VOLVO/TNO

EUROPEAN WORKSHOP ON CHILD SAFETY IN PASSENGER CARS

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INTRODUCTION

For some time, research on child safety in cars has given rise to a great deal of interest in many quarters. On April 8-9, 1986, therefore, Volvo and the Dutch TNO Research Institute for Road Vehicles organized the "Volvo/TNO European Workshop on Child Safety in Passenger Cars" as part of the European Road Safety Year proclaimed by the EEC, to provide European researchers, car manufacturers, child accessory manufacturers and legislators with the opportunity of coming together to exchange experiences and draw up common guidelines for future safety work.

The workshop was opened by Mr. P B Van Gurp, who is responsible for traffic safety at the Dutch Ministry of Transport. Mr. Van Gurp spoke about the accident situation in the Netherlands and the rest of the world from the point of view of consequences and costs, and emphasized that traffic accidents constitute the greatest danger to child health today.

Talks were then given by Dr. Gordon Trinca from Australia, Ms Elaine Petrucelli from the USA and Mr. Thomas Turbell from Sweden, on child safety work in their respective countries.

Dr. Gordon Trinca is the Chairman of the Australian Road Trauma Committee and the Royal Australasian College of Surgeons. His talk included an account of child safety equipment, accident type distribution and legislation on the Australian continent.

Ms Elaine Petrucelli is President of the American Association for Automotive Medicine. Ms Petrucelli spoke about American child safety legislation and its effects, as well as the incorrect use of safety equipment which occurs.

Mr. Thomas Turbell, Research Leader at the Swedish Road and Traffic Institute, spoke about the Swedish loan system for baby seats, the European legal requirements (ECE 44), and test dummies and associated problems.

After the introductory talks, the participants were divided into five working groups. The two main subjects discussed in the groups were:

1. Experiences of child safety equipment from the point of view of accident data, incorrect use and consumer aspects.

2. Test methods and legislative requirements.

CONCLUSIONS

Today's biomechanical knowledge of injuries to children is very limited. This means, among other things, that the dummies used for testing child safety equipment are too far removed from reality. The dummies need improving, not only through intensified biomechanical research, but also by advantage being taken of the biomechanical knowledge already available today.

Good traffic accident data, among other things, is required as basic material for biomechanical research. Existing accident and injury data from traffic accidents involving children is too limited.

Incorrect use of child safety equipment is to be found to a relatively large extent in Europe, but the consequences — in terms of injuries to children — are generally unknown.

So as to increase and simplify the use of child safety systems, it was considered that the most important thing from the consumer point of view was a) comfort, b) ease of handling, and c) reasonable pricing.

Integrated child safety systems were considered to be the solution of the future. Until then, child safety systems should be tested in accordance with a standard procedure and a standard test rig. There should also be the possibility of testing "car-specific" systems in the car.

RECOMMENDATIONS

- Collaboration between traffic accident teams in Europe, so as to obtain basic material for improved biomechanical knowledge.
- Collaboration between accident teams and medical/biomechanical expertise to develop improved dummies.
- World standardization of test methods for child safety equipment.
- Improvement of child safety systems by manufacturers together with clear instructions for installation and use, so as to prevent incorrect use.
- Assumption of greater responsibility for child safety in cars on the part of car manufacturers, e.g. by way of recommendations for the most suitable systems for use in their products.
- Children should be permitted to travel in the front seat; it is better for a child to wear a seat belt in the front seat than to travel without a belt in the rear seat.
- Legislation on seat belts from the age of 8 — in the long-term, a belt law covering all car occupants, in all seats.
- Follow-up of any new legislation — with the help of collected accident data — so as to be able to determine the value of the law and provide a basis for improvement.
- Availability of child safety equipment for hire.
- Types of vehicle other than cars should offer the possibility of children being restrained.
- Official transports with children should be carried out only with restrained children.

ACCIDENT DATA

One of the most important conclusions drawn by all the working groups was that existing accident and injury data from car accidents involving children is too limited.

Field data must be used more than it is today as a basis for new requirements, including the development of injury criteria, dummies and test methods. In-depth studies are particularly important to increase the knowledge of injury mechanisms.

