Q10 AND HIII-10 YO IN FRONTAL IMPACT: SENSITIVITY TO RESTRAINT SYSTEMS.

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ABSTRACT

Euro NCAP is planning to use a 6 and a 10 year-old anthropomorphic test device (ATD) in rear seats for frontal and side impact assessments.
A candidate for the 10 year-old ATD is the in-development Q10.
This paper compares the sensitivity of Q10 and HIII-10 year old (HIII) ATDs to pretensioner and force-limiter equipped 3-point belts, and to high back booster child restraint systems (CRS).

Q10 and HIII were placed on the rear bench of a compact vehicle body-in-white.
Sled tests were performed with a compact car 64kph ODB acceleration pulse under 4 different test situations:

1) No pretensioner/ no force limiter seatbelt & no CRS
2) With pretensioner/force limiter seatbelt & no CRS
3) No pretensioner/ no force limiter seatbelt & with CRS
4) With pretensioner/ force limiter seatbelt & with CRS

Both ATDs were equipped with standard instrumentation in the head, neck and chest. Q10 was additionally instrumented with abdomen pressure sensors.

Using a CRS resulted for both ATDs in a reduction of head acceleration 3msec and an increase of head longitudinal displacement compared to without CRS. Video analysis suggests that additional stroke originates from seatbelt moving out from the CRS belt guide. Without CRS, pretensioner/force-limiter seatbelt usage resulted for both ATDs, in a reduction of head acceleration 3msec and head forward displacement.
For both ATDs, usage of CRS increased the chest deflection (average: Q10=+45%, HIII=+10%). HIII responded to pretensioner/force-limiter with a decrease of chest deflection (average -10%), irrespectively of CRS use. Notably Q10 without CRS experienced chest deflection increase (+28%) when using pretensioner/force-limiter seatbelt, possibly due to a smaller shoulder belt migration towards the neck.
For Q10 dummy, usage of CRS significantly reduced the left abdomen pressure (-27% for no pretensioner/no force limiter seatbelt, -52% for pretensioner/force limiter one) by preventing the lap belt migration towards the abdomen.

Reported results are based on sled tests. Neither pitch nor yaw are represented despite being showed as potentially relevant for ATD kinematics [Deguchi et al., 2012].
In line with the results of the present study, belt migration to abdomen and neck have been reported for HIII 10 year-old to be less common when using CRS and chest deflection was reported to be higher when using a CR**S** [Tylko and Bussières, 2012].

In this study, differences in the chest deflection sensitivity to restraint systems were observed between Q10 and HIII dummies. Those differences presumably originate from the difference of behaviour of the shoulder belt on the dummies' chest. It was also observed for both dummies that the chest deflection was decreasing when the lap belt was sliding up towards the abdomen.

At this point, given the limited scope of this study, it cannot be concluded whether these belt sliding phenomena represent human characteristics or if it is a dummy artefact. Further investigation is needed.

Based on this study herein, the authors recommend using the abdomen pressure sensor when assessing restraint system performance as it seems to be able to identify differences in the phenomenon of lap belt migration.

INTRODUCTION

In Europe, even though the number of child passenger fatalities has decreased of more than 50% over the last decade, still a total number of 374 children (0-13 yrs) were fatally injured as a passenger during a car accident in the EU-19 during 2008 [Kirk et al. 2012].

According to 2008 statistical data in the EU-23 (see Figure 1) , the number of car passenger fatalities seems to decrease with age until 8 years-old, but rises again between 9 and 11 years old [Kirk et al. 2012].This increase suggests that attention needs to be paid for those "older children", at the limit between childhood and adolescence.

