CRASH AND SLED TESTS USING CHILD DUMMIES

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ABSTRACT: *The child restraint designs used in Australia have been shown to provide exceptional protection to child occupants in severe crashes. Cases of serious injury are likely to involve misuse of the child restraint.*

Dynamic tests of child restraints using sleds are conducted for Australian Standard compliance and the Child Restraint Evaluation Program.

Child restraints are now included in new vehicle crash tests conducted under the Australian New Car Assessment Program. These tests are conducted in accordance with protocols developed by EuroNCAP. There are, however, concerns about the injury criteria set out by EuroNCAP. In particular, a review of the history of the development of child dummies reveals that it is not appropriate to base the assessment of child restraint performance on the injury measurements from the P-series child dummies used by EuroNCAP. These dummies are not biofidelic and there is no adequate link between dummy responses and the risk of injury in the human child.

Introduction

This paper is in two parts. The first discusses methods of assessing the performance of child restraints (CRs) using child dummies in dynamic tests. The second discusses the use of injury measurements from child dummies in the assessment of these tests.

Since the 1970s dynamic testing of child restraints has been required under the Australian Standard for child restraints.

In 1994 New South Wales introduced the Child Restraint Evaluation Program (CREP) to provide a guide to consumers. This program includes sled tests of child restraints.

In 1999 Australian New Car Assessment Program (ANCAP) aligned its testing procedures with those of EuroNCAP. Offset frontal and side impact crash tests of vehicles now include child restraints in the rear seat.

Although data about child restraint performance has been gathered during these tests ANCAP has not released the results due mainly to concerns about the EuroNCAP assessment protocol. Furthermore, EuroNCAP recently issued a proposed child restraint assessment protocol that compounds these concerns. We were asked by ANCAP to review the proposed requirements in order to provide feedback to EuroNCAP.

Dynamic Tests of Child Restraints

New Car Assessment Program

NCAP assesses the crashworthiness of new vehicles and provides a star rating for the protection provided to front seat occupants. Two types of crash test are used in the assessment - an offset frontal crash test and a side impact crash test.

The offset frontal crash is conducted at 64km/h. The vehicle hits a crushable aluminium honeycomb barrier and the crash forces are concentrated on the driver's half of the vehicle. The side impact involves a moving barrier, fitted with a crushable aluminium front, hitting the driver's side of the car at 50km/h.

ANCAP Offset Frontal Crash at 64km/h

ANCAP crash test procedures are based on those used by the European New Car Assessment Program (EuroNCAP). Under these procedures two child restraints are installed in the rear seat of the vehicle. The child dummies used are TNO P1.5 and P3, simulating 18 month and 3 year old children respectively. In the offset frontal crash the P3 sits behind the driver and the P1.5 sits behind the front passenger. The positions are swapped for the side impact crash test.

The child dummies are instrumented with head and chest accelerometers. Dummy movement is recorded on high speed film and is analysed to estimate the movement of each dummy.

The EuroNCAP assessment protocol (Version 3) includes requirements for child restraints. Due to the fundamentally different design of child restraints in Australia ANCAP does not currently apply the child restraint portions of this protocol and hence does not report the results of child restraint performance (discussed in more detail below).

EuroNCAP child restraint assessment

There are separate methods for assessing the offset and side impact crash tests.

Offset frontal crash test

Head

To obtain a 'good' result the P1.5 dummy head upward acceleration (3ms Z) should not exceed 20g. No limit applies to the P3 dummy. Under the proposed changes, a 'poor' result is obtained if the head upward acceleration exceeds 40g (P1.5 only).

It is understood that the limit on vertical head acceleration is intended as a surrogate for risk of neck injury. We have serious concerns about this assumption, as discussed later.

A ‘poor’ result (zero score) is also obtained if the head excursion (relative to the CR point) exceeds 550mm with either dummy. This is for forward facing CRs. The limit is 600mm for rearward facing CRs. It is a little difficult assessing this head excursion due to the effect of parallax and the difficulty of obtaining good camera angles (EuroNCAP proposes to introduce on-board cameras to assist with this assessment. ANCAP has been using on-board cameras for several years).

Chest

To obtain a ‘good’ result the 3ms resultant chest acceleration should not exceed 41g and the vertical component should not exceed 23g (3ms) . This applies to both dummies.

