A COMPARISON BETWEEN BIORID AND HYBRID III HEAD/NECK/TORSO RESPONSE IN MIDDLE SPEED SLED REAR IMPACT TESTS

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ABSTRACT

The most important tool used in testing methods for evaluating the performance of seat-systems in rear-end impacts is a biofidelic crash test dummy. It has been reported that there are differences in response between two kinds of such dummies, BioRID P3 and Hybrid III, in rear-end impacts at Δ V=9.2 km/h. The objective of this study is to compare the responses of these two types of dummies, at moderate speeds with HYGE sled tests (Δ V=15 km/h, 25 km/h). At Δ V=25 km/h or less, the BioRID and HYIII dummies showed clear differences in their response to a rear-end collision, and the BioRID showed higher biofidelity than the HyIII in this condition.

1. INTRODUCTION

In recent years, new types of seat/headrest systems have been developed in succession to reduce the incidence of neck injuries due to rear impacts by an automobile [1-3]. To establish a reliable method for evaluating these seat/headrest systems, it is essential to develop high biofidelity dummies.

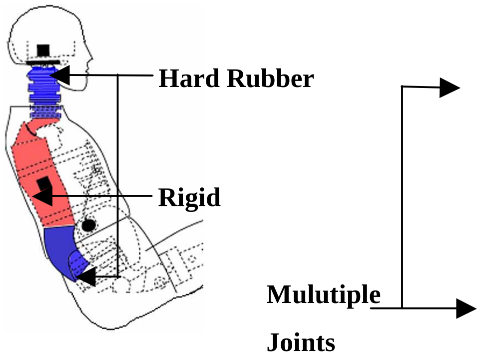
Various dummies of the kind, such as the RID-2 and BioRID, have been developed for use in rear impact tests. The Japan Automobile Research Institute has conducted low-speed (Δ V=9.2 km/h or less) rear impact response tests on the Hybrid III AM50, BioRID-P3 and on volunteers, in cooperation with Chalmers University of Technology (Sweden). The results of the dummy and volunteer tests that were compared and partially reported suggest that BioRID P3 has a higher biofidelity than Hybrid III AM50 [6], [7]. However, it does not discuss the difference in impact response between them in rear impact tests at higher speeds.

The present study compares the impact responses between the two types of dummies. Hybrid III AM50 and BioRID P3, in rear impact tests at relatively higher speeds. (Δ V=15 km/h and 25 km/h). The biofidelity of the dummies and the variations in their behaviors with changes in running speed are evaluated.

2. TEST METHOD

2.1 Features of Dummies

Fig. 1 (a) outlines the construction of the Hybrid III AM 50 (HyIII), and Fig. 1 (b) that of the BioRID-P3 (<u>Bio</u>fidelic <u>R</u>ear <u>I</u>mpact <u>D</u>ummy <u>P</u>roduct



(a) HyIII **(b) BioRID**

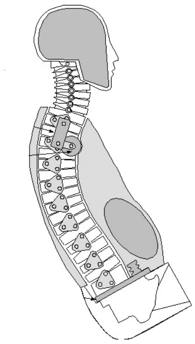


Fig.1 Schematic of Dummies.

No. 3; BioRID).

HyIII is the dummy most commonly used in front impact tests. Its impact response in a rear impact test is considered different from that of a human because a rigid frame and hard rubber are used for its spinal system.

Developed by Chalmers University of Technology, the BioRID has higher biofidelity in a rear impact than other dummies. It has two main characteristics. First, the neck, thoracic, and lumbar spines are of multi-joint construction. Second, silicon rubber, which has many characteristics of the human body, is used for the flesh and skin of the upper body. Accordingly, it is considered that the upper torso of BioRID may behave more like a human body than other dummies. This has been demonstrated in low-speed tests (Δ V=9.2 km/h or lower)[(6), (7)]. The BioRID head, lumbar part, and upper and lower extremities basically have the same parts as HyIII with little alteration.

