PASSIVE SAFETY IMPROVEMENTS IN CHILD RESTRAINT SYSTEMS PLACED IN REAR SEATS OF VEHICLES BY INTRODUCING A NEW ISOFIX ACCESSORY

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ABSTRACT

In a 3-abreast seating configuration whenever there is a child restraint system (CRS) present, and especially if it is an ISOFIX one, occupants of the central position miss the room needed in order to rest their back properly against the backrest making them prone to suffer serious whiplash injuries in frontal or rear crashes or to collide with the adjacent passengers in lateral crashes. This lack of space jeopardizes the safety of all occupants as the restraint systems cannot work properly if the passengers are not correctly seated; more so, it affects further the safety of children making safety belt fastening difficult and uncomfortable and causing their CRS to be removed prematurely from the car to give room for that third occupant.

Most of those problems can be tackled by introducing an accessory to be inserted between the vehicle ISOFIX anchorages and the CRS ISOFIX connectors, which allows to move laterally the CRS, while keeping that ISOFIX connection, from the CRS nominal position to an extreme position where the CRS is shifted aside resting against the door panel, or at least coming quite close to it.

Due to limited resources, full capacity tests have not been possible running 3-abreast configurations. To assess technical feasibility and performance, the device was submitted to the tests specified in the ECE R129 standard, comparing sled tests carried out with the CRS alone (baseline reference case) with those same CRS coupled with the device shifting their nominal position 70 mm towards the door panel to establish potential safety improvements. CRS selection was based on their popularity within the Spanish market, and the tests were performed using both Q6 and Q10 dummies for each combination.

The analysis of the results of the dynamic tests carried out showed improvements in the level of side impact protection. For instance, the average HPC15 (Head Performance Criterion), directly related with the expected level of damage in the event of an impact, measured for the Q6 dummy was 232.76, while the average HPC15 with the same seats moved closer towards the door panel was 225.08, a 3.3% improvement in average with improvements for one of the CRS of up to 22.5%. For the Q10 dummy, the results were similar with an average HPC15 of 103.75 for the stand-alone CRS and an average HPC15 of 99.23 for the CRS coupled with the accessory device, a 4.4% improvement in this case. In every test performed, the resulting values remained below the limits designated in ECE R129 for the injury assessment criteria.

The introduction of this new device could lead to important benefits on the safety of families, and children in particular, by providing an effective use of the central seat by any passenger or additional CRS, while retaining the ISOFIX connection for a CRS placed in a lateral seat. Specifically, side protection could be significantly improved preventing undesired yaw rotations, and the optimized space usage will allow extending the CRS usage period avoiding their premature removal due to the lack of space.

INTRODUCTION

It is estimated by the Spanish Statistics National Institute that, in 2016, there were 180.872 families in Spain with three children between the ages of 0 and 11 and therefore capable of using three CRS or at least two CRS and a third child not requiring one (high occupation scenario). That same year, according to Eurostat figures, an analogous situation was meet in Germany by 379.000 families, 590.000 families in France and 524.000 in the United Kingdom.

A high occupation in a vehicle rear seat can also occur with 2 children and an adult, usually seated in the central position. In 2016, in Spain there were 1.507.179 households with two children in car-seat age that can be sporadically accompanied by an adult inserted between 2 CRS.

Despite these figures, there are few studies available regarding CRS performance in impact crashes for a 3-abreast configuration in the rear seats. Those studies, based on the analysis of real-world crashes, suggest a reduced risk of injury for children sitting with other occupants compared to children seated alone yielding a kind of protective effect to adjacent occupants for rear seat passengers in side impact crashes (Arbogast et al. [1]; Lund [2]; Maltese et al. [3]).

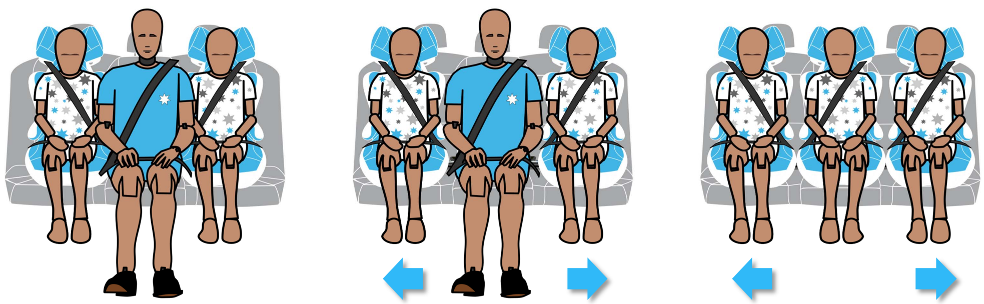

Figure 1. In 3-abreast configurations, ISOFIX CRS take part of the rear central seat invading the space needed to make a safe use of its restraint systems: ISOFIX CRS installed in their nominal position (left), interference with central occupant; CRS shifted aside with ISOFIX accessories giving room to accommodate an adult (middle), or additional CRS (right) in the central place

The limited resources available prevented carrying out confirmatory tests using this type of high occupation environment; instead, as the results presented by Charlton et al. [4], allow us to think that the use of ISOFIX attachments would help reducing the average injury risk level for three passengers in 3-abreast seating position, we focused on analysing the influence of the ISOFIX-attachment coupled with our accessory for the struck side occupant using groups II-III ISOFIX child seats. According to their results, we could anticipate an increase in the risk of injury in side impact crashes for that near-side occupant; an effect we wanted to quantify given that the introduction of an accessory that pushes the CRS towards the door may be deemed as dangerous by the average citizen.

ISOFIX DEVICE

The ISOFIX device developed (Figure 2) is an accessory for CRS that allows them to be displaced laterally, while retaining the ISOFIX connection, in order to maximize the remaining space for other occupants. It is inserted between the vehicle ISOFIX anchorages and the CRS ISOFIX connectors making it possible to position the CRS closer to the vehicle door panel. Thus, it is a device that can have certain regulations between a central position (coincident with the CRS nominal position) and an extreme position (where the CRS is displaced to its maximum, resting against the door panel or at least coming quite close to it) (Figure 3).

