

Real-world performance of vehicle crash test: the case of EuroNCAP

Maria Segui-Gomez,¹ Francisco J Lopez-Valdes,¹ Richard Frampton²

¹European Center for Injury Prevention (ECIP), Universidad de Navarra, Pamplona, Spain
²Vehicle Safety Research Centre, University of Loughborough, Loughborough, UK

Correspondence to Maria Segui-Gomez, European Center for Injury Prevention, Universidad de Navarra, Edif. Investigación, Desp 2290, Irunlarrea 1, E-31080 Pamplona, Spain; msegui@unav.es

Earlier analyses were presented at the 51th Annual Conference of the Association for the Advancement of Automotive Medicine held in Melbourne (Australia) in October 2007 and in the 'Càtedra A Plus' lecture series in Barcelona (Spain) in November 2008. Montserrat Ruiz-Perez assisted in manuscript preparation.

Accepted 29 November 2009

ABSTRACT

Objective To investigate whether the occupants in vehicles with better safety ratings according to EuroNCAP sustain fewer fatal and severe injuries than occupants in vehicles with worse experimental safety ratings when in frontal crashes.

Design Case—control study.

Setting A representative sample of crashes in Britain from 1996 to 2008 as gathered in the Cooperative Crash Injury Study (CCIS) database under the auspices of the UK Department of Transportation and augmented with EuroNCAP experimental ratings for each crashed vehicle.

Subjects Drivers and front seat passengers while occupants of vehicles for which EuroNCAP test results were available and who met inclusion criteria meant to select those in crashes similar to those in the frontal experimental setting.

Main outcome measures Fatality and severe MAIS3+ injuries to the head, thorax, pelvis and lower extremities.

Results The multivariate Poisson regression models on the 1259 cases who sustained crash conditions most similar to the experimental ones showed no statistically significant effect on either mortality or MAIS3+ injury in real-world crashes when travelling in cars with better safety ratings. For example, when compared to a driver in a vehicle rated as safest for head injuries MAIS3+ in frontal crashes, drivers in vehicles rated yellow or orange presented adjusted ORs of 0.6 (0.2 to 1.7) and 0.8 (0.3 to 2.1), respectively.

Conclusions No statistically significant relationships between the EuroNCAP safety scores and real-world death or severe injury outcomes were found, suggesting the need to review biomechanical criteria chosen to set cut-off points for the rating system.

INTRODUCTION

Motor vehicle crashes are one of the leading causes of mortality and severe injury worldwide, with some 1.2 million deaths and 38 million disability adjusted life years lost every year,¹ a problem which is expected to grow over the next decades.² In the European Union (EU-27), police records register 50 000 fatal and 1.7 million non-fatal victims yearly.³

Many behavioural, environmental and legislative measures have been implemented to address this important public health issue, yet relatively few of them have been rigorously evaluated. These evaluations point to the beneficial effects of passive safety measures, which aim to reduce forces to the occupants in the event a crash occurs.⁴ In an effort to provide a fair, meaningful and objective assessment of the impact performance of such measures,⁵ numerous assessment programmes have been developed, including the European New Car Assessment Programme (EuroNCAP) established in 1996.⁶

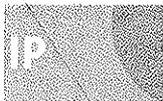
In general, these assessment programmes choose a crash configuration that is recreated in a laboratory with an instrumented crash test dummy. Different physical magnitudes (eg, accelerations, forces, deformations) sustained by the dummy during the crash in different body regions determine the safety scores the vehicle receives for each of those body regions, and these scores combined with other characteristics of the performance of the vehicle during the impact, result in a summary overall safety score. As the EuroNCAP documents state, these programmes have been designed to provide a 'fair, meaningful and objective assessment of the impact performance of cars', and 'cars that perform well in these tests should provide better protection in accidents than cars which perform less well'.⁵ However, evaluations to date of this programme are scarce and report unconvincing findings.^{7–11}

Thus, our objective was to evaluate the impact of experimental frontal crash safety ratings on real-world body-region specific MAIS3+ injuries while also evaluating the impact of these safety ratings on the likelihood of death.