2.2 Experimental Method

Here we describe the results of the following tests conducted to reproduce rear impacts at relatively higher (moderate) speeds. The objective of these tests is to compare the impact responses of the dummies. The dummies were mounted on a rigid seat on the sled. Rear impacts were reproduced by accelerating the sled, and the impact responses of the dummies were compared. Fig. 2 shows the test setting with the coordinate system used. The dummy set position was arranged the same as for a low-speed test for reference (7).

Fig. 3 illustrates the acceleration waveforms with respect to the sled. The duration of acceleration was the same as at Δ V=9.2 km/h. The objective was to compare the results of the tests with those for the low-speed tests described in reference (7). The peak value G was adjusted so that the sled was accelerated to speeds of 15 km/h and 25 km/h.

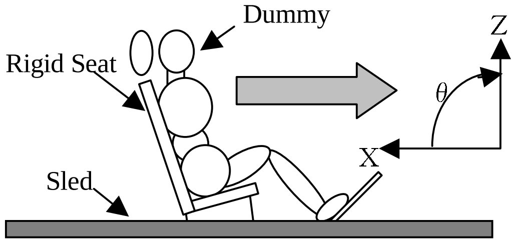
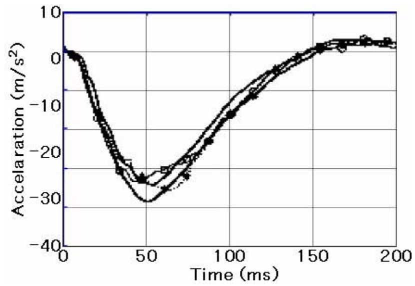
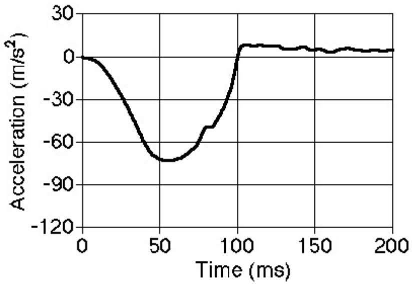


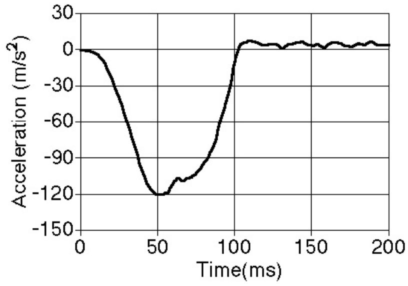
Fig.2 Test Setting.



(a) Δ V=9.2km/h Souse: Reference (7)



(b) Δ V=15km/h



(c) Δ V=25km/h

Fig. 3 Sled Accelerations.

In the low-speed (Δ V=9.2 km/h) impact rear tests, no headrest was attached[(7)]. This test is conducted with the headrest positioned in consideration of the durability of the dummy.

2.3 Parameters to be Compared

In the report, we include the following five parameters in comparing the HyIII and BioRID. These parameters were considered significant in terms of neck injuries:

(1) Forward/backward acceleration at dummy head center of gravity (H Acc)

H Acc is a value indicating to a great degree the characteristics of the neck. Since the head is on top of the neck, this value varies greatly in accordance with the rigidity and structure of the neck.

(2) Neck tension/extension moment (NMY)

It is thought that a strong relationship exists between NMY and a neck injury. The NMY value indicates the neck resistance limit.

(3) Head rotation angle relative to neck link angle (HA-NA)

(4) 1st thoracic vertebra rotation angle (T1A)

Overrotation of the neck is thought to be one cause of neck injuries. Therefore, the rotation angle of the neck is used to express the neck resistance limit. This report uses HA-NA and T1A, the rotation angle related to the neck, for purposes of comparison.

(5) Variation in distance between dummy 1st thoracic vertebra and hip point (THD)

THD has drawn attention as one cause of neck injuries. It is considered to be a value related to the neck protrusion out from the spine.

2.4 Method of Measurement

The first two parameters mentioned above were derived from sensors. The last three were obtained from the target marks attached to the dummy body parts for measuring any variation in posture using a high-speed video camera. The method used to measure each item is as follows.

(1) H Acc. was measured by means of accelerometers attached to the HyIII and BioRID head centers of gravity. It was considered positive (+) when the head center of gravity was accelerated forward.