Data collection

One suggestion was to initiate cooperation between accident investigation teams in Europe to gather an adequate sample of cases involving restrained children.

More national statistics and studies are required. If a regulation is enforced in a country, accident data should automatically be collected to enable follow-up of the value of the regulation.

An investigation must be initiated to discover which data would be appropriate for inclusion in police reports; such reports should include information about which occupants were travelling in the car (not only the injured) and the location of the occupants in the car; if possible, information on injuries and use of restraints should also be included.

To obtain a better understanding of injury mechanisms and severe non-frequent injuries, more in-depth studies are required.

An investigation to establish criteria for recording child accident data must also be started. Methods used to estimate crash severity, for example, must be comparable.

Existing data from different teams (severe types of injuries) should be coordinated so as to obtain a better and more complete sample.

Accident types

The distribution of accident types (share of front-end impacts, lateral impacts etc.) shows a direct correlation to the severity level of the accident material.

This must be taken into account when deciding which accident types are most important.

It was felt, however, that lateral impacts, rear-end impacts and, to some extent, rollover accidents are important for further study.

Reliable accident material for in-depth study is necessary for a good understanding of the injury mechanisms in different types of accident.

Injuries child restraints

Child restraints, if properly used, do not normally produce injuries. Almost every type of injury can be reduced by the use of a child restraint.

Situations where child restraints can be less effective are cases where there is more extensive intrusion of the occupant compartment and to some extent in the very rare situations where injuries are caused by burns or drowning.

Neck injuries

There is no evidence of severe (> AIS 1) neck injuries in non-contact situations from any accident material. The risk for this type of injury seems to be low, even in severe front-end impacts.

It is important to have more accident data on this subject, however.

In some cases, severe neck injuries caused by "submarining" have been observed. In these cases the shoulder belt has moved upwards against the neck.

Abdominal injuries

Abdominal injuries caused by submarining do not seem to be frequent, but do occur.

Submarining can, however, increase the risk of severe neck injuries, as mentioned above.

The use of a crotch-strap reduces the risk of submarining considerably. To guarantee this, the crotch-strap must not loosen at a low force level.

No injuries caused by the crotch-strap have been reported.

Another risk to be considered is that of injury to other occupants caused by interaction with child restraints.

MISUSE

There are several reasons for misuse: poor/non-existent assembly instructions, difficult assembly, low level of motivation by user, etc. All were agreed that misuse occurs, but the consequences as far as the degree of protection is concerned are relatively unknown, and depend on the type of system being used. So as to permit measurement of the degree and the consequences of misuse it is necessary to coordinate the collection of accident statistics in Europe. The prevention of misuse demands better instructions on how the systems are to be used. However, the most important thing is for manufacturers to improve their systems so as to minimize the risk of misuse.

Definition and frequency

Misuse can be defined as partial misuse or gross misuse. Partial misuse means:

Incorrect use of child restraint

Child not properly restrained
Wrong size or age of child
Head too high (boosters)
Restraint too old

Gross misuse means:

- Incorrect mounting or no mounting of child restraint

non-use of tether strap
incorrect mounting of lap-straps for seats
incorrect mounting of booster cushions

Reasons for misuse

Several reasons for misuse emerged in the working groups:

° Poor assembly instructions

° No assembly instructions — e.g. when equipment is bought second-hand.

° Difficult assembly as a result of over-complex systems.

° Child unwilling to be restrained, or releases the belt itself.

° System frequently moved between cars.

° Safety not the main motivation for the system, which means that motivation to use it correctly is low.

° Poor design

Consequences of misuse

The delegates were agreed that misuse is a problem, and that it most probably reduces the effectiveness of the system from the point of view of protection. However, the effects of misuse from the injury point of view are unclear, since far too little accident data is available in Europe to permit these effects to be measured. It emerged that coordination of accident material in Europe is necessary if the effects of misuse are to be measured.

The consequences of misuse must also be considered in the context of the risks of a given type of misuse. Certain systems are probably more sensitive than others. Partial misuse can, for some systems, entail a drastic reduction of protection, while for other systems the reduction may only be marginal.