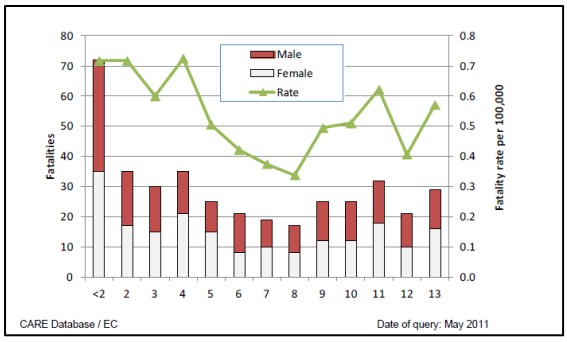

Figure 1. Child car passenger fatality number by age (2008, EU-23) [Kirk et al. 2012].

Current legislations in the EU on usage of child restraint systems for "older children" are not harmonised. For example, the usage of a child seat is mandatory until 10 years-old in France compared to 12 years-old (or 1.5m) in Germany.

From an accidents statistical study made by EEVC WG18 using a combination of European accident databases [EEVC 2008], the main body regions to be protected in frontal impact for children using a booster seat or a seatbelt are the head, the chest and the abdomen (see Figure 2). In that study, the chest injuries were found to increase for users of booster cushions compared to booster seats. This increase was attributed to the older age of booster cushion users, which appear to have less flexible chest compared to younger children. The injury outcomes for children using seatbelt only were worse than booster cushions, especially in the abdomen area.

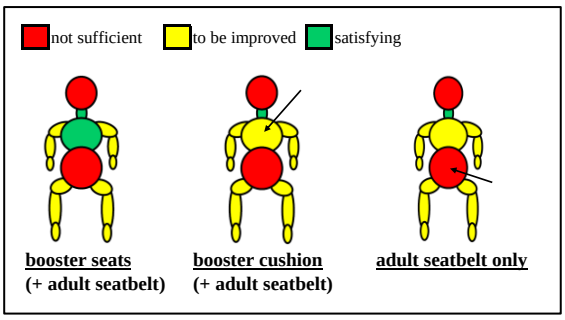

Figure 2. Protection level per child restraint type [EEVC 2008].

Even though many research projects are developing human child CAE models, currently the only tool available to estimate the protection offered by a vehicle or efficiency of a countermeasure are anthropomorphic test devices (ATDs), also called crash test dummies.

Available dummies to represent "older children" are the HIII-10 years-old dummy and the P10 dummy. A Q10 dummy is currently in development in Europe.

The HIII-10 years-old is part of the US-developed Hybrid III dummy family, whose first member, the 50th percentile male dummy, appeared in 1976. Hybrid IIIs are designed to evaluate protection performance in frontal crash.

The Q10 is part of the Q-series family, which was developed from 1993 in Europe under the International Child Dummy Working Group. The Q-series dummies were developed to be used in both frontal and side impact. Two first prototypes of the Q10 dummy are currently travelling around the world for round-robin testing.

Both HIII and Q10 dummies are instrumented to measure head accelerations, neck forces and chest deflections in order to assess impact loading to the corresponding body regions.

Q10 dummy can additionally be instrumented with Abdominal Pressure Twin Sensors (APTS) (currently prototype parts), consisting of 2 cylindrical bladders filled with gel-like material, inserted into the abdomen foam. The APTS sensor is intended to detect abdominal loadings by monitoring the pressure in the bladders.

The first purpose of this study is to compare the sensitivity of HIII-10 year-old and Q10 to the usage of a booster seat and to the usage of a pretenstioner+force limiter seatbelt. The second

purpose is to check the sensitivity of the Q10 APTS to potential different abdomen loadings from usage of booster and pretensioner+force limiter seatbelt.

METHOD

Frontal crash sled tests were performed using Q10 and HIII-10 year-old dummies. Both dummies were placed on the rear bench (symmetrical) of a compact car cut-body (no front seats). The sled was subjected to an acceleration pulse (longitudinal direction only, inverse sled test procedure) representing a compact car 64kph ODB crash test (see Figure 3).