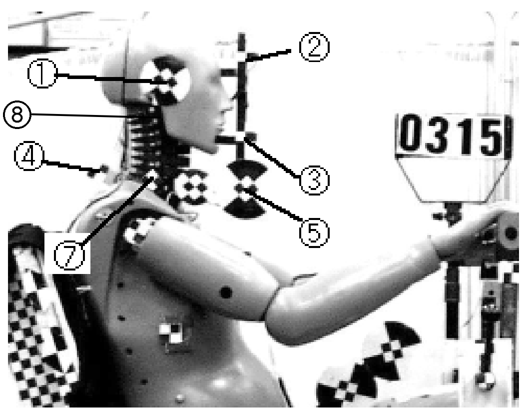


Fig. 4 Schematic of Target marks .

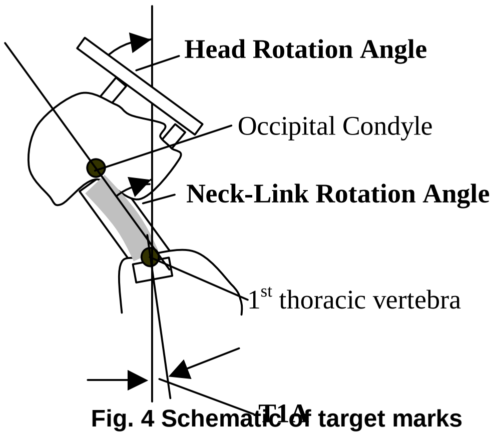


Fig. 5 Schematic of Rotation Angles.

(2) NMY was measured with a load cell equipped at the top of the dummy neck. It was considered positive (+) when the moment acted in the direction from the chest to the chin.

As shown in Fig. 4, target marks for measuring the variation in posture were attached to the following body points:

① Head center of gravity
② Upper part of head
③ Lower part of head
④ 1st thoracic vertebra (back)
⑤ Breast bone (on the longitudinal line)
⑥ Hip point
⑦ 1st thoracic vertebra (sides)
⑧ Occipital condyle

Values (3) – (5) below were obtained as follows from the position of the target marks.

(3) HA-NA was obtained by subtracting the neck link angle (NA) from the head rotation angle (HA). HA is the angle between the line connecting the two points ② and ③ and the

vertical. NA is the angle between the line connecting the two points ⑦ and ⑧ and the vertical. HA-NA was considered positive (+) when the HA value was smaller than NA.

(4) The T1A herewith was defined as the angle formed between points ④ and in ⑤ and the horizontal. It was considered positive (+) when the 1st thoracic vertebra rotated forward.

(5) THD was defined as the variation in distance between the two points, ⑥ and ⑦. It was considered positive when the distance between these two points increased.

3. RESULTS

First of all, the differences in H Acc and NMY between the two kinds of dummies for Δ V=15 km/h and their causes are described. Next, we indicate how these differences change when Δ V is increased to 25 km/h.

The differences among HA-NA, T1A, and THD and the cause of the impact response of volunteers and dummies are summarized for Δ V=9.2 km/h and Δ V=15 km/h, respectively. Then those differences are described when Δ V is increased to 25 km/h.

The measured values are based on the non-impact values (0 points) prior to the tests.

3.1 H Acc

Fig. 6 and 7 show the H Acc levels obtained. At a speed of Δ V=15 km/h, acceleration was applied before the HyIII head impact with the headrest, a phenomenon not seen with the BioRID. This difference in H Acc values between the two dummies is attributed to the difference in neck structures.

The rigidity of the HyIII neck portion is high because it is of one-piece construction. Therefore, as shown in Fig 8 (a), the neck readily follows body movement. The BioRID neck is of multi-joint construction with low rigidity, so it has lower rigidity than the HyIII and therefore does not readily follow the body dynamics (Fig. 8 (b)). This difference in structure between the dummies caused the difference in acceleration. The maximum acceleration of BioRID is slightly higher than that of HyIII.

