Responses of Hybrid III 3YO and Q3 Dummies in Various CRSs Tested Using ECE R44 Impact Conditions

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ABSTRACT

There are various types of child restraint systems (CRSs), and the child kinematic response behavior during a crash is different according to which CRS type is being used. In general, P3, Q3 and Hybrid III 3-year-old (3YO) dummies are used to evaluate the performance of the forward-facing CRSs in sled and crash tests. In this study, the Hybrid III 3YO and Q3 dummies were seated in 7 types of CRSs and were tested under the impact conditions specified in ECE R44. The tested CRSs include a 5-point harness and an impact shield, and their installations on the vehicle seat were accomplished by using the seat belt or the ISOFIX with a top tether. The dummy response and injury measures were compared.

The neck flexed in the 5-point harness CRS and the chest deflection was small due to the shoulder harness restraint. In the impact shield CRS, the chest was loaded and the chest deflection was large. The chest deflection in the impact shield CRS depends on the shield structure, and it was small when the shield supported the pelvis. For the 5-point harness CRS, the injury measures of the dummy were smaller in the ISOFIX CRS with a top tether than in the seat belt installed CRS, especially that for the head excursion. For the impact shield CRS, the injury measures were comparable between the ISOFIX CRS with a top tether and in the seat belt installed CRS.

The global dummy kinematic behavior was comparable between the Hybrid III 3YO and Q3 dummies, though the Q3 showed more flexible behavior. This less-stiff characteristics of the Q3 affected the head kinematic behavior. In the 5-point harness CRS, the neck tension force of the Q3 was higher than that for the Hybrid III 3YO, possibly because the Q3 head severely contacted the chest due to its less-stiff neck. The chest deflection of the Q3 was larger than that of Hybrid III 3YO. This large chest deflection was more prominent for the impact shield CRS where the chest was directly loaded. The bottoming-out of the chest occurred for the Hybrid III 3YO seated in the impact shield CRS.

INTRODUCTION

There are various types of child restraint systems (CRSs) such as 5-point harness and impact shield CRS. Langwieder et al. [1] have shown that the injury risks to children were low in the impact shield CRS. This likely is due to less frequent misuse of the impact shield CRSs. However, in an impact shield CRS tested in the Japan New Car Assessment Program (JNCAP) CRS test, the chest deflection of the Hybrid III 3YO dummy was so large that a bottoming-out of the chest occurred.

In Japan, the Japan Automobile Federation (JAF) examined CRS usages in the field. Seventy percent of CRSs were misused, and most of the misuse was due to seat belt slack that was introduced during installation of the CRS on the vehicle seat. An ISOFIX installation reduces this kind of misuse. On the other hand, since the ISOFIX CRS with a top tether is tightly connected to the vehicle seat, the impact response of a child seated in the ISOFIX CRS with a top tether could be affected by the vehicle acceleration.

In the ECE R44, a P dummy is specified for use in the dynamic test of the CRS. However, it is indicated that the measurement capacity of the P dummy is limited. Therefore, a new child dummy, the Q dummy, was developed and is under investigation. Meanwhile, in the US, the Hybrid III 3YO (3-year-old) dummy is used in the FMVSS 213. In Japan, the Hybrid III 3YO dummy is used in JNCAP to evaluate the dynamic performance of forward facing CRSs.

There are some studies that have compared the Hybrid III 3YO, P3 and Q3 dummies. Ratingen [2] compared the P3 and Q3 behavior in the ECE R44 test. He concluded that the injury measures of both dummies were comparable if the injury criteria prescribed in the ECE R44 were used. Crandall et al. [3] identified the mechanical characteristics of the neck of the Hybrid III 3YO and Q3 dummies based on laboratory testing, and indicated that the Hybrid III 3YO neck has a stiffer spring constant than that of the Q3. Berliner et al. [4] examined the dummy responses of the Hybrid III 3YO and Q3 dummies in dummy calibration tests and static out-of-position airbag tests. In the dummy thorax pendulum impact calibration test condition, the Q3 showed stiffer chest characteristics than the Hybrid III 3YO. Based on finite element (FE) simulations, Kapoor et al. [5] compared the kinematic behavior of the Hybrid III 3YO and Q3, under the FMVSS 213 test condition. The acceleration of the head and chest was comparable between the Hybrid III 3YO and the Q3. The neck of the Hybrid III 3YO was stiffer than that of the Q3. The head excursion of the Q3 was larger than the Hybrid III 3YO. They also compared the Hybrid III 3YO and Q3 dummy responses with a child FE model, and found that the Q3 responses are more comparable with the child FE model with respect to the head excursion and neck stiffness.

In this study, sled tests were carried out using Hybrid III 3YO and Q3 dummies seated in 7 types of CRSs. The dummy responses were compared for a 5-point harness CRS and an impact shield CRS under install conditions on the vehicle seat by a seat belt and by an ISOFIX with a top tether. The Hybrid III 3YO and Q3 kinematic behavior and injury measures were compared for these various types of CRSs.

METHOD

Test Conditions

Figure 1 and Table 1 show the tested CRSs and their specifications. In classification of child restraint type, CRSs A, B, C are an impact shield CRS, and the CRSs D, E, F, G are a 5-point harness CRS. In classification of CRS installation on vehicle, the CRSs A, B, D, F are installed by the seatbelt, and CRSs C, E, G are an ISOFIX with a top tether type CRS. The CRSs B and C, CRSs D and E, or CRSs F and G are models made by the same manufacturer, and the difference between the two models is the car seat installation of the CRS with a seat belt or with an ISOFIX and a top tether. In a CRS A tested in JNCAP, the chest deflection of the Hybrid III 3YO was so large that the chest was bottomed out. The CRSs A and B are an impact shield type CRS, and the shield height of CRS B was higher than that of CRS A, which covered an area ranging from the thorax to the pelvis of the dummy. The two types of 5-point harness CRS were tested in order to confirm that the same type CRS has comparable performance of dummies kinematic behavior and injury measures.