According to accident data from the USA, a correctly used safety seat reduces the fatality risk by 71%, while a partially misused seat reduces fatality risk by 44% (see Appendix 3).

<u>How can we prevent misuse?</u>

Against the background of the section "Reasons for misuse", the groups put forward the following proposals for the prevention of misuse:

- Better instructions on the use/assembly of the system — handbook to be included with the system.
- Instructions to be glued to the system.
- Better — and above all simpler — design of systems.
- Information and training for parents via paediatricians, governments, consumer organizations, car manufacturers.
- Reduction of the number of systems.
- Increased standardization of systems from the point of view of installation — click-on systems.
- Instructions to users via dealers

NON-USE

Child safety systems are used far too little in Europe today. Use must increase. Children should be permitted to travel in front and rear seats. It is better for a child to be restrained in the front seat than unrestrained in the rear seat.

The frequency of use of child safety systems varies from one country to another. However, a clear trend is that up to the age of 2, frequency is relatively high (approx. 50%), after which it declines drastically. Children ages 3-10 are the most exposed group today, since they travel unprotected to a great extent. One reason for this can be that parents restrain small children not primarily for safety reasons but just to have somewhere to put them.

A law which prohibits children in the front seat can give the impression that the rear seat is safe and that the child does not need to be restrained. This can be a further reason for the low frequency of use of systems for children in the rear seat.

CONSUMER ASPECTS

If the use of child safety systems is to be increased and simplified, one requirement is a high degree of acceptance for the systems among consumers. To achieve this acceptance, it was considered of the utmost importance that child safety systems are a) comfortable for the child, b) easy to handle c) reasonably priced.

The most important measures from the consumer point of view were considered to be:

- That car manufacturers provide a list of the systems which suit their cars.
- That the cars be built ready for installation of child safety systems, e.g. holes for top-tether, attachment points.
- Loaner programmes to increase the usage of child safety systems.

Recommendation:

Progress by: transfer of responsibility towards car manufacturer.

Stage 1 Universally-approved systems, but specific CRS recommended by car manufacturer.

Stage 2 Vehicle-specific CRS offered by car manufacturers.

Stage 3 Vehicle integrated systems (1995 —).

A revision of Regulation 44 is needed to encourage the development of more acceptable systems.

LEGISLATION AND ENFORCEMENT

Ultimately, it should be a legal requirement that all car occupants be restrained (US, Canada, Australia). Alongside such legislation, training and information should be provided to motivate people to observe the law. Legislators must follow up the law in the field to see how it works.

TEST METHODS

Current and future test methods for child safety equipment were discussed in the working groups. Comparisons included test methods used in the USA (FMVSS 213), in Europe (ECE 44) and certain national regulations in, for instance, F, S and UK.

In short, it can be said that the delegates were agreed that test methods should be the same everywhere. It was also considered to be extremely important that car manufacturers take greater responsibility for child safety systems really being suitable and functioning in the car environment.

Main points

The following points emerged as common ground in the final discussions between the groups:

* All were agreed that CRS should be tested in accordance with a standard procedure in a standard test rig. It should, however, be possible to test in a car so that the car-specific systems can be permitted to exist and be developed. It was also considered that car-integrated child safety systems are the solution of the future, but until then universal systems will have to be relied upon, which is why standard test rigs will be required.

* In tests in standard test rigs it is important that the components or dummies which can influence results are included in the test. Examples are front seats in rear-seat tests and instrument panels for front-seat tests.

* Car manufacturers should take greater responsibility for child safety systems actually fitting and functioning in the car environment. One way in which this could be done is for the car manufacturers to test some systems in full-scale crashes in their normal development tests. The systems which function best would then be recommended in information material for consumers, in car instruction books etc.

* It is considered important that there be a common test method for all countries rather than a development of different national test methods. To start with, the European countries should unite around ECE 44, and all future changes should be based on this. ISO should initiate a working group for an international standardization of the test method.

Requirements may, however, differ somewhat between different countries as a result of differences in traffic environments, vehicle parks and traffic situations.

Subjects for discussion

The following points emerged in the different working groups:

* It was considered important that frontal collisions should not command exclusive attention when developing CRS. Side collisions, for example, should also be taken into account. There was, however, disagreement concerning the introduction of a new test method for this. Some felt it necessary, others not.