The H Acc levels were compared in the Δ V=15 km/h and Δ V=25 km/h tests. At these speeds, acceleration was applied to the HyIII head prior to rear impact. This phenomenon can not be seen with the BioRID. In this case, the difference in acceleration waveforms between the dummies is almost the same as in the Δ V=15 km/h test. The difference is not seen at Δ V=25 km/h, although the maximum acceleration of BioRID is slightly higher than that of HyIII at Δ V=15 km/h.

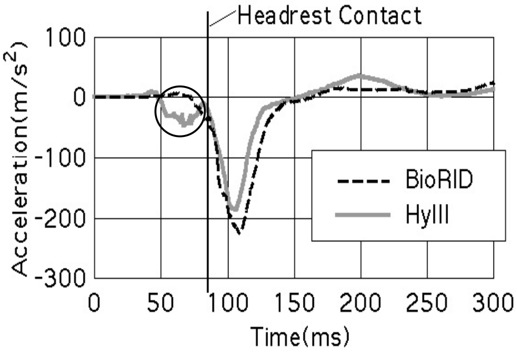


Fig. 6 H Acc (Δ V=15km/h).

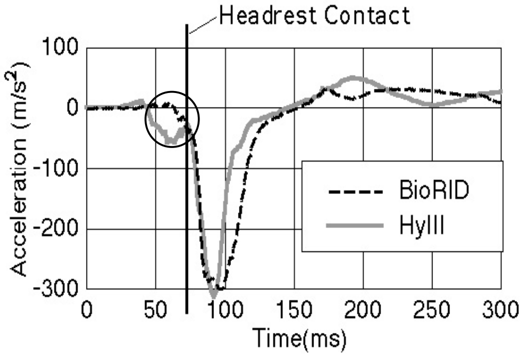
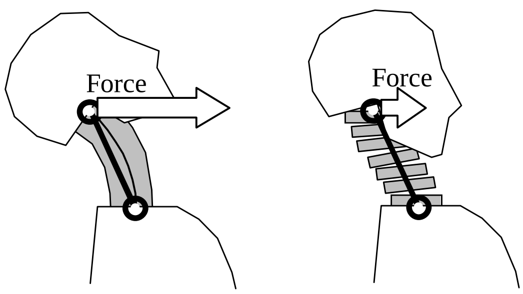


Fig. 7 H Acc (Δ V=25km/h).



(a) HyIII **(b) BioRID**

Fig. 8 Head and Neck Motion in Rear Impact Tests.

3.2 NMY

Fig. 9 and 10 show the NMY levels obtained.

At a speed of Δ V=15 km/h, the HyIII had NMY values higher than the BioRID. This difference is considered to be due to the different spinal structure of the two dummies. For the same reasons as with the H Acc, the HyIII neck more readily conforms to the body dynamics than the BioRID (Fig. 8). It is thought that the NMY of HyIII grew more than that of BioRID because this force generates NMY.

The NMY levels obtained were then compared between the Δ V=15 km/h and Δ V=25 km/h tests. NMY increases with the increase of either HyIII or

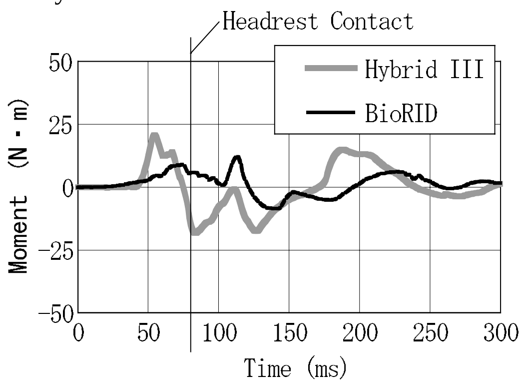


Fig. 9 NMY (Δ V=15km/h).