Figure 2 shows the tested dummies. As indicated above, Hybrid III 3YO and Q3 dummies were used in the tests.

Test conditions with CRS and dummy are presented in Table 2. An acceleration-type sled facility was used in the tests (Figure 3). The tests were conducted in accordance with ECE R44 with the exception that the Hybrid III 3YO and Q3 dummies were used instead of the P3 dummy. The acceleration of the sled and its corridors are shown in Figure 4. Table 3 shows the injury assessment reference values (IARVs). HIC15, neck tension force, chest deflection, and head excursion are checked as dummy injury criteria. The dummy injury measures were compared with the IARVs. For the Hybrid III 3YO, the acceptance levels of FMVSS 208 were used. For the IARVs of the Q3, the AIS 3 at a 50% risk level was used as based on the logistic regression (LR) injury risk curves from the EEVC report [6].

(a) A (b) B (c) C

(d) D (e)E

(f) F (g) G

Figure 1. Tested CRSs

Table 1. Type of tested CRSs

CRS	A	B	C
type of restraint	impact shield	impact sheild	impact shield
type of anchorage	seat belt	seat belt	ISOFIX + top tether

CRS	D	E	F	G
type of restraint	5-point harnes	5-point harness	5-point harness	5-point harness
type of anchorage	seatbelt	ISOFIX + top tether	seat belt	ISOFIX + top tether

(a) Hybrid III 3YO (b) Q3

Figure 2. Tested dummies

Table 2. Test conditions

Test No.	1	2	3	4	5
CRS	A	B	C	D	E
Dummy	Hybrid III 3YO	Hybrid III 3YO	Hybrid III 3YO	Hybrid III 3YO	Hybrid III 3YO

Test No.	6	7	8	9	10
CRS	F	G	A	B	C
Dummy	Hybrid III 3YO	Hybrid III 3YO	Q3	Q3	Q3

Test No.	11	12	13	14
CRS	D	E	F	G
Dummy	Q3	Q3	Q3	Q3

Figure 3. Sled system

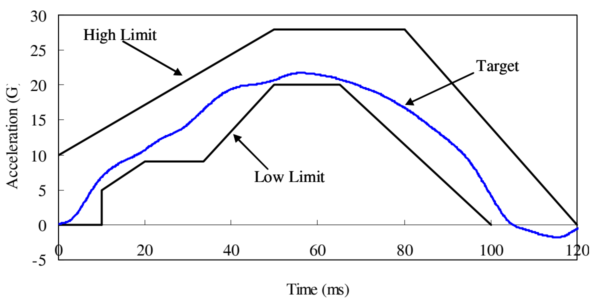


Figure 4. Sled acceleration

Table 3. Injury criteria

injury criteria	IARV	
	Hybrid III 3YO (FMVSS208)	Q3 (EEVC report)
HIC15	570	1000
Neck tension force	1130 N	1705 N
Chest deflection	34 mm	53 mm
Head excursion	550 mm	550 mm

FE Simulation

To examine the interaction of the shield with a dummy, an FE simulation with a Hybrid III 3YO dummy model using LS-DYNA was carried out. The FE models of CRS A and B were developed because they have difference in the shield shape. Figure 5 shows the CRS model.

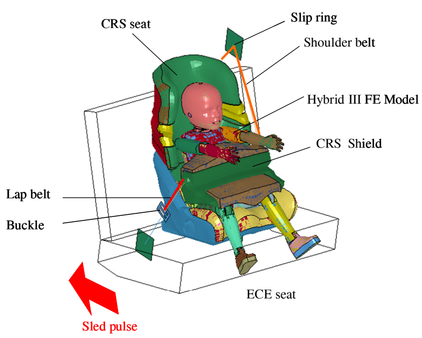


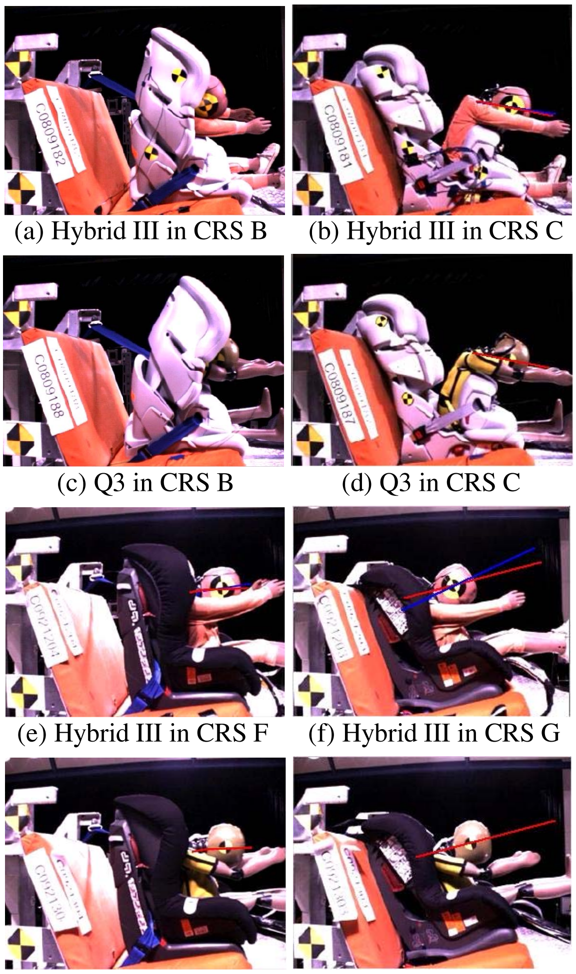
Figure 5. FE model for the CRS sled test