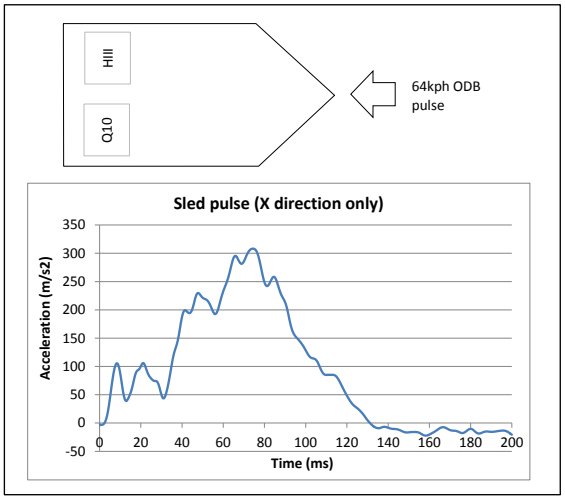

Figure 3. Test set-up.

The Q10 dummy used during this testing was one of the two prototypes used for round-robin testing in Europe, Asia and US.

Both dummies undertook a series of 4 tests. In each test, the dummies were restrained with 3-point seatbelts. For 2 tests, the dummies were sitting on a Group 2-3 high back booster CRS without Isofix. Test matrix (see Table 1) was developed to investigate sensitivity of both dummies to high back booster seat and to seatbelt equipped with both pretensioner (P/T) and force-limiter (F/L).

Table 1.
Test matrix

	Seatbelt	CRS	Dummies
Test 1	no P/T, no F/L	no CRS	Q10 (right), HIII (left)
Test 2	P/T + F/L	no CRS	↑
Test 3	no P/T, no F/L	CRS	↑
Test 4	P/T + F/L	CRS	↑

Both dummies were equipped with standard instrumentation in the head, neck and chest. Q10 was additionally equipped with a prototype version of Abdominal Pressure Twin Sensors (APTS).

In addition to dummy instrumentation, 2 high-speed cameras monitored the kinematic of both dummies in side and front views. The side view was used to measure head longitudinal displacement relative to initial head position.

RESULTS

As no front seats were installed on the cut-body, no head contact occurred during the tests. Even though head acceleration 3msec value is commonly used to assess head protection level in case of head contact, it was computed and given as an indication of the loading to the head.

All values provided in the graphs are normalised with respect to a base condition, indicated on each graph. In case of time-history plots, the maximum value of the base condition is set to 100.

Sensitivity to usage of CRS

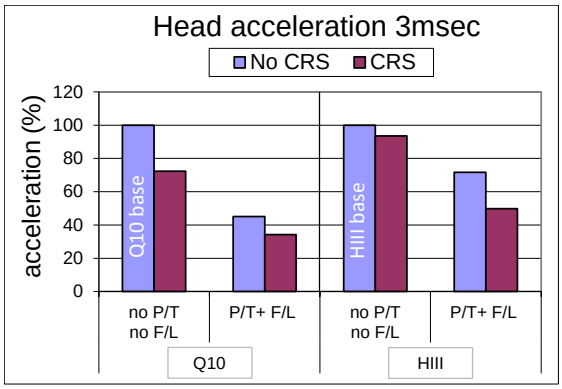

Figure 4. Influence of CRS on Head Acc. 3msec.

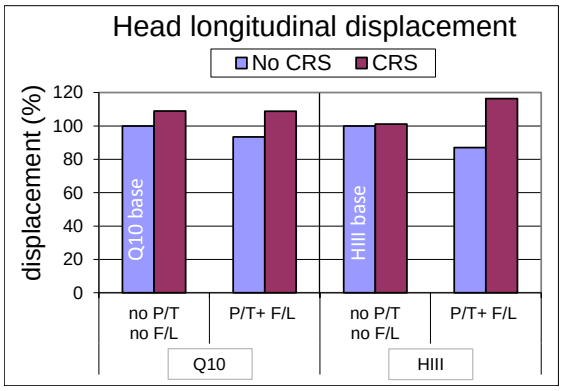

Figure 5. Influence of CRS on head displacement.