Figure 2. RiveMove (RM) device

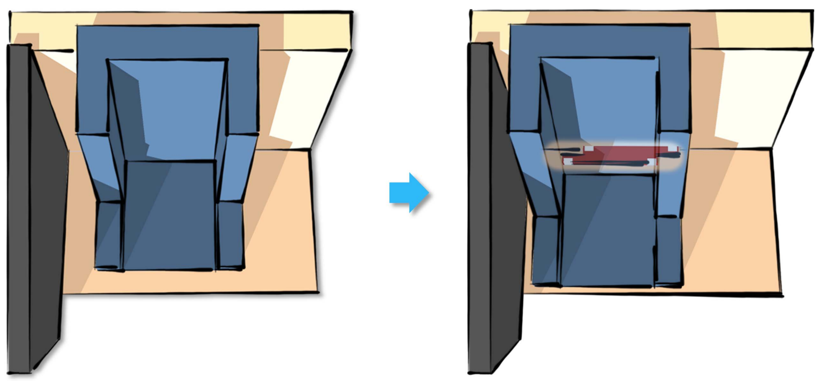

Figure 3. Nominal position (left). Shifted position where the CRS' ISOFIX connectors are attached to the device with a 50mm or 70mm offset towards the door panel (right)

The device designed has been carefully defined to absorb part of the energy put in place in the event of an accident contributing to reduce damage values and increasing the overall safety level for three rear seat occupants. Therefore, the technology is mainly aimed to families that make full use of the rear seat with three occupants and up to 3 CRS.

After installation, the CRS should allow regulating its own ISOFIX connectors' position to avoid undesired forward displacements due to our system's dimensions. Finally, the CRS has to be secured as well using the adult seatbelt available and any anti-rotation device it may have (Figure 4).

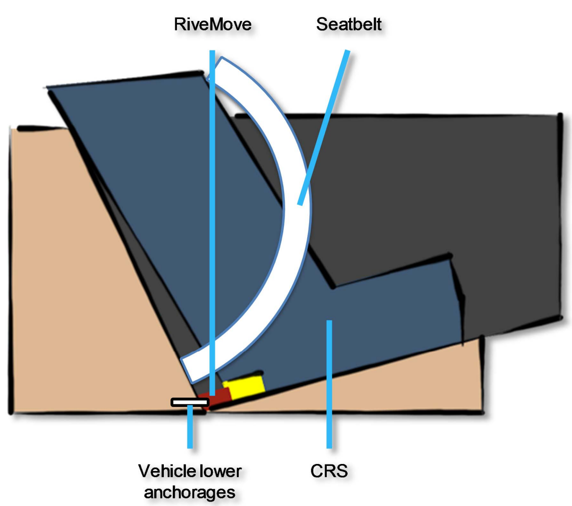

Figure 4. General disposition of the system

METHOD

To assess technical feasibility and performance, the device was submitted to the tests specified in the ECE R129 standard. First, by carrying out a sled test with the CRS alone (right out of the box) to establish the baseline reference case; then, a new seat of the same CRS model coupled with the device shifting their nominal position 70 mm towards the door panel looking for potential safety improvements.

Figure 5. Positioning of the dummy mid-plane at 350mm from the door panel (left), according to ECE R129 specifications for the baseline tests. Displacement aside of the dummy mid-plane closer to the door panel in the CRS+ISOFIX accessory configuration, regulation set at 280mm (right)

The introduction of the device resulted in a displacement forward of the ISOFIX anchorage points that was compensated, depending of the particular CRS, regulating the CRS' ISOFIX connectors to place flush the CRS backrest against the test bench. Something that not always was possible to do as will be mentioned later.

All the dynamic tests were carried out by CSI, S.p.A. with a deceleration sled according to the requirements defined in the ECE R129 standard.

The selection of the groups II-III CRS was based on their popularity within the Spanish market, including the CRS commonly used in the EuroNCAP tests.

RESULTS

The dynamic tests performed included frontal, lateral and rear impacts. For the first two a graphically comparison with the dummy values obtained is shown in the figures below.

Preliminary tests

The first tests conducted where intended to obtain a general knowledge on the modifications introduced by the ISOFIX accessory on the risk of injury for a Q10 dummy submitted to lateral impact. Therefore, a series of tests were defined for two types of CRS in which we could assess the potential differences between the baseline case, the shifted regulation of the device with a 70mm displacement, and an intermediate position with just a 50mm displacement. Their corresponding values are shown in the next figures (from left to right), for the two CRS initially considered.

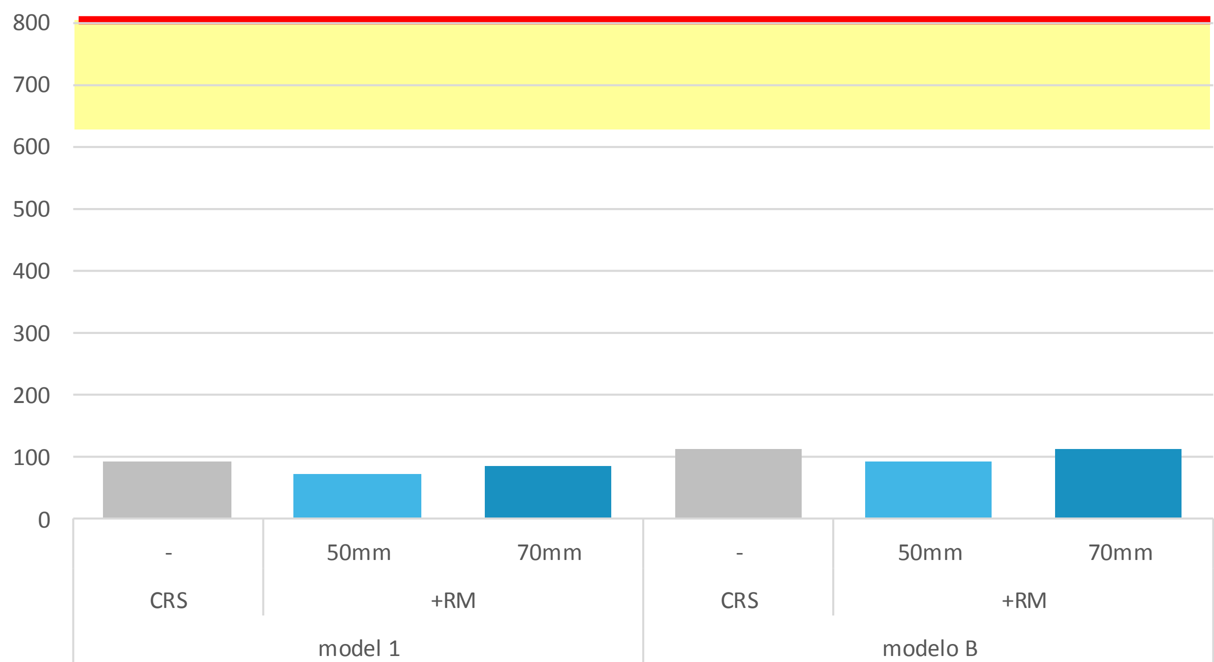

Figure 6. Q10 dummy HPC15 values (lateral impact)

From Figure 6 and Figure 7, it is obvious that the best results are obtained with a lateral displacement of 50mm, whereas a displacement of 70mm still yields better results than the baseline reference but is closer in value. Anyway, we decided to select the 70mm displacement as sort of a worst-case scenario and kept that displacement for the rest of the study as the case against which the baseline reference would be measured.