RESULTS

Sled Tests

Dummy Kinematic Behavior

The dummy showed different kinematic behavior according to which CRS type was being used. Figure 6 shows the kinematic behavior for a dummy seated in the impact shield CRSs (CRS B and C) and the 5-point harness CRSs (CRS F and G) at the point in time during the test when the head excursion was at its maximum. In the impact shield CRSs, the dummies were restrained by the shield and the torso flexion angle was large. The head made contact with the shield. The dummies in the CRSs installed with a seat belt had substantial yawing rotation while the dummies in the ISOFIX CRSs with a top tether had no yawing rotation. The dummies' forward movement in the impact shield CRSs was similar for both the CRS installed by a seat belt and the ISOFIX CRS, though the forward movement of the CRS installed by a seat belt was much larger than that for the ISOFIX CRS. In the 5-point harness ISOFIX CRS with a top tether, the CRS forward movement was small with the ISOFIX attachment, and the CRS forward pitching was small with the top tether. In the 5-point harness CRS installed with a seat belt, the CRS forward movement and forward pitching were large because of the stretch of seat belt. As a result the dummy's forward movement in the CRS installed seat belt was larger than that in the ISOFIX CRS with a top tether. The flexion angle of the dummy torso was small since the dummy was restrained by the CRS shell with shoulder harness. The Hybrid III 3YO and Q3 dummies showed almost similar behavior. In the impact shield CRS, the head flexion angles were similar between the Hybrid III 3YO and the Q3. In the 5-point harness CRS, the head rotation angle of the Hybrid III was smaller than that of the Q3, which indicated that the Q3 is more flexible than the Hybrid III 3YO.



(a) Hybrid III in CRS B (b) Hybrid III in CRS C

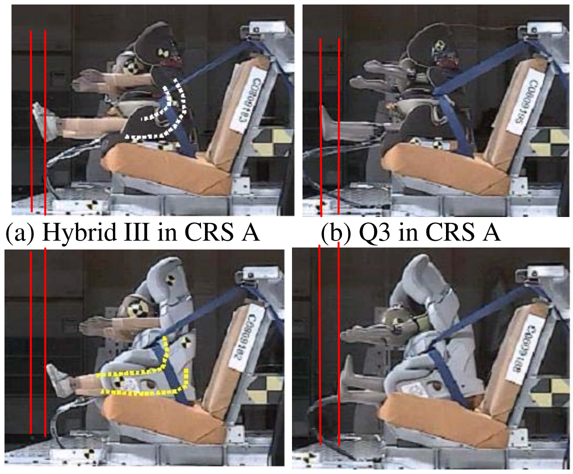
(c) Q3 in CRS B (d) Q3 in CRS C

(e) Hybrid III in CRS F (f) Hybrid III in CRS G

(g) Q3 in CRS F (h) Q3 in CRS G

Figure 6. Dummy behaviors at the time of head maximum excursion

The difference in dummy behavior was also observed for the impact shield CRSs A and B of which the shield shape was different. Figure 7 shows the dummy kinematic behavior in CRS A and B at a point during the tests when the chest deflection was at its maximum. The dummy foot forward motion was larger in the CRS A than in the CRS B, which indicates that the pelvis restraint was different between CRSs A and B.

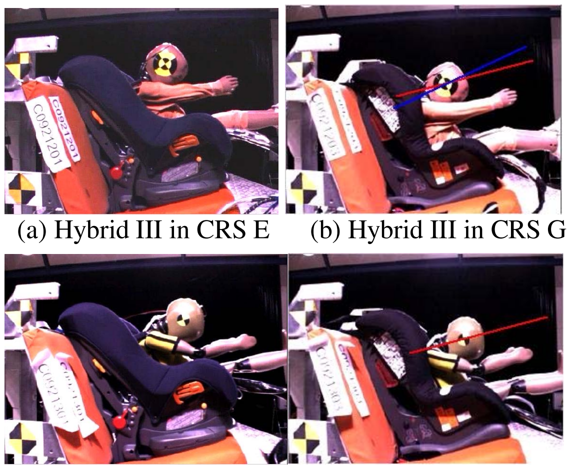


(a) Hybrid III in CRS A (b) Q3 in CRS A

(c) Hybrid III in CRS B (d) Q3 in CRS B

Figure 7. Dummy behavior at the time of maximum chest deflection in impact shield CRS A and B

Figure 8 shows the dummy behavior in CRSs E and G at the time during the test when the head excursion was maximal. The dummy behavior of the different 5-point harness CRSs was similar.



(a) Hybrid III in CRS E (b) Hybrid III in CRS G

(c) Q3 in CRS E (d) Q3 in CRS G

Figure 8. Dummy behaviors at the time of head maximum excursion in 5-point harness CRS E and G