* It should be possible to offer a CRS on all markets. Today it is not possible, for instance, to offer a rearward-facing CRS in the USA because a rearward-facing CRS may not be leaned against the instrument panel or against the rear-seat back in certification tests.

* A review of today's vehicle park should be undertaken from the point of view of distances and internal dimensions. The reason for this is that material should be produced for review of ECE 44's head displacement requirements.

* A standard test is better than nothing, since no car geometries and crash pulses are alike. A standard test is also useful in production tests. It is also impossible to simulate the different ways in which people are restrained by a CRS.

* Testing of different forms of misuse was not considered realistic. However, to reduce the frequency of misuse, CRS manufacturers should take possible misuse into account and manufacture better and simpler products with this in mind. Warnings of the dangers of misuse should be displayed on the products.

* Universal child protection is not available in practice. There are always some cars in which it is impossible or inappropriate to fit the systems .

* Better accident investigation is required to enable appropriate requirements and requirement levels to be chosen.

* The biggest problems in rollover accidents are the risk of being thrown out of the compartment and the intrusion of components and objects in the compartment. It was not considered necessary to review current ECE 44 requirements.

INJURY CRITERIA

Existing accidentological and biomechanical data on child injuries is limited. Research must be intensified in these areas if it is to be possible to set relevant injury criteria. More biomechanical studies are needed if the relation between injuries and trauma is to be understood.

The criteria level to be chosen should also be discussed further. For certain impact problems it is suitable to focus on severe and fatal injuries, while in situations involving impact to the actual restraint (i.e. shields) the criteria should deal with minor injuries.

An attempt was made to list the types of injury found in accident studies today and to establish priorities. Three levels of priority were used:

1 An injury criteria must be set

2 The injury should be detectable in dummies

3 Non-interesting

Head injuries

a) Non-contact injuries = priority 3, since no such injuries have been found in accident studies. It is, however, important to search further for evidence of the non-existence of non-contact brain injuries.

b) Contact injuries = priority 1. Some delegates stated that the head impacts occurred with intruding structures belonging to the car or to exterior objects. These impacts could, therefore, not be avoided by improving the child restraint. however, several working groups concluded that it is important to limit the displacement of the child during an impact.

Acceleration measurements in dummy head CG should be used as the measurement technique. Requirements of maximum displacement could be replaced by a performance criterion in which a surface/seat back or similar is place in a realistic position. Restraints which allow large displacements will cause impact into the surface and the accelerations will be recorded in the dummy head. If the restraint surface is padded, this padding must include all areas liable to impact.

Facial injuries

a) Facial fractures = priority 1.

b) Soft tissue injuries = priority 2. It is important to avoid injuries caused by facial impact with the restraint itself.

For forward-facing restraints installed in the rear seat, head and face impact with the front seats must be considered.

Facial injuries should be detected by load sensing devices. The technique has to be developed. Research is required on the biomechanical question of injury mechanism and load tolerance levels.

Injuries:

a) Neck injuries due to extension or compression = priority 3. Attention was focused on this type of injury in the discussions about potential injuries caused by forward-facing child restraints. However, no such injuries have been reported to the experts present at the working groups. The general conclusion was that this type of injury occurs only very rarely, but if it happens it is severe. Today it is interesting to continue to look for it in accident studies and to develop measuring devices. The whip-lash injury (AIS 1) was not felt to be important because it was not common and children were not thought to suffer long-term consequences.

b) Neck injuries due to submarining = priority 1. Injuries to the neck due to submarining occur in child restraints with torso belts, both with and without lap belts. The injury mechanism(s) are not well known and should be investigated further. Measuring techniques need to be developed.

c) Abrasion on neck = priority 3. Many of the AIS 1 injuries in accident statistics are believed to be abrasions.

<u>Chest</u>

Injuries:

Chest injuries = priority 1. There is no known case of rib fracture due to belt loading. Compression of the chest can give internal damage to the heart, lungs, etc.

Deflection/compression seems to be more important to study than acceleration, but the injury frequency and injury mechanisms are not well understood. Research is needed.

