

# **EURO NCAP CHILD OCCUPANT PROTECTION – HOW THE 2016 PROTOCOL IMPROVED CARS AND CRS COMPATIBILITY AND DYNAMIC INTERACTION**

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## **ABSTRACT**

In 2015 Euro NCAP updated its test protocols and in 2016 Euro NCAP updated its assessment protocol. The aim of this was to advance the vehicle restraint systems in the second seat row for both small adults and children. This included the introduction of a full width frontal test and modification to the existing offset frontal and side impact tests.

The update to the protocols aimed to enhance the vehicle restraint systems towards a more efficient one, including belt load limiters and belt pretensioners. As far as child occupant protection is concerned the objective of Euro NCAP was to seek a combined restraint strategy allowing both the vehicle restraint system and the child restraint system (CRS) to work together. The child restraint systems used for the crash testing are a highback booster for the Q6 and a booster cushion for the Q10.

The aim of this study was to investigate the performance of the vehicles tested with regards to the three key areas covered by the protocol: i.e. CRS installation checks, safety provisions in the vehicle and crash performance. The test results from 97 vehicles tested by Euro NCAP between January 2016 and December 2018 were analysed. Where possible the reasons for differences between the best and worst performers for each assessment were investigated.

## **BACKGROUND**

The aim of Euro NCAP's 2015 and 2016 updates to the testing and assessment protocols was to advance the restraint systems in vehicles' second seat row for both small adults and children. Amongst the features of this protocol were two key new features:

- Full width frontal impact including a 5<sup>th</sup> percentile adult dummy occupant sat in the rear of the vehicle introduced since 2015
- Using larger child dummies, Q6 and Q10 in frontal offset and side impact tests introduced since 2016

The introduction of a full width crash test, using the 5<sup>th</sup> percentile Hybrid III dummy in the rear seat of a vehicle, with its associated performance criteria was a way to enhance the vehicle restraint system towards a more efficient one, including belt load limiters and belt pretensioners.

The test conditions of the pre-existing frontal offset deformable barrier (ODB) and side mobile deformable barrier (MDB) tests remained unchanged. However, as far as child occupant protection (COP) is concerned the objective of Euro NCAP was to seek a combined restraint strategy allowing both vehicle restraint system and the child restraint system (CRS) to work together.

For this purpose, the protocol was changed from the previously used Q1.5 and Q3 child dummies, to assessing the ability of the vehicle to protect older children. Therefore, Q6 and Q10 dummies representing older children were used. The child restraints used to protect these older children were therefore also updated to a highback booster for the Q6 and a booster cushion for the Q10.

## OBJECTIVE

This study investigated all the vehicles tested by Euro NCAP between January 2016 and December 2018. In addition, data collected at the Euro NCAP manufacturers viewings sessions was used. Where possible video footage was used to understand the performance of the vehicle seat belt restraint in frontal impact and the curtain airbag interaction with the Q10 dummy in side impact.

The aim of this study was to investigate the performance of the vehicles tested with regards to the three key areas covered by Euro NCAP's child occupant protection (COP) assessment protocol [1]:

- CRS installation checks  
Assessing the vehicle's ability to accommodate a large range of different designs of child restraints
- Safety provisions in the vehicle  
Provisions of 3-point seat belts, i-Size positions and markings, top tether markings, passenger airbag warning label and deactivation information and ability to install large rearward facing ISOFIX CRSs
- Crash performance  
Q6 and Q10 dummy responses in frontal offset deformable barrier (ODB) impact test and side mobile deformable barrier (MDB) impact test

The relationship between the vehicle overall star rating and the size of the vehicle was also investigated to see if any trends could be identified.

## Euro NCAP CHILD OCCUPANT PROTECTION PROTOCOL

The following sections describe how the child occupant protection protocol assesses vehicles in each of the three key areas.

### CRS installation checks

Child restraints are designed to protect the occupant in the event of an impact. However, if the child restraint cannot be installed correctly in a vehicle, it can diminish the ability of that child restraint to protect the occupant. Euro NCAP attempts to reduce the likelihood of a mismatch between the child restraint and the vehicle by installation checks for each seating position in the vehicle.

Child restraints, representing different designs and installation methods available on the market, are installed in the vehicle to assess the ease of installation. Euro NCAP publish a "Top Pick List" [2] of child restraints that are used for the installation checks (Figure 1). The top pick list contains child restraints with at least a good rating in consumer testing.



Figure 1. Euro NCAP child restraint top picks (2016-2018)

The installation checks of the different child restraints mean a number of different vehicle characteristics are assessed including: seat belt length, belt buckle location, ISOFIX anchorage accessibility and CRS stability. The top picks list also includes large rearward facing child restraints to encourage vehicles to provide space for these types of child restraint.

The vehicle is rewarded if the child restraints on the top pick list can be installed correctly and easily on all suitable seating positions in the vehicle. The vehicle handbook should clearly mention the seating positions where a CRS cannot be installed. If a certain child restraint cannot be installed in a position it loses points. If the CRS cannot be installed easily or there are vehicle interference problems the points score is reduced.

### **Safety provisions in the vehicle**

All child restraints must be tested and Type Approved to either UN Regulation 44 (R44) or UN Regulation 129 (R129) before they can go on sale in Europe. R129 was introduced in July 2013 and it introduces the concept of i-Size child restraints compatible with i-Size vehicle seating positions. Current vehicle regulations do not mandate the requirement to have i-Size ready seating positions in the vehicle, it is optional for the vehicle manufacturer.

However, the Euro NCAP assessment encourages the availability of i-Size ready seating positions in the vehicle. The vehicle is also rewarded for providing important features such as ISOFIX anchorages, a top tether anchorage and a strong vehicle floor for each seating positions. Points are also awarded for clear i-Size labelling, a front seat airbag-disabling switch with clear user instructions and integrated vehicle child restraints as a standard option.

Points are awarded if the following criteria are fulfilled:

- Seat belt length (Gabarit installation) on all passenger seats
- Ability to install large size “ISO/R3” CRS in two or more seating positions
- Integrated child restraints in one position
- More points are awarded if there are integrated child restraints in two or more positions
- i-Size and top tether markings (conspicuous design, permanent labels) for each i-Size seating position
- At least two i-Size seating position available
- More points are awarded if there are three or more i-Size seating positions
- Passenger airbag disabling for the front passenger seat(s)

### **Crash performance**

Four different impact tests are conducted as part of the Euro NCAP assessment. However only the frontal offset deformable barrier (ODB) impact test [3] and the side mobile deformable barrier (MDB) impact test [4] have child dummies installed in the rear of the vehicle.