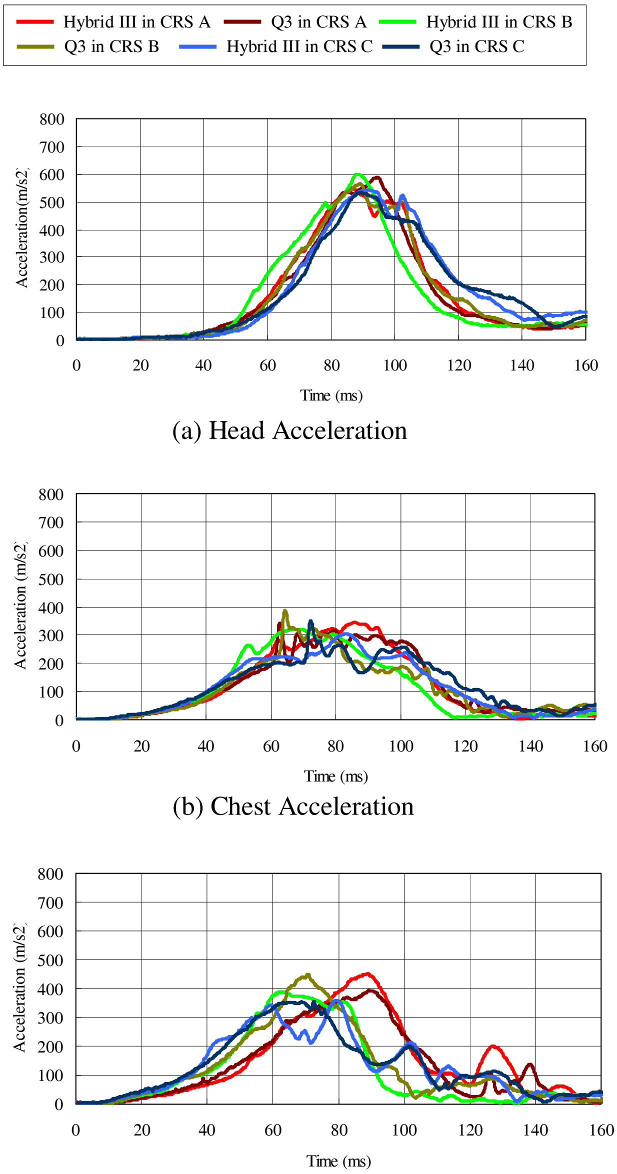
Dummy Readings

Figures 9 and 10 shows the head, chest, and pelvis acceleration time histories for the impact shield CRSs and the 5-point harness CRSs, respectively. In the impact shield CRSs, the chest and head accelerations were similar in the tests even though the CRS type and dummy types were different. For the impact shield CRSs, the pelvis and the chest accelerations started to increase almost simultaneously, and finally the head acceleration increased. The pelvis acceleration was delayed in the CRS A as compared with CRSs B and C for Hybrid III 3YO and Q3. In the impact shield CRSs, the accelerations of head, chest, and pelvis were similar for Hybrid III 3YO and Q3. The delay of the pelvis acceleration in CRS A as compared to the responses in CRSs B and C occurred because of the shield structure.

The acceleration of each body region started later in the 5-point harness CRS than in the impact shield CRS. For the 5-point harness CRSs, the pelvis acceleration stared to increase with the lap harness restraint, then the chest acceleration increased with the shoulder harness, and finally the head acceleration increased. In the 5-point harness CRSs, the accelerations of each body regions were different by the CRSs. By comparison with the CRS manufacturer, the acceleration of the dummy in the CRS F or G started earlier than that for the CRS D or E. The pelvis accelerations were comparable between the Hybrid III 3YO and Q3 dummies. The chest acceleration of the Q3 dropped temporarily around 80 ms though this phenomenon was not observed for the Hybrid III 3YO. The head acceleration of Q3 also dropped during its increase. The Q3 head acceleration had a sharp peak which was not observed in the acceleration of the Hybrid III 3YO.

The accelerations of the dummy were compared by the CRS installation method on the vehicle seat, such as the seat belt installed CRS and the ISOFIX CRS with a top tether. The accelerations of each body region were comparable in the impact shield CRSs. For the 5-point harness CRS, the accelerations increased earlier for the ISOFIX CRS with a top tether than for the seat belt installed CRS in both Hybrid III 3YO and Q3 dummies. In comparison of the 5-point harness CRS with the same manufacturer (CRS D, E or CRS F, G), the peak accelerations of the dummy were smaller in the ISOFIX CRS with a top tether than that in the seat belt installed CRS.

The dummy accelerations start times were comparable between the impact shield CRSs and the 5-point harness ISOFIX CRSs with a top tether.

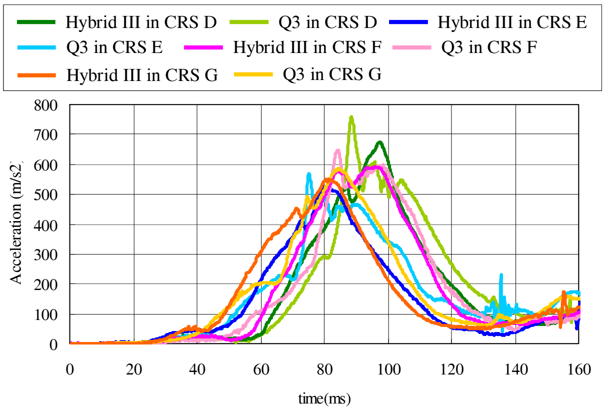


(a) Head Acceleration

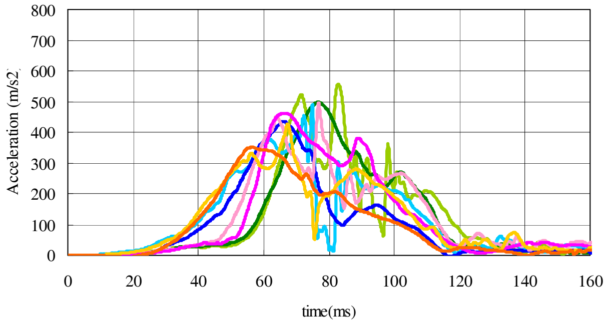
(b) Chest Acceleration

(c) Pelvic Acceleration

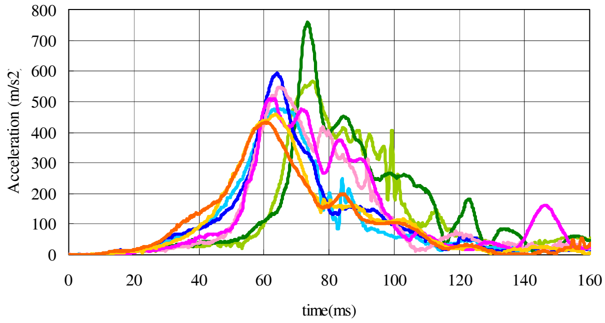
Figure 9. Dummies in impact shield CRSs acceleration time histories



