CHALLENGES IN THE DEVELOPMENT OF A REGULATORY TEST PROCEDURE FOR NECK PROTECTION IN REAR IMPACTS: STATUS OF THE EEVC WG20 AND WG12 JOINT ACTIVITY

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ABSTRACT

A new EEVC Working Group, WG20 (Rear Impact test procedure(s) and the mitigation of neck injury), was given the task to develop test procedures for rear end collisions, with a prime focus on neck injury reduction (whiplash). The work is carried out in collaboration with the EEVC WG12 (Advanced Anthropometry Adult Crash Dummies). WG20 is responsible for the definition of the test conditions and the overall coordination of this activity. WG12 is responsible for the selection of an appropriate crash test dummy and identification of biomechanically based injury criteria with known injury risk functions.

WG20 carried out a review of field accident data, clinical data, available sled test methods, biomechanical research on injury causation and human subject dynamic response, proposed injury criteria, available impact dummies, and instrumentation and dummy positioning methods. The findings of the WG20 review provide the basis for the future work of the group and are summarised here.

WG20 has a work programme to develop and validate a test procedure to assess the geometry of head restraints as a first stage in their approach to whiplash injury mitigation. In the longer term a sled-based dynamic assessment of injury risk or seat performance will be developed and validated.

WG12 has defined draft biofidelity requirements for rear impact crash test dummies and will evaluate the available rear impact dummies against these requirements once they are finalised. This paper summarises the chosen biofidelity requirements and the criteria by which they were selected. It also outlines the further work programme of the group to evaluate and validate biomechanically based injury criteria for rear impact crash testing.

INTRODUCTION

No regulatory test exists in Europe to assess injury risk in rear impacts, in particular low severity rear impacts. A number of accident studies and claims statistics coming from the insurance industry clearly indicate that low-speed rear impact can lead to neck injuries causing long-term disablement and discomfort. These injuries, often referred to as whiplash injuries, are usually classified as AIS 1 (Abbreviated Injury Scale).

Outside of the regulatory framework a number of organisations have been investigating WAD injury (Whiplash Associated Disorder). Two EC projects have supported some areas of this work. A rear impact, sled based test procedure, against which to assess vehicle seats has been proposed to GRSP and ISO. As of the year 2000, the EEVC had not developed a viewpoint on rear impact and WAD type injury. As a result, the EEVC Steering Committee asked EEVC WG12 to create an *ad hoc* Working Group to investigate the possibility of developing an EEVC view on rear impact and WAD injury.

The *ad hoc* Group [EEVC WG12, 2002] found that there was a significant amount of research data available and that interesting and promising research projects were ongoing. It recommended that the EEVC Steering Committee start up a new activity with the aim of developing a proposal for a new European regulatory test for whiplash injury (AIS1 neck injury) protection in rear impacts.

The EEVC Steering Committee formed a new Working Group, WG20, to develop and evaluate a test procedure, or range of test procedures, suitable for regulatory use. The test procedures should have a prime focus on neck injury reduction, but should give due regard to the potential for injuries to other body regions. The EEVC Steering Committee also gave WG12 additional terms of reference regarding the selection of an appropriate crash dummy and injury criteria for a rear impact test procedure.

This paper will summarise a state-of-the-art review of rear impact accidents and injuries undertaken by the members of EEVC WG20. This review will form the basis for the further work of the Group. The paper will also summarise the work of WG12 to develop biofidelity requirements for a rear impact dummy and to evaluate the suitability of existing dummies that have been proposed for use in rear impact test procedures.

Finally, the paper will outline the further work programmes of the two Groups.

EEVC WG20 STATE-OF-THE-ART REVIEW

As its first action, EEVC WG20 undertook a review of the current state of knowledge on rear impact accidents and injuries. This review built upon and updated the work of the WG12 rear impact *ad hoc* group [EEVC WG12, 2002]. A summary of the findings of the review is given in the sections below.