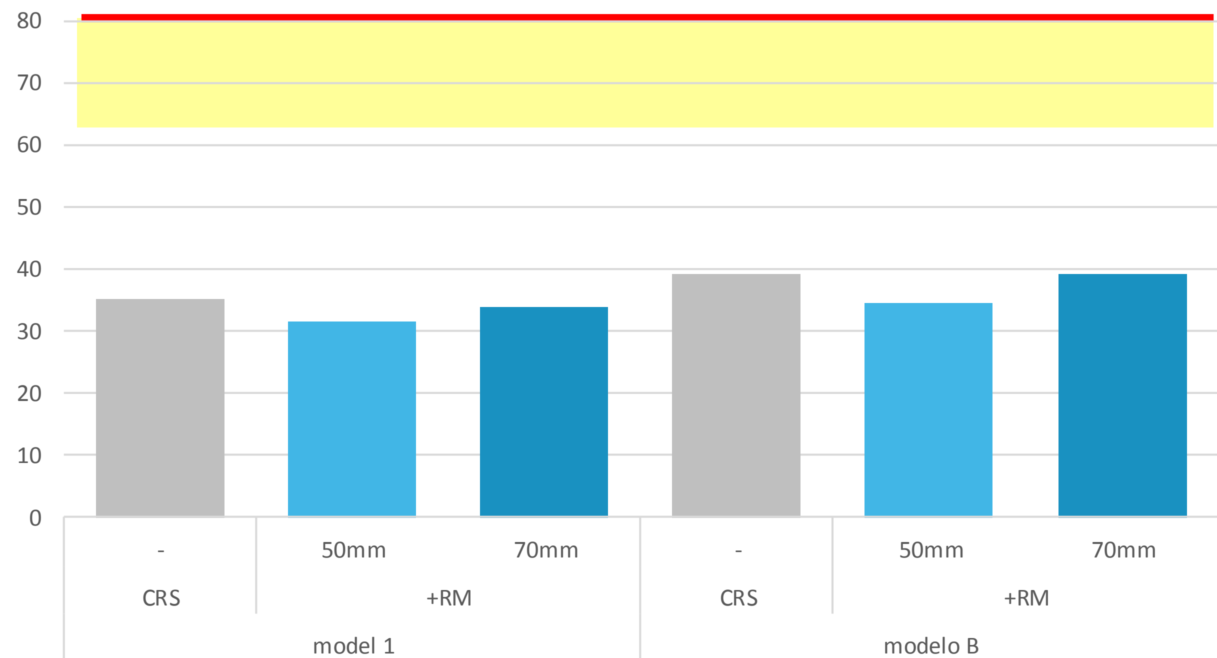

Figure 7. Q10 dummy 3ms head acceleration values (lateral impact)

Q6 dummy

Frontal impacts

For each CRS model tested, the first column presents the CRS-alone dummy readings while the second one gathers the corresponding CRS+ISOFIX accessory value, always with a 70mm displacement towards the door panel.

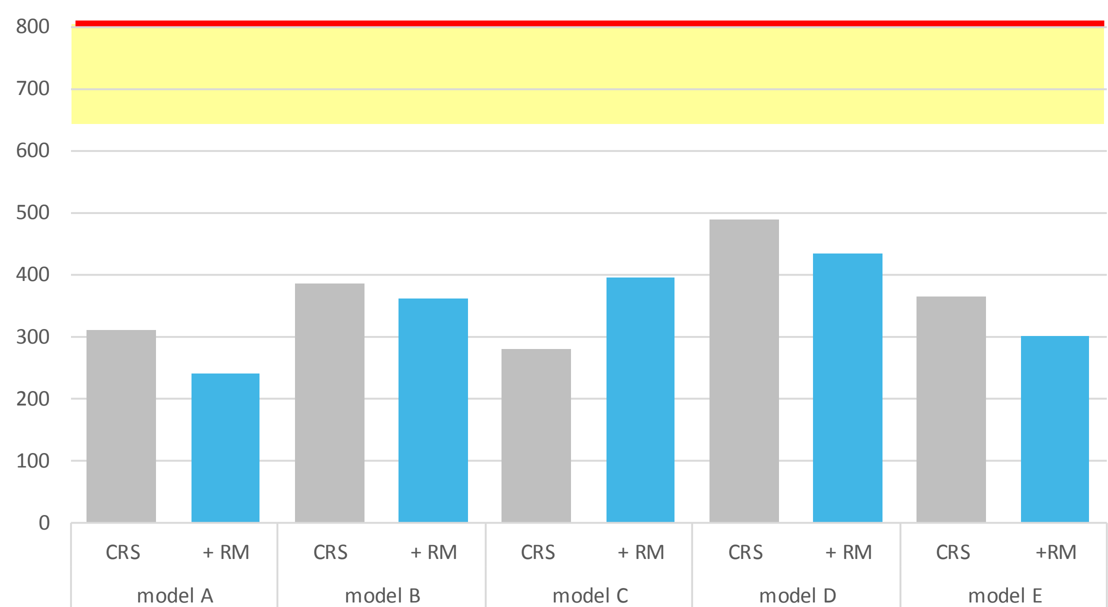

Figure 8. Q6 dummy HPC15 values (frontal impact)