(a) Head acceleration



(b) Chest acceleration



(c) Pelvic acceleration

Figure 10. Dummies in 5-point harness CRSs acceleration time histories

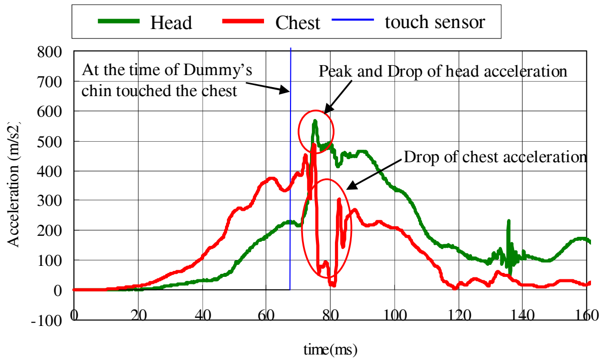


Figure 11. Head and chest acceleration time histories of dummy in CRS E

Figure 12. Q3 behavior at 70ms in CRS E

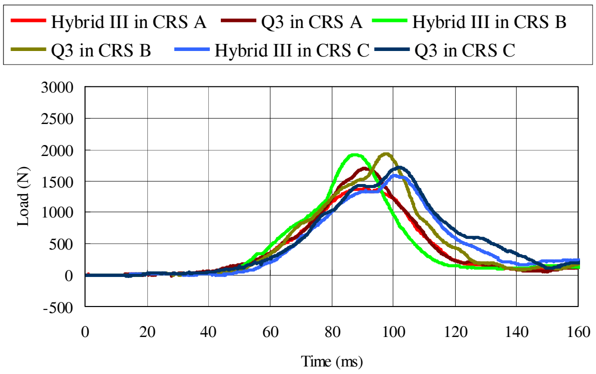
Figure 13. Touched sign of Q3 Dummy clavicles and spine after the test of 5-point harness CRSs

Figure 11 shows the accelerations of the head and chest, and the chin/chest contact sensor of the Q3 seated in CRS E. The Q3 kinematic behavior at 70 ms is shown in Figure 12. After the chin and chest contacted, the head acceleration increased and the chest acceleration decreased. But it is unknown whether there is a correlation between the contact of the chin to the chest and the decrease in chest acceleration. Figure 13 shows the Q3 after Test 12. As can be seen, there were traces of contact of chin/clavicle and clavicle/spine (by noting the blue grease paint).

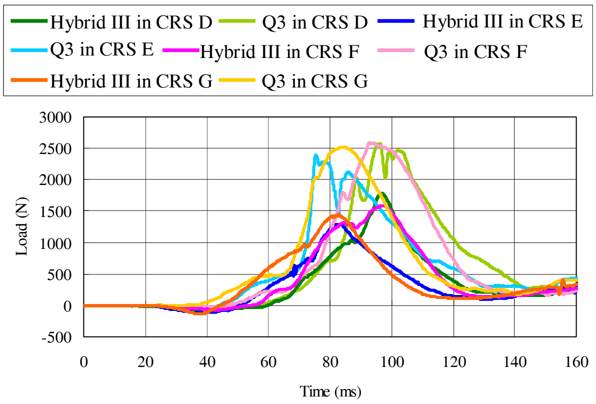
Figure 14 shows the upper neck tension force time histories. Figure 15 shows the upper neck shear force time histories. In all CRSs, the upper neck tension force of the Q3 was larger than that of the Hybrid III 3YO. In the impact shield CRSs where the dummy head impacts the shield, the difference of the upper neck force between the Hybrid III 3YO and the Q3 was small. For the 5-point harness CRSs, there was a large difference of upper neck tension force between the Hybrid III 3YO and the Q3. The upper neck shear forces were small in the 5-point harness CRSs for the Q3, while they were large for the Hybrid III 3YO. Accordingly, for the 5-point harness CRSs, the flexion angle of the dummy torso was small, so the difference of the neck stiffness between the Hybrid III 3YO and the Q3 dummies had a large influence.

The tension and shear force of the dummy were comparable in the seat belt installed CRSs and the ISOFIX CRSs with a top tether.

Figure 16 shows the upper neck moments. The neck moment was larger for the 5-point harness CRSs than for the impact shield CRSs because the neck flexion angle was larger in the 5-point CRSs. In all CRSs, the upper neck moment of the Hybrid III 3 YO was larger than that of the Q3.