METHODS

We combined real-world crash data from the British Cooperative Crash Injury Study (CCIS) with information from the EuroNCAP frontal crash test programme. Both datasets are described in more detail below. However, since our evaluation strategy, the variables needed for the analyses and the case inclusion/exclusion criteria are so closely linked with the EuroNCAP experimental procedure, we summarise it next and in figure 1^{12 13}.

The front of the vehicle impacts a deformable barrier at 64 km/h with a 40% overlap to the driver's side. Two 50th percentile Hybrid-III belted dummies sitting in the front seats (driver and passenger) are used. For each dummy, loads are measured as they act on four main body areas: (1) head and neck; (2) thorax; (3) pelvis, femur and knee; and (4) lower leg, ankle and foot. Using established criteria, the likelihood of injuries is assessed for each body region and different safety points are given. For example, the dummy driver in figure 1 shows the results of a test indicating that the probability of the most severe injury in the neck or head (as defined by a Maximum Abbreviated Injury Score¹³ of 3 or higher) was less than 5%. If this probability is not exceeded, the body region receives the maximum safety score and this is presented visually using coloured segments within body outlines (in this case, green). If this performance is not reached, then the body region receives a lower score and a different colour (yellow, orange,



Real-world performance of vehicle crash test: the case of EuroNCAP

Maria Segui-Gomez, Francisco J Lopez-Valdes and Richard Frampton

Inj Prev 2010 16: 101-106

doi: 10.1136/ip.2009.023812

Updated information and services can be found at:
<http://injuryprevention.bmj.com/content/16/2/101.full.html>

References

These include:

This article cites 3 articles

<http://injuryprevention.bmj.com/content/16/2/101.full.html#ref-list-1>

Email alerting service

Receive free email alerts when new articles cite this article. Sign up in the box at the top right corner of the online article.

Notes

To order reprints of this article go to:
<http://injuryprevention.bmj.com/cgi/reprintform>

To subscribe to *Injury Prevention* go to:
<http://injuryprevention.bmj.com/subscriptions>

Original article

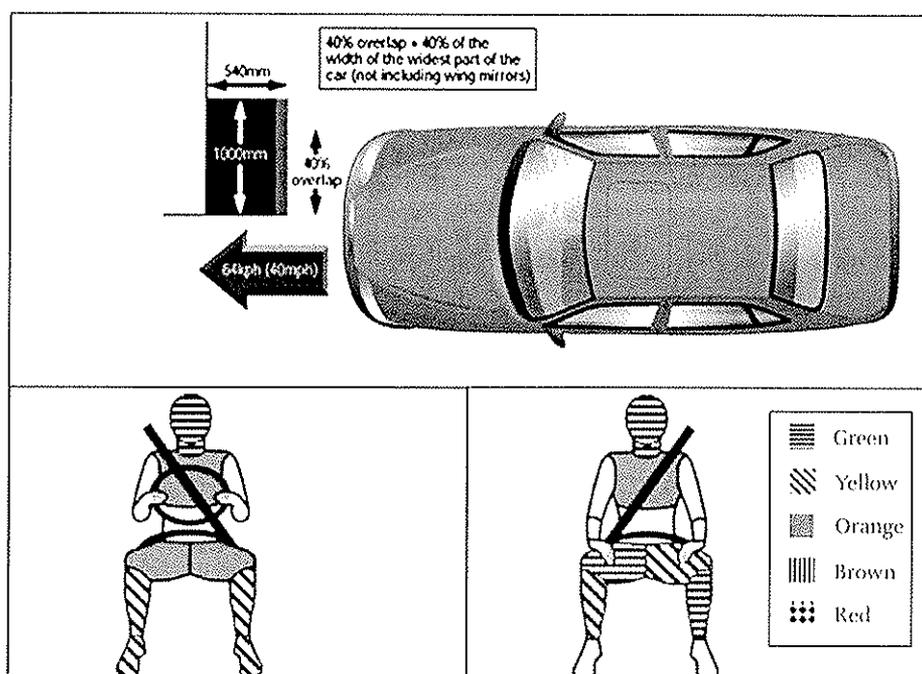


Figure 1 Frontal crash test procedure and example of body-region specific colour scale for driver and passenger. Source: www.euroncap.com.

brown and red), indicating increasing probabilities of sustaining the more severe injuries.

