THE EURO NCAP WHIPLASH TEST

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Paper Number 09-0231

ABSTRACT

Recently a new set of tests has been introduced in Euro NCAP that assesses the performance of front seats and head restraints in relation to the risk of whiplash-associated neck disorders in low severity rear-end collisions. In the absence of a clearly understood and generally accepted cause for these symptoms, the aim of this new procedure is to reflect real world seat performance, to highlight seats with known good and poor performance and to provide the maximum incentive to manufactures to move towards best practice in seat design.

Based on real world evidence and a review of the state-of-the-art in dummies, whiplash test experience and the real-world performance of commercially available seats on the market, a test procedure and criteria were developed that take into account both geometrical aspects and dynamic performance of the seat in three meaningful test severities.

Being one of the most comprehensive "whiplash" assessments of its kind, the paper provides the background and technical details to the procedure as well as a synthesis of the first results. The results highlight the potential for further improvement in the performance for the majority of car seats on the market today.

INTRODUCTION

Established in 1997, the European New Car Assessment programme provides consumers with a safety performance assessment for the majority of the most popular cars in Europe. Thanks to its rigorous crash tests, Euro NCAP has rapidly become the driver of major safety improvements to new cars. Rather than focussing exclusively at life threatening injuries, the intention from the start has been to encourage manufacturers to make improvements in all areas and to avoid concentrating attention on any individual area of the car [1].

So far, Euro NCAP has assessed the protection for car occupants in frontal and side impact as well as the protection afforded by the car's front to pedestrians. However, it has not included a rear impact test, yet. The interest to actively address the problem of "whiplash" associated neck injuries, which represent a low threat to life but high risk at injury, was first raised in 2000 as part of Euro NCAP future development strategy.

The Whiplash Problem

Whiplash associated neck injuries in car collisions constitute a serious problem with immense implications for the individual as well as for the society. Whiplash neck injury, caused by sudden neck distortion, particularly occurs in low speed rear-end collisions and is the most commonly reported injury in crashes today [2]. Whiplash or cervical vertebral column injuries are notoriously underreported in accident statistics as after the crash the problem may not manifest itself immediately and the vehicles are often still in driveable condition. In many instances police attendance and/or tow away is not required and therefore these cases and any subsequent treatment to the injury are not included in the national accident statistics.

The rate of claims related to whiplash associated injuries reported by the motor insurance industry is generally considered to be a better indicator of the magnitude of the problem in Europe. Statistics from the Comité Européen des Assurances [3] show that four countries have a very high rate of claims for whiplash associated injuries, including the United Kingdom (76% of bodily injury claims), Italy (66%), Norway (53%), and Germany (47%), compared to an average of 40% in Europe. Figure 1 shows the overall cost of whiplash trauma, expressed as a percentage of the overall cost of bodily injury for a number of Western-European countries [4]. According to this analysis, the country with the highest costs for whiplash claims is the United Kingdom (50% of all costs related to bodily injury).

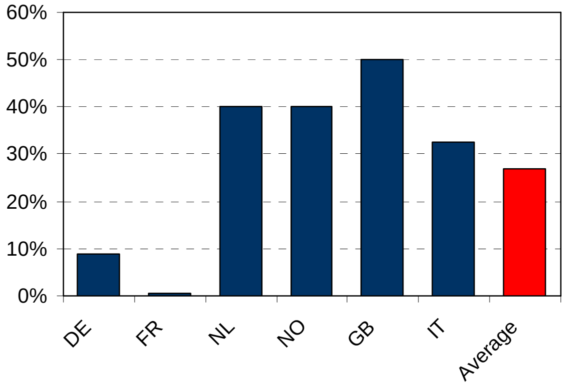

Figure 1. Cost of whiplash trauma as percentage of total bodily injury cost (from [4]).

It is well understood that whiplash claims are in part the result of the legal system of compensation. Regardless, whiplash remains the most frequently reported injury on European roads. As whiplash associated injury leads to long term consequences, with 10% of people suffering long term discomfort and 1% permanent disability, addressing “whiplash” injuries, their causes and prevention has been an important priority for the European Commission in the last decade.