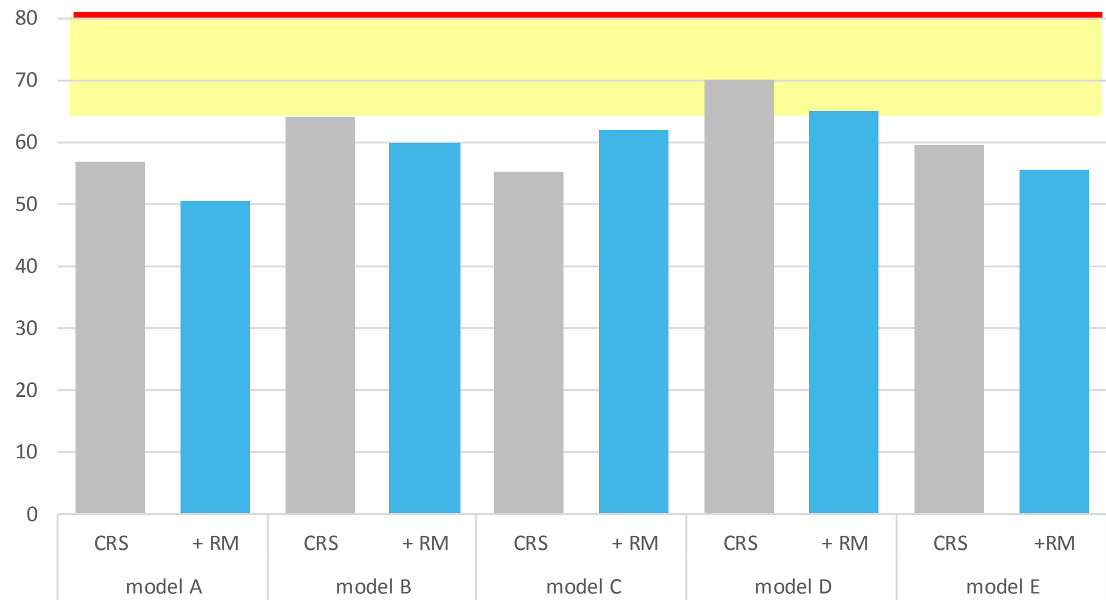

Figure 9. Q6 dummy 3ms head acceleration values (frontal impact)

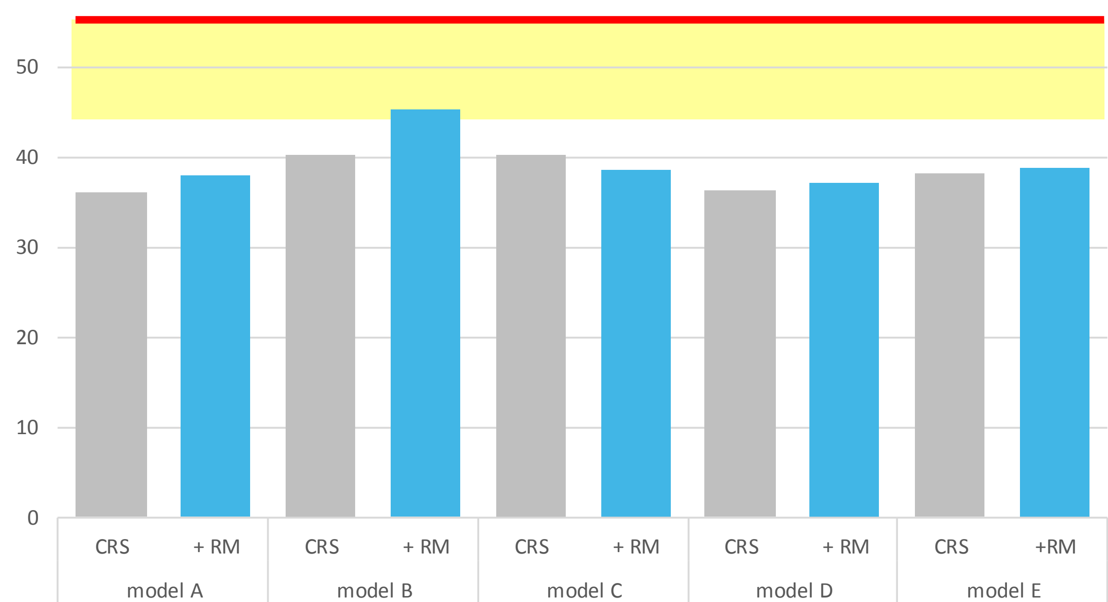

Figure 10. Q6 dummy 3ms chest acceleration values (frontal impact)

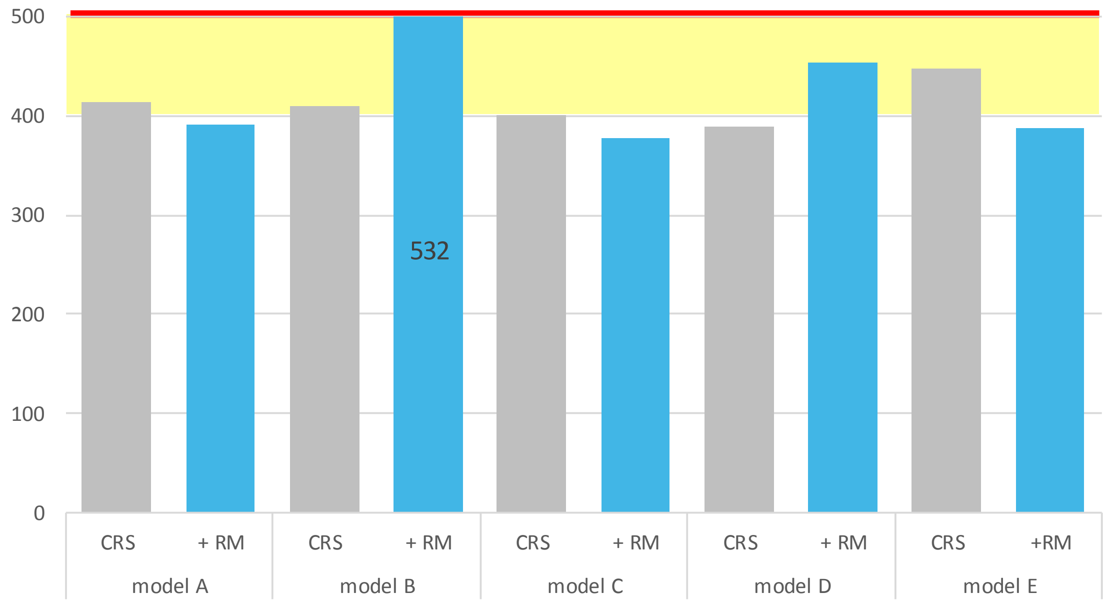

Figure 11. Q6 dummy head excursion X values (frontal impact)

