Evaluation of the Testing Capabilities of the Q10 Prototype Dummy

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Abstract *Research objective* The EPOCh project aimed to develop, test and evaluate a Q10 prototype dummy. The tests were split in three main groups. The research aims: (1) for restraint loading were to evaluate the response of the Q10 dummy to different test set-up conditions, (2) for sensitivity to seat design testing were to evaluate the response of the Q10 dummy to different child seat designs, for the durability testing were to evaluate how many tests the Q10 dummy could withstand before damages to occur, to create a maintenance checklist and to identify how frequently it should be checked during a test programme. *Methodology* A test matrix was developed to assess the performance of the Q10 prototype dummy. As more than 250 tests were carried out in different crash laboratories and there were only two Q10 prototype dummies available a careful action-plan had to be established. Therefore, a Gantt chart had to be developed. Certification static tests were carried out. Then, tests to compare the P10 dummy with the developed Q10 prototype were carried out. Front impact tests using Reg. 44 were performed to check the dummy behaviour when submitted to an existing

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test procedure. Dynamic tests, following the NPACS side and front impact test procedures, were also conducted. *Results* The certification tests showed that the Q10 prototype dummy correlates well with the biomechanical targets specified in the design brief. From the analysis carried out using the results from the Reg. 44 testing, was concluded that the Q10 dummy is sensitive to changes in the test setup. It was noted that the dummy detected differences in the kinematics and the loading in different setups. From the analysis of the results from the NPACS testing, which were the most severe tests across the testing program, was concluded that the Q10 dummy was capable of detecting differences in the child restraint design and in the test setup in both side and frontal impact tests. The dummy showed good repeatability from the durability front and side impact tests. It was concluded that the dummy is capable of producing repeatable results with up to 30 min recovery time for NPACS side impact tests. A NPACS 5 band scoring system was extended up to the Q10 dummy. *Conclusion* The following conclusions can be made based on results of the front impact testing of the Q10: (1) The Q10 produced the expected loading in the important body regions, (2) the Q10 is capable of producing repeatable results in the important body regions, (3) the Q10 is capable of differentiating between different child restraint designs, (4) the Q10 NPACS scoring system has been expanded, to achieve a rating system, applicable to the Q10.

Keywords Evaluation · Testing · Prototype · Development · Q10

Enabling **P**rotection for **O**lder **Ch**ildren (EPOCh) is a part of the 7th European Community's Seventh Framework Programme (FP7/2007–2013). The consortium, consisting of five partners, set several goals, the achievement of which should improve the child safety in cars.

The implementation of Directive 2003/20/EC from April 8, 2003 means that children of up to 150 cm should use a restraint system when travelling in cars or goods vehicles. As a result, children should be using restraint systems for longer (up to 12 years old, depending on their height). That is why the first objective of the EPOCh project was to produce a 10/12 year old prototype dummy (Fig. 1).

The main goal of the EPOCh project was to develop, test in crash laboratories and evaluate a Q10 prototype dummy. In order to provide better protection the NPACS testing and rating protocols were adjusted and extended for older children, which was the second goal of the project. The last objective of the EPOCh project was to make proposals for dummy's usage in UN-ECE Regulation.

1 Methodology

A test matrix was developed in order to assess the performance of the Q10 prototype dummy. As more than 250 tests were carried out in different crash laboratories and there were only two Q10 prototype dummies available a careful