The driver's body-region specific scores are combined to compute an overall frontal impact protection score. However, if the passenger dummy scores are worse than those of the driver for any body region, this information is incorporated in the overall frontal scores. This global frontal score for the vehicle is an integer that ranges from 1 to 16.

Finally, to obtain the overall safety ratings and until January 2009, an additional safety score was produced adding the scores of frontal and side tests. This total score is transformed into the 5-star system commonly used to report NCAP results to the general public.

Apart from the EuroNCAP programme, the other data source used was the CCIS, one of the most comprehensive ongoing real-world crash investigation programmes in Europe. Since 1983, data have been collected on approximately 1500 crashes per year; for a more detailed description of the programme, the reader should refer to MacKay.¹⁴ Briefly, the programme selects cases for investigation using a stratified random sampling procedure based on injury severity. The accident sampling selects crashes involving towed cars less than 7 years old at the time of the accident in geographical regions selected to represent urban and rural roads in Great Britain. CCIS examines about 80% of serious and all fatal injury crashes meeting the selection criteria.

Inclusion criteria for this paper related to being a driver or front seat passenger in a crash between 1996 and 2008 (both inclusive) while in a vehicle of known make, model and year and of model year 1996 or newer. The front seat occupant had to be ≥ 16 years old and have known safety belt status. In addition, there had to be information on crash severity as measured by the equivalent test speed (ETS), be in a frontal impact as defined by principal direction of force (ie, between 11 and 1 o'clock), and had to have known and valid car-to-car mass ratios. To limit our analysis to occupants in real-world crashes of severity equal or less than that imposed in the crash test, vehicles in crashes with

an ETS >64 km/h and with mass ratios exceeding a 0.28–3.50 range were excluded.

The information on the safety ratings of vehicles was obtained from the recently revised EuroNCAP official website (www.euroncap.com). For each vehicle in a real-world crash in the CCIS data, we gathered the experimental colour-coded body region specific score, the overall frontal safety score and the 5-star overall safety score. We excluded from analysis any occupants for whom the EuroNCAP ratings for their vehicles could not be identified on the EuroNCAP website.

Since EuroNCAP safety ratings are so linked to the probability of sustaining severe injuries, we created one dummy variable for each of four body regions (head and neck; thorax; pelvis; femur and knee, and lower leg, including ankle and feet) to summarise whether the occupant sustained a MAIS3+ injury. In addition, we created a variable summarising whether the occupant died or not.

Since fatal and MAIS3+ injury scores followed a Poisson distribution, Poisson multivariate logistic regression models were used. Models were run with the EuroNCAP rating as the main independent variable(s) and safety belt use, crash severity (ETS) and mass ratio as covariates. The six models were: one to evaluate the relationship between death and the frontal overall safety system; another to evaluate the relationship between death and the overall 5-star safety ratings; and four for each of the four body-region specific safety ratings. In these four models, safety ratings were introduced as dummy variables (one for each safety colour using 'green' as the reference category); the dependent variable was whether real-world MAIS3+ injuries in those body regions had occurred.

Statistical significance was established at $p < 0.05$. Results are reported as odds ratios (ORs) and their corresponding 95% CIs. Analyses were performed using Stata V.9.0.¹⁵

RESULTS

There were 4876 drivers and 1420 front seat passengers in frontal crashes, adding up to a total of 6296 occupants in the CCIS data for years 1996–2008 (inclusive). EuroNCAP data on the safety

ratings of their vehicles was publicly available for approximately 55% of cases, reducing the number of cases to 3477. Further restricting to those for whom belt use was known and mass ratio and ETS were within valid limits, yielded a total of 1259 cases for analyses (971 drivers and 288 front seat passengers).

Table 1 summarises the personal, vehicle and crash characteristics of these individuals, as well as the car safety ratings of their vehicles. Of these 1259 cases, 11 of their vehicles were rated 'green' across all four body regions. MAIS3+ injuries to the head were sustained by 2.7% (34/1259) of occupants, while 6.9% (87/1259) sustained these types of injuries to the thorax, 5.2% (65/1259) to

the pelvis–femur–knee, and 1.4% (42/1259) to the lower leg region. Forty-two occupants died in these crashes, although all of them had MAIS3+ injuries in at least one body region.