Accident Data and Insurance Statistics

From accident data and insurance statistics the impact severity in rear impacts is relatively well known, both when the occupants are uninjured and when they report whiplash injury. From crash recorder data at Folksam, obtained from a single make of car, it was found that long-term WAD symptoms are rare at mean accelerations below 3 g [Krafft *et al.*, 2001; Krafft *et al.*, 2002; Kullgren *et al.*, 2003]. The finding is also supported by several volunteer test studies [McConnell *et al.*, 1995; Ono and Kaneoka, 1997; Siegmund *et al.*, 1997]. Based on accident statistics from several countries, the majority of whiplash injuries are reported in crashes at medium impact severity, typically at a change of velocity between 10 and 15 km/h. Women have about twice the injury risk compared to men [Krafft, 1998; Hell *et al.*, 1999; Ydenius and Kullgren, 2001; Berglund, 2002]. Most of the reported injuries were short-term injuries where the occupants recovered within a couple of weeks [Spitzer *et al.*, 1995].

Furthermore, there is knowledge regarding the impact severity when occupants sustain more long-term WAD symptoms. Based on crash recorder data from real world accidents (from a single car make), the average change of velocity and the mean acceleration was quantified [Krafft *et al.*, 2001]. Those injuries leading to WAD symptoms lasting more than one month was found to occur at approximately 20 km/h and 5 g respectively, while those recovering within a month had approximately 10 km/h and 4 g respectively. The average values for occupants classified as WAD Grade 2 and 3 [Spitzer *et al.*, 1995] was approximately 16 km/h and 5 g. Therefore a proposed test speed and acceleration will vary, depending on whether the test is focusing on all reported whiplash injuries or on the more severe ones.

At higher impact speeds there is an increased risk of uncontrolled seat back deflection or failure, with an attendant risk of serious injuries. A seat-back deflection test or a high-speed test could be added to cover this situation. To ensure that sub-optimisation is avoided, a low severity test could also be added.

Current accident data show similar trends world wide (except deviations from different social security and insurance systems in various countries).

Biomechanics

WAD injury symptoms are well documented, but the injuries causing the acute symptoms are not completely known. The relation between acute injury and chronic pain is also not fully understood. The kinematics of the head and neck during rear impact is relatively well known. Derived from the known kinematics, a number of biofidelity requirements have been formulated and were used as a basis for the development of several rear impact dummies.

Several injury criteria have been suggested. Three principal ways of verifying injury criteria were identified:

1. By identification, in the clinic, of the actual acute injury that causes chronic pain. This would probably tell us which injury mechanism is the cause and give an indication as to which injury criterion to use.
2. An alternative would be to evaluate proposed criteria against experimental data where certain injuries have been caused and where injury threshold levels can be identified (this will however leave an uncertainty about the relationship between the observed injuries and the symptoms experienced by living patients).
3. By high quality evaluation of injury criteria against field accident data. Reconstruction crash tests and computer modelling may be used in parallel.

Some currently proposed injury criteria are acceleration based, like NIC [Boström *et al.*, 2000]; velocity based (T1 rebound velocity); displacement based like, for instance, IV-NIC [Panjabi *et al.*, 1999] and NDC [Viano and Davidsson, 2001]; or load based, like N_{km} [Muser *et al.*, 2000] and LNL [Heitplatz *et al.*, 2003]. A few of these proposed injury criteria, e.g. NIC, have been used in different versions and this must be taken into account when making comparisons. The International Insurance Whiplash Prevention Group (IIWPG) uses a combination of such measurements in a seat performance criterion. An injury criterion that correlates to injury risk is a requirement for a future test procedure. It would however be possible to identify such a criterion even if the injury and injury mechanism is not fully known. (Medical symptoms can often be treated even if the origin of the symptom is not fully understood.) The term WAD Risk Assessment Parameters (WAD-RAP) was introduced as a replacement for "injury criteria" in the present situation where the actual injury causing the WAD symptoms is unknown.

From a regulatory perspective it is essential that there is a good correlation between the WAD-RAP and risk. Any given WAD-RAP should be accompanied by a risk function. Some recent findings, verified according to method 3 above, indicate that NIC_{max} and N_{km} fulfil these requirements [Eriksson and Kullgren, 2003; Linder *et al.*, 2004]. These findings are based on data from a few Toyota car models. A wider data sample covering more car models as well as an evaluation of the applicability of the criteria in sled testing would be desirable.