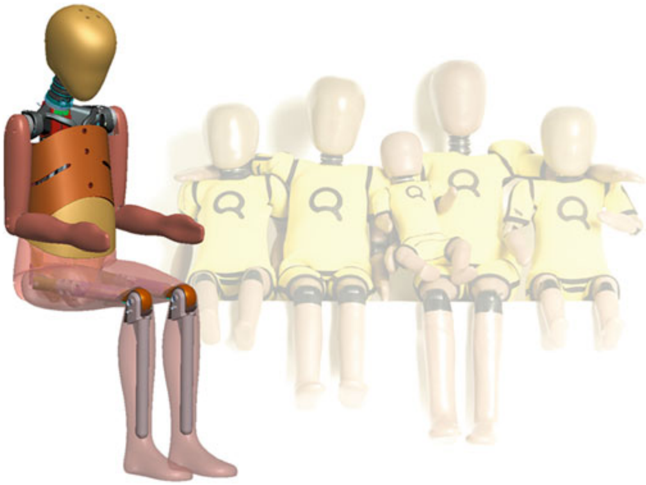

Fig. 1 The Q10 prototype dummy with the other dummies from the Q family

action-plan had to be established. A Gantt chart, showing the starting and finishing dates, the dependency of the work from previous work and allowing some space gaps for unexpected delays, had to be developed.

At the beginning, certification static tests were carried out. Then, tests to compare the P10 dummy with the developed Q10 prototype were carried out. Front impact tests using Reg. 44 were carried out in order to check the dummy behaviour when submitted to an existing test procedure. The dynamic tests, following the NPACS side and front impact test procedures, were conducted in different laboratories and by using both deceleration and acceleration sleds. The tests were split in three main groups in order to check the dummy's sensitivity to restraint loading, sensitivity to child restraint design and durability.

One of the aims of the project was to create a 5 band scoring system for the Q10 prototype dummy. This would then allow it to be used in the NPACS test procedure, which would mean that all child restraint types could be assessed to the NPACS protocols.

2 Test Environment Requirements

The testing of child restraint systems (CRS) is currently done under UNECE Regulation 44 (Reg. 44), using P dummies. The developed Q10 prototype dummy was evaluated according to this regulation. Additionally, a comparison with the P dummy was made. The tests, unless otherwise specified, were set up and executed according to Reg. 44 (Table 1). Prior to each phase a calibration test was conducted as required.

Table 1 Test conditions for dynamic performance testing

Condition	Details
Test bench	Reg. 44 test bench and specified cushions
Anchorages	Belt anchorages A, B_0, C Rearmost ISOFIX anchorages
Sled mass	Heavy sled to minimise dummy inertia effects on the pulse TRL—1130 kg, DOREL—752.5 kg
Test pulse	Reg 44 FRONT IMPACT pulse
Impact sSpeed	50 +0/−2 km/h
Test conditions	Pre-impact speed, stopping distance as specified in Reg. 44 (650 = 50 mm)
Setup instrumentation	Sled Uni-axial accelerometrs Seat belt force load cells located as prescribed in Reg. 44

The NPACS front impact test was designed to represent a real world frontal impact event at 65 kph (+0/−2). These tests were carried out at IDIADA on an acceleration sled. Also, side impact tests were carried out following the NPACS procedures. Examples of the set-ups are shown on Fig. 2.

3 Results

The Q10 prototype dummy was submitted and evaluated on certification style testing on biomechanical performance, sensitivity, repeatability and durability. These tests were performed at component and full body level, using standard dummy certification test equipment. Certification procedures were developed.

The dummy showed trends in the sensitivity studies that were carried out to validate the Q10 prototype dummy. Additionally, the durability met the requirements specified in Task 1.2 “Biomechanical requirements and design brief” [1]. The results of the testing were repeatable in general and all of the coefficients of variation were within the required 5 %. The certification tests that were carried out showed that the dummy correlates well with the biomechanical targets specified in the design brief for frontal loading conditions. For lateral impact, the response was too stiff initially and too soft at later stages relative to side impact biofidelity corridors.

The Q10 dummy has a total of 71 measuring channels. However, it is expected that for Reg. 44 only a selection of them will be used. In total 114 front impact tests, following the Reg. 44 testing requirements, were conducted in the EPOCh project.

From the analysis carried out using the results from the Reg. 44 testing, can be concluded that the Q10 dummy is sensitive to changes in the test setup. It was noted that the dummy detected differences in the kinematics and the loading in different setups.