Table 2 represents the bivariate distribution of MAIS3+ injuries by body region and NCAP safety score for that body region. No occupant sustained MAIS3+ injuries in the head or neck while in vehicles rated brown or red for this body region.

The two models relating the likelihood of death with the frontal summary score or the 5-star overall safety rating of the vehicle showed no statistically significant effects of the NCAP scores with ORs of 0.96 (0.87 to 1.07) and 0.95 (0.67 to 1.36) respectively, while all other covariates in these models (severity of crash, safety belt use and mass ratio) had statistically significant effects. For example, the star-rating model showed that belt use had a protective effect with an OR of 0.3 (0.1 to 0.6), whereas unit increases in ETS or mass ratios had injurious effects (OR 1.07 (1.07 to 1.07) and OR 3.2 (1.3 to 7.7), respectively). Similar results were found in the frontal score model (data not shown).

The four models evaluating the effect of the safety rating system on MAIS3+ injuries by body region showed statistically significant results in regard to all covariates. For example, each unit increase in ETS increased the likelihood of sustaining MAIS3+ injuries in all models with ORs ranging from 1.058 (1.04 to 1.08) in head and neck to 1.064 (1.05 to 1.08) in pelvis–femur–knee. Seat belt use was found to be statistically significant across all body regions except for the lower leg–ankle–foot region. It always showed protective effects in decreasing the likelihood of sustaining MAIS3+ injuries. Adjusted odds ratios for this reduction were 0.41 (0.17 to 0.97) for the head, 0.44 (0.26 to 0.76) for the chest and 0.52 (0.27 to 0.98) for the upper extremity. Increasing mass ratios were statistically significantly injurious for the head (4.52, 1.86 to 10.95), thorax (2.47, 1.33 to 4.57) and pelvis–femur–knee region (3.24, 1.59 to 6.61). Yet, as figure 2a–d summarises, none of the EuroNCAP scores were found to be significant for any body region. All CIs include the value of 1.

DISCUSSION

Principal findings

No statistically significant effect has been found in our evaluation of the real-world performance of the experimental EuroNCAP frontal test protocols. It cannot be stated that front seat occupants in vehicles with a worse safety rating according to the test procedures are more likely to die or to sustain a MAIS3+ injury in any body region than occupants in vehicles rated as the safest.

Table 2 Number of front seat occupants with MAIS3+ injuries by body region according to their vehicle body region-specific EuroNCAP safety score; front seat occupants in frontal crashes meeting inclusion/exclusion criteria, CCIS 1998–2008, both inclusive (N=1259, although it varies from body region to body region due to missing Abbreviated Injury Scale (AIS) data)

	Head and neck N=1179	Thorax N=1180	Knee, pelvis, femur N=1181	Leg, foot N=1178	Total
Green	24	7	10	1	42
Yellow	5	32	16	1	54
Orange	5	31	21	3	60
Brown	0	12	6	2	20
Red	0	5	12	10	27
Total	34	87	65	17	203 (16% of 1259)

Table 1 Front seat occupants, vehicle and crash characteristics in frontal impacts; Cooperative Crash Injury Study (CCIS) data 1998–2008 (both inclusive), except when otherwise noted

Occupants meeting inclusion criteria †	(Drivers/front seat passengers)	6296 (4876/1420)
	Car information available in EuroNCAP*(yes)	3477
Occupants meeting inclusion and exclusion criteria ‡	(Drivers/front seat passengers)	1259 (971/288)
	Belted (yes)	1143
Car safety ratings*	Head/neck or head	1259
	Green	860
	Yellow	279
	Orange	102
	Brown	1
	Red	17
	Thorax	1259
	Green	61
	Yellow	450
	Orange	512
	Brown	199
	Red	37
	Pelvis–femur–knee or pelvis	1259
	Green	317
	Yellow	191
	Orange	430
	Brown	126
	Red	195
	Lower leg–ankle–feet	1259
	Green	169
	Yellow	418
	Orange	212
	Brown	196
	Red	261
Occupant overall scores	MAIS	1259
	0	181
	1	682
	2	167
	3	92
	4	27
	5	25
	6	5
	Unknown	80
	MAIS3+ §(yes)	203
	Head and neck	34
	Thorax	87
	Pelvis–femur–knee	65
	Lower leg–ankle–feet	17
	Fatally injured §(yes)	42

*According to EuroNCAP.