Development of Whiplash Testing

Whiplash may occur in all impact directions but the injury is most frequently observed and its risk most effectively addressed in rear-ends impacts. For this injury type, no biomechanically based safety regulations exist, mainly as a consequence of the limited (or inconclusive) knowledge available on whiplash. Research has demonstrated that in the event of a rear-end collision the vehicle seat and head restraint are the principle means of reducing neck injury however [5].

Starting from the assumption that lowering the loads on the neck lessens the likelihood of whiplash associated injury, first stand-alone test methods for seat and head restraint have been derived by the International Insurance Whiplash Prevention Group (IIWPG) [6] and the Swedish Road Administration (SRA) [7, 8], respectively. Both, however, adopted a different viewpoint in selecting the relevant seat performance parameters, one putting heavy emphasis on real world validation (IIWPG), and the other on plausible hypotheses regarding the causes of whiplash associated injury (SRA).

Euro NCAP set up a Whiplash group in 2002 with the intention of developing a test that could compliment the existing whole vehicle consumer crash tests. In 2008, Euro NCAP completed its work and formally included the whiplash test as part of the new car assessment programme. This paper describes the Euro NCAP whiplash assessment test procedure, its background and the points rating system. The paper also reports on the first series of results publish under this new scheme.

EURO NCAP WHIPLASH TEST PROCEDURE

The overall objective of the Euro NCAP whiplash seat assessment procedure is to reduce real world whiplash associated injuries in EU-27 by promoting the best practice in seat design amongst manufacturers and by increasing consumer awareness. With no significant advancement in knowledge of the injury mechanisms of whiplash, and little difference shown in real world performance of the two existing test procedures [9], the proposed Euro NCAP test is effectively a combination of the earlier IIWPG and SRA procedures with further refinements. For the time being, the focus is on whiplash protection of the driver and front passenger.

Methods

The “best practice” approach aims to promote seat and head restraint designs that reduce the distance between the head and head restraint that will support the head early and/or absorb energy so that the differential movement between the head and neck is lowered, and hence the risk of whiplash associated injury is reduced. As the overall performance of the seat system is governed by both geometric and dynamic characteristics, the assessment includes a static and dynamic part. The use of sled testing, as opposed to whole vehicle testing, was found most straightforward, cost effective and acceptable for this purpose.

The seat is mounted on the sled to a standardised method that approximates the basic geometry of the subject vehicle. The seat mount brackets replicate the correct seat rail angle and distance to the floor pan of each subject vehicle. The seats are set to achieve a 25°±1° torso angle of the H-point manikin fitted with an HRMD.

Static Assessment – Euro NCAP’s geometric assessment is based upon the procedure for static geometric evaluation of head restraint geometry established by RCAR (Research Council for Automobile Repairs) to encourage positioning of head restraints closer to the driver's head. Ideally the head restraint should be high enough to protect tall occupants and be at small distance to the head (small back set). Euro NCAP's criteria for geometry are more demanding than those used previously by other rating systems.

Figure 2. SAE J826 H-point manikin combined with Head Restraint Measuring Device (HRMD).

After the seat is mounted onto the sled and set correctly, a modified SAE J826 H-point manikin is employed combined with the Head Restraint Measuring Device (HRMD) [10, 11] (Figure 2) and is used to assess the design position of the head restraint with respect to the head. Furthermore this measurement is used to define the H-point, head restraint geometry and other parameters used in set up of the test dummy. The Euro NCAP whiplash test protocol calls for three measurements on each individual seat and specifies maximum permissible skew (i.e. the positional differences between the left and right-hand H-points) on each installation, plus a maximum variation between the three drops. Consequently, static repeatability is controlled and dynamic variation due to a single outlying static measurement is rendered unlikely.

As a majority of motorists are still putting themselves at risk of neck injuries because of incorrectly positioned head restraints, Euro NCAP also assesses "worst case" geometry (or "ease of use") of the head restraint. This is achieved by checking whether the head restraint can be correctly positioned for different sized occupants, preferably without specific action from the occupant other than simply adjusting the seat track position to suit the leg length.