Dummy Development

Currently, the dummies that are most likely to be useful for rear impact testing, are the BioRID II [Davidsson *et al.*, 1999] and the RID2 [Cappon *et al.*, 2001] or RID^{3D} [Cappon *et al.*, 2003]. Each of these has been based on a different set of biofidelity requirements [Philippens *et al.*, 2002]. A third alternative for rear impact is the American frontal impact dummy prototype, THOR, which has been evaluated with partly promising results. The BioRID II has the advantage of being more established and more widely used in automotive industry, while the RID is more recently released. The prototype RID^{3D} is a further development of the RID2 with improvements in the rebound phase and in ramping. One advantage of the RID2 / RID^{3D} is that it has a slightly more comprehensive instrumentation capability, with a lumbar load cell, and is intended to be able to handle oblique impacts.

All three dummies still have practical limitations, which are likely to be solved throughout the course of their use. There is an ongoing world wide evaluation of the dummies, which has lead to stepwise adjustments. This process is expected to make them acceptable for use in a regulatory framework. Appropriate setting up and certification procedures are also evolving during this evaluation process. The Hybrid III, although it is being used world wide, is not considered suitable for low severity rear impact testing due to its limited biofidelity in low-speed rear impact conditions [Philippens *et al.*, 2002].

For head restraint geometry evaluation the H-point machine was extended with a Head Restraint Measuring Device (HRMD) which is used in a rating procedure by the Research Council for Automobile Repairs (RCAR) [RCAR, 2001]. Various versions of the H-point machine exist and the difference between the versions requires investigation.

Car and Seat Design

Vehicle structures are reported to have become stiffer since the mid 1990s and this trend in increasing stiffness is continuing [Muser *et al.*, 2000; Avery and Zuby, 2001]. This may be due to enhanced crash performance driven by, among other requirements, the low speed insurance impact test and high speed frontal impact regulatory and consumer tests, and may have lead to an increase in whiplash type injuries. Although some attempt could be made at the local softening of perimeter structures of the vehicle, the biggest gains in mitigating whiplash injuries are expected to come from the enhancement of seat back and head restraint performance.

Within seat design, good head restraint geometry has been shown to be important in mitigating soft tissue neck injuries [Farmer *et al.*, 1999], although occupant kinematic control and effective energy management have also been shown to be of importance. Seat back yield-strength has increased and along with other parameters is coincident with a rise in reported injuries. Current research suggests that where high seat back yield strength is used in conjunction with 'good' head restraint geometry a reduction in injuries is observed.

New, improved head restraint and seat systems have been shown to be effective at improving the neck injury protection in terms of a reduction in insurance claims. For such systems to be effective, energy absorbing capability could be employed to reduce occupant energy whilst controlling head and thorax motion, and good head restraint geometry could be utilised to control head kinematics early in the crash event (by gaining early contact between head and head restraint).

Any future dynamic whiplash test assessment may have to feature a range of impact velocities to prevent sub-optimisation of these systems.

Test Procedures

Several proposals for procedures for whiplash protection assessment in rear impact have been proposed or implemented in different fora (e.g. ISO, IIWPG, SRA, ADAC, EuroNCAP, NHTSA) in recent years. Static as well as dynamic test procedures have been developed. Most of the test procedures have the same origin and are gradual upgrades that have been included as new knowledge has become available.

Most of the procedures include a dynamic sled test of the seat using a modern rear impact dummy. The speed changes proposed are typically 15 to 16 km/h, and in some cases additional tests in the range 10 to 30 km/h have been proposed. The low-speed tests are intended to avoid sub-optimisation and the high-speed tests are proposed for evaluating seat integrity. Currently, a generic acceleration pulse is commonly used and several injury criteria or assessment parameters have been suggested. A static geometrical head restraint rating is currently used by RCAR [RCAR, 2001].

Ongoing and Finalised Research Programmes

A number of ongoing or finalised research initiatives, relevant for the development of a rear impact test procedure, were identified:

- EU Whiplash I (finished);
- EU Whiplash II (on going at the time of the review, now finished);
- Swedish research programs (Chalmers University, Folksam, Swedish Road Administration, Volvo Car, Saab Automobile);
- The International Insurance Whiplash Prevention Group (IIWPG). The objective of this working group is to develop dynamic test procedures to evaluate and compare seat/head restrain designs;
- ISO (on going). A test procedure was finalised during 2004, but it does not include a decision on a crash dummy nor on any injury criterion;
- OSRP/USCAR (on going). The Occupant Safety Research Partnership of the United States Council for Automotive Research has conducted a rear impact evaluation program to compare the BioRID II and Hybrid-III dummies;
- NHTSA is working on upgrades of FMVSS 202 and 203. An evaluation of the currently available dummies was carried out;
- UK spinal injury: volunteer and dummy testing plus human and dummy modelling, including the derivation of design target corridors;
- ACEA: repeatability and reproducibility of proposed rear impact whiplash protection test procedures.
- Examples of other active research laboratories:
    - TU Graz, Austria
    - Allianz ZT, Germany
    - ETH, Switzerland
    - Medical College of Wisconsin, USA: PMHS tests, thesis on facet injury mechanism
    - Wayne State University, USA: PMHS tests, thesis on facet injury mechanism
    - JARI, Japan: volunteer tests, thesis on facet injury mechanism
    - MacInnis Engineering, Canada: volunteer tests, dummy evaluation

Conclusions from the State-of-the-Art Review

- Rear impact and WAD-type (Whiplash Associated Disorder) injury is a serious problem in terms of both injury and cost to society. A lot of work has taken place in trying to quantify the problem and determine effective means of injury and cost reduction. The WAD symptoms are well documented, but the actual injury remains to be established, although several injury locations and injury mechanisms have been suggested. The dynamic motion of the human head-neck system during a low-speed rear impact is known from volunteer test data.
- To date, several special test dummies and test devices have been developed for the assessment of WAD injury and several test procedures have been developed, both static and dynamic.
- Both mean and peak acceleration appear to be important crash severity parameters together with delta-v.
- Women have about twice the injury risk compared to men.
- Energy absorbing seats, active head restraints and good head restraint geometry all seem to be beneficial, based on claims evidence.
- Multiple test severities must be considered to avoid optimisation for a single condition and to test seat integrity at higher severity.
- The proposed WAD risk assessment parameters NIC_{max} and N_{km} appear to correlate to real world risk of WAD causation and risk curves have been presented based on field accident findings from a limited number of car models from a single manufacturer. Further work is therefore needed before a WAD risk assessment parameter (LNL, Nkm, T1-rebound velocity, NIC, NDC, IV-NIC, etc.) can be finally established. The exact injury site has still not been established and thus, no biomechanical explanation to the injury causation is available. A biomechanical evaluation of an injury criterion is not expected in the near future.

- Injuries other than neck injuries and impact types other than pure rear impacts need to be considered in the definition of the test procedure.
- The BioRID II and the RID2/RID^{3D} are the best suited dummies for rear impact whiplash prevention testing.

EEVC WG12 REAR IMPACT DUMMY BIOFIDELITY REQUIREMENTS

In order to respond to the request by the EEVC Steering Committee to select an appropriate dummy and injury criteria for the WG20 rear impact test procedure, WG12 adopted a work plan consisting of the following steps:

- Identification of the expected use of the dummy in the new test procedure, and the constraints following from this for the dummy such as anthropometry, reproducibility, durability, required adjustments, and so forth;
- Development of biofidelity impact response requirements for low severity rear impact loading of the spine (including the rebound phase), defining how the dummy should behave both in kinematic and dynamic responses in agreement with human volunteers and/or PMHS;
- Review of biomechanical evidence that may support the use of various injury criteria for neck injury assessment, including definition of measurements to be taken by the dummy;
- Review of existing dummy designs and performance with respect to the requirements developed by WG12. This will lead to a recommendation on the best dummy to use for the WG20 rear impact test procedure.

Rear Impact Dummy Biofidelity Requirements

Of these tasks, the development of biofidelity requirements for a rear impact dummy is the most advanced. The criteria for the selection of rear impact biofidelity test conditions included:

- The availability of the full data set;
- Quality of the test set-up and instrumentation;
- Reproducibility;
- Relevance of the test conditions, loading condition and velocity change;
- Distribution of subject anthropometry, gender and age;
- The number of tests and test subjects.

Nineteen sets of rear impact volunteer and PMHS data that could be used to define biofidelity requirements for a rear impact dummy have been assessed. To date, five data sets have been chosen and documented in detail. They include four volunteer and one PMHS test programme with a variety of impact conditions. Even this small sample of biofidelity test conditions gives rise to a large number of biofidelity requirements. The draft biofidelity test conditions and requirements are summarised below.