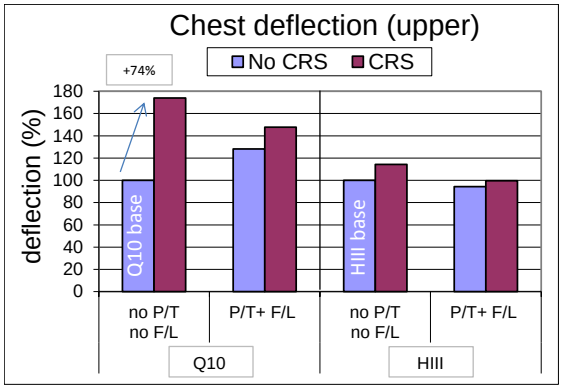

Figure 6. Influence of CRS on chest deflection.

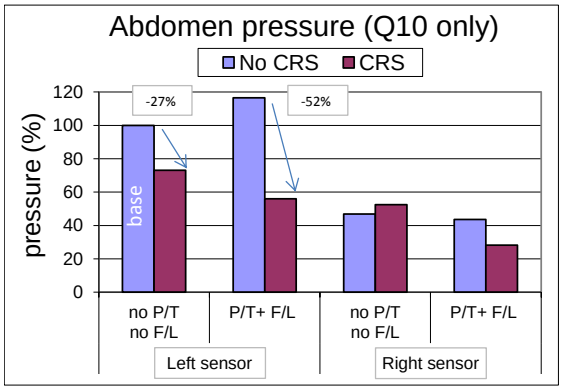

Figure 7. Influence of CRS on abdomen pressure.

For head assessment, both HIII and Q10 dummies showed similar sensitivities: head acceleration 3msec decreased (see Figure 4) and head longitudinal displacement increased (see Figure 5) when using CRS. This trend might be explained by the shoulder belt moving out from the CRS belt guide, as illustrated in Figure 8. This suggests a force limiter effect, reducing the head acceleration 3msec and at the same time increasing the head longitudinal displacement.

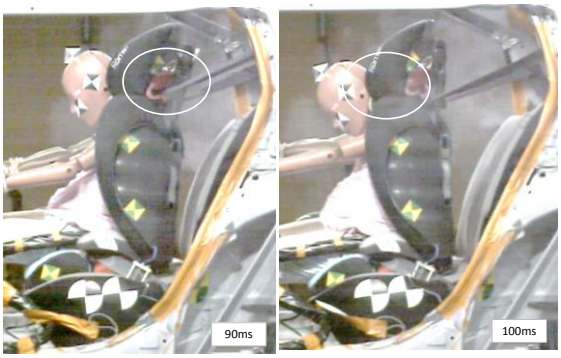

Figure 8. Shoulder belt moving out from belt guide.

For the chest, both dummies showed increase of chest deflection when using a CRS (see Figure 6). But Q10 particularly showed a high chest deflection increase when using a CRS, with 74% more chest deflection than without CRS.

For HIII, the difference of chest deflection may be explained by the lap belt sliding off the pelvis into the abdomen when no CRS is used (see Figure 9). When comparing chest deflection of HIII with and without CRS (see Figure 10), it can be seen that chest deflection starts to be lower in case no CRS is used when the lap belt starts sliding towards the abdomen.

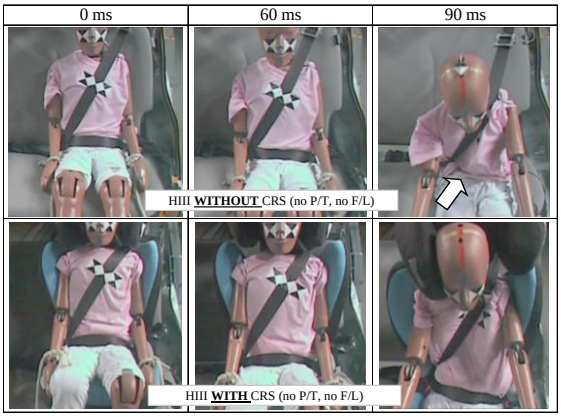

Figure 9. HIII without CRS shows lap belt sliding into the abdomen (90ms, top), but not when using a CRS (90ms, bottom).