<u>Dynamic Assessment</u> – In the absence of a process to define representative vehicle specific pulses, the use of generic sled pulses has been preferred. Instead of using a single sled pulse, Euro NCAP has adopted three tests of different severity to avoid sub-optimisation to a single pulse and to ensure seat stability at a higher test severity. These pulses cover the range of speeds at which the highest risk at short and long term injury is observed and at which severe neck injury claims peak, as shown by Folksam [12] amongst others.

Accident data suggests whiplash tests should include crashes in the 16 km/h range (10 mi/h). The first pulse used is at 16km/h ΔV pulse with a 5.5g mean acceleration, representative of one of the crash scenarios in which whiplash associated injuries would occur. This pulse, originally double wave in shape but simplified to a triangular pulse, has been used by IIWPG. The two other pulses used are trapezoidal in shape and simulate a "low" 16 km/h ΔV (peak 5g) and "high" 24 km/h ΔV (peak 7.5g). The latter pulses have been defined and exclusively used by SRA.

The three pulses, shown in Figure 1, are termed "low" (16km/h, SRA), "medium" (16km/h, IIWPG) and "high" (24km/h SRA) within the Euro NCAP whiplash scheme. Time corridors and requirements for ΔV, ΔT, average mean acceleration and acceleration at T0 have accurately been defined to control the input pulses [13].

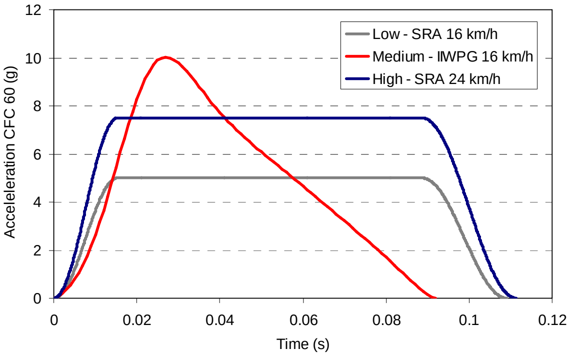

Figure 3. Three sled pulses used in Euro NCAP whiplash testing.

All testing is carried out with the BioRID 50th percentile male test dummy developed to mimic the human response in low to moderate speed rear impacts (Figure 4) [14]. This dummy is considered the most human-like dummy available with respect to human response corridors and in comparison with other candidate dummies [15]. Since 2000, various design iterations of the dummy have been released following the recommendations by the BioRID Users Group and others. Euro NCAP prescribes the use of the BioRID-IIg or subsequent versions.

For the dynamic test, the head restraint is positioned in mid vertical and horizontal position where locks are fitted. If no locking is present under the definition of the test procedure then the most down and rear position is used. The BioRID is seated according to positioning data from the static measurements. Three individual tests are run using new identical seats using each of the three pulses. At each run, dummy variables (as well as the seat back angle deflection at the high severity test) are taken.

Table 1.
Higher performance, lower performance and capping limits for low, medium and high pulses

Criteria	Units	Low severity			Medium severity			High severity		
		HPL	LPL	CL	HPL	LPL	CL	HPL	LPL	CL
NIC	m^2/s^2	9.00	15.00	18.30	11.00	24.00	27.00	13.00	23.00	25.50
Nkm	-	0.12	0.35	0.50	0.15	0.55	0.69	0.22	0.47	0.78
Head rebound velocity	m/s	3.0	4.4	4.7	3.2	4.8	5.2	4.1	5.5	6.0
Fx upper	N	30	110	187	30	190	290	30	210	364
Fz upper	N	270	610	734	360	750	900	470	770	1024
T1 acceleration up to head contact	g	9.40	12.00	14.10	9.30	13.10	15.55	12.50	15.90	17.80
Head restraint contact time	ms	61	83	95	57	82	92	53	80	92
Seatback deflection	deg	n/a			n/a			32		

Figure 4. Cross-sectional view of the BioRID upper torso, showing its segmented spine for human-like response and seat interaction.

