IMPACT RESPONSES OF THOR MOD KIT UNDER DIFFERENT CONDITIONS IN SLED TESTS AND VEHICLE CRASH TESTS

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ABSTRACT

In order to contribute to the development and improvement of the THOR dummies, the impact responses of the THOR Mod Kit were compared with the THOR-NT and the Hybrid III, based on the kinematic and dynamic responses to different conditions in the frontal sled and vehicle crash tests. In a 56 km/h frontal sled test where a dummy was installed on the driver seat of a white body, the responses of the THOR Mod Kit with SD3 shoulder to the differences of the seating procedures and restraint conditions were evaluated comparing with the THOR-NT and the Hybrid III. Moreover, two crash tests using a small passenger car at 55 km/h FWRB and 64 km/h ODB corresponding to JNCAP conditions were conducted, and the responses of the THOR Mod Kit were compared with that of the Hybrid III.
Difference of seating procedure affected the responses of the thoracic deflection, abdominal deflection, and iliac force, etc. Compared with the THOR-NT, the THOR Mod Kit clearly showed difference on each measurement location and the forward displacement of its shoulder on the unrestrained side was more pronounced. Regardless of the D-ring positions, the shoulder belt slippage didn't occur in the Hybrid III, whereas belt slippage occurred in the THOR Mod Kit when the D-ring was at the lowest position. When the load limiter force of the seatbelt was higher, forward displacements of the thorax became smaller in both the THOR Mod Kit and the Hybrid III and the neck flexion of the THOR Mod Kit became larger. Accompanying the difference of kinematics, the responses of the head acceleration, neck force and thoracic deflection also differed. In both the FWRB and ODB tests, the maximum rotation angle of the ankle eversion exceeded the preliminary IARV for the THOR at the rebound phase, not at the intrusion phase.
From the results above, it turned out, that the THOR Mod Kit response to the difference in seating procedure was more sensitive than that of the THOR-NT. The sensitivity of the THOR Mod Kit to the D-ring position was higher than that of the Hybrid III, and that the difference of load limiter affected the difference of kinematics and dynamic responses of the upper body in both the THOR Mod Kit and the Hybrid III.

INTRODUCTION

While the Hybrid III is widely used in regulation and assessment in various countries, it has been expected that a more advanced dummy with higher biofidelity and higher measurement ability will be developed to advance the occupant protection performance of vehicles. From this background, the advanced frontal crash test dummy – THOR (Test device for Human Occupant Restraint), was developed. In 2001, the THOR-Alpha was released [1], and the THOR-NT, which had improved biofidelity, anthropometry, and durability from the THOR-Alpha, was introduced in 2005 [2].
Many researchers had a great interest in the THOR dummy, and further improvements on the biofidelity, repeatability, reproducibility, durability and usability of the THOR-NT were discussed under the SAE THOR Evaluation Task Force Group. Based on discussions in the THOR Task Force, the THOR Task Force Design Team investigated necessary improvements on the specifications of the THOR, drafted a development plan for a short-

term improvement of the THOR, and in 2010 the THOR Mod Kit, which added modifications to each component of the THOR-NT by utilizing the latest biomechanical data was manufactured [3]. At about the same time in Europe, the THORAX Project, the seventh framework program of the European Union, was initiated to perform studies on thoracic injury mechanisms considering the diversity of factors such as age, gender and the physique of the occupants in traffic accidents. In order to reflect the project's efforts to improve the THOR, research and development for the THOR's thorax were performed. The NHTSA had evaluated the THOR Mod Kit in collaboration with individual organizations from the U.S., Europe, and Japan, and they also developed the THOR Metric which redesigned all components based on the metric system.
Under these circumstances, JAMA/JARI has continuously conducted evaluation tests and proposed activities aimed at contributing to the development and improvement of the THOR dummies. In this study, the impact responses of the THOR Mod Kit were compared with the THOR-NT and the Hybrid III, based on the kinematic and dynamic responses to different conditions in the frontal sled and vehicle crash tests.

THOR MOD KIT DUMMY

The THOR Mod Kit is a dummy which has added modifications to each component of the THOR-NT by utilizing the latest biomechanical data in order to further improve the biofidelity, repeatability, reproducibility, durability and usability of the THOR-NT. The SD3 shoulder, upgraded by the EU THORAX project from the original SD2 shoulder developed by Chalmers University of Technology, had been installed onto this dummy [4][5].

SLED TEST

In order to contribute to the research and development of the THOR, sled tests of the THOR Mod Kit were conducted in different test conditions and its performance was evaluated. This included a comparison between its responses and that of the THOR-NT and the Hybrid III. In the test, a dummy was installed on the driver seat of a white body of sedan-type vehicle fixed on a sled. The sled was launched rearward so as to reach the maximum speed of 56 km/h. For the restraint system, the front air bag, seatbelt with force limiter and a double pretensioner at the retractor and outer lap belt anchorage were used.

Comparative Conditions for Evaluation of the Dummy Dynamic Responses

To evaluate the influences on kinematic and dynamic responses of the THOR Mod Kit in different test conditions, the following three comparative conditions were considered and five sled tests were conducted. The data of the THOR Mod Kit from these tests are placed in the NHTSA biomechanics database. The NHTSA test numbers which correspond to these tests are shown in Table 1. Furthermore, the test results of the THOR Mod Kit were compared with those of the THOR-NT and the Hybrid III.

(1) Difference of the seating procedure

(2) Difference of the D-ring position

(3) Difference of the seatbelt load limiter

Table1. Matrix of the sled tests.

NHTSA Biomechanics Database Test No.	Test Parameter for THOR Mod Kit				Other Dummy Data	
	Sled G Pulse	Seat Belt		Seating Procedure	THOR-NT	Hybrid III
		D-ring Position	Load Limiter			
11185	35 mph	Highest	N	FMVSS 208	□	□
11186	35 mph	Highest	N	UMTRI	□	□
11187	35 mph	Highest	N	MP-30	□	□
11188	35 mph	Lowest	N	UMTRI		□
11190	35 mph	Highest	N＋α(2kN)	UMTRI		□

Dummy Seating Procedure

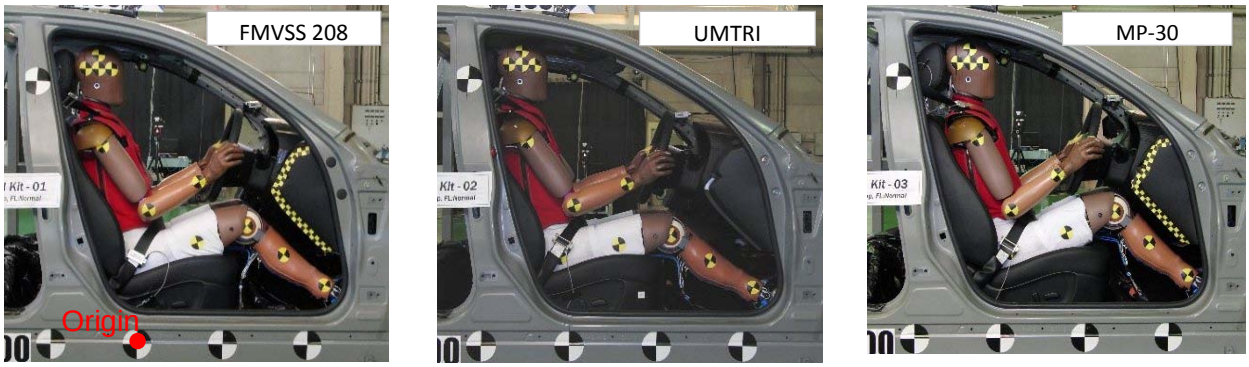
The dummy positioning was subject to the following three seating procedures:

(1) FMVSS 208; specified for the Hybrid III,

(2) UMTRI (the University of Michigan Transportation Research Institute); the seat position depends on the driver occupant size, geometry of steering wheel and accelerator pedal, and range of seat adjustment [6],

(3) MP-30; according to the FMVSS 208 procedure basically, only the seat slide was adjusted 30 mm forward from the mid position.

With respect to the seating posture of the THOR Mod Kit in different seating procedures, the right view photographs and the position plot of each body region in the X-axis (horizontal) and Z-axis (vertical) coordinate are shown in Figure 1. As the seat position differs among the three seating procedures, the positions of the head C.G., shoulder, H-point and knee in each procedure varied accordingly.



Seat Slide: Mid	Seat Slide: 49 mm rearward*	Seat Slide: 30mm forward*
Seat Lifter: Lowest	Seat Lifter: 16 mm upward*	Seat Lifter: Lowest

* Relative Positions to FMVSS 208

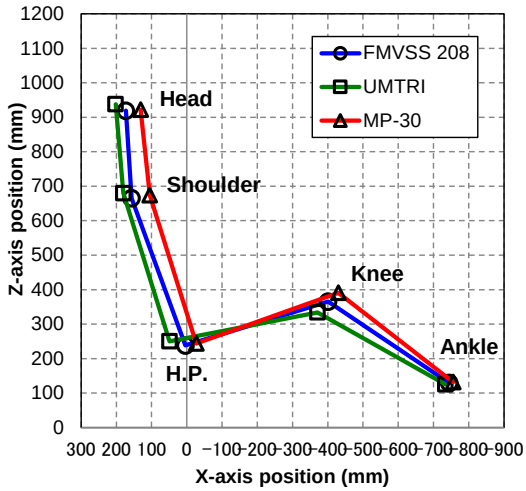


Figure 1. Seat positions and THOR Mod Kit's seating posture in the three seating procedures.

VEHICLE CRASH TEST

In order to evaluate the performance of the THOR Mod Kit, two high-speed frontal crash tests corresponding to JNCAP condition were conducted using a small passenger car as the representative of Japanese cars. One was a 55 km/h Full Width Rigid Barrier (FWRB) test. Another was a 64 km/h Offset Deformable Barrier (ODB) test. The data from these crash tests are placed in the NHTSA biomechanics database. The NHTSA test numbers which correspond to these tests are shown in Table 2. Based on these test results, the response, measurement ability, and durability were compared between the THOR Mod Kit and the Hybrid III. The THOR Mod Kit and the Hybrid III were installed on the driver seat and front passenger seat of the small passenger car. Since the Hybrid III was seated in the front passenger seat merely as a weight dummy, the measurements for the Hybrid III were not taken. Take note that the Hybrid III measurements used in this paper are from JNCAP tests. For the restraint system, the test vehicle was equipped with airbag and the seat belt had pretensioner and load limiter.

Table2. Vehicle crash tests in this study.

NHTSA Biomechanics Database	Test Condition
11204	55 km/h FWRB
11205	64 km/h ODB

Dummy Positioning

Figure 2 shows the comparison of the seating posture between the THOR Mod Kit and the Hybrid III in the FWRB and ODB tests. Since the THOR Mod Kit and the Hybrid III differ in structure and in dimension, the position coordinates of each body region differed in each dummy. Compared with the Hybrid III, the THOR Mod Kit was positioned more rearward and upward in the head, more forward and upward in the shoulders, more upward in the Hip-Point (H.P.), and more forward and upward in the knees. Although the H.P. of THOR Mod Kit could be placed at almost the same position as the H.P. of the Hybrid III in the X-axis, it was not possible to lower the H.P. of the THOR Mod Kit to the HP level of Hybrid III in the Z-axis due to the difference in length of the lower legs.

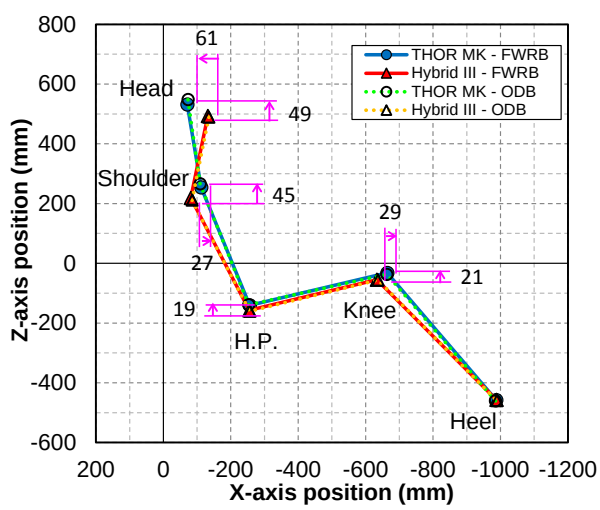


Figure 2. Seating posture of the THOR Mod Kit and the Hybrid III.

RESULTS

Comparison of Dummy Responses with Different Seating Procedures in Sled Test

Figures 3 shows the comparison of the thoracic deflections, lower abdomen deflections and iliac forces between the THOR Mod Kit and the THOR-NT. With respect to the four point thoracic deflections of the THOR-NT, there was little difference among the three seating procedures, whereas for the THOR Mod Kit, the upper right and lower left deflections in the FMVSS 208, which the seat belt had passed through a closer point to the dummy centerline, indicated smaller responses than those from the other two seating procedures. Because both the lower abdomen deflections (left and right) and the iliac forces (left and right) of the THOR Mod Kit indicated larger responses than those of the THOR-NT, it appears that the THOR Mod Kit improved with regard to sensitivity to seat belt compression compared with the THOR-NT. These differences in dummy responses are believed to be because of the following reasons: the thoracic and abdominal deflection measurement systems of the THOR Mod Kit were changed from the CRUX and the DGSP in the THOR-NT, respectively, to the IR-TRACC systems, and the iliac load cells were also redesigned.