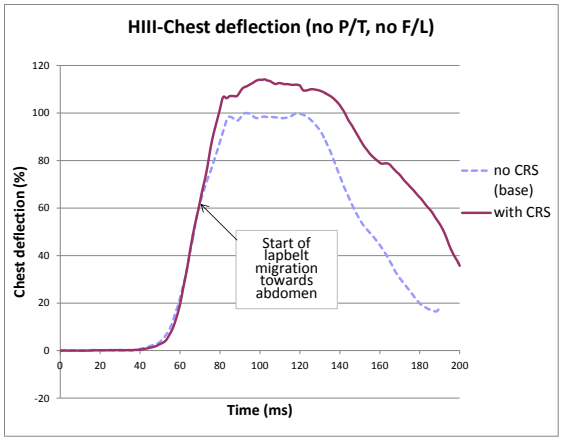

Figure 10. HIII chest deflection vs. time (no P/T, no F/L).

For Q10, difference of chest deflection between with CRS and without CRS appears much earlier than the lap belt migration towards the abdomen (see Figure 11). This difference seems to be the consequence of the shoulder belt sliding towards the neck (and therefore away from deflection measurement point). Indeed, in case Q10 is not using a CRS, the shoulder belt slides more towards the neck than when using a CRS (see Figure 12). The CRS belt guides and seatback seemed to partially limit the shoulder belt from sliding towards the neck. This sliding phenomenon is not seen in any of the HIII tests.

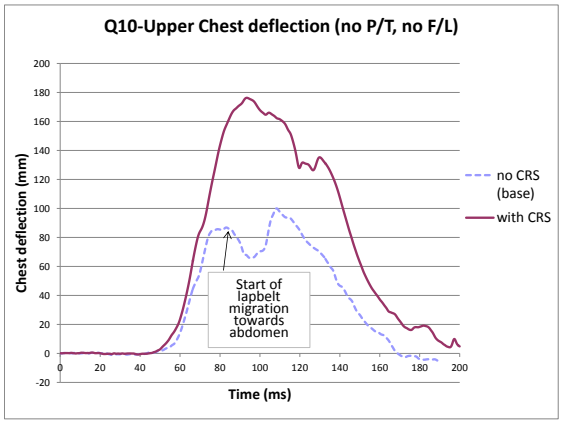

Figure 11. Q10 chest deflection vs. time (no P/T, no F/L).

Figure 12. Q10 (no P/T, no F/L). Belt slides more towards the neck in case of no CRS.

For Q10, abdomen pressure was measured (see Figure 7). The usage of CRS significantly reduced the left abdomen pressure (-27% for no pretensioner/no force limiter seatbelt test and -52% for pretensioner/force limiter one).

During the tests without CRS, the lap belt moved upwards on the buckle side (left side) and then migrated towards the left area of the abdomen (see Figure 13).

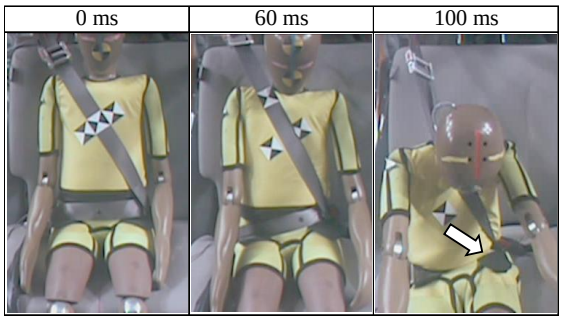

Figure 13. Q10 without CRS (P/T+F/L seatbelt). At 60ms, lap belt in diagonal position. At 100ms sliding into the left area of the abdomen.