†Passenger vehicles of known make, model year \geq 1996, known safety belt status, known crash severity information (ETS), frontal (principal direction of force) and known mass ratios.

‡We further excluded occupants whose vehicle's mass ratio was beyond admitted range and/or ETS was >64 km/h.

§Variable distributed according a Poisson distribution ($\mu=\sigma^2$).

Original article

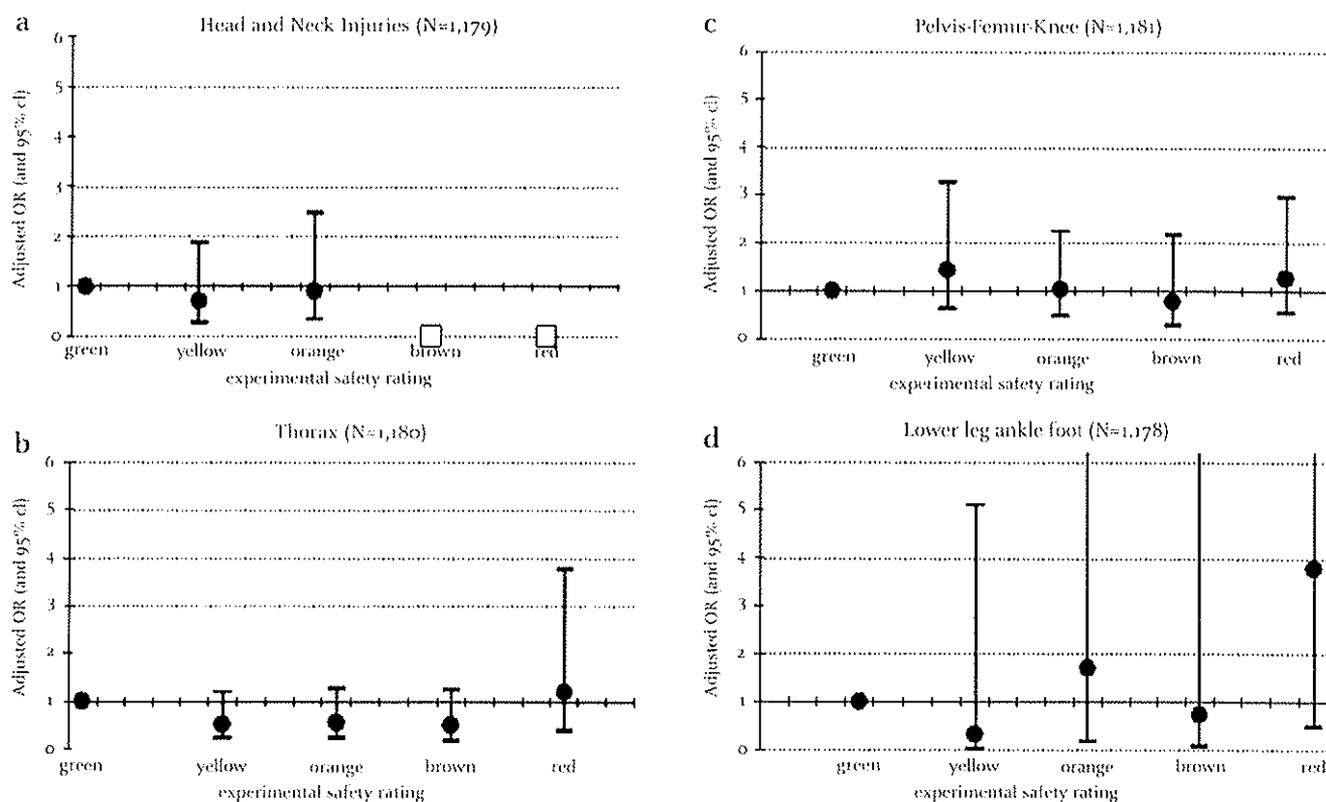


Figure 2 Adjusted* OR (and 95% CIs) of sustaining MAIS3+ injuries as front seat occupant in frontal crashes by EuroNCAP body region-specific safety rating. (a) Head and neck injuries (N=1179). (b) Thorax (N=1180). (c) Pelvis–femur–knee (N=1181). (d) Lower leg–ankle–foot (N=1178). *Adjusted by safety belt use, mass ratio and ETS. 'Green' is the safety rating used as reference value. ORs represented as squares relate to unstable findings due to the lack of occupants sustaining MAIS3+ injuries to head or neck in vehicles with brown or red coding for that region.

Strengths and weaknesses of the study

The CCIS, like many other in-depth crash databases, contains missing or invalid values which reduce the number of cases available for analysis. Further, we lost almost another 50% of the frontal crash front seat occupants collected in the CCIS because of missing information concerning the EuroNCAP scores of their vehicles. Despite the fact that our paper presents the largest number of cases ever analysed with this purpose, it could be argued that we may have lacked enough statistical power to allow any effects to be shown. Yet, this was not true for the covariates in the models. For example, crash severity comes out as a statistically significant risk factor in all models, whereas the use of the seat belt was a significant protective factor in frontal crashes, preventing MAIS3+ injuries to the head, thorax or pelvis–femur–knee region, but not to the lower extremity region. Thus, if EuroNCAP scores are not showing statistical effects, it may be concluded that the magnitude of their effect is, at best, smaller than that observed for these covariates.

To our knowledge, this paper summarises the most comprehensive real-world evaluation of a broadly implemented car safety rating system in Europe, using real-world crash data from the only in-depth crash investigation system representative from, at least, one European country.

As with any other effectiveness studies based on an in-depth data system, it could be argued that if occupants in vehicles with safer ratings were protected from suffering any injuries, they would not be found in the data system. Yet, the setting of our analysis as a case–control study, where we first identify whether occupants have been injured and then we check on the safety rating of their vehicle, precludes this argument.