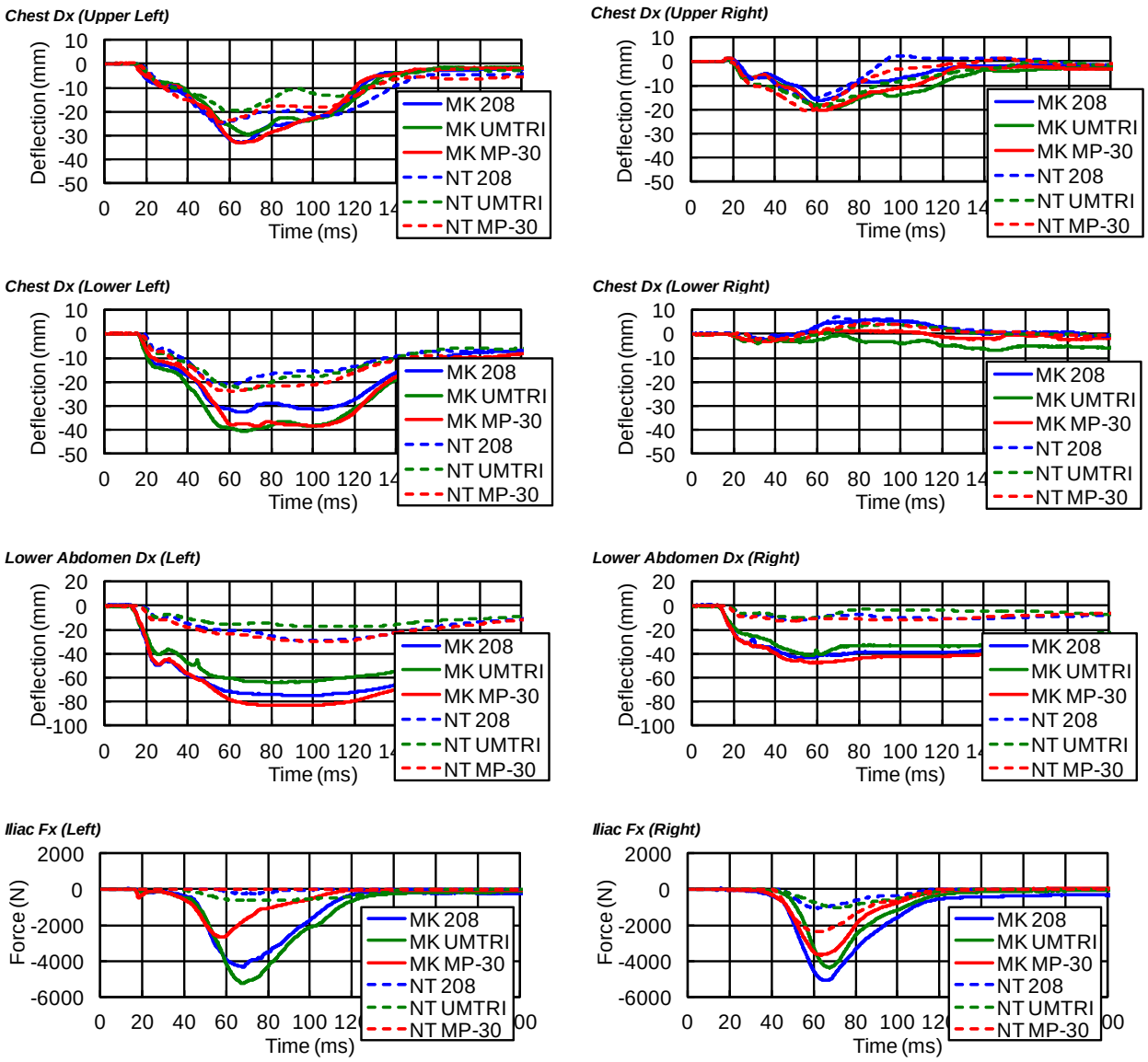


Figure 3. Thoracic deflections, lower abdomen deflections, and iliac forces of the THOR Mod Kit and the THOR-NT.

Figure 4 shows the difference in forward movement of the shoulder between the THOR Mod Kit and the THOR-NT in FMVSS 208. The forward movement of the right shoulder was approximately equivalent between the two dummies, whereas the left shoulder of the THOR Mod Kit indicated a larger forward movement than that of the THOR-NT. The left shoulder of the THOR Mod Kit moved forward more than its thorax after approximately 60 ms, and the forward movement at 100 ms was considerably large.

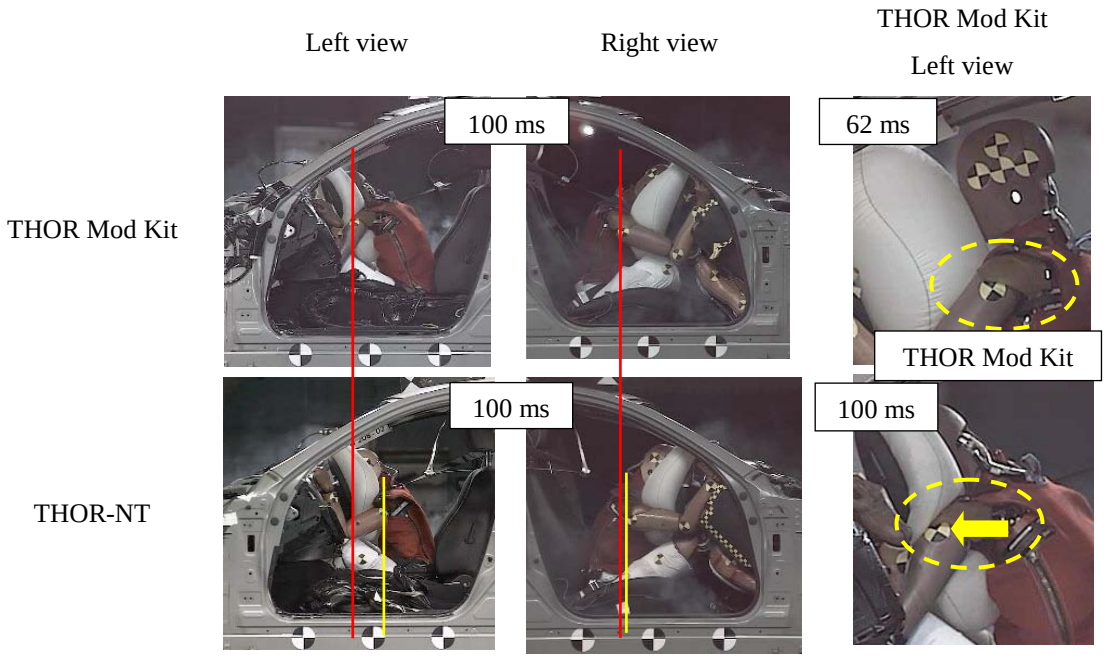


Figure 4. Difference of shoulder forward displacements between the THOR Mod Kit and the THOR-NT in the FMVSS 208 seating procedure.

Comparison of Dummy Responses at Different D-ring Positions in Sled Test

Based on the captured images from the high-speed video camera, the comparison of the kinematics for the THOR Mod Kit and the Hybrid III at different D-ring positions (load limiter - normal) is shown in Figure 5. Regardless of the D-ring position, shoulder belt slippage didn't occur in the Hybrid III, whereas belt slippage occurred in the THOR Mod Kit when the D-ring was at the lowest position. The belt path on the shoulder of the THOR Mod Kit had passed outward compared with that of the Hybrid III because of the difference in shoulder height between the dummies. Furthermore, the shoulder structure of the THOR Mod Kit with SD3 differs from that of the Hybrid III. These differences are presumed to bring about this phenomenon of slippage or non-slippage of the shoulder belt between the dummies.

