect intra-individual changes in risk perception related to helmet use. As a surrogate for this procedure, we compare the frequency of

Key points

- The possible influence of a risk compensation mechanism on helmet use by cyclists has not been adequately assessed.
- The commission of driving infractions may be used as a surrogate for careless cycling behaviors.
- In a sample of cyclists involved in traffic crashes, helmet use was associated with a lower frequency of committing infractions not accompanied by a speeding infraction.
- Careless cyclists, who are more likely to be involved in a crash, seem also to be those for whom the health consequences of a crash are greater.
- Our results do not support a strong influence of risk compensation on voluntary helmet use in Spain, although such an influence cannot be entirely ruled out.

infractions between helmet users and non-helmet users. But this comparison may undoubtedly be confounded by the *a priori* (and unmeasured) perceived risk of each cyclist, as noted above.

These considerations prevent us from making definite statements concerning the validity of risk compensation theory. Evidently, our results do not support the existence of a strong risk compensation mechanism in connection with voluntary helmet use in Spain, although they obviously cannot rule out that such a mechanism may operate. In spite of this ambiguous conclusion, our results show that two imprudent patterns of cycling—non-use of a helmet and the commission of infractions related with the risk of involvement in a crash—are associated, at least in cyclists involved in traffic crashes in Spain. Therefore, the subgroup of cyclists with a higher risk of being involved in a traffic crash seem to be also those for whom the health consequences of the crash will probably be higher. This fact should be of concern to all cyclists as well as to health planners, and should be taken into consideration in efforts to accurately assess the effectiveness of generalized helmet use and to define high risk subgroups of cyclists.

ACKNOWLEDGEMENTS

We are grateful to the Dirección General de Tráfico for providing access to their database of traffic crashes with victims in Spain. We thank K Shashok for translating significant parts of the manuscript into English.

Authors' affiliations
P Lardelli-Claret, J J Jiménez-Moleón, M García-Martín, A Bueno-Cavanillas, R Gálvez-Vargas, Department of Preventive Medicine and Public Health, University of Granada
J de Dios Luna-del-Castillo, Department of Statistics, University of Granada

REFERENCES

1 **Wilde GJS**. Risk homeostasis theory: an overview. *Inj Prev* 1998;**4**:89–91.
2 **Hedlund J**. Risky business: safety regulation, risk compensation, and individual behavior. *Inj Prev* 2000;**6**:82–90.
3 **Assum T**, Bjornskau T, Fosser S, *et al*. Risk compensation—the case of road lighting. *Accid Anal Prev* 1999;**31**:545–53.
4 **Sagberg F**, Fosser S, Saetermo IF. An investigation of behavioural adaption to airbag and antilock brakes among taxi drivers. *Accid Anal Prev* 1997;**29**:293–302.
5 **Thompson DC**, Thompson RS, Rivara FP. Risk compensation theory should be subject to systematic reviews of the scientific evidence. *Inj Prev* 2001;**7**:86–8.
6 **Thompson DC**, Rivara FP, Thompson R. *Helmets for preventing head and facial injuries in bicyclists (Cochrane review)*. Oxford: Cochrane Library, Update Software, 1, 2002.
7 **Attewell RG**, Glase K, McFadden M. Bycicle helmet use: a meta-analysis. *Accid Anal Prev* 2001;**33**:345–52.
8 **Robinson D**, Acton C. Helmet laws and health. *Inj Prev* 1998;**4**:170–2.
9 **Adams J**, Hillman M. The risk compensation theory and bicycle helmets. *Inj Prev* 2001;**7**:89–91.
10 **Dulisse B**. Methodological issues in testing the hypothesis of risk compensation. *Accid Anal Prev* 1997;**29**:285–92.
11 **Wilde G**, Robertson L, Pless B. For and against. Does risk homeostasis theory have implications for road safety. *BMJ* 2002;**324**:1149–52.
12 **O'Neill B**, Williams A. Risk homeostasis hypothesis: a rebuttal. *Inj Prev* 1998;**4**:92–3.
13 **Jefatura del Estado**. Ley 43/1999, de 25 de noviembre, sobre adaptación de las Normas de Circulación a la Práctica del Ciclismo. *Boletín Oficial del Estado* 1999;**283**:40947–9.
14 **Baden U**, Poulsen E, Godefrooij T, *et al*. *Improving bicycle safety without making helmet-use compulsory*. Brussels: European Cyclists' Federation, 1998.
15 **Amics de la Bici-Agrupación de usuarios y usuarias**. *Por qué nos oponemos al uso obligatorio del casco* (available at: http://www.amicsdelabici.org/c_casbre.htm).
16 **Lourens PF**, Vissers JAMM, Jessurun M. Annual mileage, driving violations, and accident involvement in relation to driver's sex, age and level of education. *Accid Anal Prev* 1999;**31**:593–7.
17 **Simon F**, Corbett C. Road traffic offending, stress, age, and accident history among male and female drivers. *Ergonomics* 1996;**39**:757–80.
18 **Hosmer DW**, Lemeshow S. *Applied logistic regression*. New York: John Wiley, 1989.
19 **StataCorp**. *Stata statistical software: release 7.0*. College Station, TX: Stata Corporation, 2001.
20 **Spaite DW**, Murphy M, Criss EA, *et al*. A prospective analysis of injury severity among helmeted and nonhelmeted bicyclists involved in collisions with motor vehicles. *J Trauma* 1991;**31**:1510–6.
21 **Farris C**, Spaite DW, Criss EA, *et al*. Observational evaluation of compliance with traffic regulations among helmeted and nonhelmeted bicyclists. *Ann Emerg Med* 1997;**29**:625–9.
22 **Rosman DL**. The Western Australian road injury database (1987–1996): ten years of linked police, hospital and death records of road crashes and injuries. *Accid Anal Prev* 2001;**33**:81–8.
23 **Alsop J**, Langley J. Under-reporting of motor vehicle traffic crash victims in new Zealand. *Accid Anal Prev* 2001;**33**:353–9.
24 **Austin K**. The identification of mistakes in road accident records: part 2, casualty variables. *Accid Anal Prev* 1995;**27**:277–82.
25 **Harborview Injury Prevention and Research Center**. *Bicycle helmet effectiveness*. Washington: University of Washington, 1997 (http://depts.washington.edu/hiprc/childinjury/; last updated 5 July 2001).
26 **Leblanc JC**, Beattie TL, Culligan C. Effect of legislation on the use of bicycle helmets. *Can Med Assoc J* 2002;**166**:592–5.
27 **Puder DR**, Visintainer P, Spitzer D, *et al*. A comparison of the effect of different bicycle helmet laws in 3 New York City suburbs. *Am J Public Health* 1999;**89**:1736–8.