Performance Criteria – As the injury mechanism is not well enough understood, the assessment is based on 7 seat performance criteria which are not fully confirmed by biomechanical research: head restraint contact time, T1 x-acceleration, positive upper neck shear force, positive upper neck tension force, head rebound velocity, NIC and Nkm. This set of variables, referred to as *seat performance criteria* or *seat design parameters*, is a combination of the parameters used by IIWPG [6] and SRA [7] to rate seats. While some of these criteria correlate to hypothesised whiplash injury mechanisms, there is still debate in the international research community on the validation of those criteria. All seat design parameters however encourage the basics of energy absorption by the seat and head restraints that are close to the occupant's head and for that reason these parameters are used collectively by Euro NCAP.

WHIPLASH RATING SCHEME

Points Scoring

Sliding Scales – The Euro NCAP assessment applies a sliding scale system of points scoring, which involves two limits for each seat design parameter. Two performance limits (lower and higher) are set at the 70th percentile and the 5th percentile values respectively of the variable distribution observed in an earlier 31 car seat program undertaken jointly by Thatcham, Folksam and SRA [16]. The more demanding "higher" performance limit (HPL) below which a maximum score was obtained, and a less demanding "lower" performance limit (LPL) above which no points are scored. These limit values, representing the range in performance of seats currently on the market, are given in Table 1 for each of the seven measured variables for each test pulse. If the test value recorded falls between the lower and upper limits, the points score is calculated by linear interpolation.

Capping – For the first 5 variables in Table 1, the score is "capped" at the 95th percentile value (CL) of the above variable distribution, meaning that if any single measured variable exceeded the 95th percentile limit, then a zero score is recorded for the complete test. For T1 acceleration and head restraint contact time, a slightly more complex approach is required. If both head restraint contact time and T1 acceleration were worse than the lower performance limit and either one of these variables exceed the 95th percentile, then capping is applied and the score is also zero for that test.

The purpose behind capping is to avoid trade-offs between seat design parameters where one or more parameters would be allowed to "max out" while keeping others low. This, for instance, would be the case where low Fx or NIC would be achieved by allowing more seat back deflection thus raising Fz during extension. Capping therefore encourages a proper balance between the seven seat performance criteria.

Whiplash Raw Score – The maximum score for each parameter is 0.5 points. For each of the pulses, the score for each of the seven parameters is

calculated. The scores for the NIC, Nkm, head rebound velocity, neck shear and neck tension are summed, plus the maximum score from either T1 acceleration or head restraint contact time. There is a maximum possible score of three points for each test pulse, hence 9 for the overall series of dynamic tests.
To calculate the raw whiplash score, the overall dynamic score is combined with the result from the geometric assessment. The static assessment of design head restraint position can either add or reduce the score with maximum one point, depending on how well aligned the position is with respect to the head. In addition, for seats that score well dynamically, per seat an additional 1/n points can be gained for the “worst case” geometry or ease of adjustment (where n=the number of front seats).

Finally, the score can be reduced where excessive dynamic deflection of the seat back was observed during the “high” severity test (minus three points) or where there is evidence of exploiting a dummy artefact (minus 2 points). These latter modifiers have been introduced to prevent occupant ramping, which in extreme case can lead to occupant ejection, or compromise of rear seat passenger space and to discourage seat designs that intentionally misuse dummy features to enhance the performance. The dynamic test points combined with the assessment and modifier points (whether positive or negative) form the Whiplash Raw Score (Figure 5).

Scaled Points –The overall whiplash raw score is scaled to four points, which is the final score for the seat and the maximum contribution of the whiplash test to the Adult Occupant Protection score (maximum 36 points) of the overall rating of the vehicle. The points are scaled to balance whiplash protection against the various other forms of protection assessed in the other Euro NCAP tests. For the purpose of graphical representation, the final four point score is divided into three coloured bands. A score of 0 to 1.49 scaled points is coloured “Red” or “Poor” (different from other assessments where “Red” is zero points only), a score of 1.50 to 2.99 is coloured “Orange” or “Marginal”, and finally a score of 3.0 to 4.0 is coloured “Green” or “Good”. The coloured bands are used as an additional indicator to raise public awareness and aid understanding of whiplash protection.