This phenomenon of lap belt migration towards the abdomen did not occur in case a CRS was used and the abdomen pressure sensors were able to identify this difference.

Sensitivity to seatbelt with P/T and F/L

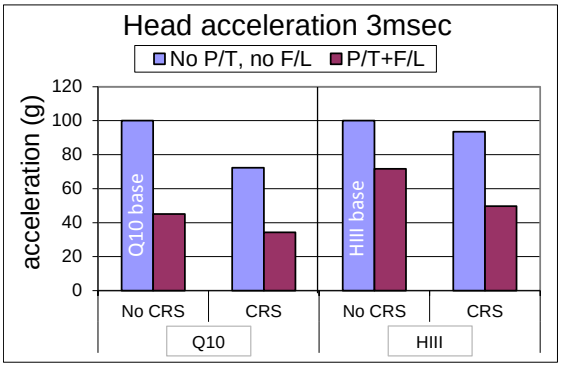

Figure 14. Influence of P/T and F/L on Head Acc. 3msec.

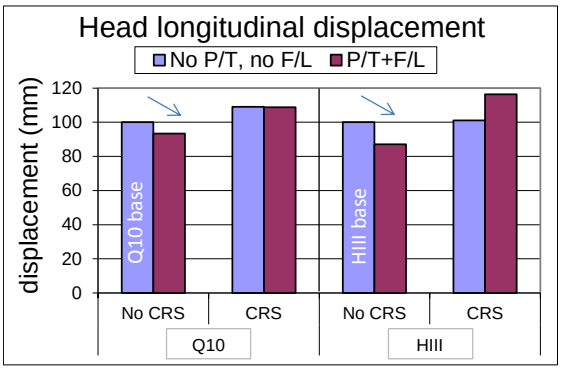

Figure 15. Influence of P/T and F/L on head displacement.

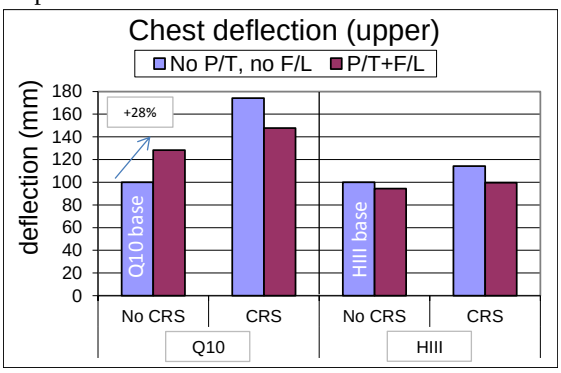

Figure 16. Influence of P/T and F/L on chest deflection.

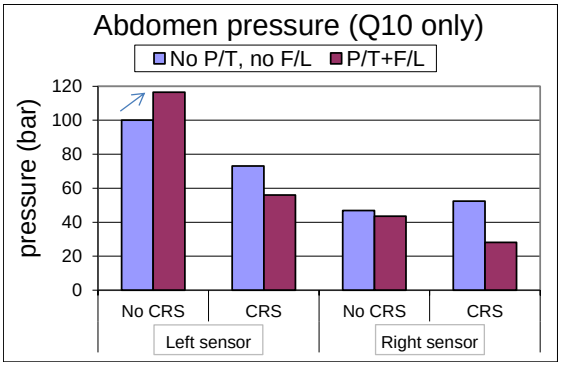

Figure 17. Influence of P/T and F/L on abdomen pressure.

For the head, both dummies showed similar sensitivities to the usage of P/T and F/L (see Figure 14 and Figure 15). In these tests, usage of P/T and F/L resulted in a reduction of head acceleration 3msec. In case no CRS were used, both dummies showed reduction of head longitudinal displacement. For HIII with CRS, the usage of P/T and F/L resulted in an increase of head longitudinal displacement.