Figure 6 shows the comparison of the head accelerations and thoracic deflections respectively of the THOR Mod Kit with respect to difference of the D-ring position (load limiter - normal). The peak acceleration in the X-axis indicated a higher value in the highest D-ring position than in the lowest D-ring position, whereas the peak acceleration in the Y-axis indicated the opposite result to that of the result in the X-axis. Since the seat belt slippage from the shoulder occurred in the case of the lowest D-ring position, the torsion of the dummy upper body about the Z-axis became large and the head lateral acceleration increased. Therefore, it seems that the head acceleration measurements of the THOR Mod Kit are able to sensitively respond to the difference of its own kinematics. Since in the lowest D-ring position the seat belt slippage occurred due to the effect of the seat belt path and the belt strongly compressed the right side of the thorax, the deflection on the thoracic upper right indicated larger values than in the highest D-ring position. It demonstrated that the THOR Mod Kit has high sensitivity to the seat belt path and has a high measurement ability utilizing the multi-point deflection measurements.

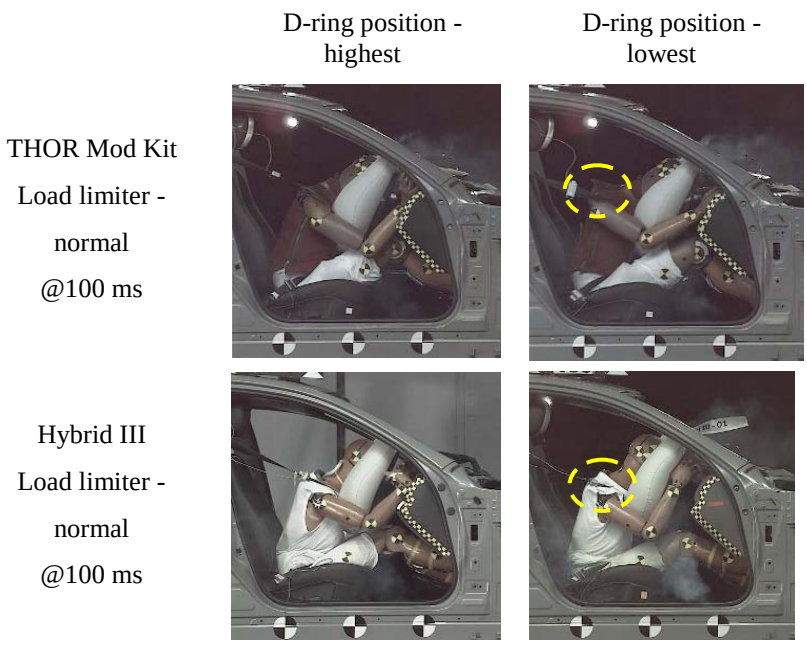


Figure 5. Comparison of kinematics for the THOR Mod Kit and the Hybrid III at different D-ring positions.

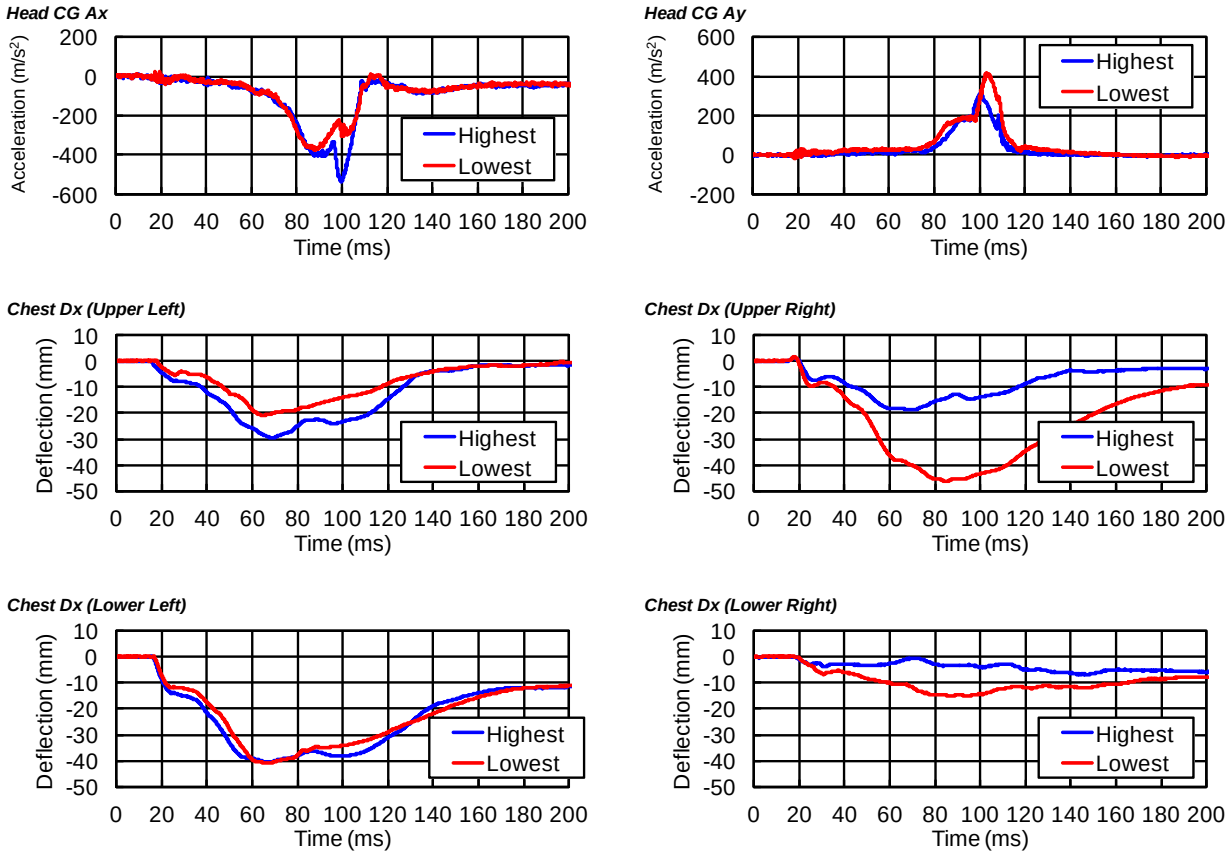


Figure 6. Head accelerations (X- and Y-axes) and thoracic deflections (UL, UR, LL, LR) of the THOR Mod Kit.

Comparison of Dummy Responses with Different Seat Belt Load Limiter in Sled Test

Comparison of the kinematics for the THOR Mod Kit and the Hybrid III with different load limiter forces (where the D-ring position was at the highest position) is shown in Figure 7. When the load limiter force was higher, the forward movement of the upper body of both the THOR Mod Kit and the Hybrid III was smaller than with a normal load limiter.