Provisions for Proactive and Reactive Seats

As a result of encouraging seats to offer better whiplash protection, new systems have been introduced on the market for which the head restraint position and/or seat geometry is actively altered as a result of the impact. In case where such a system is activated by the inertia of the occupant’s body mass the term “reactive” is used. Systems that not use the occupant’s energy to activate the system but require an external trigger (i.e. by a sensor) to deploy are referred to as “proactive”.

For both types of systems, Euro NCAP currently allows the geometric assessment based upon the deployed geometry considering the system always deploys in a stable position prior to the head contacting the head restraint [13]. As proof of proper functioning, tests such as the low speed bumper test (RCAR) [17] are considered where the 5^{th} percentile female Hybrid-III dummy is used.

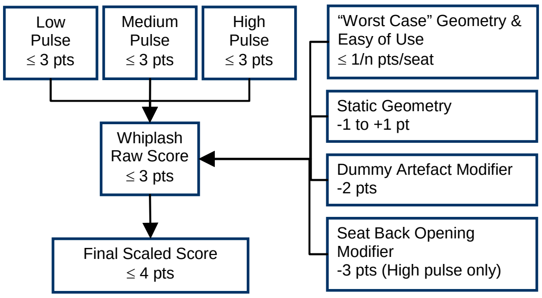

Figure 5. Whiplash Points Calculation.

VALIDATION

In the final phase of the development of the Euro NCAP whiplash test and assessment procedure, a number of critical aspects have been thoroughly validated. These include the reproducibility in dummy positioning and accuracy of geometric assessment, the feasibility of sled pulse corridors, the repeatability of dummy measurements in relation to the limits and the discriminating resolution of the rating limits correlated to field data.

Reproducibility of Static Measurements

The test procedure involves the definition of seat geometry and dummy seated position. The static measurement has a significant influence on the dynamic test result and the overall score. The repeatability and reproducibility of the static definition is therefore critical to the testing process. Static measurements may differ due to variations in set up process, variations in measuring equipment and production variation in the seats themselves. Static measurement variation can be characterised both in terms of its repeatability and reproducibility using individual seats, and also across a production batch of seats.

According to the protocol, head restraint geometry is defined by height and back set and is achieved after setting the seat and installing the SAE manikin and HRMD in a closely prescribed manner. In order to understand and control the potential variations in testing, an inter-laboratory harmonisation process was undertaken in 2006 involving Thatcham, ADAC, BASt, IDIADA, TNO and UTAC. One typical issue noted within this phase was that the build condition of the SAE manikin was often away from the RCAR standard, for instance with head room probe still attached. Secondly, the installation process was frequently not followed exactly, adjustments being made to seat position mid process, and either excessive or inadequate forces and support being applied such that a consistent H-point position was not achieved. This study highlighted that in order to minimise inter-laboratory differences, the SAE manikin and HRMD needed to better controlled and installation procedures should be more strictly adhered to.

To improve the static repeatability, various process controls were subsequently introduced and a new certification process for the SAE manikin and HRMD was defined [18]. In the final phase of harmonisation, three examples of a further seat model were once more measured by each laboratory. Across four of the participating laboratories, the average back set and height could be controlled within a window of ±2 mm variation in both measurements, showing that where the protocol is followed exactly, repeatable and reproducible static measurements could be obtained.

Sled Pulse Corridors

Zuby et al. [19] have shown that differences in pulse shape affect the dummy response for a given seat test. Consequently, the Euro NCAP pulse corridors were designed with the most stringent limits possible taking the known capability of the various test equipment used into consideration.

Firstly, a procedure to time index all data to a common point was adopted to avoid any influence on the time base. Every sled pulse must be individually time-offset, such that all data then passed through 1g at a common timing. If the process documented in the Euro NCAP whiplash protocol [13] is followed, a “time offset” value for any given test can be determined and the windows for corridor compliance and data analysis can be predictably defined. Very close control of speed change (ΔV), acceleration (dA) and with pulse duration (dT) was targeted since variation in these values can lead to reduced repeatability and reproducibility and variations in final scores of the same seat tested at different locations.