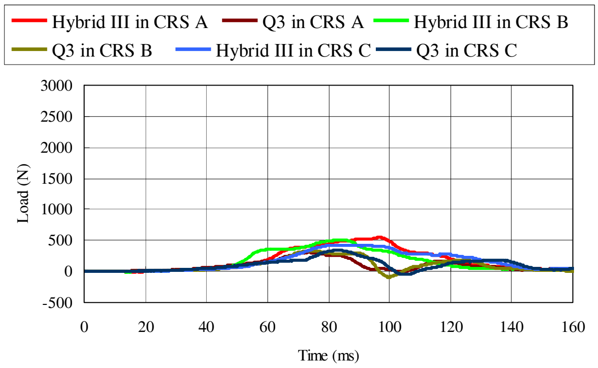


(a) Impact shield CRSs

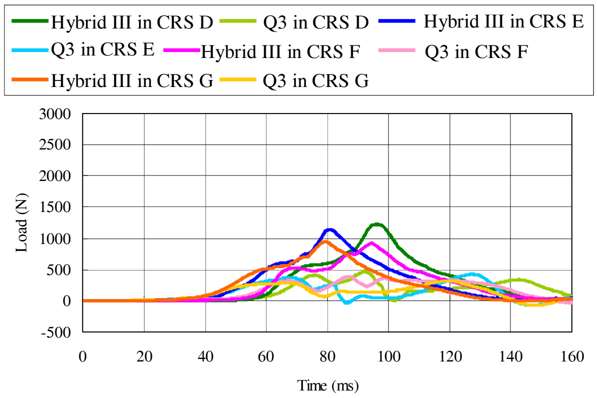


(b) 5-point harness CRSs

Figure 14. Time histories of upper neck tension force

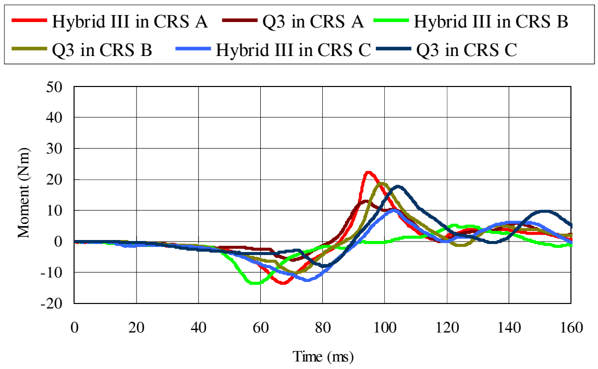


(a) Impact shield CRSs

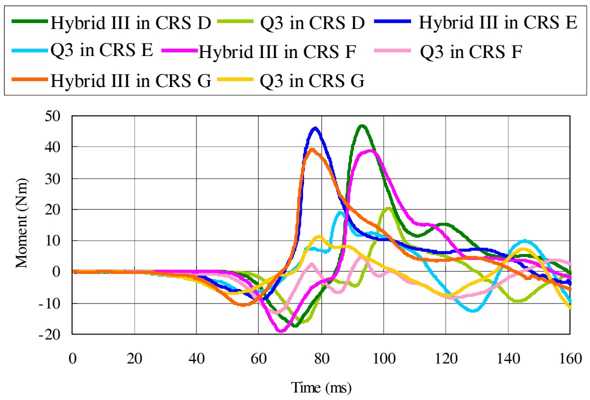


(b) 5-point harness CRSs

Figure 15. Time histories of upper neck shear force



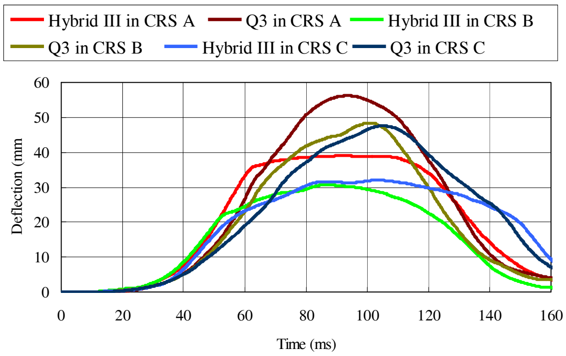
(a) Impact shield CRSs



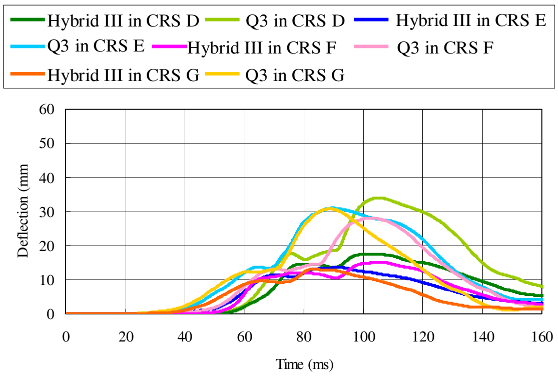
(b) 5-point harness CRSs

Figure 16. Time histories of upper neck moment

Chest deflection time histories are shown in Figure 17. The chest deflection was larger in the impact shield CRSs than that in the 5-point harness CRSs. The Q3 had larger chest deflections than the Hybrid III 3YO. For the Hybrid III 3YO seated in the CRS A, a flat top occurred in the chest deflection. In the CRSs B and C, it did not occur.



(a) Impact shield CRSs



(b) 5-point harness CRSs

Figure 17. Time histories of chest deflection

Injury Measures

Table 4 presents the HIC15, neck tension force, chest deflection, and maximum head excursion. Figure 18 shows the ratio of the injury measures to the IARVs for the Hybrid III 3YO and Q3 dummies. The HIC15 was less than the IARV for all tests. The HIC15 ranges from 237 to 426 with the various CRS types, and the differences of HIC15 between the Hybrid III 3YO and the Q3 dummies were small.

The neck tension forces exceeded the IARV in all tests except Test 8 (CRS A with Q3). In Test 8, the neck tension force was 1704 N, which was comparable with IARV (1705 N). In comparing the responses of the Hybrid III 3YO and Q3, the neck tension forces of the Hybrid III 3YO and Q3 were comparable for the impact shield CRSs (CRS A, B, C). However, on the other hand, the neck tension forces of the Q3 were larger than those of the Hybrid III 3YO for the 5-point harness CRSs (CRS D, E, F, G).