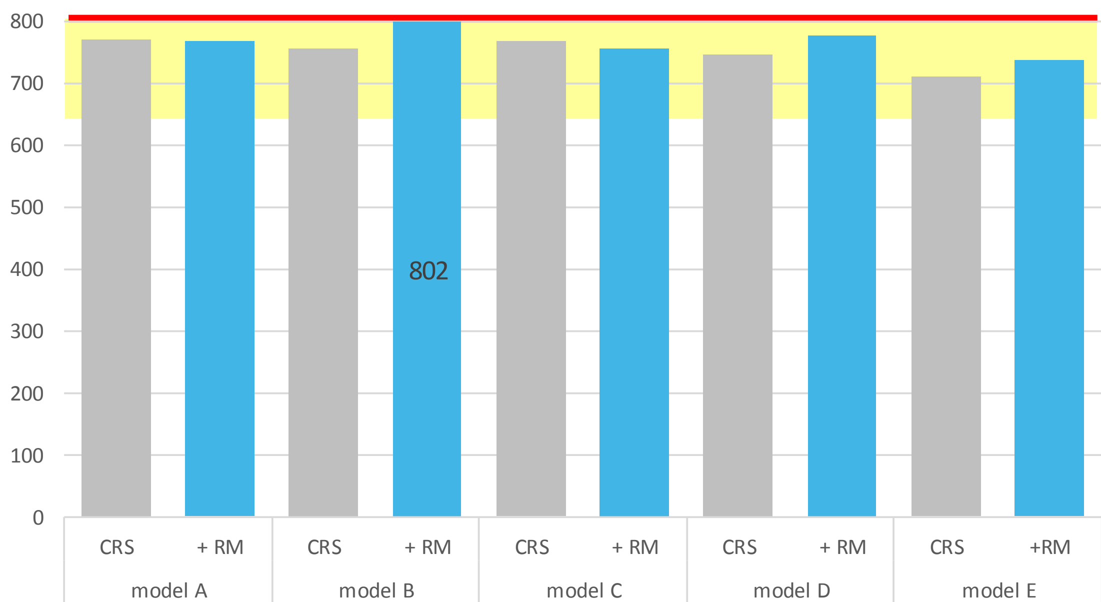

Figure 12. Q6 dummy head excursion Z values (frontal impact)

Generally, the overall performance of the CRS considered is improved by introducing the ISOFIX accessory: PDC15 and 3ms head acceleration values are reduced, with some increase in the 3ms chest acceleration. Regarding head excursion displacements in X and Z axis they're lower for most of the seats.

However, there are two major discrepancies to that statement. First, while the results for the baseline and the displaced configuration were within the average values for the other CRS models, the model C CRS behaved in a totally opposite way to the rest of the seats. Analysing in detail the tests, it was found that its bulky structure combined with the RiveMove device interfered with the anchorage points of the 3-points seatbelt.

The second issue is the excessive values for the head excursion obtained with the model B CRS, surpassing the limits defined in the normative. Model B is a CRS so rigid that prevented reclining the backrest so that it kept a uniform gap, top to bottom with the test bench. The detection of such a problem has led to a new line of work addressing this effect.

Both facts highlight the importance of installing the CRS properly guaranteeing enough space to avoid totally undesired contacts between the child's head and interior elements from the vehicle.

Lateral impacts

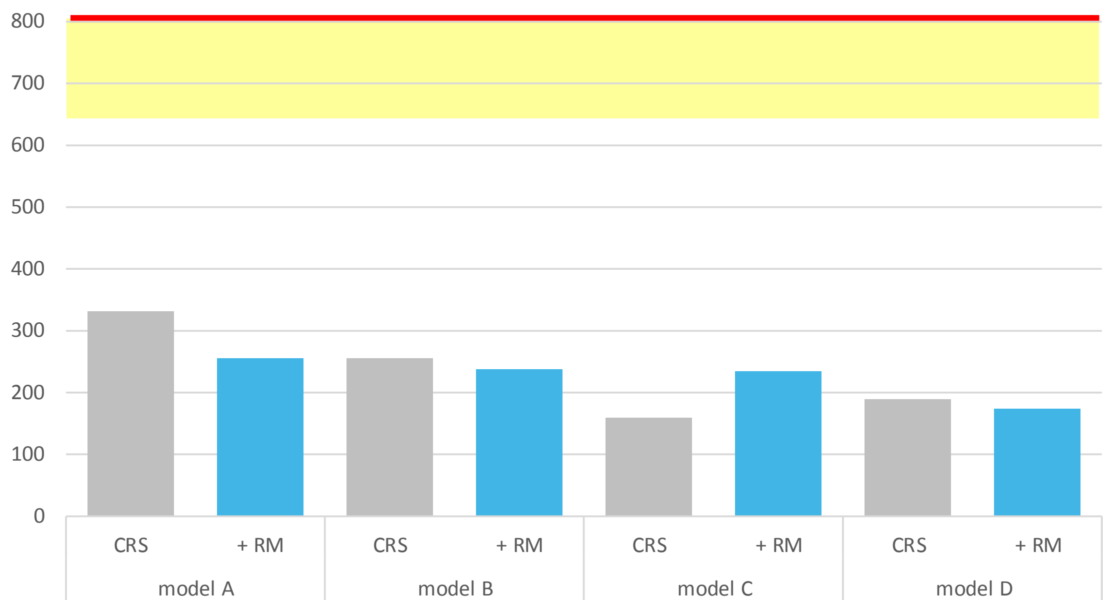

Figure 13. Q6 dummy HPC15 values (lateral impact)

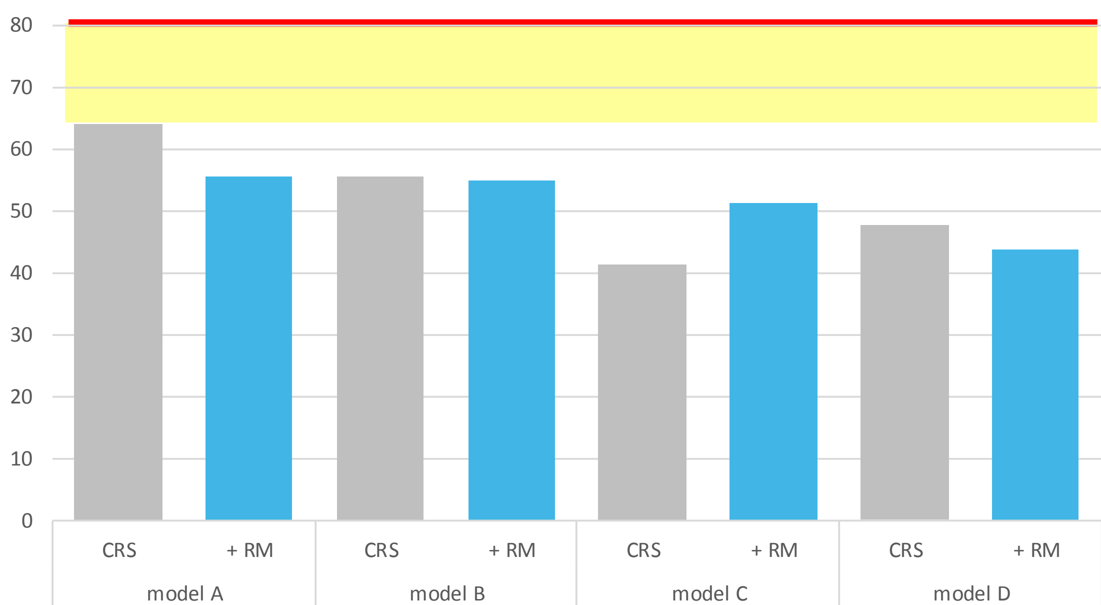

Figure 14. Q6 dummy 3ms head acceleration values (lateral impact)