Frontal offset deformable barrier (ODB) impact test The vehicle is tested with child dummies representing a 6 year-old child (Q6) and a 10 year-old child (Q10). The Q6 is seated in a highback booster recommended by the vehicle manufacturer and the Q10 is seated on a booster cushion (either recommended by the manufacturer or from the Euro NCAP list). The Q6 is placed behind the driver in the vehicle (Figure 2).

During the frontal impact test the assessed vehicle is propelled at 64 km/h into a deformable barrier. There is a 40% overlap between the vehicle and the barrier.

Head displacement, head acceleration, upper neck force and chest accelerations are the main dummy criteria measured during the tests. The vehicle is rewarded if test criteria remain below defined limits and if neither dummy was ejected from its seat or made any hard contact with the vehicle interior during the impact. This ensures that the child remains correctly restrained during the crash event.

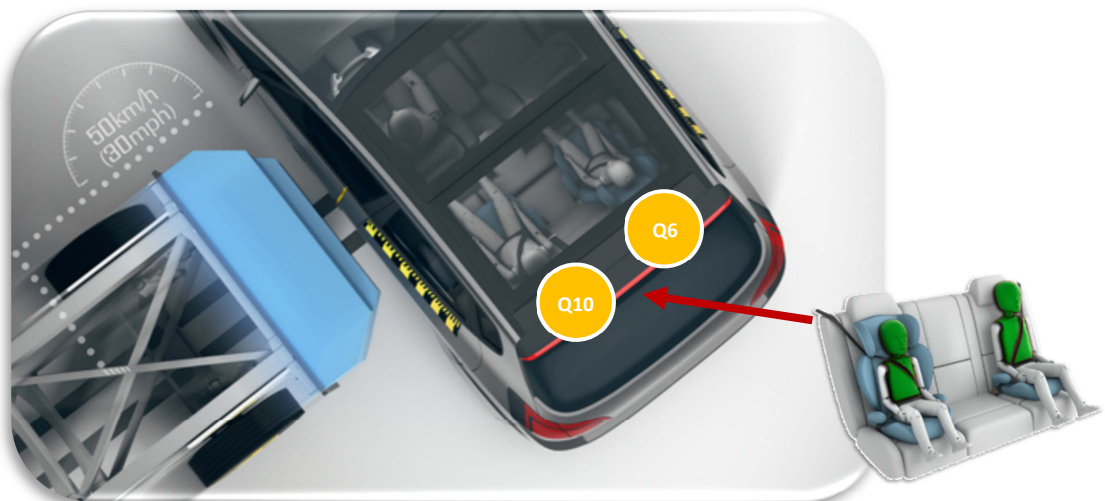


**Figure 2. Frontal impact offset deformable barrier (ODB) test [5]**

Side mobile deformable barrier (MDB) impact test The vehicle is tested with the same child dummies and child restraints as the frontal impact test. The Q10 is placed on the stuck side of the vehicle (Figure 3).

During the side impact test the assessed vehicle is struck at 50 km/h by a mobile deformable barrier.

Head acceleration, upper neck force and chest accelerations are the main dummy criteria measured during the tests. The vehicle is rewarded if test criteria remain below defined limits and there is no hard contact with the vehicle interior during the impact.



**Figure 3. Side impact mobile deformable barrier (MDB) test [6]**

### Overall Rating

A vehicle can score a total of 49 points for the child occupant protection (COP) score. The COP score accounts for 20% of the final overall rating of the vehicle [7].

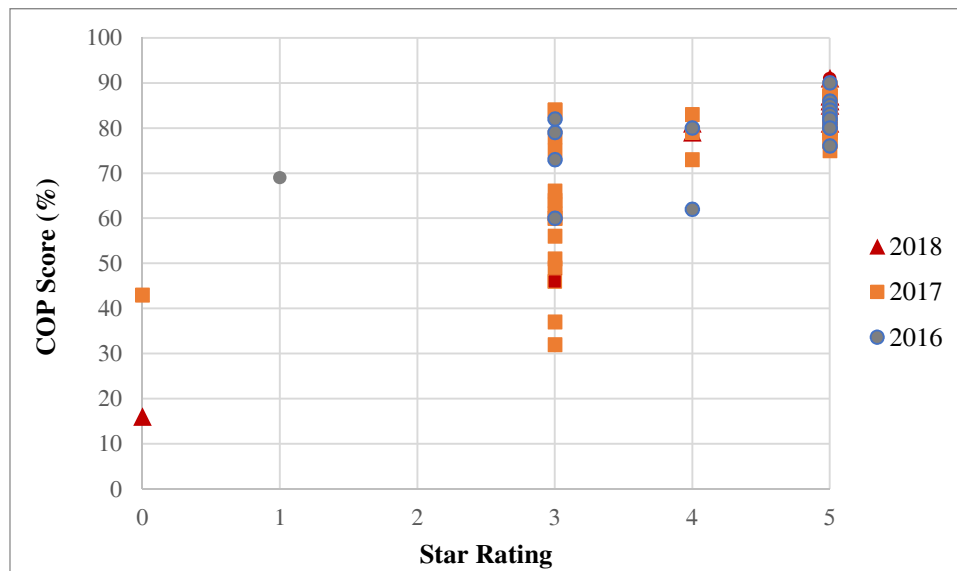
However there are also balance limits that means for a vehicle to score 5 stars overall it needed to score at least 75% COP score when tested between 2016 and 2017. From 2018 vehicles needed to score 80% COP score to achieve 5 stars overall. Similar balance limits exist for adult (80%), pedestrian (60%) and safety assist (50%) assessments. This is to ensure the vehicle provides all round protection.

## RESULTS ANALYSIS

Analysis of the Euro NCAP Child Occupant Protection (COP) test results from vehicles assessed between 2016 and 2018 has been carried out. The results only from the standard versions of each vehicle was analysed. If a reassessment had been carried out, only the reassessment has been included in the analysis. In total, the results from 97 different vehicles tested by Euro NCAP have been analysed.

### COP Score

Figure 4 shows the comparison of overall vehicle star rating with child occupant protection score. Figure 4 shows that some 3 star vehicles were able to provide a high level of child occupant protection (>80%).



*Figure 4. Overall star rating vs child occupant protection score (COP)*

Table 1 shows the average score per assessment category for each class of vehicle. This shows that for installation checks and safety provisions in the vehicle, Executive and Large Family vehicles are on average the highest scoring vehicles. On average the lowest scorers in these categories are Small MPVs. Therefore, these categories were analysed in greater detail to identify the reasons for the scoring differences.