The difference in criteria between the USA (60g) and Europe R44 (55g) has no biomechanical support, and for the sake of harmonization one of these should be chosen. As no acceleration injuries have been recorded, 60g seems to give sufficient protection.

As biomechanical research takes time, it is also urgent that a short-term solution dealing with the loading of the torso be found. As the TNO dummy P10 must be redesigned in torso and shoulder, the possibilities of some simple deflection measuring device should be considered.
Vertical chest acceleration seems to have no biomechanical basis. Does it give other important information about the restraint system?

<u>Abdominal and pelvic injuries</u>

Abdominal injuries = priority 1. Submarining injuries occur in some restraint systems under certain conditions, and this must be avoided. Penetration into the abdomen must not occur.

Abdominal injuries can also be caused by restraints other than belts loading this area of the body and not the pelvis.

Present measuring techniques are unsatisfactory and development work is required. TRRL is studying pressure devices.

Injuries due to crotch-straps have not been recorded in accidents (USA and UK) As there seems to be no injury risk, crotch-straps should be allowed. The use of a crotch-strap is an effective way of avoiding submarining.

Leg and arm injuries

Injuries to the extremities = priority 3

When designing child restraints, surrounding occupants should be considered and the aggressiveness of the restraint frame etc. should be minimized. Special tests for the exterior of the restraint could be adopted (e.g. ECE R21).

To conclude: The knowledge of injury criteria for children is far too little and research in this area should be given high priority.

TEST DUMMIES

There is a great need for a new or modified generation of dummies incorporating current biomechanical knowledge. Feed-back from accident investigations is required and biomechanical research should be performed. Follow-up studies to examine the outcome of legislation in the field were strongly recommended.

Existing dummies

To evaluate the performance of a Child Safety System (CRS), a test dummy is required. Today, a number of Anthropomorphic Test Devices (ATD) are used.
The European Regulation 44 uses different sizes of TNO dummies. These include 9-month and 3, 6, and 10-year-old child dummies. In the USA, a 3-year-old dummy, the Part 572C dummy, is used in accordance with FMVSS 213. Another make is the Ogle dummy.

Both the TNO and the US dummies were developed about 15 years ago, and therefore do not incorporate current biomechanical knowledge.

New dummy generation

It is considered to be very important to develop a new dummy generation or modify the present dummy generation. Improvements in biofidelity can be made in at least two ways:

1. Feed-back from accident analysis combined with laboratory test results; reconstruction of field accidents in the laboratory.

2. Research to gain more biomechanical data.

These two methods should be combined in order to gain the maximum knowledge.

Measuring capabilities

The measuring capabilities of test dummies need to be improved:

head injury measurement: The TNO dummy does not assess this. Head acceleration should be measured.

neck injury. Although neck injuries are seen in limited numbers in the field, there is still a need to be able to measure the level of neck violence. This can be accomplished by measuring neck flexion and extension at the occipital condyles. The neck forces, tensile, compressive and shear forces should also be measured.

chest injury. Both dummies measure chest acceleration at the spine, but for certain environments chest deflection is of value. This is, however, not seen as a high priority item.

abdominal injuries. A method of detecting "submarining" — the lap portion of the belt slipping over the iliac crest — is used in the TNO dummy; modelling clay on the spine. However, test experience shows that the method does not work correctly in practice. A new, improved method is necessary. Other abdominal injuries, those caused by abdominal pressure for instance, should also be incorporated.

Regarding "submarining": this can occur both in testing with dummies and in traffic accidents. Knowledge of any correlation is, however, limited.

Dummy kinematics

Shoulder belt sliding off the dummy chest and shoulder — known as "jack-knifing" — has been observed in testing. This is particularly frequent with the bigger 10-year dummy. This is probably a dummy artefact resulting from a combination of shoulder design, stiff chest/ribcage and the design of the lumbar spine.

Follow-up of legislation

Within the different groups, there was a very strong recommendation that child safety requirements should be evaluated "in the field". Accident performance must be compared with actual requirements, so as to gain knowledge in order to enable improvements in legislation and its test tools — the test dummies. This must be a major concern in the regulatory process.