Figure 8 shows the comparison of the head resultant acceleration and Figure 9 shows the neck tensile force and the thoracic deflection, respectively, for the THOR Mod Kit and the Hybrid III with different load limiter forces (D-ring position was at the highest position). When the load limiter force was higher, the head accelerations of both dummies indicated lower values, while their thoracic deflections indicated larger values, compared with a normal load limiter. For the neck tensile force, the THOR Mod Kit indicated a higher value with a higher load limiter force than with a normal load limiter but there was little difference in the Hybrid III, because the neck flexion of the THOR Mod Kit became larger but that of the Hybrid III differed only slightly when the load limiter force was higher.

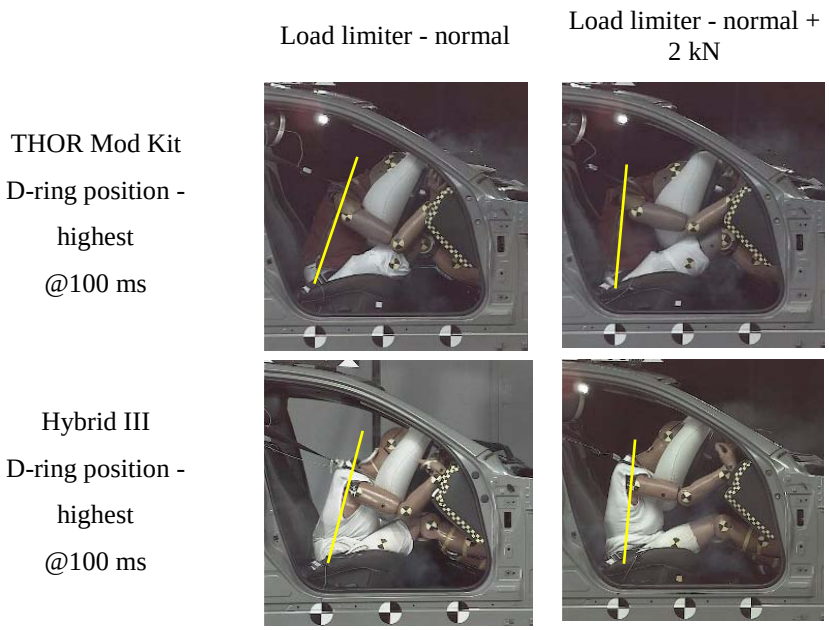


Figure 7. Comparison of kinematics for the THOR Mod Kit and the Hybrid III with different load limiter forces.

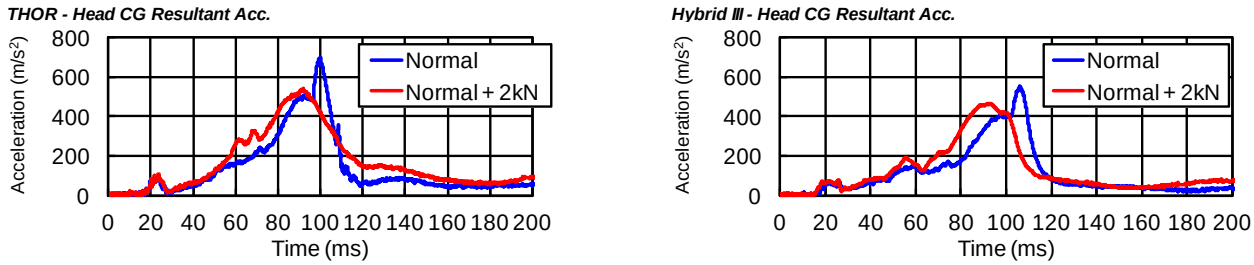


Figure 8. Head accelerations of the THOR Mod Kit and the Hybrid III.

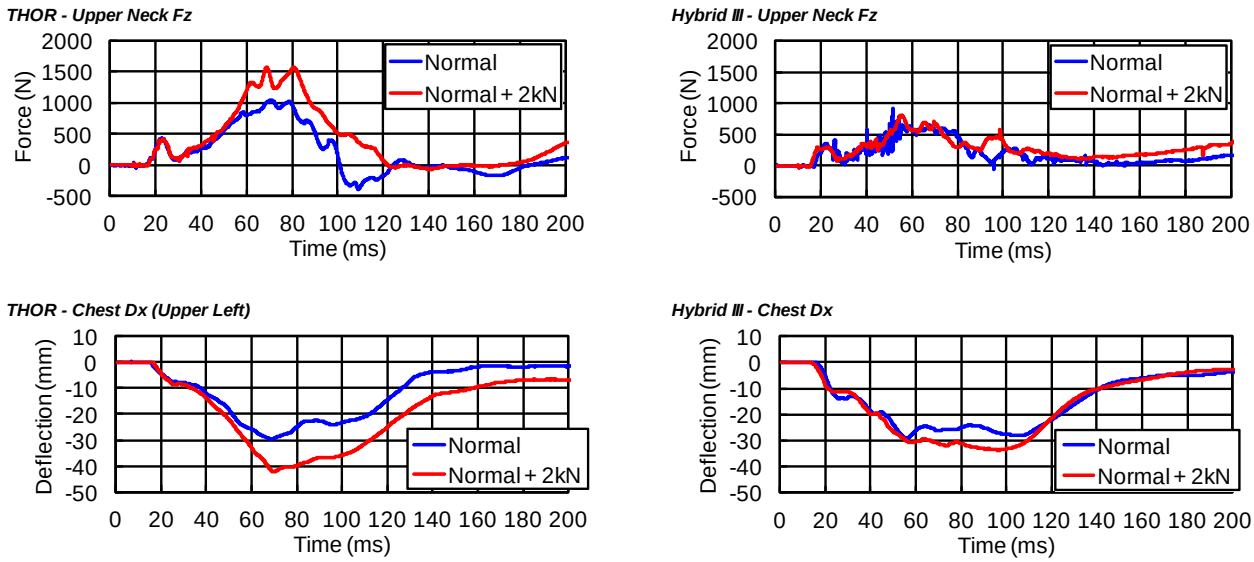


Figure 9. Neck forces and thoracic deflections of the THOR Mod Kit and the Hybrid III.

Kinematics of the THOR Mod Kit with SD3 Shoulder in ODB Test

Figure 10 shows the captured images from a high speed camera behind the dummies and Figure 11 shows some measurement curves of the THOR Mod Kit. After the left elbow of the THOR Mod Kit came in contact with the instrument panel at approximately 90 ms, its left shoulder moved rearward and upward because of the rebound of its upper body after 100 ms. At 120 ms, the right shoulder moved forward and torsion of the upper body occurred. T1 acceleration rapidly increased at 90 ms because the force was transmitted to the spine by the contact between the left elbow and the instrument panel. Furthermore, the force in Y-axis and moment about X-axis on the spine and the head angular velocity about Z-axis rapidly varied at 100 ms because of the upper body torsion.