Furthermore, acceleration corridors were defined to replicate the maximum level of control as demonstrated by the various laboratories using different equipment (for example Figure 6). This definition was reached after taking into account various designs of “reverse acceleration” type sleds as well as hydraulically braked “stopping sleds”. Further acceleration controls were applied to a time window before the start of the test, and another immediately following the end of the pulse as these areas can affect the final result, either in terms of dummy pre-loading or position before test, or dynamic response during rebound. Additionally, these latter controls help to ensure that sled braking is significantly outside of the time window during which dummy criteria are assessed. All pulse requirements are given in detail in [13].

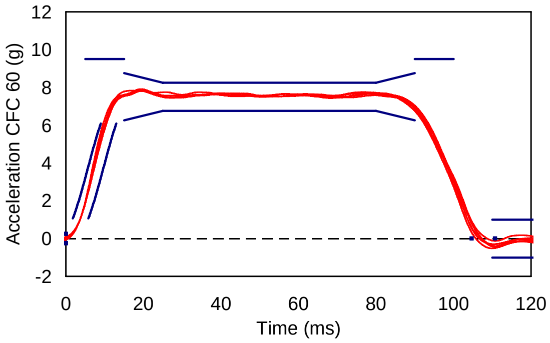

Figure 6. Typical laboratory pulse compliance (high severity pulse).

Repeatability of Criteria

In 2007 the labs involved in Euro NCAP whiplash testing ran a round-robin test program using five different seats to prove out reproducibility between the labs and to fine-tune the testing protocol. Due to the high test complexity of the protocol and the, at the time, big differences in whiplash test experience between the labs, only a sub-set of the data collected qualified for further analysis. Using data from one particular seat (taken from the Saab 9-3 model) and one representative pulse (medium severity), the reproducibility of the BioRID-II criteria was investigated. The Objective Rating Method (ORM) [20] [21] was applied to calculate correlations for pairs of scalars (peaks and timing) and curve shapes. According to [20], ORM > 65% indicate a high repeatability of results.

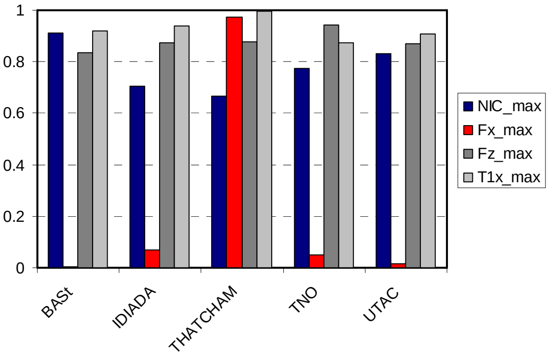

Figure 7. ORM values for BioRID-II criteria between the labs involved in whiplash testing.

Figure 7 shows the ORM values for the correlation of ADAC lab results (arbitrary choice) with the other labs for some of the criteria investigated. The overall results indicated that with exception of the neck forces all criteria demonstrated good reproducibility between the labs. Acceleration peak values generally scored higher than 90%, while timing and shape scored between 60% and 95%. Neck loads, in particular Fx, however scored generally much lower than 65% however, this result, although suspect, was found to be biased by the extremely low values found for this parameter in the tests of the Saab seat.

Rating Limits Related to Real-world Performance

Recent studies have shown a correlation between whiplash consumer crash testing by IIWPG and SRA and real-world injury outcome [9, 22]. Both these studies indicate that a seat rated as “poor” have a higher risk of whiplash associated injury compared with seats rated as “good” but there is little resolution between “acceptable” and “marginal” rated seats in the real world. The three coloured bands used for the Euro NCAP whiplash points, effectively combining the two middle sections as one, therefore are expected to correlate better to the resolution found in the analysis of real world whiplash claims.

RESULTS

Test Series

The first official round of testing was carried out during 2008 with 25 seats tested for publication in November 2008. A further six seats were tested between November 2008 and January 2009 and were released in February 2009. All systems tested were driver seats taken from the best selling, basic safety specification variant of the car tested by Euro NCAP. These cars included supermini’s, small family and large family cars, small MPV’s and small and large off-roaders. Each seat was assessed according to Euro NCAP Whiplash test and assessment protocol Version 2.8 [13].