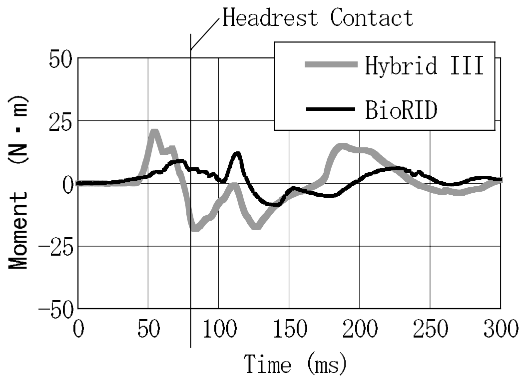


Fig. 10 NMY (Δ V=25km/h).

BioRID when the measured NMY values between Δ V=15 km/h and Δ V=25 km/h are compared. The difference between the two dummies were greater than in the Δ V=15 km/h tests.

3.3 HA-NA

Fig. 11 to 13 list the HA-NA values. Differences in the HA-NA values among the volunteers, HyIII, and BioRID at a speed of Δ V=9.2 km/h are shown in Fig. 15, and the cause for these differences are summarized. For the volunteers and BioRID, the HA-NA values suggest a bending forward (+ side) and then backward (- side). Unlike the volunteers and the BioRID, the HyIII bent backward from the initial stage of the rear impact.

These variations may well be due to the different neck strength among the volunteers, BioRID and HyIII.

The neck of the volunteers and BioRID are of multi-joint construction with low rigidity. Therefore, the neck does not readily follow the body movement and is not forcefully pulled forward at the time the body moves forward. As is apparent from Fig. 14 (b), the HA-NA values bent forward in this connection. On the other hand, the HyIII neck is of monocoque

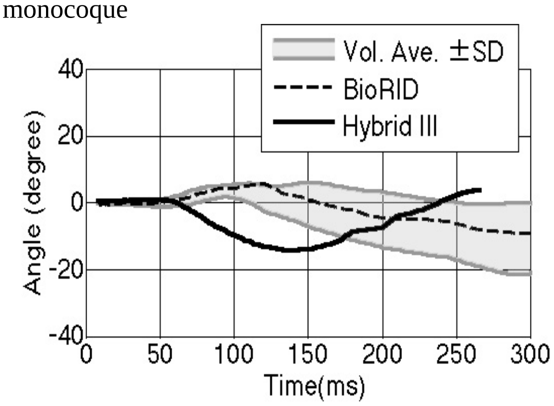


Fig. 11 HA-NA (Δ V=9.2km/h) Souse: Reference (7).

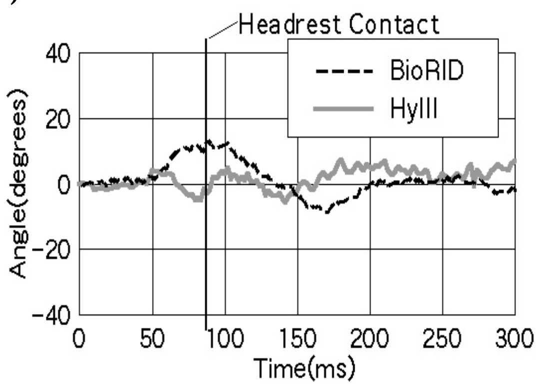


Fig. 12 HA-NA (Δ V=15km/h).

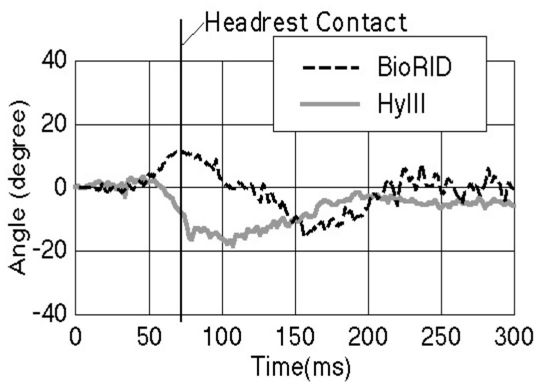
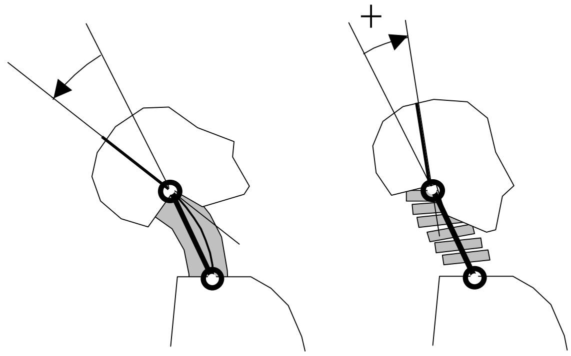


Fig. 13 HA-NA (Δ V=25km/h).