80 ms	90 ms	100 ms	120 ms
	Left elbow hit to dashboard	Left shoulder is pushed to rearward and upward	Right shoulder (belted side) move forward and torso is twisted

Figure 10. Kinematics of the upper body of the THOR Mod Kit in the ODB test.

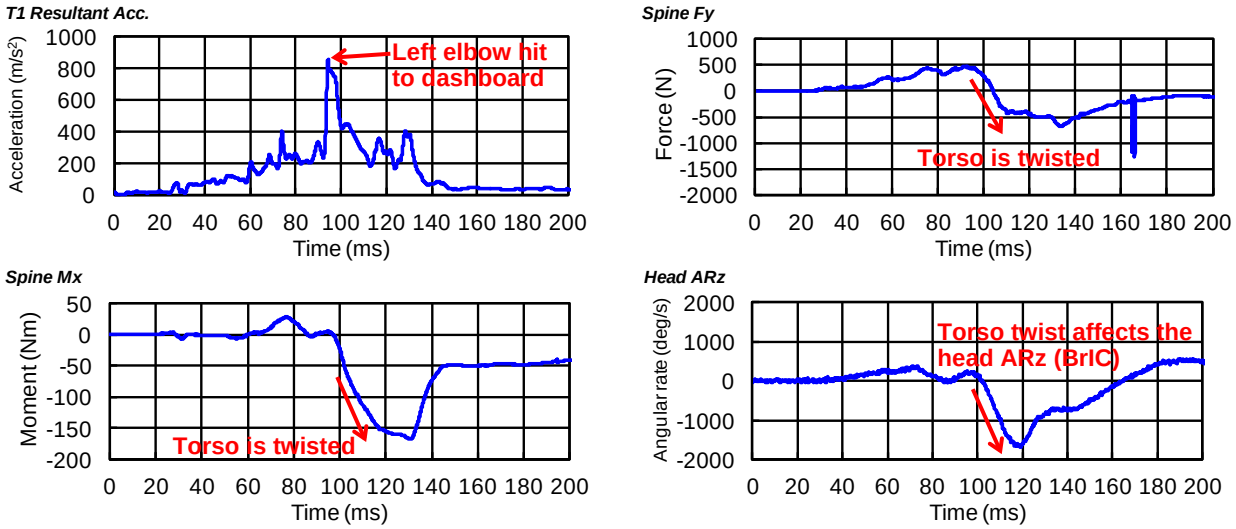


Figure 11. Measurement curves of the THOR Mod Kit in the ODB test.

Ankle Rotation Responses of the THOR Mod Kit in the FWRB and ODB Tests

Figure 12 shows the kinematics of the ankles of the THOR Mod Kit from a high speed camera on the floor of the driver side and Figure 13 shows the measurement curves of the right ankle rotation. In both the FWRB and ODB tests, the ankles of the THOR Mod Kit indicated eversion responses. A angle of the ankles in the FWRB test reached the maximum at about 80 ms, while in the ODB tests it reached the maximum at about 100 ms, and their values exceeded the preliminary reference value of 35 degrees. They were in the rebound phase of the vehicle after 63 ms in the FWRB test and in that after 90 ms in the ODB test.

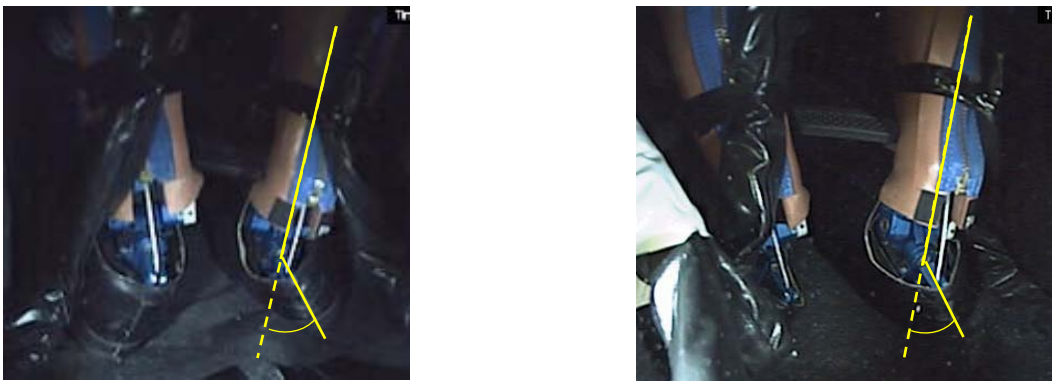
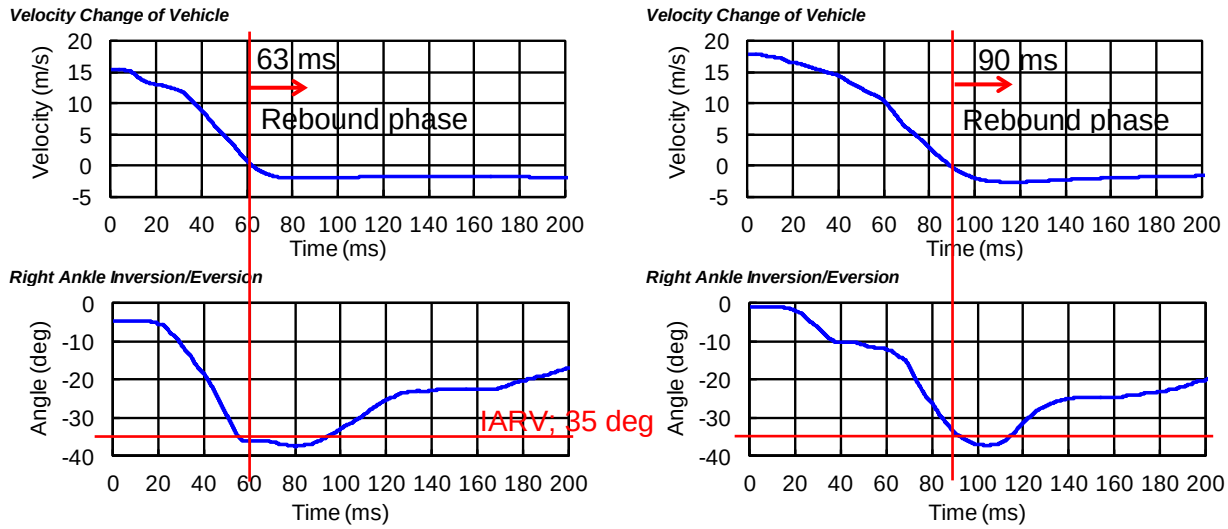


Figure 12. Kinematics of the ankles of the THOR Mod Kit in the FWRB and ODB tests.



(a) FWRB test (b) ODB test

Figure 13. Measurement curves of the right ankle of the THOR Mod Kit in the FWRB and ODB tests.