Executive vehicles are also amongst the highest scoring in the dynamic tests, whereas Superminis are on average the lowest scoring.

Pick-up and Roadster vehicles were not considered for the analysis due to the low number of vehicles tested.

*Table 1. Euro NCAP child occupant protection average score per category*

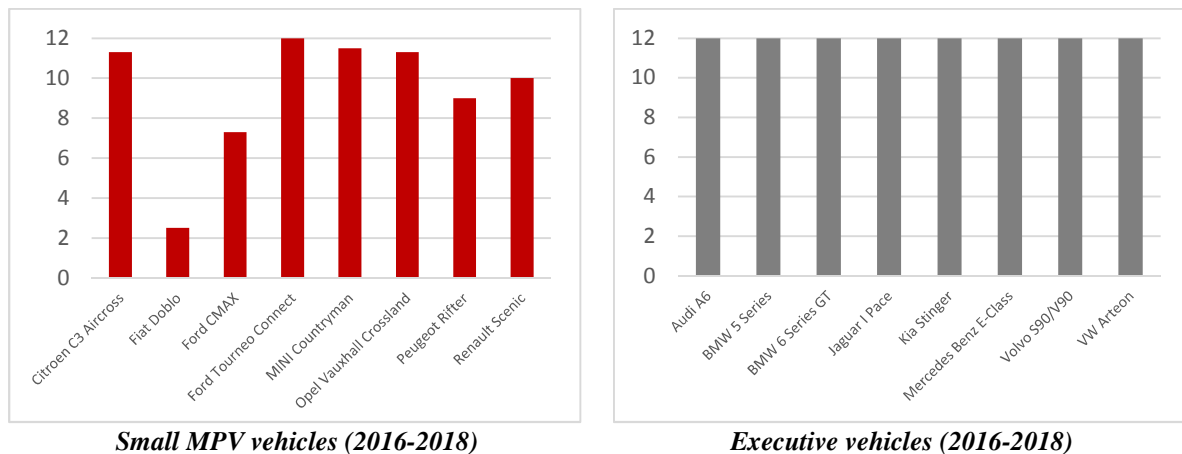
Class	No. vehicles	Installation Checks /12	Safety provisions in the vehicle /13	Dynamic Test /24	Total /49
Large Family	8	11.7	7.0	22.9	41.6
Executive	8	12.0	7.0	22.4	41.4
Small Off-road	21	11.5	6.8	22.5	40.8
Large Off-road	13	11.4	6.9	22.1	40.5
Small Family	19	10.9	6.1	20.2	37.3
Small MPV	8	9.4	5.3	22.0	36.6
Supermini	17	10.8	5.4	17.2	33.4
Pick-up	2	11.2	8.5	22.0	41.7
Roadster	1	2.2	0.0	13.6	15.8

**CRS installation checks**

This assessment is scored out of 12 points. The score is calculated based on whether it is possible to fit each of the different child restraints from the Top Pick list in each available vehicle seating position. If a certain child restraint cannot be installed in a position it loses points. If the CRS cannot be installed easily or without problems the points score is reduced.

Figure 5 shows the comparison of the CRS installation checks results for the Small MPV and Executive vehicle classes. This shows that all Executive vehicles scored full points for this assessment. However, for Small MPVs there is a wide range of scores between 2.5 points and 12 points.

It is common for points to be lost for seating positions which could not accommodate large rearward facing child restraints. In addition, vehicles with 3 rows often have seat belt length that are not suitable for rearward facing child restraints. The lowest scoring vehicle lost points because it was not possible to fit any ISOFIX or i-Size child restraints in the vehicle.

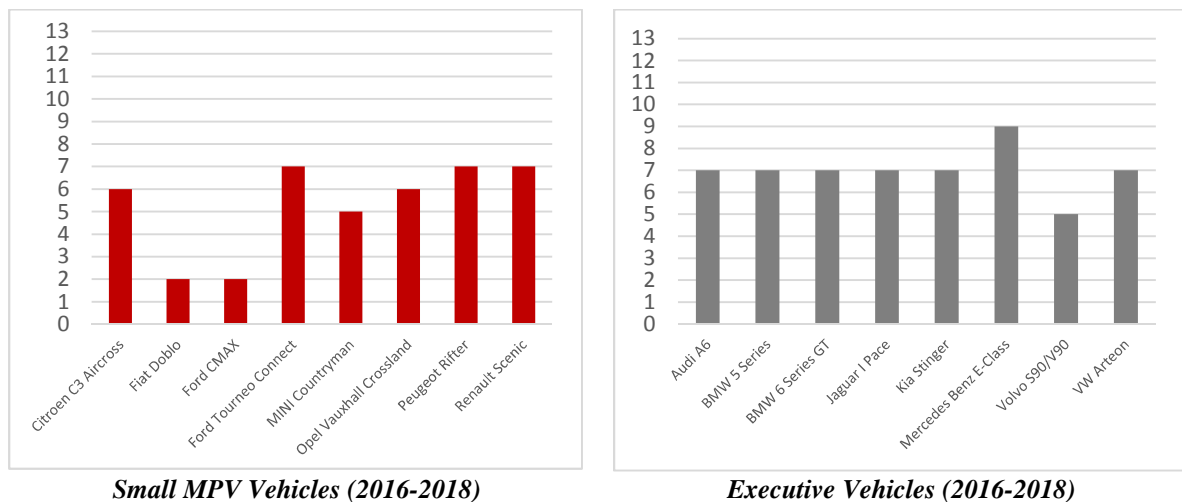


*Figure 5. CRS installation checks results*

**Safety provisions in the vehicle**

This assessment is scored out of 13 points. Points are awarded based on the assessment described previously.

Figure 6 shows the comparison of the safety provisions in the vehicle results for the Small MPV and Executive vehicle classes. This shows that none of the vehicles score the full 13 points. 9 points is the joint highest score for this assessment for all the vehicles assessed between 2016 and 2018 (7 vehicles). As shown in Table 1, 7 points is typically the best average score for vehicles.



*Figure 6. Safety provisions in the vehicle results*

The reasons vehicles don't score full marks for this assessment is that they don't have at least two integrated child restraints fitted in the vehicle as a standard option (3 points) and that they are not equipped with three i-Size positions (1 point). Vehicles without an automatically disabling front airbag also miss out on a further 2 points. Meaning for most vehicles 7 points is the maximum points they can score.

Figure 6 shows that the majority of Executive vehicles scored 7 points for this assessment. However, for Small MPVs there is a wide range of scores between 2 points and 7 points.