A ‘poor’ chest result is obtained if 3ms resultant chest acceleration exceeds 55g or the vertical component exceeds 30g (3ms). This applies to both dummies.

The vertical limit on chest acceleration is derived from ECE Regulation 44 for child restraints. However, the ECE Regulation specifies that the limit applies only to upward acceleration, possibly with rearward facing child restraints in mind. In the case of forward facing child restraints the peak acceleration is usually downwards and they are likely to have great difficulty meeting the EuroNCAP requirement. There appears to be no justification for applying the limit in both directions.

Side impact crash test

The protocol notes that “in the absence of satisfactory child dummy and bio-mechanical criteria for side impact, the criteria chosen have been kept simple”!

Head

3ms resultant head acceleration should not exceed 80g.

In addition the dummy kinematics are assessed for "head containment". Version 3 of the EuroNCAP protocol states ”No part of the head shall pass outside the forward projected exterior surface of the child restraint”. It is difficult to assess this requirement given the awkward video angles that are available, particularly with the EuroNCAP videos. ANCAP uses two onboard cameras that give a much better view of the child dummies than the EuroNCAP videos but analysis is still difficult.

Under proposed changes to the EuroNCAP protocol the definition of head containment would be tightened to "The child’s head is considered to be contained if the energy absorbing section of the side wing stays between the side structure of the vehicle and the child’s head during the impact, and the supporting seat shell retains its integrity

This proposal encourages the use of head-protecting side wings on the child restraints.

ANCAP Side Impact Crash at 50km/h

Australian Standards

Child restraints used in Australia must comply with AS1754. The dynamic testing for CRs is set out in AS3629.1. This specifies sled tests for child seats (type B restraints) as follows:

- a frontal impact at about 49km/h with a peak deceleration of 24g and
- a 90 degree side impact test with a peak deceleration of 14g and an impact speed of 32km/h.
- a rear impact test with a peak deceleration of 14g and an impact speed of 32km/h.
- Inverted test at 16km/h to simulate a rollover crash (rearward facing restraints).

Systems are assessed for:

- retention of the CR
- retention of the dummy
- separation of load bearing components
- fragmentation of rigid components
- adjuster slip

These assessments are made in all test configurations.

Child Restraint Evaluation Program

The Child Restraint Evaluation Program (CREP) is operated by the NSW RTA, NRMA and RACV in association with the Australian Consumers Association. The outcome is a buyers guide to CRs. The assessments are based on the Australian Standard but involve higher crash forces and additional test procedures. In addition to the AS1754 tests described above a frontal test at 56km/h and 34g is conducted.

The side and rear impact tests are conducted at the same speed as the AS but, in the side impact test, a structure that is intended to replicate the interior of a side door is added to the test configuration.

A side impact test is also conducted at an impact angle of 45 degrees.

With child seats a P6 dummy is used for the frontal test and a P3/4 for the other tests.

CREP 45^{o} Side Impact with Door Structure

Assessment Criteria

The CREP assessment criteria include those covered under AS1754. The following assessments are made Head acceleration

- Harness strap forces (frontal test)
- Tether forces, harness forces and seat belt forces (frontal test)
- Head displacement (frontal test) – including rebound – limits apply to upward and rearward excursion (during rebound) *but not to forward excursion*.
- Head retention (containment) – side impact tests
- Retention of device and dummy
- Adjuster slip
- Buckle release force (frontal tests)

CREP Frontal Impact Sled Test at 56km/h

Note that chest decelerations are measured for infant capsules (Type A) but not child seats.

With most criteria there are no limits set for performance – the models of restraint are simply ranked in order of measured values and good performers tend to stand out in these lists. There are specific reasons for excluding child restraints from the 'preferred buy' list:

- Not passing requirements of Australian Standard in all test configurations
- Head excursion outside prescribed limits in frontal test or rear impact test
- Head contact with test rig during side impact test

Discussion

Real world crashes

Top tethers, as used on all Australian child restraints, are extremely effective at limiting forward head excursion - considered to be the most hazardous feature of child kinematics in a frontal crash. Australian crash experience shows that children correctly restrained in forward facing child seats with top tethers can withstand severe crash forces without serious head, neck or chest injuries (Henderson 1994). "Restraint design should place a high priority on the minimisation of excursion of the upper body in order to prevent head contact" (Henderson 1995)

Concerns about the use of child dummy injury measurements

This issue is dealt with in more detail in a separate paper (Brown 2001). In brief, there are concerns about the lack of biofidelity in the P-Series child dummy, the lack of research linking dummy injury measurements with injury risk in humans and the assumptions about the risk of neck injury with forward facing restraints.