Comparison of the Injury Measures in the FWRB and ODB Tests

The preliminary injury assessment reference values (IARVs) for the THOR [7][8] and the injury measures of the THOR Mod Kit and the Hybrid III obtained from the FWRB and ODB tests are shown in the APPENDIX. In the preliminary IARVs for the THOR, the kinematic rotational brain injury criterion (BRIC), abdominal deflection, acetabulum force, and ankle rotation are newly proposed, compared with the IARVs for the Hybrid III specified in FMVSS 208 and UN/R94. BRIC has been developed to estimate the risk of brain injury due to the rotation of the skull and is calculated by angular velocity and angular acceleration of the head center of gravity as shown in Eq. (1). The IARV of BRIC is 0.89, which corresponds to a 30% risk of AIS 3+ traumatic brain injury [9]. Furthermore, in 2013, the updated BrIC was developed [10]. As shown in Eq. (2), although the new BrIC is calculated only by angular velocity of the head center of gravity, the IARV has not been proposed yet as the study still in progress.

In the FWRB test, most of the injury measures of both dummies were less than the preliminary IARVs, however, the eversion on the right ankle of the THOR Mod Kit exceeded the reference value of 35 degrees. The moment My on the left upper tibia of the THOR Mod Kit was not measured because there was a disconnected wire problem on the load cell sensor (moment My) of the left upper tibia before the test. Due to that problem, calculating the tibia index was not done. In the ODB test, most of the injury measures of both dummies were less than the preliminary IARVs, however, the eversion on the right ankle of the THOR Mod Kit exceeded the reference value of 35 degrees.

Figure 14 shows a ratio of the injury measures of the THOR Mod Kit and the Hybrid III relative to the provisional IARVs in the FWRB and ODB tests. In the FWRB test, although the HIC 36 of both dummies were less than the reference value, the value of the Hybrid III was 285, whereas that of the THOR Mod Kit was 521. The THOR Mod Kit was approximately 1.8 times higher than the Hybrid III. For the neck tensile force, the THOR Mod Kit also indicated higher values than the Hybrid III. It is presumed that the contact force between the head and the steering wheel was larger because the upper body forward displacement and neck flexion of the THOR Mod Kit were larger than those of the Hybrid III. Among the four thoracic points of the THOR Mod Kit, the deflection at the upper left was the largest, which was approximately 1.4 times of the deflection at the chest center of the Hybrid III. The chest 3 ms clip G was almost the same between the two dummies. Compressive forces on the left and right femurs indicated higher values in the THOR Mod Kit than in the Hybrid III. The tibia index for the left tibia of the THOR Mod Kit was lower but that of its right tibia was higher than those of the Hybrid III. Particularly, on the right-lower tibia, the THOR Mod Kit indicated a tibia index of 0.56, which was 2 times over compared with a tibia index of 0.2 in the Hybrid III. In the ODB test, although the HIC 36 of both dummies were less than the reference value, the value of the Hybrid III was 263, whereas that of the THOR Mod Kit was 510. The THOR Mod Kit was approximately 1.9 times higher than the

Hybrid III. For the neck tensile force, the THOR Mod Kit also indicated higher values than the Hybrid III. Among the four thoracic points of the THOR Mod Kit, the deflection at the upper left was the largest, which was approximately 1.4 times of the deflection at the chest center of the Hybrid III. The chest 3 ms clip G was almost the same between the two dummies. Compressive forces on the left and right femurs indicated higher values in the THOR Mod Kit than in the Hybrid III. The tibia index for the left and right tibias of the THOR Mod Kit indicated higher values than those of the Hybrid III. Particularly, on the right-lower tibia, the THOR Mod Kit indicated a tibia index of 0.83, which was about 4 times higher compared with the tibia index of 0.2 in the Hybrid III.

$$BRIC = \frac{\omega_{max}}{\omega_{cr}} + \frac{\alpha_{max}}{\alpha_{cr}} \qquad \textbf{(1)}$$

ω = angular velocity at head CG , α = angular acceleration at head CG , max = maximum resultant value

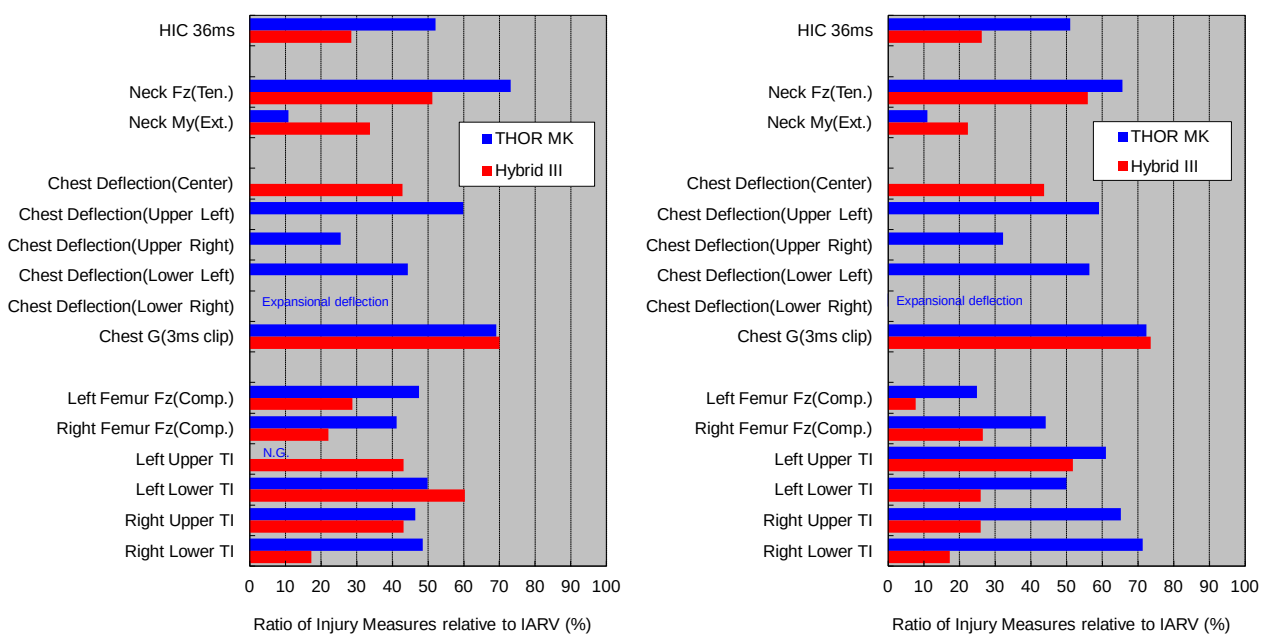
cr = critical value for THOR, $\omega_{cr} = 63.5\ rad/s,\ \alpha_{cr} = 19501\ rad/s^2$

$$BrIC = \sqrt{\left(\frac{\omega_x}{\omega_{xC}}\right)^2 + \left(\frac{\omega_y}{\omega_{yC}}\right)^2 + \left(\frac{\omega_z}{\omega_{zC}}\right)^2} \qquad \textbf{(2)}$$

$\omega_x, \omega_y, \omega_z$ = maximum angular velocities about X-, Y-, Z-axes, $\omega_{xC}, \omega_{yC}, \omega_{zC}$ = critical angular velocities

$\omega_{xC} = 66.25\ rad/s$ (Average of CSDM and MPS), $\omega_{yC} = 56.45\ rad/s$ (Average of CSDM and MPS)

$\omega_{zC} = 42.87\ rad/s$ (Average of CSDM and MPS)



(a) FWRB (b) ODB

Figure 14. Ratio of the injury measures of the THOR Mod Kit and the Hybrid III in the FWRB and ODB tests relative to preliminary IARVs.