The reasons vehicles don't score 7 points is due to poor labelling of the i-Size position, accessibility of the ISOFIX and poor labelling of the top tether. Some examples of good and poor i-Size execution are shown in Figure 7. The poor examples require the user to move the cushion to find the ISOFIX anchorages. Whereas for the good examples, the anchorage locations are clearly labelled and easy to access.



**Figure 7. Examples of good and poor i-Size execution**

Figure 8 shows a good example of a clearly labelled top tether anchorage and a top tether anchorage, although labelled, the anchorage itself is hidden within the seat back.



**Figure 8. Examples of good and poor top tether execution**

For the lowest scoring vehicles either it was not possible to deactivate the front passenger airbag or it was not clear to the user when the airbag was deactivated.

Figure 9 shows that over the last three years that the majority of vehicles tested now have at least two i-Size positions in the vehicle. This is positive trend as it means that vehicle/CRS compatibility is increasing.

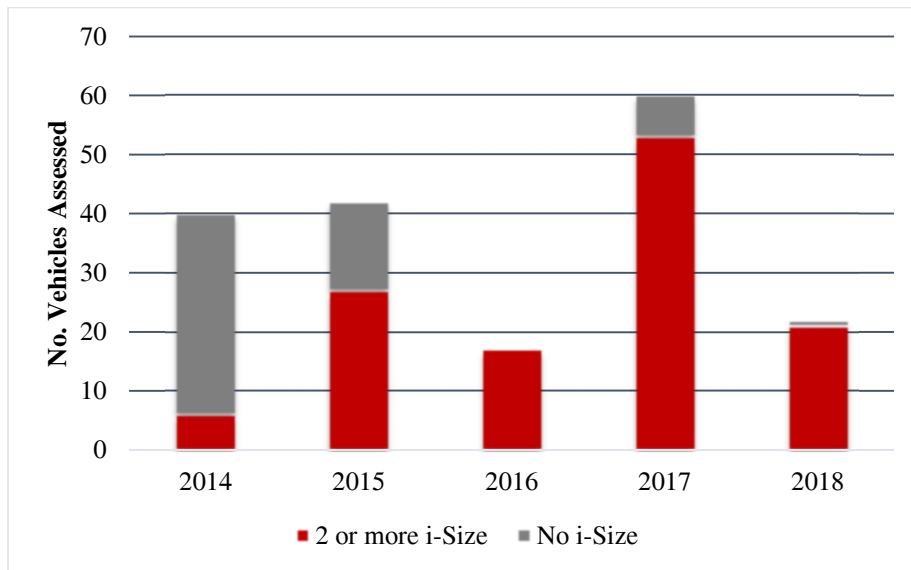


Figure 9. i-Size penetration

### Crash performance

A total of 24 points can be scored for crash performance. For frontal impact each dummy receives a score out of 8 points. For side impact each dummy is scored out of 4 points.

The responses of the Q6 and Q10 dummy have been analysed in the frontal offset barrier and side impact tests. The dummy readings from each of the scored body regions have been analysed to identify any trends.

Frontal impact – Head displacement A check of the dummy’s horizontal movement is made from the video footage to verify the head has not exceeded a certain limit. However, an exact excursion measurement is not necessarily recorded. Therefore, a comparison of head displacement is not possible.

Frontal impact – Head acceleration Figure 10 shows that prior to 2018 that only one vehicle failed to score full points for head resultant acceleration. This is likely to be one of the reasons why the points limits were adjusted to a lower threshold. For the vehicles tested in 2018, two vehicles failed to score full points for the Q6 and two vehicles failed to score full points for Q10.

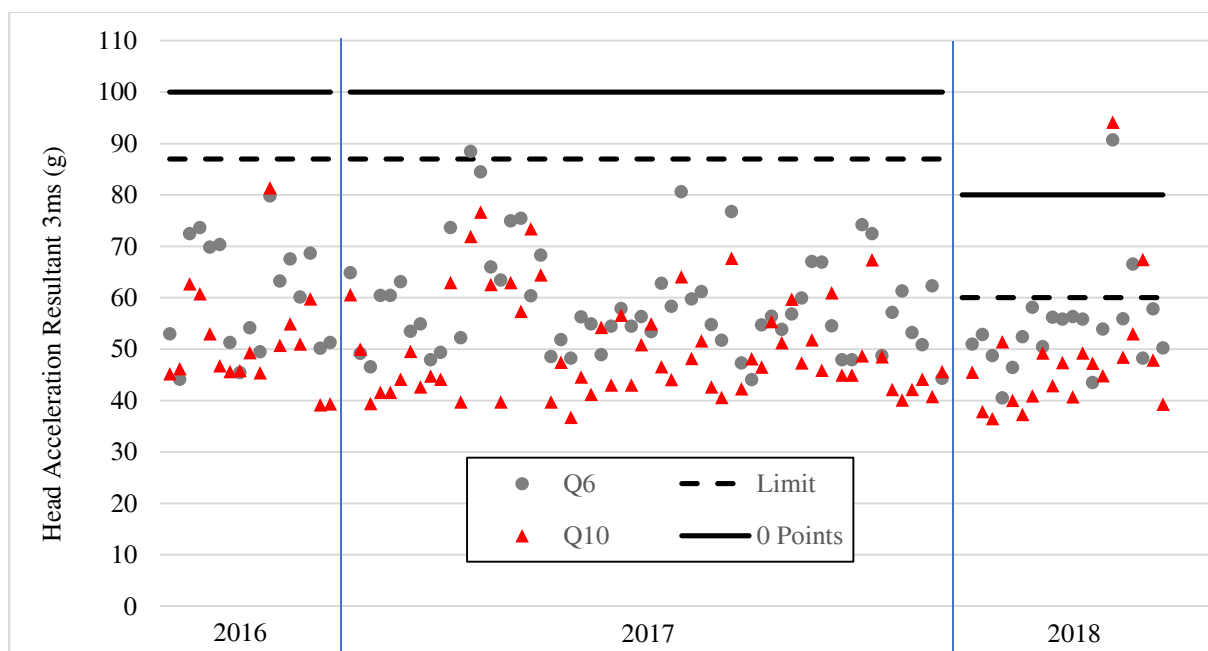
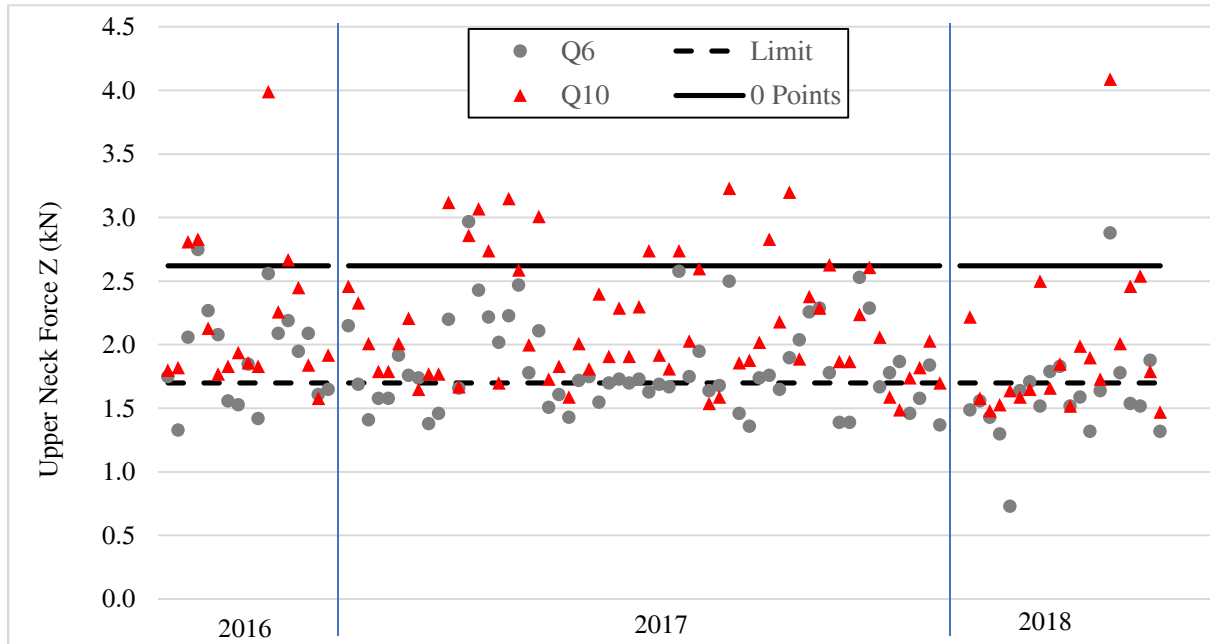