GDV / Allianz (Whiplash II)

GDV and Allianz undertook two series of five rear impact sled tests with five volunteers, two male and three female, as part of the Whiplash 2 EC project. The mean age of the subjects was 35 years (18 to 43), their mean height was 1.67 m (1.57 to 1.78 m) and their mean mass was 74 kg (60 to 95 kg). The impacts had a delta-v of 7 and 9 km.hr^{-1}, with a peak acceleration of 35 and 40 m.s^{-1} respectively.

A specially designed yielding seat, with a head restraint, was used (see Figure 1). Accelerometers and film markers were attached to the head and T1. Head angular accelerations were also measured.

Figure 1: The GDV / Allianz sled, volunteer and yielding seat.

Response parameters included:

- Head centre of gravity (CG) trajectory (2D)
- Head flexion angle
- T1 trajectory (2D)
- T1 flexion angle
- Head CG acceleration
- Head angular acceleration
- T1 acceleration

JARI

These volunteer tests were carried out 1997 and 1998 at the Japanese Automobile Research Institute (JARI) and are summarised in [Davidsson *et al.*, 1999]. Seven healthy male volunteers (25 ± 4 years old) of approximately 50th percentile stature were exposed to a total of 28 rear impact deceleration sled tests at delta-v's of 1.9 to 2.6 m.s^{-1} (7.0 to 9.3 km.hr^{-1}) and mean peak decelerations of 36.2 to 39.0 m.s^{-2}.

Both standard car seats (13 tests) and a rigid ECE Regulation 16 bench (15 tests) were used. In 22 tests a standard driving posture was used (see Figure 2) and in six tests the subject was leaning forward 10° from the standard driving posture at the time of impact. No head restraint was used in any of the tests.

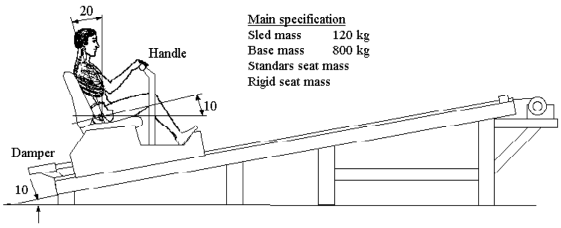

Figure 2: Schematic of the JARI sled, volunteer and Regulation 16 seat.

Film markers were mounted at the head, T1 sternum and iliac crest, and accelerometers were fitted to the head and T1. The location of the accelerometers and film targets (except the iliac crest marker) relative to the occipital condyle was determined from X-ray images of the instrumented volunteer. A Tekscan pressure sensor mat with 48 x 40 cells each 10 x 10 mm square covered the seat back surface.

Biofidelity requirements (mean ± σ) were developed for:

- Linear and angular displacements of the head, T1, occipital condyle and iliac crest;
- Head angular acceleration and T1 and pelvis linear accelerations
- Upper neck forces and moments.

TRL

TRL performed a series of rear impact tests with ten male volunteers with a mean age 26.4 years, height of 1.79 m and weight of 77.5 kg [Roberts *et al.*, 2002; Hynd *et al.*, 2004]. A rigid seat based on the ECE Regulation 44 bench was used, with the seat back raised to support the shoulders and a head restraint added (Figure 3).

A sled-to-sled impact system was used, with a block of aluminium honeycomb used between the sleds to give the desired acceleration pulse. The delta-v was 1.9 $m.s^{-1}$ (7 $km.hr^{-1}$) and the acceleration was limited to approximately 20 $m.s^{-2}$.

Film markers and accelerometers were placed on the head and T1 and an accelerometer was placed on the sacrum. Seat back and head restraint inertia-compensated forces were measured and a Tekscan 5315 mat was used to measure seat back pressure distribution.

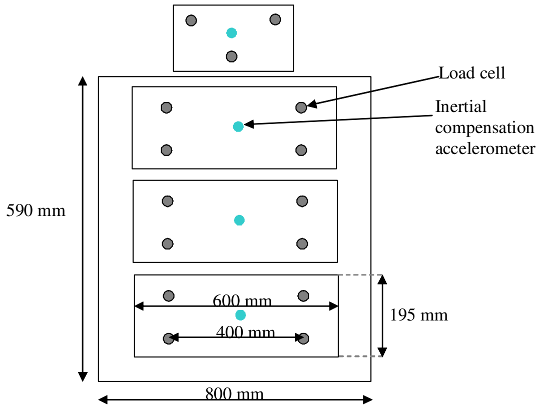

Figure 3: Schematic of the TRL seat back and head restraint, showing the force plates, load cells and inertia compensation accelerometers.