DISCUSSION

Shoulder Belt Slippage with Difference of D-ring Position in Sled Test

Regardless of the D-ring positions, the shoulder belt slippage didn't occur in the Hybrid III, whereas belt slippage occurred in the THOR Mod Kit when the D-ring was at the lowest position. Further verification of the biofidelity of the shoulder kinematics between the Post-Mortem Human Subjects (PMHS) and the ATD (Anthropomorphic Test Device) is needed.

Difference between the Left and Right Shoulder Movements in Sled Test

From the image of the high speed camera, it was observed that the difference between the left and right shoulder movements of the THOR Mod Kit was large. How the seat belt restrains the shoulder, which is an important to design the specification of the seat belt and its location. Since the sensitivity of the shoulder restraint performance to the D-ring position was high in a series of tests, further verification for the shoulder motion is needed.

Kinematics of the THOR Mod Kit with SD3 Shoulder in ODB Test

From the image of the high speed camera and some measurement curves of the dummy, it was presumed that the torsion of the upper body of the THOR Mod Kit occurred because its left elbow came in contact with the instrument panel, and this kinematics affected some measurement curves of the dummy. However, as for that, in the future, it needs to verify by comparing the dummy responses under the different condition, for instance, with and without the instrument panel. Furthermore, it is necessary to verify whether this dummy kinematics is human like in this test mode.

CONCLUSIONS

In order to contribute to the development and improvement of the THOR dummies, the impact responses of the THOR Mod Kit were compared with those of the THOR-NT and the Hybrid III, based on the kinematic and dynamic responses to different conditions in the frontal sled and vehicle crash tests. From the results of this research, it turns out that:

- The response of the THOR Mod Kit to the difference of seating procedure was more sensitive than that of the THOR-NT
- The sensitivity of the THOR Mod Kit to the D-ring position was higher than that of the Hybrid III
- The difference of load limiter affected the difference of kinematics and dynamic responses of the upper body in both the THOR Mod Kit and the Hybrid III
- As for durability of the THOR in two JNCAP test conditions, there was no dummy failure and unusual mode.
- As for the relation between the contact between the elbow of dummy and the instrument panel and the increase of the spine moment about the X-axis in the ODB test, further verification by re-testing etc is needed.
- In both the FWRB and ODB tests, the eversion on the ankle of the THOR Mod Kit exceeded IARV at the rebound phase of the vehicle.

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APPENDIX

Table A1. Preliminary IARVs for the THOR and the injury measures in the FWRB test.

		IARV	Ref	THOR Mod Kit	Hybrid III
Head	BRIC(Previous Version)	0.89	[8]	0.54	No sensor
	BrIC(Latest Version)	TBD	[10]	0.50	
	HIC 36ms	1000	[8]	520.8	284.8
	HIC 15ms	700	[8]	376.4	-
	3ms clip (G)	80	[7]	59.7	-
Upper Neck	Tension Force (N)	2520	[8]	1842.1	1290
	Compression Force (N)	3640	[8]	234.9	-
	Flexion at OC (Nm)	48	[7]	1.5	-
	Extension at OC (Nm)	72	[7]	7.8	24.3
Chest	Deflection(Center)	63	[8]	No sensor	27.0
	Deflection(Upper Left) (mm)			37.7	No sensor
	Deflection(Upper Right) (mm)			16.1	
	Deflection(Lower Left) (mm)			27.9	
	Deflection(Lower Right) (mm)			-9.5	
	3ms clip (G)	60	[8]	41.5	42.0
Abdomen	Deflection (mm)	90	[8]	69.6	No sensor
Acetabulum	Left Resultant Force (N)	3316	[8]	1486	No sensor
	Right Resultant Force (N)			1042	
Femur	Left Femur Force (N)	9040	[8]	4288	2600
	Right Femur Force (N)			3725	2000
Tibia	Left Upper Tibia Index	1.16	[8]	Sensor N.G.	0.5
	Left Lower Tibia Index			0.58	0.7
	Right Upper Tibia Index			0.54	0.5
	Right Lower Tibia Index			0.56	0.2
Ankle	Left Inversion/Eversion (deg)	35/35	[8]	26.6	No sensor
	Left Dorsiflexion/Plantarflexion (deg)			16.1	
	Right Inversion/Eversion (deg)			37.4	
	Right Dorsiflexion/Plantarflexion (deg)			14.8	

Note
Currently all IARVs are preliminary.
Negative value in chest deflection means chest expansion.
Hybrid III measurements are from JNCAP tests.

Table A2. Preliminary IARVs for the THOR and the injury measures in the ODB test.

		IARV	Ref	THOR Mod Kit	Hybrid III
Head	BRIC(Previous Version)	0.89	[8]	0.60	No sensor
	BrIC(Latest Version)	TBD	[10]	0.72	
	HIC 36ms	1000	[8]	510.1	262.7
	HIC 15ms	700	[8]	291.5	-
	3ms clip (G)	80	[7]	53.0	-
Upper Neck	Tension Force (N)	2520	[8]	1653.5	1410
	Compression Force (N)	3640	[8]	803.3	-
	Flexion at OC (Nm)	48	[7]	1.6	-
	Extension at OC (Nm)	72	[7]	7.9	16.1
Chest	Deflection(Center)	63	[8]	No sensor	27.5
	Deflection(Upper Left) (mm)			37.2	No sensor
	Deflection(Upper Right) (mm)			20.3	
	Deflection(Lower Left) (mm)			35.5	
	Deflection(Lower Right) (mm)			-17.8	
	3ms clip (G)	60	[8]	43.4	44.1
Abdomen	Deflection (mm)	90	[8]	68.7	No sensor
Acetabulum	Left Resultant Force (N)	3316	[8]	1121	No sensor
	Right Resultant Force (N)			1485	
Femur	Left Femur Force (N)	9040	[8]	2247	700
	Right Femur Force (N)			3995	2400
Tibia	Left Upper Tibia Index	1.16	[8]	0.71	0.6
	Left Lower Tibia Index			0.58	0.3
	Right Upper Tibia Index			0.76	0.3
	Right Lower Tibia Index			0.83	0.2
Ankle	Left Inversion/Eversion (deg)	35/35	[8]	33.5	No sensor
	Left Dorsiflexion/Plantarflexion (deg)			23.2	
	Right Inversion/Eversion (deg)			37.2	
	Right Dorsiflexion/Plantarflexion (deg)			21.5	

Note
Currently all IARVs are preliminary.
Negative value in chest deflection means chest expansion.
Hybrid III measurements are from JNCAP tests.