Description of Seats

Various seat designs are included the first series of whiplash testing carried out.

Passive Seats – A seat that uses passive foam technology to absorb the energy of the crash and allows the occupant to engage the head restraint without neck distortion.

Reactive Head Restraints – A head restraint that automatically moves up and forward during the crash, actuated by the weight of the occupant in the seat.

Re-active Seats – An entire seat and head restraint that absorbs the energy of a rear end crash.

Pro-Active Head Restraints – A head restraint that automatically moves up and forward at the start of the crash, actuated by crash sensors on the bumper or within the car

Ratings

Table 2 (Appendix) summarises the results for the 31 seats released up to February 2009. A wide range of points scores were achieved ranging from 0 to over 3.5 points. Some seats score zero points, the minimum possible. These seats typically score some points in certain criteria, but are capped due to exceeding the capping limit for one or more criteria. On the other hand, there are seats scoring over 3 points. In these cases the seats tend to score over 2 points for each of the test pulses, then have positive modifier scores added for ease-of-use and/or good geometry.

In this series of tests, all seats rated as “good” featured certain “anti-whiplash” design characteristics shown to offer greater levels of protection in real world crashes. These include passive energy absorbing seats, re-active seats or re-active head restraints.

DISCUSSION

The initial testing for Euro NCAP indicates that a wide variety of seats designs are in current production and that there is a large distribution in the scores achieved in the Euro NCAP test procedure. Some new models being launched and are able to achieve a score of over 3.5 (out of 4), a promising trend that illustrates that manufacturers are readily able to achieve high points scores using existing designs. However some new models are shown to score poorly, suggesting that these designs require development to offer improved whiplash protection. This testing provides a span of results from zero to over 3 points (over 75% of the available whiplash points) for new model seats that are representative of the range of new seats found in the real world.

Within the first phase it became apparent that consideration should be given by manufacturers as to the availability of positive modifier and assessment points, such as “ease of adjustment”. Qualification for these points resulted in at least one manufacturer achieving a “good” rating since they help to ensure that a wide range of real world users are given protection from whiplash associated injuries.

Every “good” rated seat scores over 60% of available geometry points in this phase of testing. Every “poor” rated seat conversely scores less than 20% of the available geometry points. This highlights the importance of geometry in seat design for manufacturers based on historical studies that link geometry to protection against whiplash associated injury [5, 23, 24]. Another trend revealed in the testing is that any seat dynamically achieving a capped score in any of the tests has a negative geometry points score. While negative geometry points are not necessarily a predictor of capped dynamic performance, a common trend was observed.

Last but not least, continued analysis of real world injury claims collected by Folksam, etc. show that seats that have done well in the tests, have lower real world injury claims. This suggests that a "best practice" test procedure can be a useful way forward even where injury mechanisms are not well understood.

CONCLUSION

Development of the Euro NCAP test procedure has built upon existing whiplash test experience and real world field studies. The procedure combines facets from IIWPG and SRA assessment programs with further additions. In the last phase of the development, where the focus was on repeatability and reproducibility of results, a significant step forward was made collectively in defining dummy test position procedures and pulse definitions. The test procedure is now presented as version 2.8 [13] with minor refinements forthcoming as part of Euro NCAP's standard review process.

The Euro NCAP whiplash test procedure encourages best practice in vehicle design to prevent whiplash associated injuries. This is necessary since no injury mechanism for whiplash has neither been identified nor validated. The initial tests indicate that a wide range of results are possible, from 0 to over 3.5 points, confirming that some seat designs still need improvement for whiplash protection.

Finally, it should be well understood that technical developments associated with vehicle design are not sufficient to resolve the entire problem of cervical injury claims in Europe. However, it is clear that by implementing state of the art seat design across the majority of cars sold on the European market, the effect of one of the dominant contributing factors may significantly be reduced.

Research will continue to monitor the effectiveness of the whiplash testing by Euro NCAP in the real world. Future investigations will be made into dummy and HRMD/SAE manikin calibration with the aim of improving overall test repeatability and reproducibility. In addition, the relevance and additional benefit of the three prescribed test pulses and seven criteria may be further examined in relation to the test costs in the near future.