Biofidelity corridors were developed according to the method of EEVC WG9 [Roberts *et al.*, 1991]. Corridors were developed for:

- Head and T1 linear and angular displacements;
- Head, T1 and pelvis linear accelerations.

Seat back pressure distributions versus time are also available for qualitative assessment of the seat back interaction of rear impact dummies.

Allianz ZT / Chalmers

The kinematic responses of four volunteer subjects (in five tests) with anthropometry close to the 50^{th} percentile male were extracted from a larger database with 13 subjects (subset 7V) [Davidsson *et al.*, 1998]. A custom made seat (see Figure 4) was mounted on a stationary sled which was impacted by a second sled. The delta-v was 1.9 $m.s^{-1}$ (7.0 $km.hr^{-1}$), with a peak acceleration of the target sled of about 33 $m.s^{-2}$.

The seat back consisted of four stiff panels covered by 20 mm thick soft Tempur foam and 30 mm thick medium Tempur foam and all covered with the same cloth fabric as used in a Volvo car seat. The seat back and head restraint were all mounted on springs to give the same stiffness characteristics as a Volvo 850 car seat, and the seat base was a standard cushion from a 1993 Volvo 850.

Head, T1 and iliac crest accelerations were measured and film markers were placed on the seat back frame, head, T1, shoulder, upper torso, chest, knees and H-point.

The following biofidelity response requirements were defined (mean ± σ):

- Head x and z displacement with respect to the sled co-ordinate system;
- T1 x and z displacement with respect to the sled co-ordinate system;
- Head relative to T1 x and z displacement;

- Head angular displacement with respect to the sled co-ordinate system;
- T1 angular displacement with respect to the sled co-ordinate system;
- Head relative to T1 angular displacement;

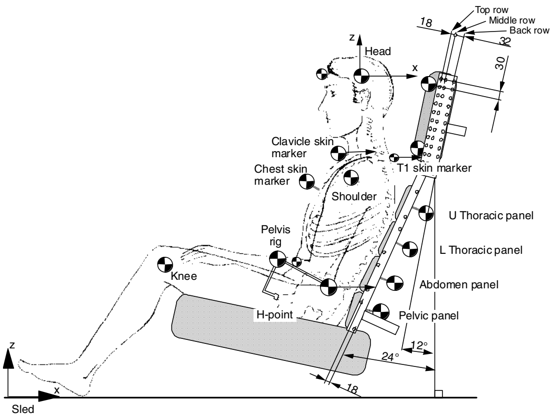

Figure 4: Schematic of the volunteer and AZT / Chalmers seat.

LAB (Whiplash I)

Six acceleration sled tests were performed with three different PMHS subjects [Bertholon *et al.*, 2000]. A rigid seat, without headrest, was subjected to a rear impact with an impact velocity of 10 km.hr^{-1} and an acceleration of 160 m.s^{-2} (Figure 5).

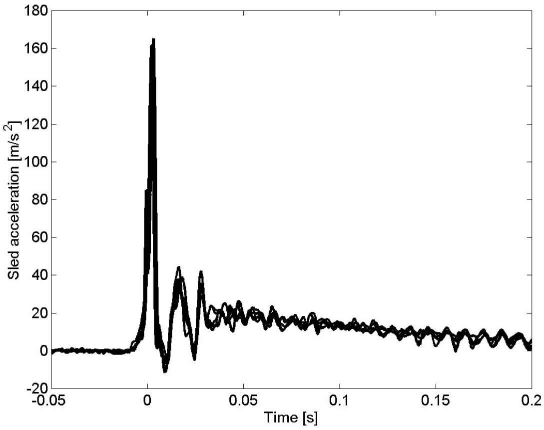

Figure 5: LAB sled acceleration pulse.

The subjects, all male, had a mean age of 80 years, height of 1.64 m and weight of 50 kg. The subject was strapped to the seat at the thigh, pelvis and thorax.