Figure 10. Q6 & Q10 head accelerations frontal ODB impact tests

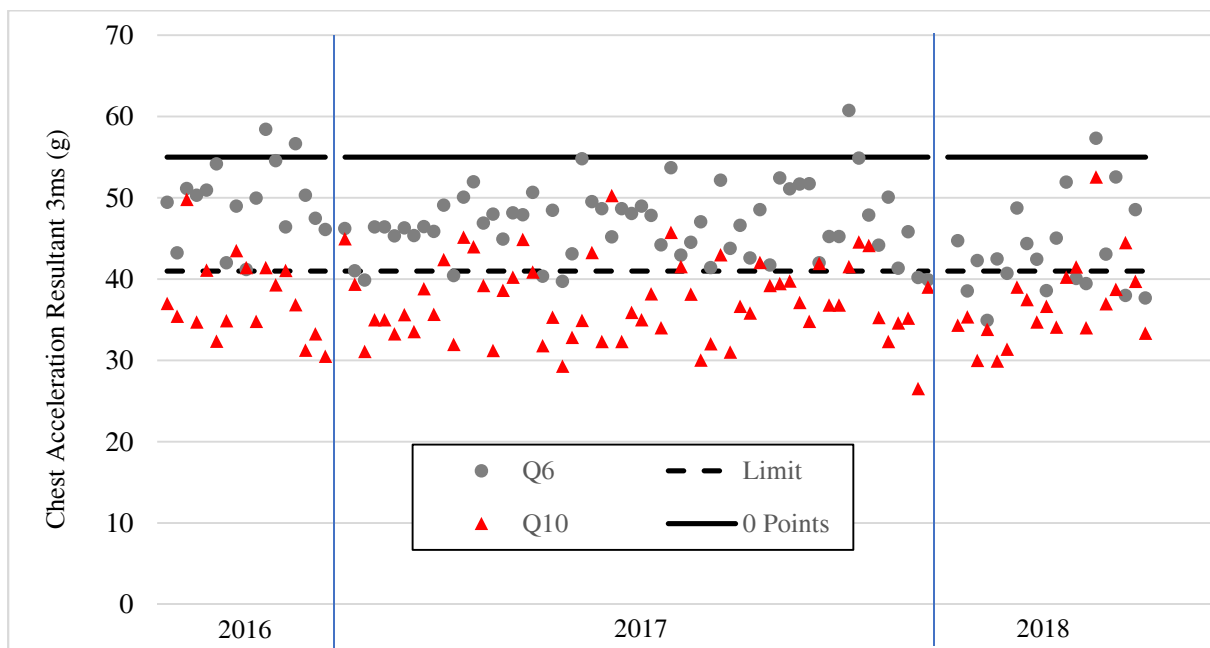


Frontal impact – Upper neck force Figure 11 shows that only a small number of vehicles have scored full points for the Q6 and Q10 upper neck force. There does not seem to be a trend relating to vehicle size.



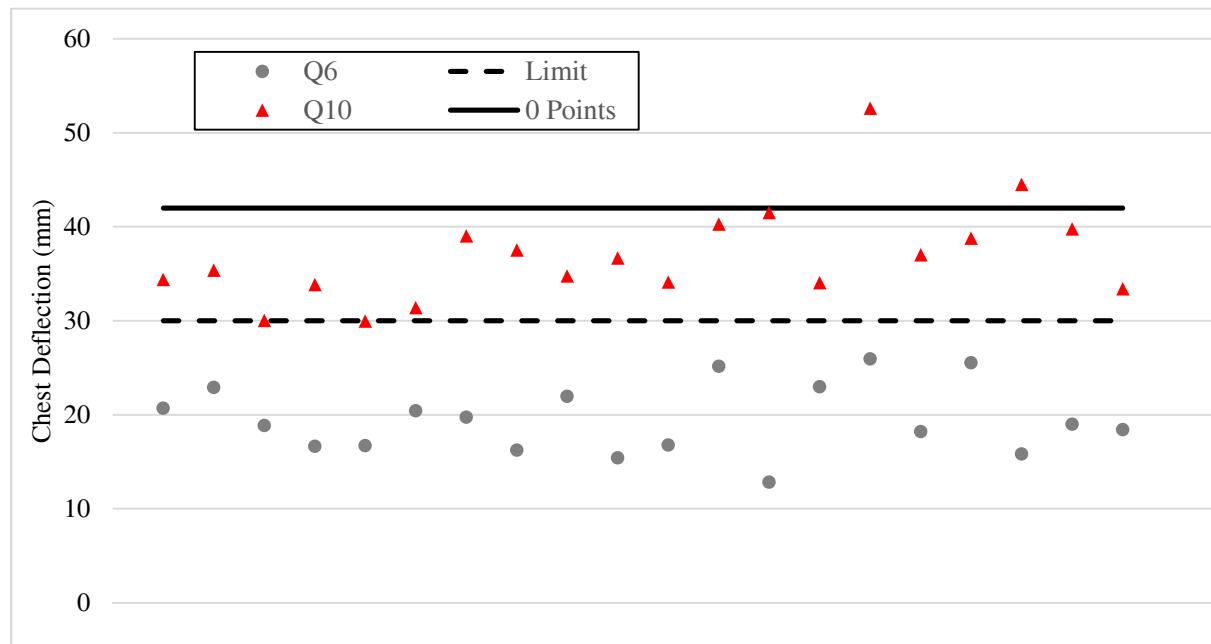
*Figure 11. Q6 & Q10 upper neck forces frontal ODB impact tests*