(a) HyIII **(b) BioRID**

Fig. 14 Head and Neck Rotation In Rear Impact Tests.

construction with high strength.

Therefore, it is together with the head, strongly pulled forward when the body moves forward. As is apparent from Fig. 15 (b), the HA-NA values bent forward in this situation.

At the speed of Δ V=15 km/h shown in Fig. 12, a difference in behavior was seen from the ΔV=9.2 km/h tests since rotation was suppressed by the headrest. The BioRID tended to bend forward at the initial stage of rear impact, whereas the HyIII did not. Therefore, like the tests at a speed of Δ V=9.2 km/h, any difference in behavior between the two dummies is considered due to the difference in their neck structures.

The HA-NA values were compared for the Δ V=15 km/h and Δ V=25 km/h tests. In the Δ V=25 km/h tests, the HyIII HA-NA values indicated greater backward bending than in the Δ V=15 km/h tests. The difference between the HyIII and BioRID values in the Δ V=25 km/h tests were greater than in the Δ V=15 km/h tests.

3.4 T1A

Figures 15 to 17 show the T1A values. The differences in T1A among the volunteers, HyIII, and BioRID at a speed of Δ V=9.2 km/h are shown in Fig. 15, and their causes are summarized. For the volunteers and BioRID, the T1A values indicated that they rotated, whereas the HyIII hardly rotated at all. These variances are due to the differences in spinal structure among the two dummies and the volunteers.

For the volunteers and BioRID, other vertebra could continue to rotate even if the thoracic vertebra was in contact with the rigid frame seat because of their multi-joint spinal makeup. Therefore, the BioRID T1A values can be increased. For HyIII, other vertebra could not continue to rotate if part of the thoracic vertebra was in contact with the seat because of its hard thoracic vertebra. Therefore, the HyIII T1A values can not be increased.

At the speed of Δ V=15 km/h shown in Fig. 16, the same as with the results of the Δ V=9.2 km/h test, the HyIII hardly rotated at all, whereas the BioRID rotated. The variation is considered due to the difference in spinal structure.

The T1A values in the Δ V=15 km/h and Δ V=25 km/h tests were compared. The results revealed the same trend in both tests. In addition,

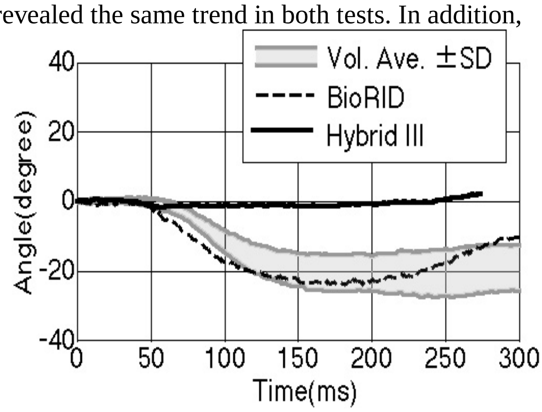


Fig. 15 T1A (Δ V=9.2km/h) Souse: Reference (7).

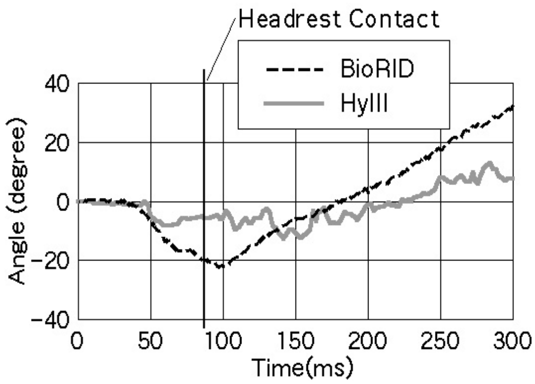


Fig. 16 T1A (Δ V=15km/h).