Again, we face the same opposite behaviour of model C CRS compared to the rest due to the aforementioned interference with the 3-points seatbelt anchorage points. Nevertheless, the resulting values remained closed to the average values obtained with all the other CRS.

Figure 15. Resulting deformation in the RiveMove device (right) after one of the side impact tests

Q10 dummy

Frontal impacts

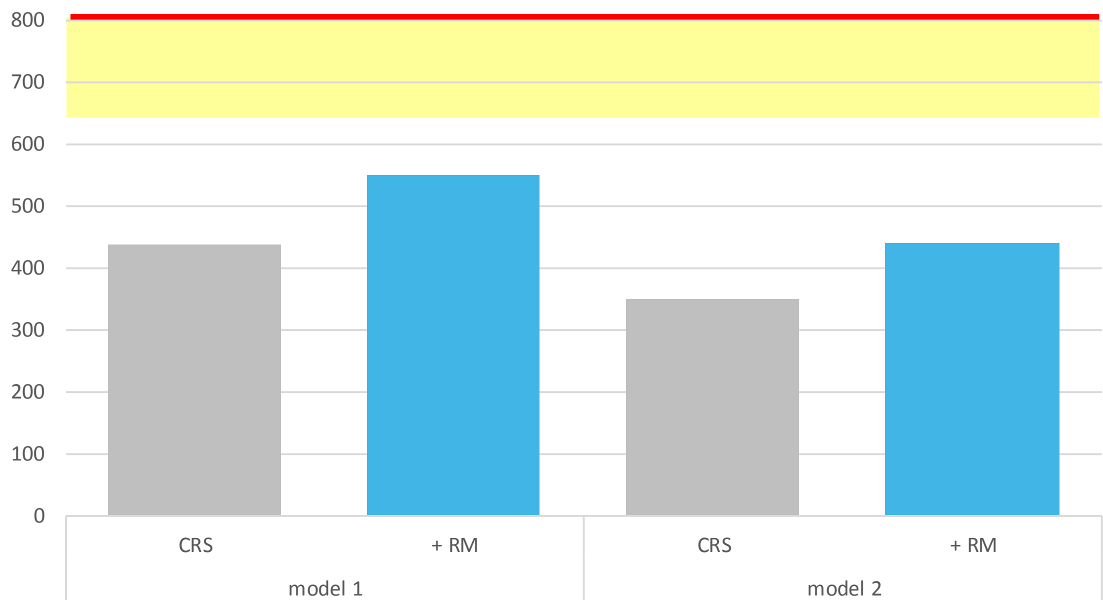

Figure 16. Q10 dummy HPC15 values (frontal impact)

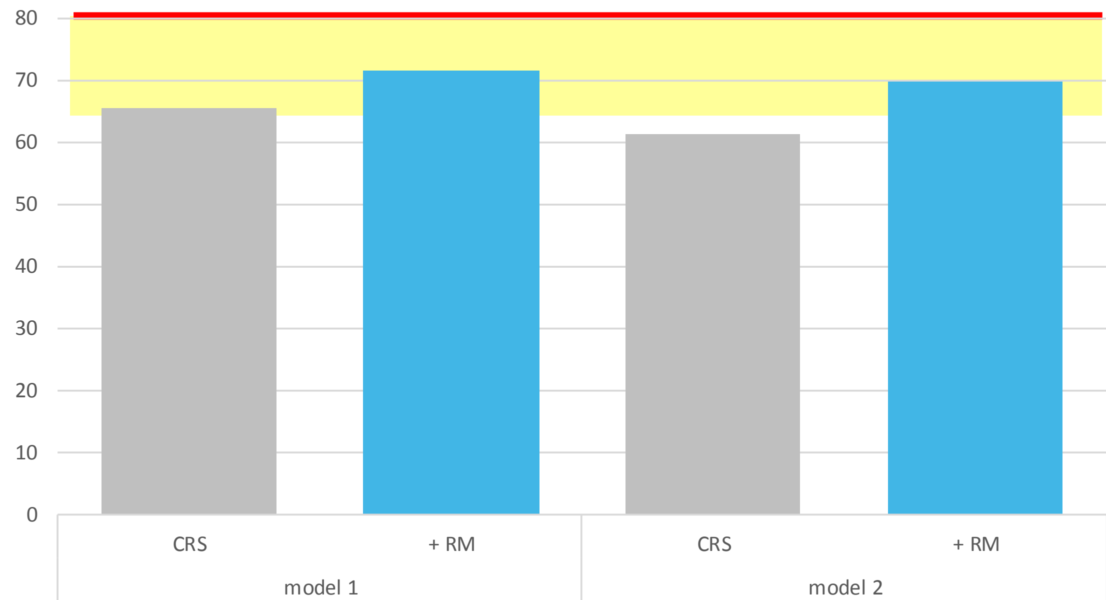

Figure 17. Q10 dummy 3ms head acceleration values (frontal impact)