Frontal impact – Chest Acceleration Figure 12 shows that the majority of vehicles score full points for the Q10. However only a small number of vehicles have scored full points for the Q6 chest resultant acceleration. Though, from 2018 chest acceleration was no longer scored for the Q6. Instead chest deflection was measured and scored for the Q6.



*Figure 12. Q6 & Q10 chest accelerations frontal ODB impact tests*

**Frontal impact – Chest Deflection** Figure 13 shows that measured chest deflection for Q6 and Q10 for vehicles tested in 2018. Though only the Q6 chest deflection is scored. Prior to 2018 the chest deflection results were not necessarily recorded. This shows that all the vehicles scored full points for the Q6 deflection.

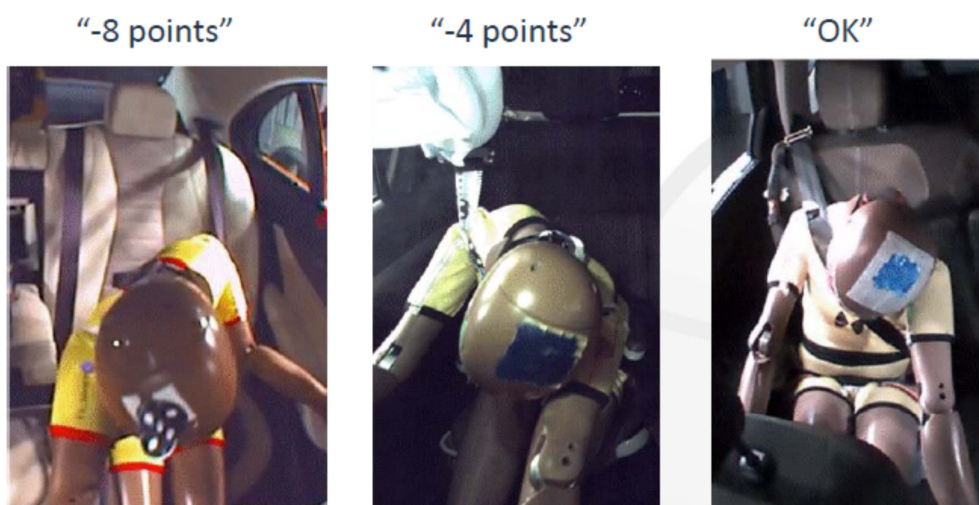


*Figure 13. Q6 & Q10 chest deflections frontal ODB impact tests (2018 vehicles)*

**Frontal impact – Modifiers** For frontal impact testing a score modifier is apply if one of the following occurs:

- Diagonal belt slips off the shoulder
- Submarining
- Dummy ejection
- Failure of restraint system components

The position of the diagonal belt on the shoulder of the dummy is assessed from the in-vehicle video footage. A sliding points scale is applied depending on the position of the diagonal belt during the impact (Figure 14). If the belt remains on the shoulder of the dummy no modifier is applied. If however the belt slips towards the arm and gets caught in the arm-shoulder gap then a -4 point modifier is applied. If the belt slips of the shoulder completely then a -8 point modifier is applied, meaning that the dummy scores zero points in the frontal test.



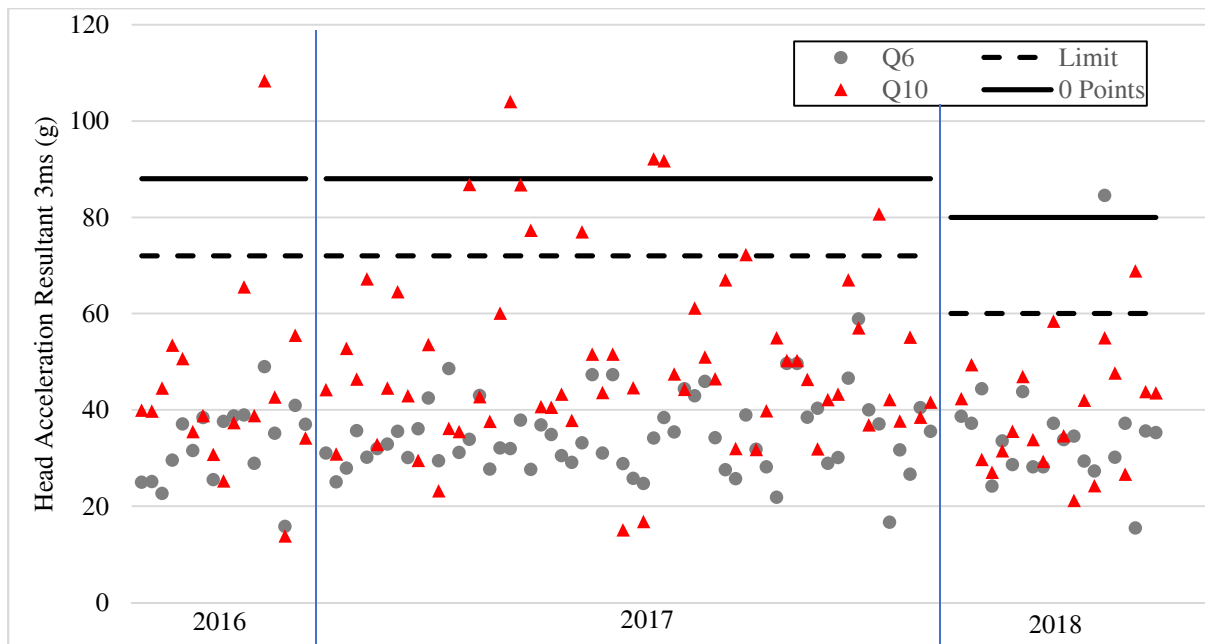
*Figure 14. Diagonal belt position modifier assessment*

If submarining of the dummy under the lap belt occurs (Figure 15) during the frontal test a modifier is applied. This occurred for one vehicle in 2016.