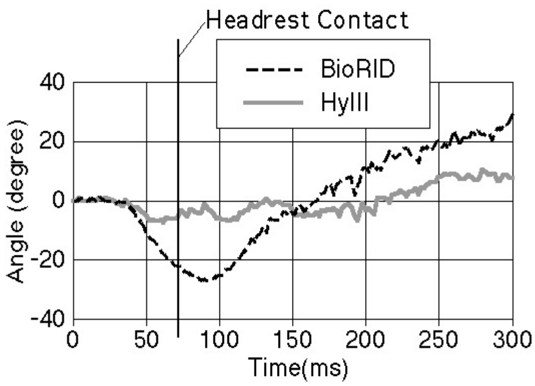


Fig. 17 T1A (Δ V=25km/h).

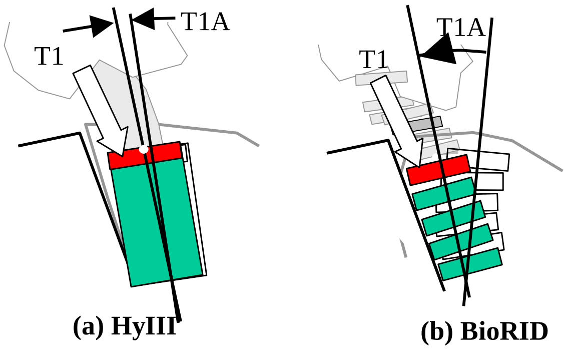


Fig. 18 Schematic of 1st thoracic vertebra In Rear Impact Tests.

BioRID had a larger maximum rotation angle than HyIII. The difference in the T1A values between the two dummies became larger as the running speed increased.

3.5 THD

Figures 19 to 21 show the THD values. Differences in behavior among the volunteers, HyIII, and BioRID at a speed of Δ V=9.2 km/h are shown in Fig. 19, and their causes are summarized. For the volunteers and BioRID, the THD values increase by almost the same amount, while HyIII evidenced almost no variation. The differences may be attributed to the difference in spinal structure among the volunteers, HyIII, and BioRID.

Since the spines of volunteers were of multi-joint structure, they bent at the initial stage of rear impact; they then straightened out under impact from the back side, resulting in larger THD values. As seen in Fig. 22 (a), the HyIII spine is composed of a rigid frame and hard rubber. It does not deform even under impact from the rear, and the THD values do not change. As seen in Fig. 22 (b), since the BioRID spine has a multi-joint construction like the volunteers, it bends at the initial stage of rear impact. The THD values may thus increase.

As with a speed of Δ V=9.2 km/h, at Δ V=15 km/h almost no change was observed in the THD values for HyIII, whereas they occurred for BioRID. Like the Δ V=9.2 km/h tests, this variation may be due to the differences in spinal structure.

The THD values of the Δ V=15 km/h and Δ V=25 km/h tests were compared. The results showed the same trend in both tests. The difference in THD between the two dummies became smaller at a speed of Δ V=25 km/h than at Δ V=15 km/h.

4. DISCUSSION

4.1 Difference in Impact Response of Dummies Due to a Change in Speed

The test results showed that as the speed increased, the differences in NMY, HA-NA and T1A between HyIII and BioRID became larger, while those iin THD and H Acc became smaller. Therefore, the effect of the increase in speed clearly depended on the part of the dummy affected. The rear impact response of HyIII and that of a rear impact dummy have been conventionally assumed to

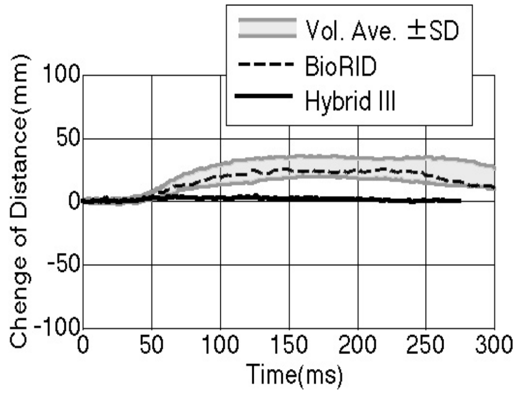


Fig. 19 THD (Δ V=9.2km/h) Souse: Reference (7).