The chest deflections of the dummies in the impact shield CRSs (CRS A, B, C) were substantially larger than that for the dummies in the 5-point harness CRSs, and they were close or exceeded the IARVs. The chest deflections of the Q3 were larger than those of the Hybrid III 3YO by 13-18 mm. In CRS A, the chest deflections were over the IARVs for both the Hybrid III 3YO and the Q3 dummies.

The head forward excursions were less than the IARV (i.e., 550 mm) for all tests. Head excursions were about 500 mm for all the seat belt installed CRSs. For the 5-point harness ISOFIX with a top tether CRSs (CRS E, G), the head excursions were far smaller than the 550 mm. However, even for the ISOFIX with a top tether CRSs, the head excursion in the impact shield ISOFIX and a top tether CRS (CRS C) was slightly larger than that in the CRS B, which was installed by the seat belt.

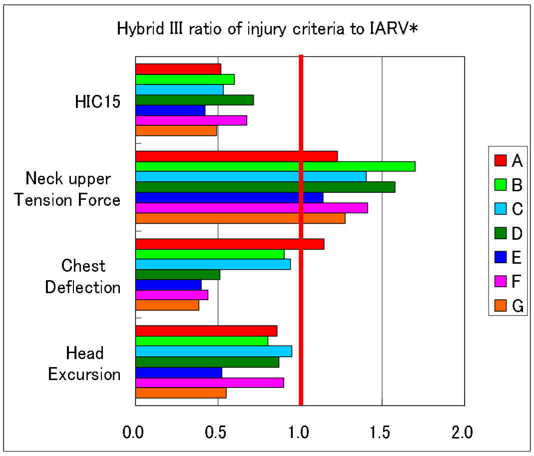
The injury measures of the dummy were compared between the seatbelt installed CRSs and the ISOFIX and a top tether CRSs. For the 5-point harness CRSs, the injury measures of the dummy seated in the ISOFIX and a top tether CRSs were comparable or smaller than those in the CRSs installed by the seat belt. For the impact shield CRSs, the injury measures were comparable between the seatbelt installed CRSs and the ISOFIX and a top tether CRSs.

The rank order of the injury measures was almost similar between Hybrid III 3YO and Q3.

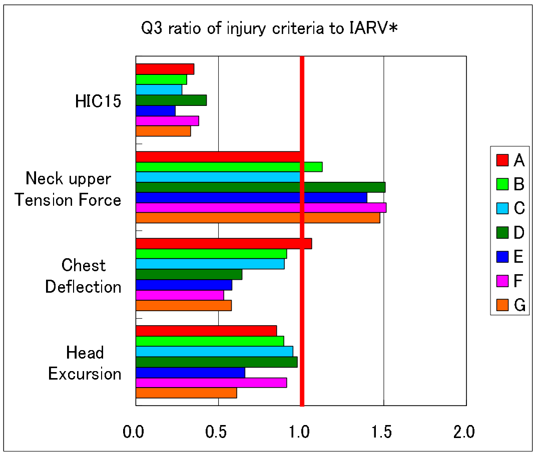
Table 4. Injury Measures

Dummy	Hybrid III 3YO							
CRS	A	B	C	D	E	F	G	IARV*
HIC15	295	344	305	410	242	384	280	570
Chest Deflection (mm)	**39**	31	32	18	14	15	13	34
Neck upper tension force (N)	**1385**	**1920**	**1586**	**1783**	**1290**	**1594**	**1437**	1130
Head excursion (mm)	474	442	523	481	289	495	303	550

Dummy	Q3							
CRS	A	B	C	D	E	F	G	IARV*
HIC15	354	306	279	426	237	383	329	1000
Chest Deflection (mm)	**56**	48	48	34	31	28	31	53
Neck upper tension force (N)	1704	**1923**	**1716**	**2574**	**2382**	**2584**	**2515**	1705
Head excursion (mm)	470	493	522	536	363	503	336	550



(a) Hybrid III 3YO

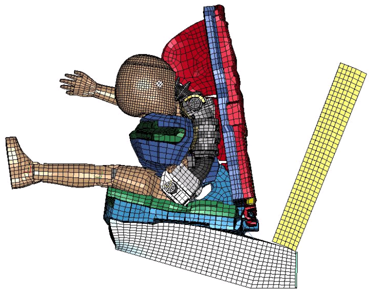


(b) Q3

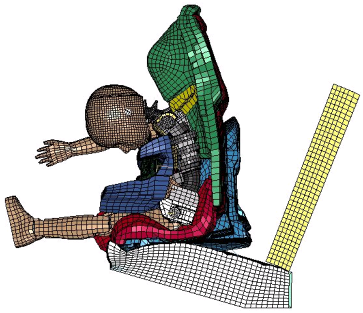
Figure 18. Ratio of injury criteria to IARV

FE Analysis

The kinematic behavior of the Hybrid III 3YO in the CRSs A and B from the FE simulation is shown in Figure 19. In CRS A, the pelvis rotated and only the upper edge of the ilium made contact with the shield. Therefore, the inertial forces of the lower extremities were not supported by the shield. As a result, loading of the Hybrid III 3YO was concentrated on the thorax. On the other hand, in CRS B, the shield interacted with the ilium, and thus prevented forward motion of the pelvis. Accordingly, the shield shape has a large influence on the pelvis interaction



(a) Hybrid III 3YO in CRS A



(b) Hybrid III 3YO in CRS B

Figure 19. Dummy kinematic behavior in FE analysis

DISCUSSION

The Q3 dummy showed more flexible behavior in flexion than the Hybrid III 3YO. The head of the Q3 flexed at a large angle as compared to the Hybrid III 3YO dummy. This flexible behavior of the Q3 affected the head acceleration and neck forces. In the 5-point harness CRSs, the head acceleration of the Q3 increased later during the crash than that of the Hybrid III 3YO (see Figure 10(a)). The shear forces of the Hybrid III 3YO were larger than that of the Q3 (see Figure 15). The stiffness of the Q3 is smaller than that of the Hybrid III 3YO. Then, during head swing motion, the transfer force of the neck would be small for the Q3, which leads to small head acceleration. Since the Q3 chin made contact with the thorax more severely than that for the Hybrid III 3YO, the upper neck tension of Q3 was larger. For the Q3, due to chin/thorax contact, the clavicles interacted with the spine, which might cause oscillations in the chest acceleration. In the impact shield CRSs, the neck force was similar between the Hybrid III 3YO and the Q3. This is because the head made contact with the shield and there were no chin/thorax contacts.