Fig. 2 NPACS Front Impact Test bench (*left*) and side impact test bench (*right*) (images distorted to anonymise CRS)

The Q10 prototype dummy's sensitivity to child restraint design was evaluated using the Reg. 44 testing requirements. The dummy distinguished between the different seats in at least one of the tests. In Fig. 3 is shown a comparison of the head acceleration resultants from the tests for sensitivity to child restraint design. This strengthens the conclusion that the Q10 detected the differences between the four different child restraint systems that were tested. The curves of each group of tests are presented in the same colour for easier interpretation of the data dispersion.

It was concluded, after conducting all of the Reg. 44 tests, that the Q10 dummy is durable under this regulation's conditions. A few weaknesses were found and corrected. Additionally, the tests showed that the Q10 is capable of producing repeatable results over extended testing. As a result, it was recommended that the recalibration of the Q10 dummy is conducted after every 20 tests for the Reg. 44 tests, as long as the Q10 does not exceed the 150 % of the loading levels specified.

A comparison between the Q10 and P10 dummies was carried out, comparing the kinematics of each dummy in a number of booster seats and booster cushions Reg. 44 tests. The appropriateness of applying Reg. 44 limits to Q10 was investigated and, where necessary, revised limits were calculated. On Fig. 4 is shown a comparison between Q10 and P10 at the point of maximum head excursion.

In total, 51 frontal and 64 side impact tests were carried out using the NPACS protocol. They evaluated the dummy's sensitivity to restraint loading, sensitivity to child restraint design and durability.

Ten frontal and 12 side impact tests were carried out to determine the dummy's sensitivity to restraint loading. From the results obtained can be concluded that the dummy measured as expected in the major body regions. Additionally, it detected variations in the kinematics response to different loadings. On Fig. 5 is shown that there was a clear difference between the pelvis acceleration loadings measured by

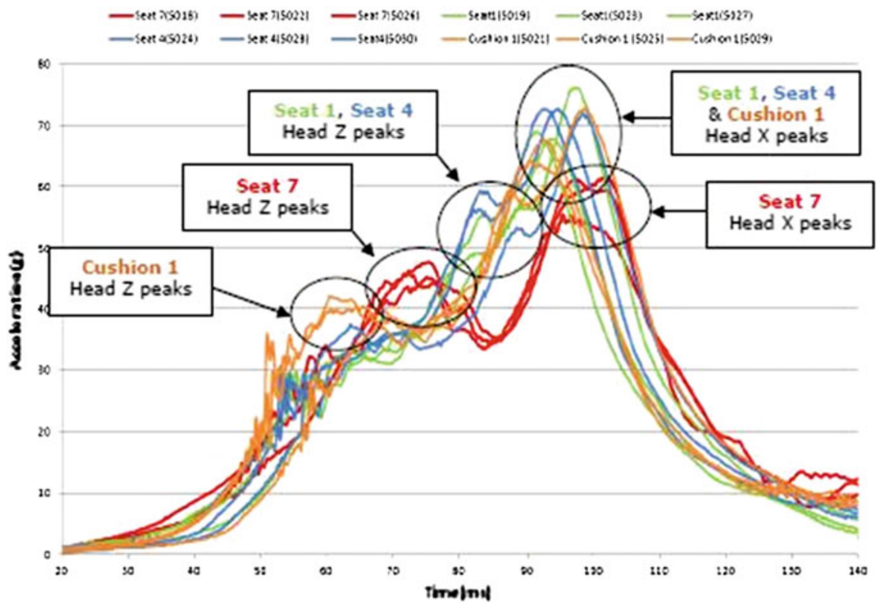

Fig. 3 Sensitivity to child restraint design—head acceleration resultant

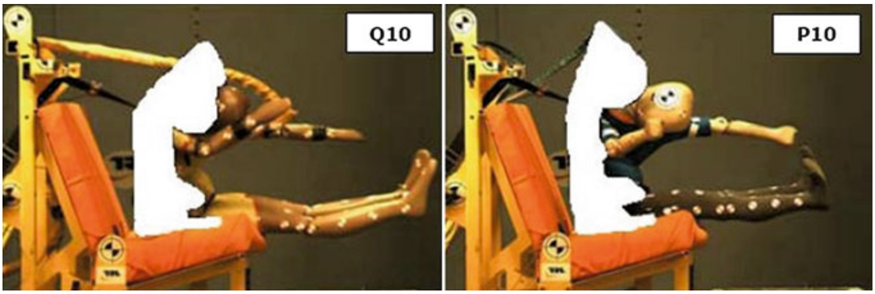

Fig. 4 Comparison between Q10 and P10 at the point of maximum head excursion

the Q10 dummy in the front impact tests with extra belt tension (see red and yellow curves) in comparison to the baseline tests.