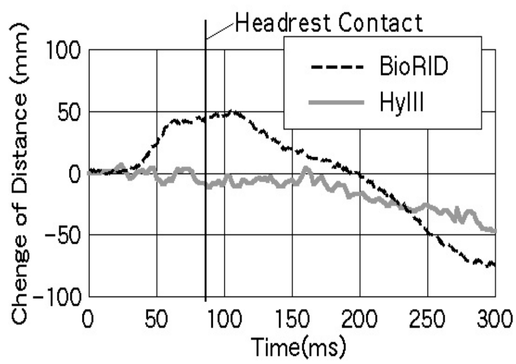


Fig. 20 THD (Δ V=15km/h).

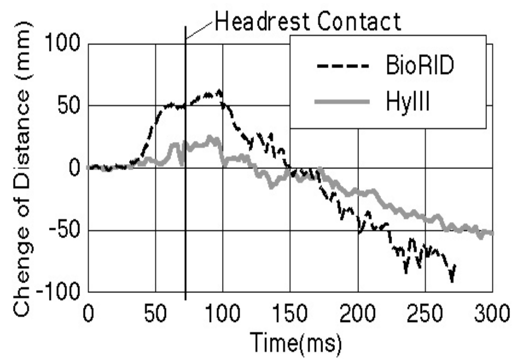
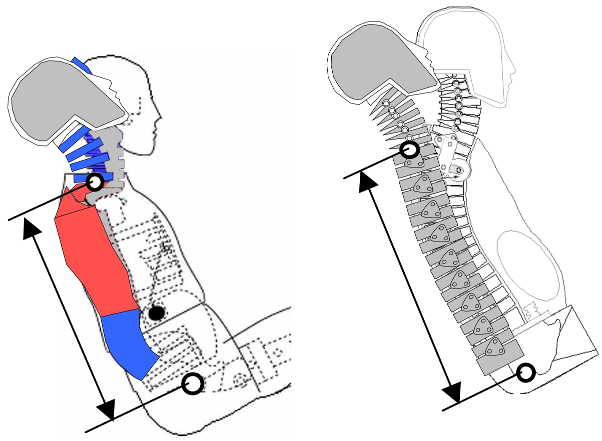


Fig. 21 THD (Δ V=25km/h).



(a) HyIII (b) BioRID

Fig. 22 Schematic of Spine in Rear Impact Tests.

show little difference at high speeds. However, our investigations using the BioRID at Δ V=25 km/h or less demonstrated that this assumption is incorrect.

4.2 Comparison of Dummy Impact Responses at the Δ V=15km/h and Δ V=25km/h Tests

Based on the 5 parameters initially presumed to have a close relation to injuries sustained, differences in impact response were observed between the two dummies, HyIII and BioRID. These differences showed almost the same trend at either speed used in testing.

In particular, the same differences among HA-NA, NMY, and T1A were observed for the same reasons as for the case of Δ V=9.2 km/h. From the above-mentioned observations, BioRID displayed higher biofidelity than HyIII in the Δ V=15 km/h and Δ V=25 km/h tests.

5. CONCLUSION

Tests were conducted in which rear impacts were simulated at moderate speeds (Δ V=15 km/h and Δ V=25 km/h) using the HYGE sled. The differences in responses to a rear impact between the HyIII and BioRID dummies at a speed of Δ V=9.2 km/h were compared.

The results showed that:

(1) At a rear impact speed of Δ V=25 km/h or less, there was a clear difference in impact response between the HyIII and BioRID dummies.

(2) At Δ V of 25 km/h or less, the difference in the behavior of HyIII and BioRID was similar regardless of the speed. BioRID had higher biofidelity than HyIII for Δ V=9.2 km/h.

(3) BioRID showed higher biofidelity than HyIII even at moderate speeds of Δ V=15 km/h or Δ V=25 km/h.

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