For the chest deflection, the use of P/T and F/L seatbelt resulted in a reduction of chest deflection for both dummies, except in the case of Q10 without CRS (see Figure 16). This tendency is not in line with forces indicated by the shoulder belt force gage (see Figure 18), which indicates that the shoulder belt force was lower when using the force pretensioner and force limiter seatbelt.

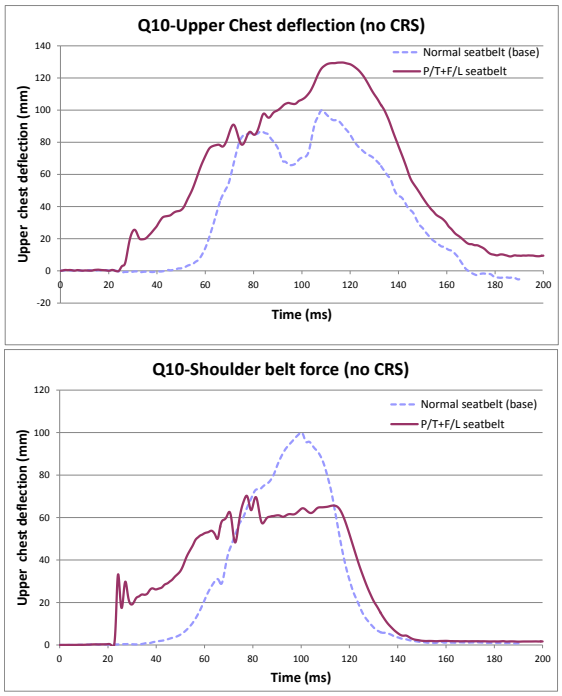

Figure 18. Q10 chest deflection and shoulder belt force (no CRS).

This increase of chest deflection in case Q10 uses a F/L and P/T seatbelt can be explained by the position of the shoulder belt on the chest during the test. As it can be seen on Figure 19, when Q10 is not using the pretensioner and force limiter seatbelt, the shoulder belt tends to slide more towards the neck. For HIII, no sliding of the seatbelt towards the neck is observed.