ACKNOWLEDGEMENTS

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Euro NCAP
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A. Hobbs (Retired)
M. van Ratingen (Chair 2007-2008)

Members and laboratories
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A. Lie (SRA)
B. Lorenz (BASt)
F. Minne (UTAC)
R. Moran (DfT)
J. Roberts (VSC, on behalf of ICRT)
R. Satué (IDIADA)
O. Vázquez (CTAG-IDIADA)
T. Versmissen (TNO)

Industry
C. Adalian, PSA Peugeot Citroën
R. Sferco, Ford Motor Europe

The members of the group would like to thank the members of IIWPG, SRA and Autoliv for their support and valuable input. Euro NCAP thanks Ed Giblen at Thatcham for his help and technical contribution.

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APPENDIX

Table 2.
Euro NCAP Whiplash Test Results November 2008 – February 2009

Model	Final Scaled Score	Raw Whiplash Score	High Severity (unscaled)	Mid Severity (unscaled)	Low Severity (unscaled)	Geometry	Restraint Type
Volvo XC60	3.544	9.746	1.909	3	2.876	0.961	Passive
Alfa Romeo MiTo	3.349	9.209	2.503	2.355	2.47	0.881	Reactive
Toyota Avensis	3.344	9.196	2.731	2.274	2.191	1	Reactive
VW Golf	3.306	9.092	2.514	2.051	2.527	1	Passive
Audi A4	3.155	8.675	2.346	2.594	2.135	0.6	Passive
Opel/Vauxhall Insignia	3.064	8.426	2.339	1.94	2.147	1	Reactive
Renault Koleos	2.938	8.081	2.404	2.641	2.444	0.592	Passive
Toyota iQ	2.706	7.44	1.699	2.136	2.157	0.448	Passive
Lancia Delta	2.616	6.693	1.979	1.818	1.637	0.759	Reactive
Subaru Impreza	2.458	6.759	2.396	1.998	2.276	0.089	Passive
BMW X3	2.44	6.71	2.484	2.264	2.112	-0.15*	Proactive
Renault Kangoo	2.378	6.54	1.75	2.237	2.022	0.531	Passive
Renault Mégane	2.376	6.533	1.451	0.888	2.194	1	Passive
Honda Accord	2.26	6.214	1.903	2.205	1.67	0.436	Reactive
Skoda Superb	2.217	6.096	2.428	1.331	1.656	0.681	Passive
Hyundai i30	2.212	6.083	0.935	2.005	2.471	0.672	Reactive
Ford Fiesta	2.207	6.07	1.755	1.871	1.969	0.475	Passive
Mazda 6	2.073	5.701	2.41	1.659	1.84	-0.208	Passive
Mitsubishi Lancer	2.04	5.609	1.697	2.05	1.866	-0.004	Passive
Seat Ibiza	1.963	5.397	2.192	1.244	1.639	0.322	Passive
Mercedes Benz M Class	1.824	5.017	1.086	1.523	1.715	0.693*	Proactive
Dacia Sandero	1.582	4.349	1.058	1.793	1.304	0.194	Passive
Daihatsu Cuore	1.1	3.025	2.21	2.086	1.729	0	Passive
Citroen Berlingo	1.043	2.868	0.526	1.235	0.982	0.125	Passive
Hyundai i10	0.938	2.579	1.173	0	1.814	-0.408	Passive
Citroen C5	0.57	1.568	0.471	0.44	0.513	0.144	Passive
Ford Kuga	0.444	1.222	0.238	0.713	0.36	-0.089	Passive
Citroen C3 Picasso	0.338	0.93	0	0.571	0	0.359	Passive
Daihatsu Terios	0	-0.054	0	1.455	1.63	-0.139	Passive
Suzuki Splash	0	-0.336	0	0	0	-0.336	Passive
Peugeot 308CC	0	-0.233	0	0	0	-0.233	Passive

*Geometric assessment based on “undeployed” head restraint. Result under review as part of 2009 protocol update.