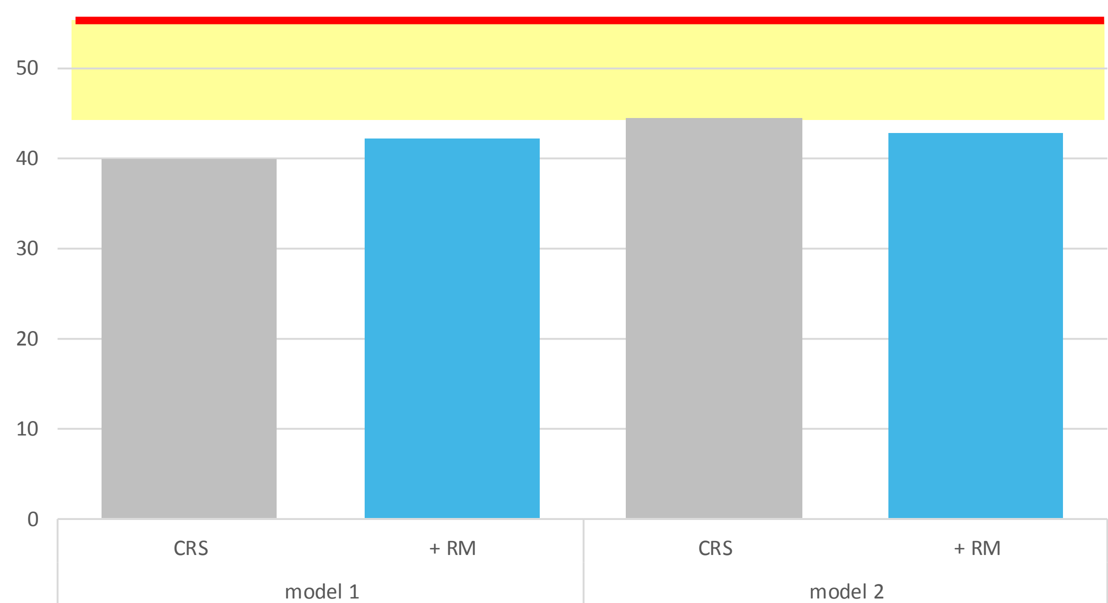

Figure 18. Q10 dummy 3ms chest acceleration values (frontal impact)

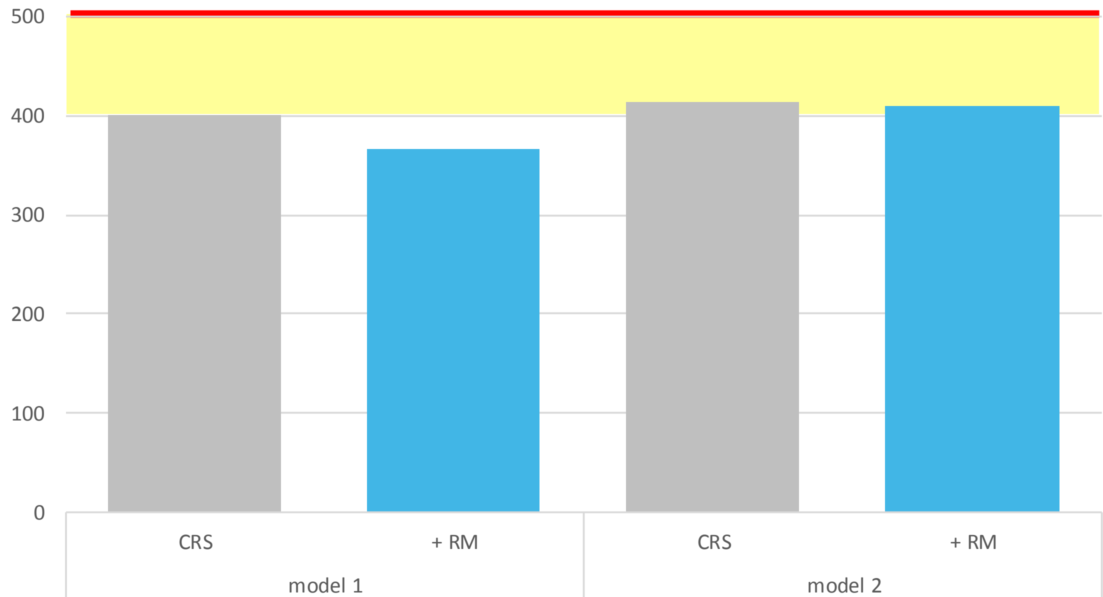

Figure 19. Q10 dummy head excursion X values (frontal impact)

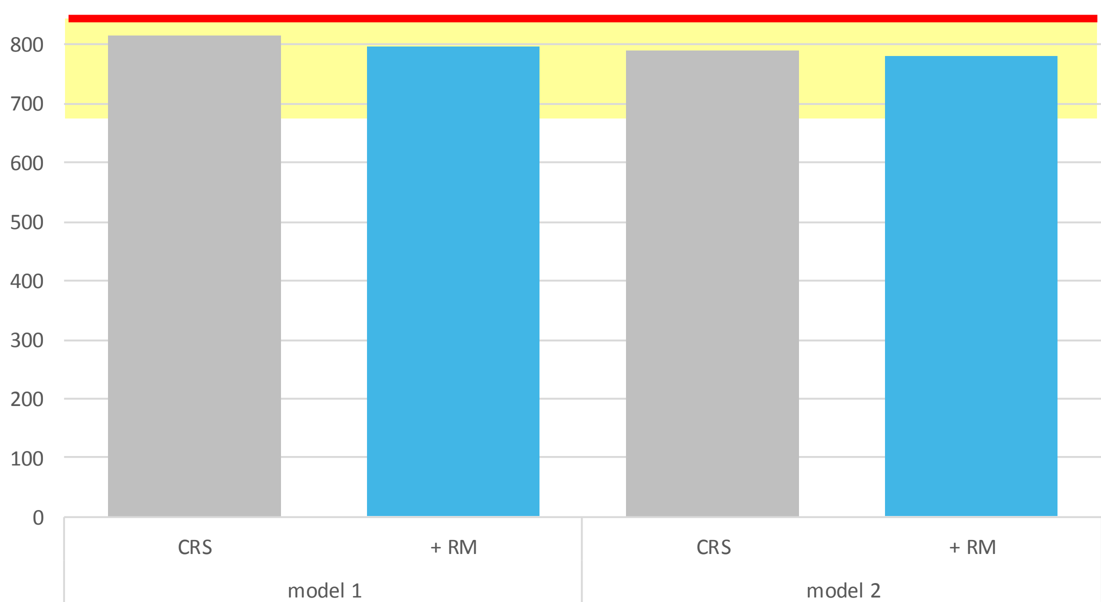

Figure 20. Q10 dummy head excursion Z values (frontal impact)

In this case, the dummy values obtained are worse for the HPC15 and 3ms head acceleration, whereas 3ms chest acceleration results were similar and the head excursion displacements slightly better.