The chest deflection was different in the dummy types (Hybrid III 3YO and Q3) as well as in the CRS types. The chest deflections of the dummy in the impact shield CRSs were larger than those in the 5-point harness CRSs since the shield restrained and loaded the chest in the impact shield CRSs. In all tests, the chest deflection of Q3 was larger than the Hybrid III 3YO by 13-18 mm. The likely reason is that the Q3 thorax is less-stiff than the Hybrid III

3YO, and the rib cage of the Q3 is cone-shape. In CRS A, a flat top was observed in the chest deflection time history for the Hybrid III 3YO. This is likely due to the bottoming-out of the chest. For the Q3 seated in the CRS A, the chest deflection was larger than the Hybrid III 3YO, though the bottoming-out of the chest did not occur. The upper limit of the measurement of the chest deflection of the Q3 is larger than that for the Hybrid III 3YO. Thus, the Q3 could be used in tests where there are more severe loading conditions to chest.

Even for the impact shield, the bottoming-out of the Hybrid III 3YO chest did not occur in the CRSs B and C. This is likely due to the structure of the shield. As shown in Figures 7 and 19, the shield of the CRS B restrained the pelvis as compared to the CRS A. As the pelvis forward motion was limited in the CRS B, the shear force transferred from the pelvis to the chest was small, which led to a small chest deflection. The pelvis restraint condition was also reflected in the pelvis acceleration which started late in the CRS A (see Figure 9). Based on the tests, it was demonstrated that the chest deflection could be less than the IARV with the structure of the impact shield CRS, even though the chest was loaded by the shield.

In the impact shield CRS, the dummy was restrained by the shield and the torso flexion angle was large and the neck flexion angle was small (see Figure 6). As a result, the influence of the less-stiff characteristic of the neck was small and the accelerations of the head, chest, and pelvis were similar for the Hybrid III 3YO and Q3 dummies.

In this study, the ISOFIX CRSs with a top tether and the seat belt installed CRSs were compared. The injury measures of the Hybrid III 3YO and Q3 dummies were smaller in the ISOFIX CRSs with a top tether than in the seat belt installed CRSs, especially for the head excursion. Since the seat belt slack is smaller in the ISOFIX CRS with a top tether than in the seat belt installed CRSs, the child dummy moved earlier in the ISOFIX CRSs with a top tether. Thus, as shown in Figure 10, the dummy acceleration started early in the ISOFIX CRS with a top tether. As a result, the difference of speed between the dummy and CRS at the start of dummy movement was smaller in the ISOFIX CRSs with a top tether than in the seat belt installed CRSs, and the necessary energy for the dummy to catch up with the CRS was small. Accordingly, the loading to the dummy was small. In the impact shield CRSs, the injury measures of the dummy were comparable between the ISOFIX CRSs with a top tether and the seat belt installed CRSs. In the impact shield CRSs, the shield is installed by the belt. Therefore, the dummy loadings would be strongly affected by the belt characteristics in the impact shield CRSs. The 5-point harness CRSs have two belt systems which consist of harness and seat belt. The ISOFIX CRSs with a top tether and impact shield CRSs have one belt system. The number of belt systems can affect the restraint start time of the dummy.

In all tests, the neck injury measures exceeded the IARV for the Hybrid III 3YO and Q3 dummies. In accidents, neck injuries of children are not frequent if head contact does not occur. The neck stiffness and the chin/chest contact characteristic of the dummy can affect the neck injury measures. Accordingly, research is needed to investigate the dummy characteristics as well as the IARV of the child neck.

The Q3 dummy used in this study was a first edition device. In the current generation of Q3s, the characteristics of the Q3 may have been improved.

SUMMARY

The Hybrid III 3YO and Q3 dummies seated in a 5-point harness CRS and an impact shield CRS were tested using ECE R44 impact conditions. The results are summarized as follows:

1. The dummies showed different kinematics by the CRS types. The neck flexed in the 5-point harness CRSs, whereas the torso flexed around the shield in the impact shield CRSs.

2. In the impact shield CRSs, the chest deflection was large, since the chest was directly loaded. The chest deflection could be less than the IARV, which is dependent on the shield structure and on the shield supporting the pelvis.

3. For the 5-point harness CRSs, the injury measures of the dummy were smaller in the ISOFIX CRS with a top tether than in the seat belt installed CRSs. The head excursion was far smaller than 550 mm in the 5-point harness ISOFIX CRS with a top tether. For the impact shield CRSs, the injury measures were comparable between the ISOFIX CRSs with a top tether and the seat belt installed CRSs.

4. In general, the kinematic behavior was comparable between the Hybrid III 3YO and Q3 dummies, though the Q3 showed more flexible behavior.

5. The chest deflection of the Q3 dummy was larger than that of Hybrid III 3YO dummy. This large chest deflection was more prominent for the impact shield CRS. The bottoming-out of the chest occurred for the Hybrid III 3YO seated in one type of impact shield CRS.

6. In all tests, the neck injury measures exceeded the IARVs. Further research is needed for

investigating the dummy neck characteristics and IARVs.

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