Head and chest accelerations are not reliable indictors of injury risk with the P-series child dummies. These measurements may be useful for comparing the relative performance of similar child restraint systems but they should not be used for scoring child restraint performance in NCAP tests.

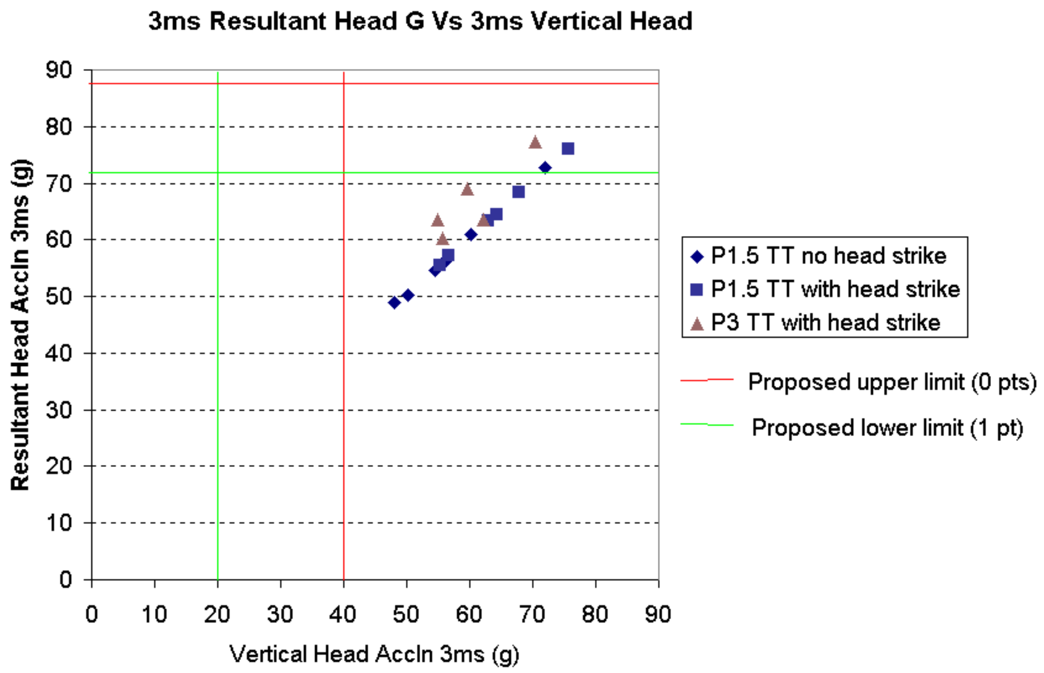
EuroNCAP uses vertical head acceleration as a surrogate for neck tension. Tests by Crashlab and others show there is poor correlation between these parameters. Furthermore, there is considerable uncertainty about injury risk to the neck - Australian crash research indicates that children in forward-facing child seats survive crashes that are much more severe than the EuroNCAP test with no serious neck or other life-threatening injuries.