From the analysis of the results was concluded that the Q10 dummy was capable of detecting differences in the child restraint design in both side and frontal impact tests. Additionally, differences in the results can be explained by the differences in the child restraint design.

The dummy showed good repeatability from the durability front and side impact tests. A few parts required improvements for their durability, but they were improved and implemented in the final version of the dummy. The investigation into dummy recovery time for side impact NPACS tests found out that the dummy is capable of producing repeatable results with up to 30 min recovery time.

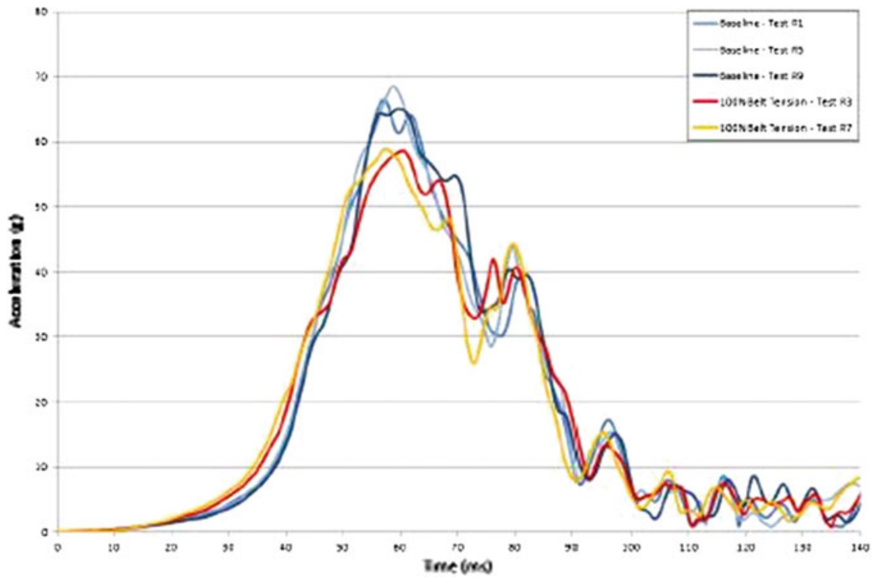

Fig. 5 Front impact: comparing the tests with 100 N seat belt tension to the baseline test for the pelvis resultant acceleration

As already explained, such a large number of tests had to be managed and a Gantt chart was used for this purpose. The following testing results information is available and can be provided if requested:

- Reg. 44
  - Sensitivity to changes in test setup

    Test matrix

    Results from the body regions, including: head, upper and lower neck, chest, pelvis
  - Sensitivity to child restraint design

    Test matrix

    Results from the body regions, including: head, upper and lower neck, chest, pelvis
  - Durability

    Test matrix

    Durability with different seats—results from the body regions, including: head, upper and lower neck, chest, pelvis

    Durability time dependency testing: tests conducted 15, 30 and 45 min after a previous test. Results from the body regions are available, including: head, upper and lower neck, chest, pelvis

Durability dummy positioning—results from the body regions, including: head, upper and lower neck, chest, pelvis

- Comparison of P10 and Q1

  Test matrix
  Results from the body regions, including: head, upper and lower neck, chest, pelvis

- NPACS: side and frontal impacts
  - Sensitivity to changes in test setup

    Test matrix
    Results from the body regions, including: head, upper and lower neck, chest, pelvis

  - Sensitivity to child restraint design

    Test matrix
    Results from the body regions, including: head, upper and lower neck, chest, pelvis

  - Durability

    Test matrix
    Durability with different seats—results from the body regions, including: head, upper and lower neck, chest, pelvis
    Durability time dependency testing: tests conducted 15, 30 and 45 min after a previous test. Results from the body regions are available, including: head, upper and lower neck, chest, pelvis
    Durability dummy positioning—results from the body regions, including: head, upper and lower neck, chest, pelvis.