**Figure 15. Diagonal belt position modifier**

Side impact – Head acceleration Figure 16 shows only one vehicle failed to score full points for head resultant acceleration for the Q6. In this vehicle a head to head contact occurred between the Q6 and Q10 dummies, resulting in high accelerations measured by both dummies.



**Figure 16. Q6 & Q10 head accelerations side MDB impact tests**

Prior to 2018, before the points limits were adjusted to a lower threshold, only a few vehicles exceeded the head acceleration limit with the Q10. The reasons for the Q10 recording high head accelerations was typically either the head missed or bottomed out the curtain airbag. This can result in head contact with the vehicle c-pillar (Figure 17). Only a few of vehicles (4) were not fitted with curtain airbags in the rear of the vehicle. This resulted in the Q10's head contacting the vehicle structure and recording high head accelerations.



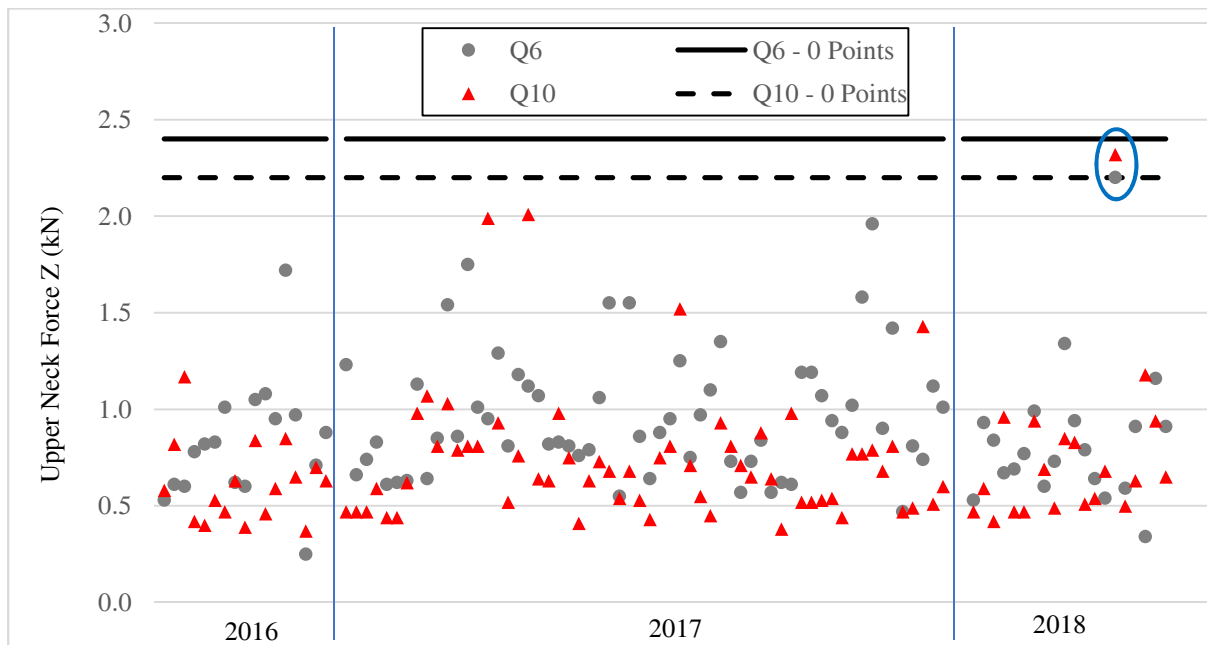
*Curtain bottoming out*



*Head contact with c-Pillar*

*Figure 17. Curtain airbag performance*

Side impact – Upper neck force Figure 18 shows that only one vehicle exceeded the limit for the Q10 upper neck force. This vehicle also had the high Q6 upper neck force. This is the same vehicle where the head to head contact occurred.



*Figure 18. Q6 & Q10 upper neck forces side MDB impact tests*

**Side impact – Chest Acceleration** Figure 19 shows that all vehicles scored full points for the Q6 chest acceleration. The majority of vehicles scored full points for the Q10. Only a small number of vehicles exceeded the chest resultant acceleration limit for the Q10. These vehicles are mostly Supermini vehicles.

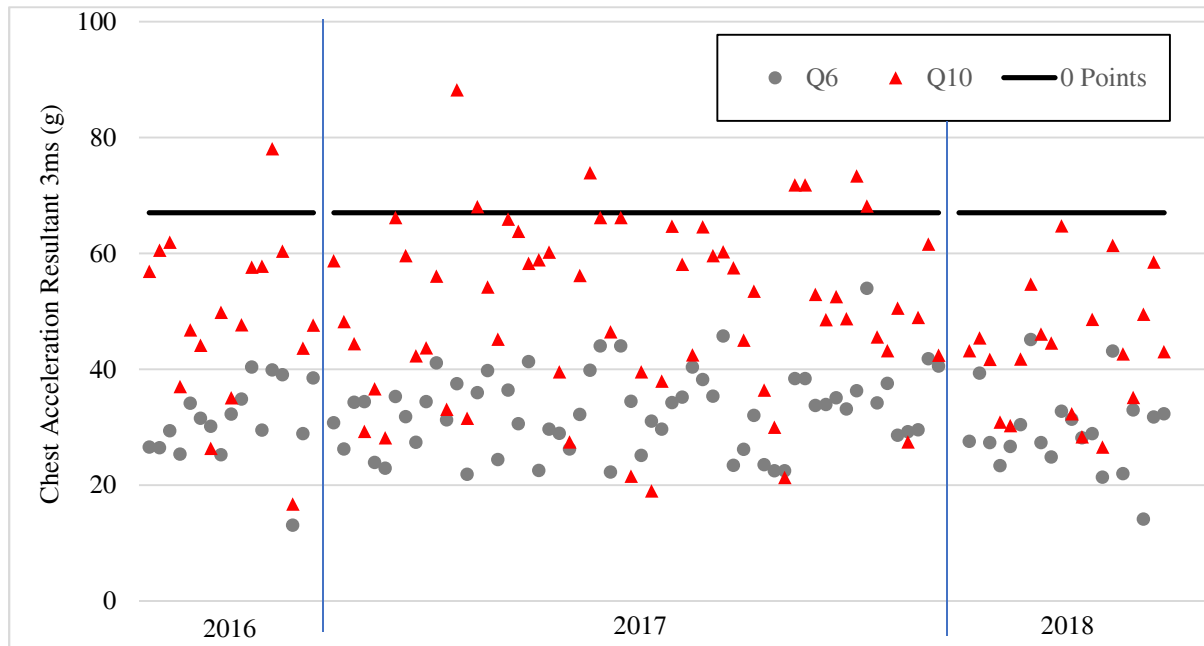


Figure 19. Q6 & Q10 chest accelerations side MDB impact tests

**Vehicle restraint observations**

From analysis of the test video footage and information provided by the Euro NCAP website [8] the following trends can be observed:

**Curtain airbags** Rear row curtain airbags are not mandated by vehicles regulations. However 93 of the 97 vehicles tested by Euro NCAP between 2016 and 2018 were fitted with a curtain airbag. Some vehicles have also started to introduce rear row side and pelvis airbags, but these are usually an optional extra.