Meaning of the study: possible explanations and implications for clinicians and policymakers

The EuroNCAP programme costs several million Euros each year. We strongly advocate for the existence of safety ratings that will motivate the motor vehicle industry, educate the motor vehicle users and allow motor vehicle researchers to control for case mix of vehicle fleet to analysis. However, such ratings need to be valid and translated in real protection in the real world—which is the only world in which real people crash. EuroNCAP, and the basic science behind passive safety, has to evolve to accommodate for shifting environments and push itself further so that the test configurations it adopts, and the injury biomechanics criteria are effective. Not only could we not identify protective effects for occupants in crashes most similar to the experimental conditions, but also those crash specifications apply to only 36% (1259/3477) of all front seat occupants in frontal crashes according to the CCIS files. This raises the issue of the representability of the chosen experimental conditions.

Current vehicle design geared to improve safety ratings in the experimental protocols may explain why 68% of our evaluated vehicles presented 'green' scores for the head region. It has been reported that in the case of side impacts, 96% of the vehicles of a comparable sample are rated as 'green' in head protection and 44% received the same score for the pelvis region.¹¹ Alzueta¹⁶ reported that in recent years, more and more vehicles are reaching the best ratings. In relation to this issue, it is possible that EuroNCAP announced changes improve its overall safety rating effective January 2009. The new and more challenging system incorporates adult and child occupant protection, pedestrian protection and safety assist (eg, electronic stability control or

speed limiters) in the frontal, side and rear crashes scoring protocol.¹⁷ Yet, the body region safety rating for frontal crashes remains as described in this paper. Thus, our results still apply in the new system.

Strengths and weaknesses in relation to other studies; important differences in results

Because of our choice of outcome (fatal and MAIS3+ injuries per body region), our choice of evaluation of the EuroNCAP scores (overall and at the body region level), the statistical framework used for the analysis (multivariate regression models accounting for Poisson distributions of the dependent variables), and the timing of it (newer vehicles in our analysis than in the one published in 2000), it is difficult to compare our findings with others.