The subjects were instrumented with accelerometers on the head and film markers placed on the head, and T1. Biofidelity requirements (mean ± σ) were defined for:

- Head angle with respect to the sled co-ordinate system;
- Head angle with respect to a rotating T1 co-ordinate system;
- T1 angle with respect to the sled;
- Head CG x- and z-displacement with respect to a rotating T1 co-ordinate system;
- T1 x- and z-displacement with respect to the sled;
- Head CG x- and z-acceleration;
- Head angular acceleration.

Summary of Rear Impact Biofidelity Requirements

To date, five rear impact volunteer and PMHS test conditions have been selected by EEVC WG12 to define biofidelity requirements for rear impact dummies. The test conditions and biofidelity requirements, in the form of target corridors, are being documented in detail so that they can be reproduced with the candidate dummies for the WG20 rear impact test procedure.

FUTURE WORK

WG20

WG20 are considering the development of a geometric assessment of head restraints (which may be a static test, a dynamic test, or both) as a first stage in the mitigation of injuries in low-speed rear impacts. In the longer term, the Group will develop a sled-based test procedure for the dynamic assessment of seat performance.

Geometric Test Procedure

Several groups have raised concerns regarding the repeatability and reproducibility of the 3D-H machine and HRMD, used in some current test procedures for the static geometric assessment of head restraints. WG20 have planned a work programme to evaluate the variability in the geometric evaluation of head restraints using these tools and to isolate the sources of any variability. Potential sources of variability may be the test tools, the test procedure or variability in the seats. The programme will also assess the influence of lumbar support and seat back angle. A cost-benefit study of the implementation of a geometric requirement for head restraints in Regulation is also in progress. The EEVC Steering Committee have set a one year time frame for the development of a geometric test procedure.

Sled-based Test Procedure

The second, longer term task for WG20 is the development of a sled-based rear impact test procedure. Issues that need to be considered in the development of such a procedure include:

- Impact pulse – vehicle specific or generic, delta-v and acceleration profile. These should be defined by knowledge of injury-causing real-world accident characteristics.
- Seat mounting and restraint systems – how the seat should be mounted to the sled (e.g., is it necessary to reproduce the vehicle floor pan accurately?), whether generic or vehicle-specific restraint systems, such as seat-belts and pre-tensioners, should be fitted and deployed.
- Cost-benefit analysis.

Recommendations on the dummy and injury criteria to be used for the test procedure will be made by EEVC WG12. A two year timescale for the development of a dynamic sled-based test procedure has been set by the EEVC Steering Committee.

WG12

Whiplash Dummy Selection

WG12 have been tasked with recommending a dummy for the WG20 rear impact test procedure. Rear impact biofidelity requirements have been drafted and the candidate rear impact dummies will be evaluated against these requirements. However, there are many requirements for a test tool other than biofidelity. The following will also be considered by WG12 (some are dependent on the parameters of the test procedure that the dummy is to be used in, so close collaboration will be maintained with WG20):

- Dummy size and gender;
- Dummy posture and seat interaction;
- The velocity and acceleration range at which the dummy will be used;
- Sensitivity, repeatability and reproducibility.

Also important in the choice of a rear impact dummy is the selection of biomechanically based injury criteria. Currently, WG12 is collating detailed information on the injury criteria that have been proposed in the literature, including determining a single definition of how each criterion is calculated as this has often changed over time. It is important to understand these changes when evaluating the biomechanical evidence presented for the criteria. This understanding will form the basis for evaluating the proposed injury criteria and for selecting and validating injury criteria to be used in the WG20 sled test procedure.

CONCLUSIONS

The EEVC Steering Committee has formed a new Working Group, WG20, with the aim of developing a test procedure, or test procedures, to be proposed as a new European regulatory test for whiplash injury protection in rear impacts. The test procedures should have a prime focus on neck injury reduction, but should give due regard to the potential for injuries to other body regions. WG12 has been tasked with recommending a dummy and injury criteria for the WG20 test procedures.

WG20 has reviewed the background information that is available and is to develop and validate a geometric approach to head restraint assessment as the first stage of their approach to whiplash injury mitigation. In the longer term, they will develop and validate a dynamic, sled-based test procedure to stimulate further a reduction in the incidence of whiplash injuries.

WG12 has developed draft biofidelity requirements for a rear impact dummy. The available rear impact dummies will be evaluated against these requirements once they are finalised. Work has also started on the evaluation and validation of a biomechanically based injury criterion for rear impact crash testing.

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