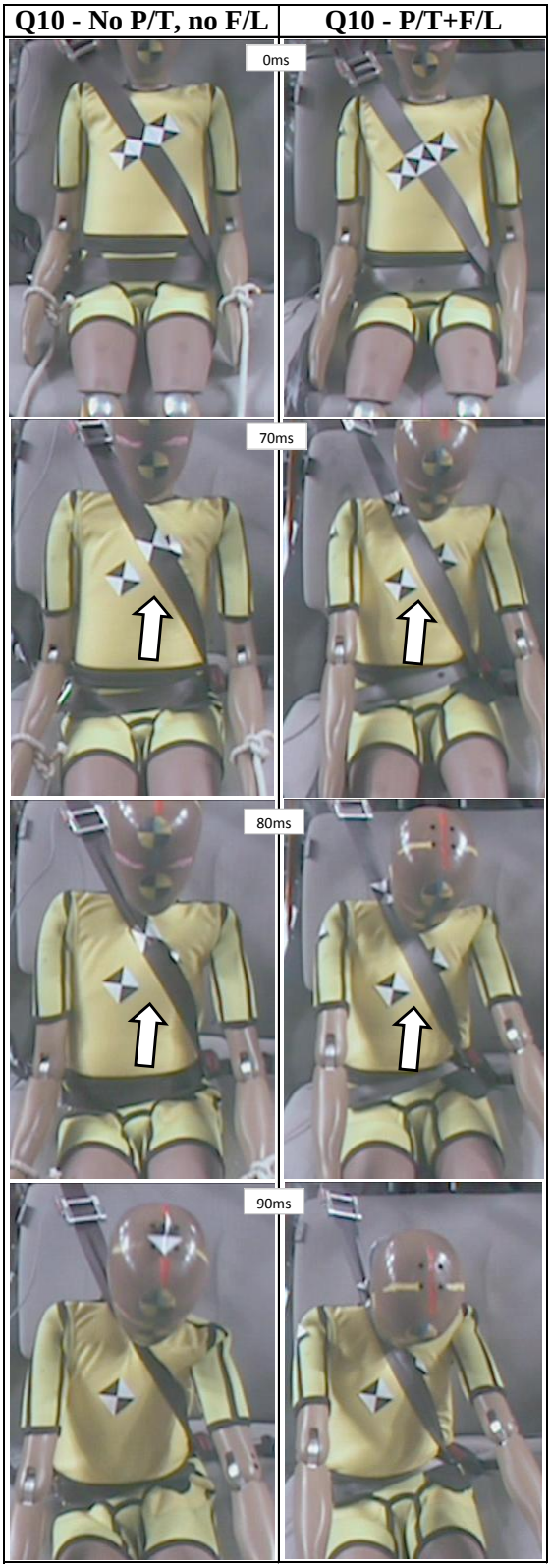

Figure 19. Q10 (no CRS). Belt slides more towards the neck in case of no P/T, no F/L seatbelt.

For Q10 abdomen pressure, in case no CRS was used, the usage of P/T and F/L seatbelt appeared to increase the left abdomen pressure (see Figure 17). From the Pressure vs Time graphs in Figure 20 , it can be confirmed that this increase is not due to the

early tension from the pretensioner, but occurs after the belt migration towards the abdomen.

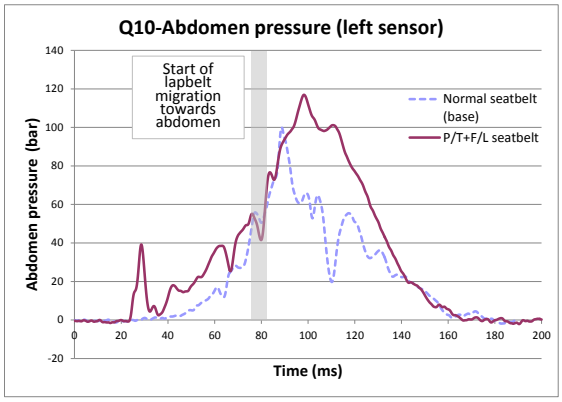

Figure 20. Q10 abdomen pressure (no CRS).

The difference of abdomen pressure in that case might be explained by the shoulder belt path passing more on the abdomen in the case of P/T and F/L seatbelt (see Figure 19, 90ms), and therefore adding to the pressure from the lap belt only.

DISCUSSIONS

This limited study reports the results of 4 rear seat uniaxial sled tests. Neither pitch nor yaw are represented despite being showed as potentially relevant for ATD kinematics [Deguchi et al., 2012]. In this study, only one type of seatbelt anchorage position, force limiter, seat geometry and stiffness, and CRS were used. Therefore, one must be careful with generalisation of these results.

In line with the results of the present study, belt sliding to abdomen and neck have been reported for HIII 10 year-old to be less common when using CRS and chest deflection was reported to be higher when using a CRS [Tylko and Bussières, 2012].

The phenomenon of belt migration towards the neck for Q10 was recently reported [Bohman, 2012].

CONCLUSION

In this study, differences in the chest deflection sensitivity to restraint systems were observed between Q10 and HIII dummies. Those differences presumably originate from the difference of behaviour of the shoulder belt on the dummies' chest. In all tests, Q10 exhibited a sliding up of the shoulder belt towards the neck, whereas no sliding of the shoulder belt was observed for the HIII.

In this study, it was also observed for both dummies that the chest deflection was decreasing when the lap belt was sliding up towards the abdomen.

At this point, given the limited scope of this study, it cannot be concluded whether these belt sliding phenomena represent human characteristics or if it is a dummy artefact. Further investigation is needed.

Based on this study herein, the authors recommend using the abdomen pressure sensor when assessing restraint system performance as it seems to be able to identify differences in the phenomenon of lap belt migration.

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