The first reported evaluation, Lie and Tingvall,⁷ used police-based data to conclude that cars awarded three or four stars produced approximately 30% less fatal and serious injuries (ie, hospitalised victims) compared to vehicles receiving less stars, although statistical significance of this estimate was not reported. This result is somewhat similar to our point estimate for overall safety and likelihood of death, with each one unit increase of a star leading to a 5% reduction in death (OR 0.95). Yet our finding does not reach statistical significance as seen in the results section. This earlier finding was tempered by the next published evaluation⁸ using 75 selected cases from the CCIS database, where agreement between EuroNCAP ratings and real-world injuries was only found in some cases. A few years later Frampton⁹ performed a descriptive analysis of CCIS data to identify the relationship between EuroNCAP ratings for body region protection and real-world injury risk. He found that the EuroNCAP scoring seemed to reflect trends in real crash injuries except for the chest, but conducted no statistical evaluation to test this hypothesis. Finally, in a paper which compared overall EuroNCAP scores with alternative safety scores developed by the Safety Rating Advisory Committee in conjunction with the European Commission DG TREN, Newstead¹⁰ used police-reported data which suggested a trend towards reduced severe injury risk with increased EuroNCAP star rating, although this claim is not entirely consistent with the figures in his paper or with statistical significance tests.

A previous evaluation of body region specific scores for 906 occupants in frontal and side impact crashes found no statistically significant effects. The exception was a borderline significant effect for occupants in frontal crashes in red-rated vehicles, for whom the likelihood of sustaining MAIS3+ injury in the pelvis–femur–knee region was higher than that of their counterparts in green-rated vehicles (OR 3.46, 95% CI 1.01 to 11.91).¹¹ Our current analysis with a larger sample size corroborated the absence of no statistical findings in body region-specific analysis, not even for the pelvis–femur and knee region.

CONCLUSIONS

We were unable to detect a statistically significant relationship between any of the EuroNCAP safety ratings and deaths or

What is already known on this subject

- ▶ Car safety ratings derived from experimental tests are widely used in marketing campaigns.
- ▶ Although the first published evaluation argued for the validity of this claim, four other attempts have failed to yield statistically significant findings.

What this study adds

- ▶ The claim that vehicles which rate safer according to an experimental protocol such as that delineated in the EuroNCAP programme (safer whether in a body region or as a whole) could not be validated in a rigorous and comprehensive evaluation of the performance of these vehicles in the real world.
- ▶ This study could not identify any statistically significant protective effects of (supposedly) safer vehicles in regard to a reduction of fatalities or severe injuries by body region among front seat occupants in frontal crashes when compared to occupants of (supposedly) less safe vehicles.

severe injuries among drivers and front seat passengers in frontal crashes of severity equal to or less than that in the experimental setting.

Unanswered questions and future research

We 'conservatively' assigned safety scores to some vehicles whose model year was in between EuroNCAP tested models. For example, if a particular make and model was 1996 and EuroNCAP data for that make and model was available for 1995 and 1997 (but not 1996), we assigned to this car the 1995 ratings. Following the same example, but if the vehicle was, instead, a 1998 model, we left it with missing EuroNCAP data since we did not have the ability to know whether significant vehicle redesign had taken place since 1997. If the EuroNCAP programme ever made available safety ratings for additional vehicles, it would be worthwhile to evaluate whether the method was an unbiased one. It would also allow increasing the sample available for analyses, and thus allow for any small but significant effect to be revealed.

Although the concept of performing experimental test is very appealing and intuitive, it is also likely that the state-of-the-art knowledge regarding force limits and actual injury likelihood is still in need of further development. We suggest that instead of experimental data, maybe EuroNCAP should be fed with real-world crash data evidence.¹⁸ Hopefully, evaluations such as this allow us to stimulate further research that will cover those gaps.

Funding This work has been supported by the Spanish Ministry of Education and Science (ref TRA 2006-14280/AUT) and partially supported by La Caixa Foundation. This paper uses accident data from the United Kingdom Co-operative Crash Injury Study (CCIS). CCIS is managed by TRL Ltd on behalf of the Department for Transport (Transport Technology and Standards Division) who fund the project with Autoliv, Ford Motor Company, Nissan Motor Europe and Toyota Motor Europe. Data were collected by teams from the Birmingham Automotive Safety Centre of the University of Birmingham, the Vehicle Safety Research Centre at Loughborough University and the Vehicle & Operator Services Agency of the Department for Transport. Further information on CCIS can be found at <http://www.ukccis.org>. All authors are independent from funders.