**Pretensioners and load limiters** The introduction of the full width barrier test in 2015 and the change to the assessment protocol to evaluate the protection of older children in the rear of vehicles in 2016 has resulted in an increase in the number of pretensioners and load limiters equipped in the rear row of vehicles as a standard option. Figure 20 shows that before 2015 only 40% of vehicles tested were fitted with a load limiter or a pretensioner and load limiter. However, since 2015 over 85% of tested vehicles have at least a load limiter.

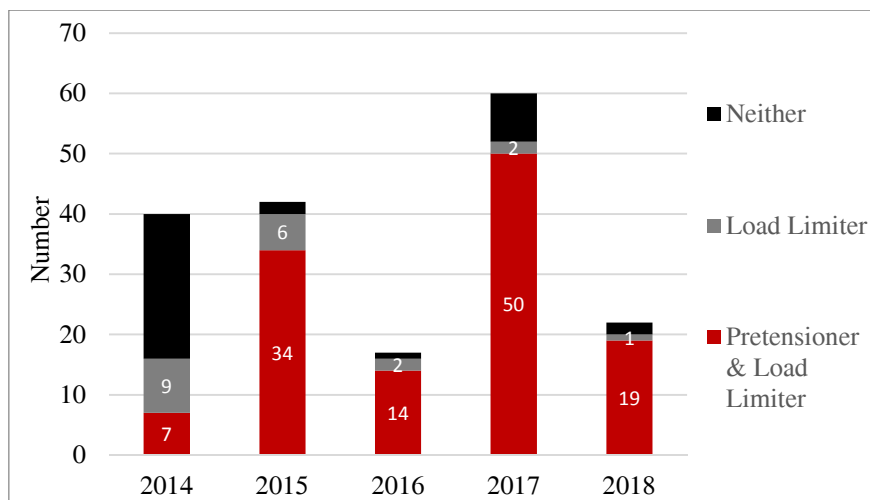


Figure 20. Pretensioners and load limiters fitted to tested vehicles

## CONCLUSIONS

The aim of Euro NCAP's 2015 and 2016 updates to the testing and assessment protocols were to advance the restraint systems in vehicles' second seat row for both small adults and children.

In terms of child occupant protection (COP) the new requirements seem to have the following effects:

- Requiring a COP of at least 75/80% to achieve an overall 5 star rating has required vehicle manufacturers to provide an improved level of protection for older child occupants
- The percentage of vehicles with at least two i-Size positions has increased (>88%)
- The majority of vehicles score good crash performance (20+ points)

Crash test requirements and performance limits have had the effect of:

- Presence of seat belt pretensioners and load limiters in the rear of vehicles is increasing (>85%) as a result of the introduction of the frontal full barrier test
- Seat belt geometry improvement to ensure correct shoulder belt position for older children
- Curtain airbags to protect older children in side impact. 96% of vehicles tested provided a curtain airbag
- Head accelerations have reduced in 2018 compared to 2016-2017, in both frontal and side impacts

Overall, most vehicles score around 20 points for crash performance. However, there is still some improvements to be made for some vehicles as far as ISOFIX visibility, accessibility and marking. The compatibility of some vehicles with some designs of child restraint could also be improved.

## THE FUTURE

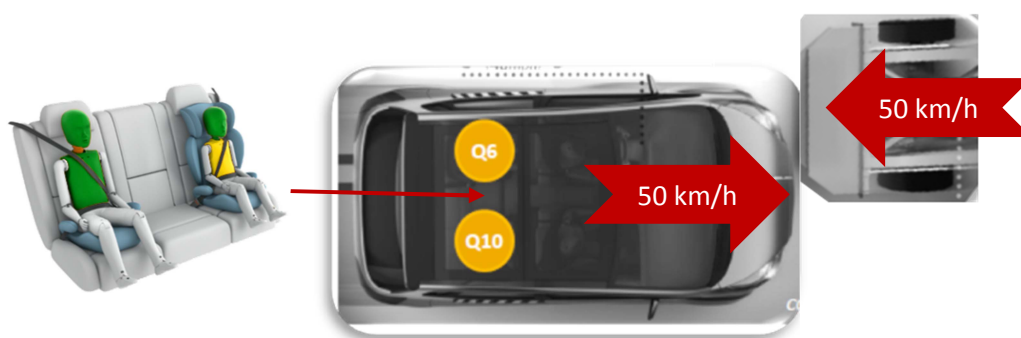
Euro NCAP is already planning to update the testing and assessment protocols to improve the performance of vehicles in 2020. These changes increase the severity of the frontal and side impact tests. This is likely to result in the need for an improved combined restraint strategy from the vehicle restraint systems and the child restraint system.

The main update changes that will affect child occupant protection in 2020 will be:

### Frontal impact mobile progressive deformable barrier (MPDB)

Instead of the vehicle striking a static impact barrier, the vehicle is now impacted into a mobile progressive deformable barrier. Both the vehicle and the mobile barrier will have an impact speed of 50 km/h (Figure 21).

The vehicle is still tested with child dummies representing 6 year-old child (Q6) seated in a highback booster and 10 year-old child (Q10) seated on a booster cushion. However, the Q10 will have a new upgrade kit that is designed to improve the interaction with the vehicle seat belt.



*Figure 21. Frontal impact offset deformable barrier (ODB) test*

### Side impact mobile deformable barrier (MDB)

The main change for this test is that the impact speed of the barrier has been increased. The vehicle is now struck by a mobile deformable barrier travelling at 60 km/h (Figure 22).

The vehicle is still tested with child dummies representing 6 year-old child (Q6) seated in a highback booster recommended by the vehicle manufacturer and 10 year-old child (Q10) seated on a booster cushion.



*Figure 22. Side impact mobile deformable barrier (MDB) test*

### ACKNOWLEDGMENT

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