4 Specification of 5 Band Rating System for Application of NPACS

In the final phase of the EPOCh project a 5 band scoring system for the Q10 dummy was created. This way the NPACS testing procedures were expanded so that all of the child restraint systems can be tested using the NPACS testing protocol.

The first approach for developing this rating system was to apply the already existing scoring tables for both front and side impact results. Ideally, the results of the testing with the Q10 dummy would have evenly spread across the scoring band. However, as this did not happen, a revised scoring table had to be created for both side and frontal tests.

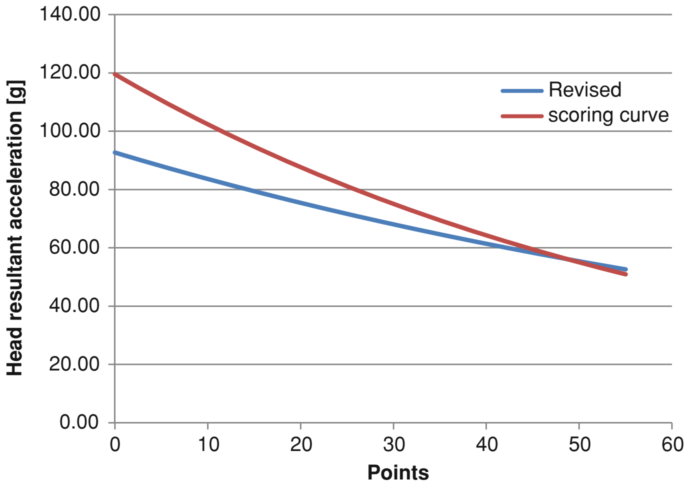

Fig. 6 Front Impact head resultant acceleration revised scoring

The tested samples were chosen in such a way that they can represent the whole range of products available at the market. It was decided that the worst performing child restraint systems should score between 0 and 10 % of the points available per body region. On the other hand, the best performing restraint systems were set to score around 75 %, which will allow some room for possible improvements in child restraint system designs. On Fig. 6 can be seen the revised scoring for front impact head resultant acceleration as an example.

5 Conclusions and Recommendations

The Q10 dummy was developed to the required specifications and was found to be sensitive, durable and repeatable on certification style testing on biomechanical performance. All of the results obtained had a coefficient of variation within the required 5 %. Certification procedures were developed for the Q10 dummy.

Based on the findings from the testing using Reg. 44 testing protocol, the following recommendations and conclusions can be made:

- The Q10 dummy is durable enough to be used in Reg. 44 front impact tests.
- The Q10 is sensitive enough to show differences and specific patterns.
- A recalibration is recommended after every 20 tests.
- The limits have to be revised if Q10 is used, in order to provide an equivalent assessment to the P10. Some of the limits need more investigation.
- Chest vertical should not be assessed for the Q10.
- A minimum of 20 min is the recovery time between tests recommended.

Based on the findings from both the side and frontal testing using NPACS testing protocol, the following recommendations and conclusions can be made:

- The Q10 is sensitive enough to show differences and specific patterns for both side and front impacts.
- The Q10 dummy is durable enough to be used in side impact tests, following the NPACS testing protocol.
- Improved parts would be implemented in the final version of the dummy to prevent the few failures that occurred in the NPACS front impact testing and to reduce the maintenance checks.
- The recommended time between tests is 30 min. This will allow enough time for maintenance checks and dummy recovery.
- The Q10 NPACS scoring system has been expanded, to achieve a rating system, applicable to the Q10.

Reference

1. Waagmeester K, Burleigh M, Lemmen P (2012) D1.2—biomechanical requirements and design brief. EPOCh