Proposed changes by EuroNCAP

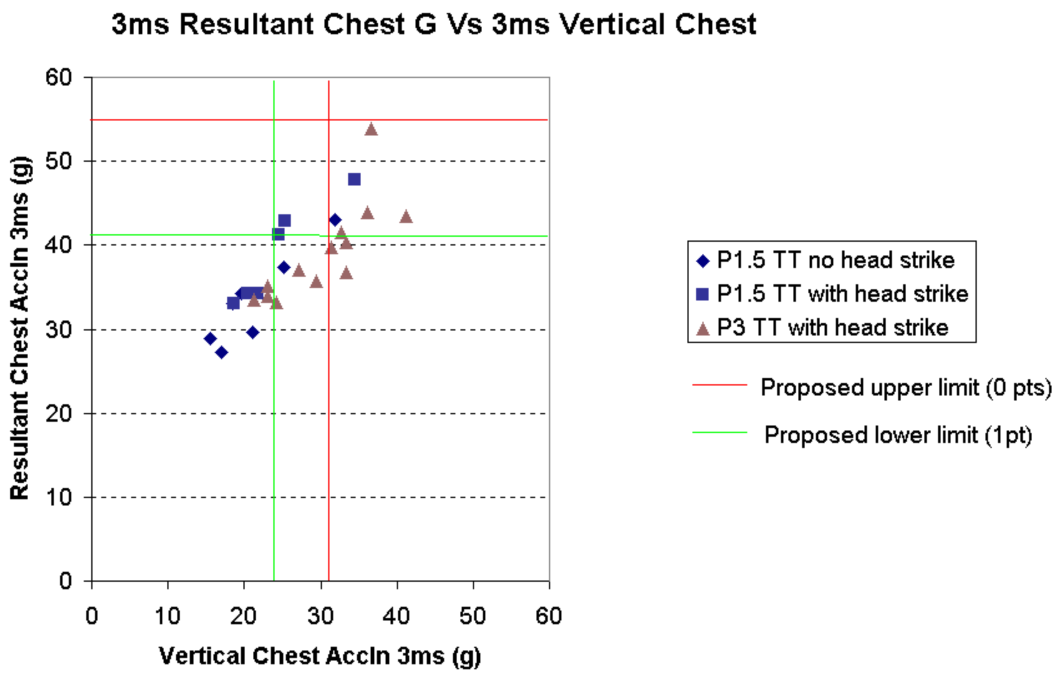
EuroNCAP has proposed changes to the assessment of child restraints and has issued a draft protocol for discussion. This introduces several new requirements.

Data from 13 offset crash tests conducted by ANCAP since 1999 have been analysed. Briefly the results for the 26 child restraints are:

- None reached the proposed upper limit on resultant head acceleration of 88g (3ms) , although several peaks exceeded 80g (usually associated with head to leg contacts - in all P3 tests the dummy head hit its legs but note that no head acceleration limits apply to the P3). Three exceeded the lower limit of 72g.
- None was below the proposed upper limit on *vertical* head acceleration of 40g (3ms) meaning that all would score zero points. The lowest value was 48g. With these restraint configurations the maximum (3ms) vertical head acceleration is very similar to the maximum (3ms) resultant head acceleration in the absence of head contacts.
- None reached the proposed upper limit on resultant chest acceleration of 55g (3ms). Seven exceeded the lower limit of 41g.
- Nine were above the proposed upper limit on vertical chest acceleration of 30g (3ms), meaning they would score zero points. Seven of these were P3 dummies.



Head Acceleration Results ("Head Strike" means head hit legs)



Chest Acceleration Results ("Head Strike" means head hit legs)

- A further two P3s and 3 P1.5s exceeded the proposed lower limit of 23g. In all cases the acceleration was directed downwards and so would not have failed the ECE 44 requirement.

The proposed scoring system takes the worst of scores for head acceleration (P1.5 only), chest acceleration and head excursion therefore most of the Australian child restraints would score zero points. This is at odds with crash experience in Australia that shows children in crashes of greater severity do not receive life-threatening injuries in the absence of head contacts.

The danger from implementing the criteria proposed by EuroNCAP is that vehicle and restraint designers will need to build greater compliance into the child restraint system in order to reduce head and chest loads. This will inevitably lead to greater excursion of the child and much greater risk of life-threatening head contacts (Webber 2000)..

Conclusions

The child restraint designs used in Australia have been shown to provide exceptional protection to child occupants in severe crashes. Cases of serious injury are likely to involve misuse of the child restraint or gross intrusion.

A wealth of data about dynamic performance of child restraints is being acquired through the NCAP and CREP programs. This information has potential for use in road safety research in addition to its primary purpose of rating the crash performance of vehicles and child restraints.

There are serious obstacles to the use of proposed EuroNCAP assessment procedures for child restraints and application of these procedures could result in less safe child restraints in Australia.

Until several issues concerning the use of child dummies for predicting injury risk in children are resolved it is recommended that child restraints are not rated on the basis of dummy injury measurements. In particular, the head and vertical chest accelerations should not form part of the scoring system. At this stage head acceleration measurements should only be used to confirm undesirable head contacts.

Implementation of the EuroNCAP proposals is likely to be counter-productive in Australia because it would probably result in greater head excursion and therefore increased risk of life-threatening head contacts.

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