Lateral impacts

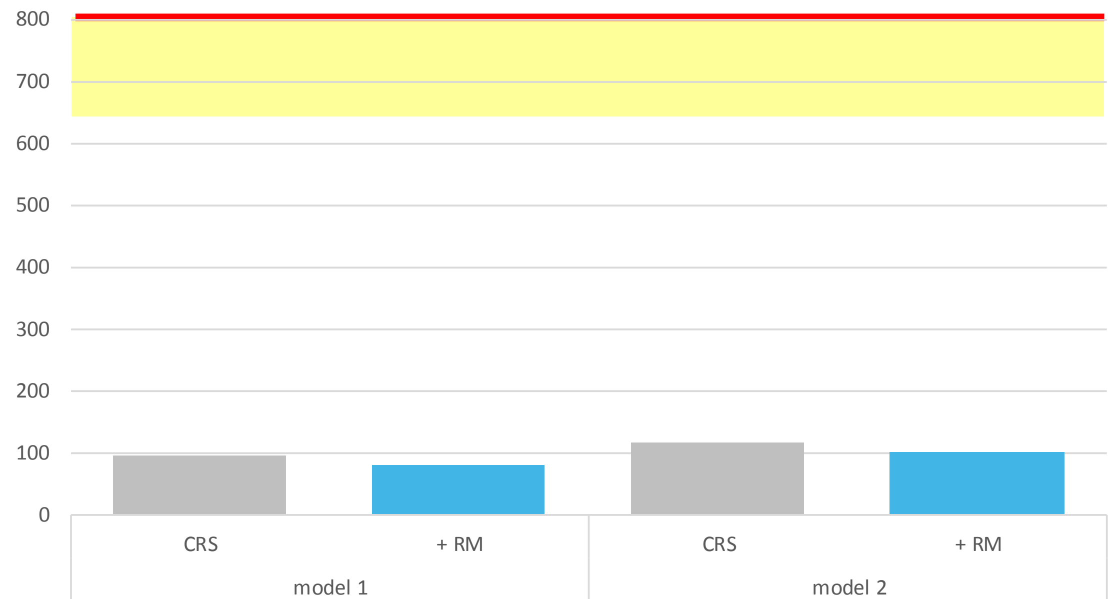

Figure 21. Q10 dummy HPC15 values (lateral impact)

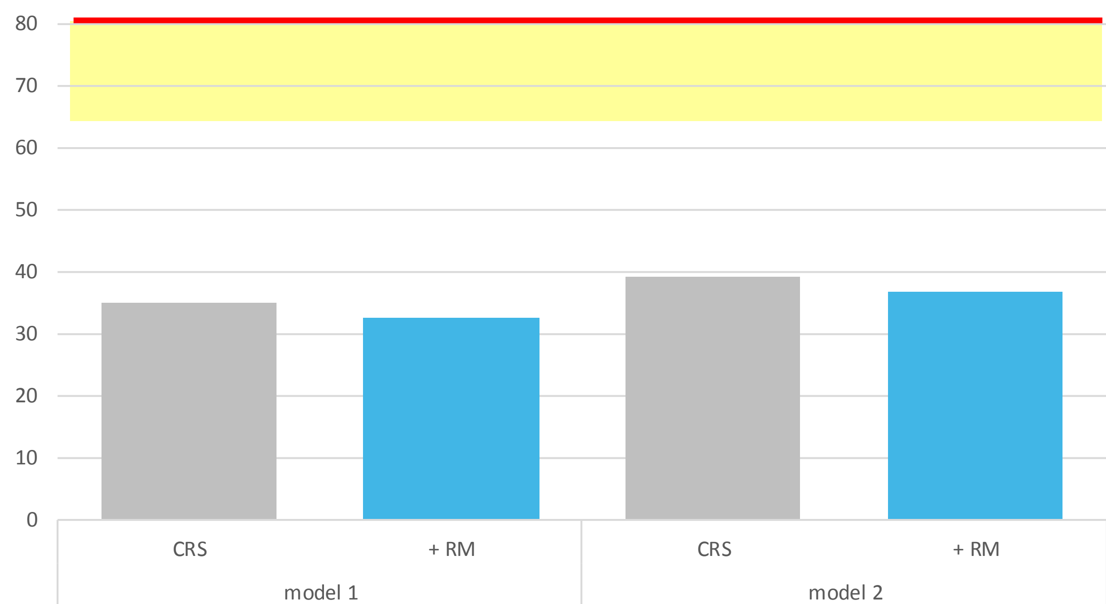

Figure 22. Q10 dummy 3ms head acceleration values (lateral impact)

With the CRS considered, both HPC15 and 3ms head acceleration results were improved compared to the baseline reference in side impacts using the Q10 dummy.

Regardless the size of the dummy and the CRS model used, the injury assessment criteria defined in ECE R129 for frontal and lateral impacts were never surpassed. Obviously not for the baseline references, but also for the CRS coupled with the ISOFIX accessory.

However, once did the head excursion limits were exceeded with a CRS whose backrest couldn't be properly rested against the test bench. It is so important to install properly the CRS and this particular case also proved that not every combination CRS + RiveMove is allowed.

Regarding side impact tests, it also should be mentioned that no head contact with the door panel was registered for any test, nor did the dummy head exceed the vertical plane identified on top of the door panel.

CONCLUSIONS

Unlike what was anticipated from existing bibliography, not only the risk of injury in lateral impact crashes did not increase for the struck-side occupant but the analysis of the results of the dynamic tests carried out showed improvements in the level of side impact protection. Thus, in the considered worst case scenario, with a 70mm displacement towards the door, the average HPC15, directly related with the expected level of damage in the event of an impact, measured for the Q6 dummy was 232.76, while the average HPC15 with the same seats moved closer towards the door panel was 225.08, a 3.3% improvement in average with improvements for one of the CRS of up to 22.5%. For the Q10 dummy the results were similar with an average HPC15 of 103.75 for the stand-alone CRS and an average HPC15 of 99.23 for the CRS coupled with the accessory device, a 4.4% improvement in this case. In every test performed, the resulting values remained below the limits designated in ECE R129 for the injury assessment criteria.

Taking into consideration as well the documented improvement in the general average risk of injury when using ISOFIX attachments for 3-abreast seating configurations, the results obtained show that the introduction of this new device could lead to important benefits on the safety of families, and children in particular, by providing an effective use of the central seat by any passenger (minimizing the possibilities of suffering whiplash injuries) or additional CRS, while retaining the ISOFIX connection for a CRS placed in a lateral seat. Specifically, side protection could be significantly improved preventing undesired yaw rotations, and the optimized space usage will allow extending the CRS usage period avoiding their premature removal due to the lack of space.

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