Contributors All authors have contributed to devising, writing, and revising this manuscript. MSG led the research hypothesis as well as the analytical strategy and drafted the manuscript, FLV participated in the analysis plan and executed it, RF secured permission to use the data and participated in the analytical plan. All three authors participated actively in the interpretation of results and the revision of previous versions of the manuscript.

Competing interests None.

Provenance and peer review Not commissioned; externally peer reviewed.

REFERENCES

1. Penden M, Scurfield R, Sleet D, et al, eds. *World report on road traffic injury prevention*. Geneva: World Health Organization, 2004.

Original article

2. **Lopez AD**, Mathers CD, Ezzati DT, *et al*, eds. *Global burden of disease and risk factors*. New York: Oxford University Press and World Bank, 2006.
3. **Angerman A**, Bauer R, Nosssek G, *et al*. *Injuries in the European Union, Summary 2003-2005, Issue II*. Vienna: Kuratorium für Verkehrssicherheit, 2007.
4. **Elvik R**, Vaa T. *The handbook of road safety measures*. Oxford: Elsevier Science, 2004.
5. **EuroNCAP**. *European New Car Assessment Programme: assessment protocol, overall rating, version 5.0*. Brussels: EuroNCAP, 2009.
6. **EuroNCAP**. *Creating a market for safety; 10 years of EuroNCAP*. Brussels: EuroNCAP, 2009.
7. **Lie A**, Tingvall C. How do EuroNCAP results correlate to real life injury risks—a paired comparison study of car-to-car crashes. *Traffic Inj Prev* 2002;3:288–93.
8. **Fails A**, Minton R. *Comparison of EuroNCAP assessment with injury causation in accidents. Document number 319*, Crowthorne, UK: TRL Ltd, 2001.
9. **Frampton R**, Williams O, Thomas P. Factors related to serious injury in post NCAP European cars involved in frontal crashes. *Annu Proc Assoc Adv Automot Med* 2004;48:15–33.
10. **Newstead S**, Delaney A, Watson L, *et al*. Injury risk assessment from real world injury outcomes in European crashes and their relationship to EuroNCAP test scores. *Proceedings of the 19th International Technical Conference on the Enhanced Safety of Vehicles (ESV)*; 6–9 June 2005, Washington DC, USA: National Highway Traffic Safety Administration.
11. **Seguí-Gómez M**, Lopez-Valdes FJ, Frampton R. An evaluation of the EuroNCAP crash test safety ratings in the real world. *Annu Proc Assoc Adv Automot Med* 2007;51:282–98.
12. **EuroNCAP**. *European New Car Assessment Programme: frontal impact testing protocol, version 5.0*. Brussels: EuroNCAP, 2009.
13. **Association for the Advancement of Automotive Medicine**. *Abbreviated injury severity scale (AIS) 1990 revision (update 1998)*. Illinois: Association for the Advancement of Automotive Medicine, 1998 National Highway Traffic Safety Administration.
14. **Mackay GM**, Ashton ST, Galer MD, *et al*. *The methodology of in-depth studies of car crashes in Britain*. SAE Technical Paper Number 850556:365–390;1985.
15. **Stata Corp LP**. *Stata SE 9.0 for Windows 1985-*. College Station, TX 2005.
16. **Alzueta I**. EuroNCAP: El juez de la seguridad. *Diario de Navarra* 2005 Nov 26;Sect. Diario del Motor:88.
17. **European New Car Assessment Programme**. *New rating to play starring role in improving car safety [press release]*. Brussels: European New Car Assessment Programme, 2009.
18. **Langwieder K**, Fildes B, Ernvall T, *et al*. SARAC—Safety rating system based on real-world crashes for supplementation of New Car Assessment programs. *Proceedings of the 18th International Technical Conference on the Enhanced Safety of Vehicles (ESV)*; 19–22 May 2003 Nagoya, Japan. Washington DC, USA: National Highway Traffic Safety Administration.

