

Comparison of Dummy Kinematics and Injury Response between WorldSID and ES-2 in Side Impact

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ABSTRACT

A new highly biofidelic side impact dummy, the WorldSID 50th percentile male, has been developed under the supervision of the International Organization for Standardization in order to harmonize a number of existing side impact dummies in one single dummy. Momentum is growing for using the WorldSID in safety tests in the EU and the US. In the present study, two Euro-NCAP pole side impact tests were conducted to compare ES-2 and WorldSID responses in a mid-size SUV with respective seating positions as stipulated in the Euro-NCAP test conditions and fitted with the same side airbag. It was found that, compared with ES-2, the chest, abdomen and pelvis accelerations of WorldSID are more sensitive to variation in the applied external load transmitted by the deployed side airbag and door intrusion.

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INTRODUCTION

Evaluations of occupant protection performance in side impacts are conducted under the New Car Assessment Programs (NCAP) implemented in the United States, Europe, Japan and in many other countries, in addition to regulatory testing. These NCAP evaluations are generally performed under conditions that are more severe than those of the regulatory tests, and the results obtained are made available to the public. Each country has adopted its own set of evaluation standards, and various types of crash test dummies are being used just in side impact tests alone. In view of this situation, the International Organization for Standardization (ISO) developed a new WorldSID 50th percentile male dummy with improved biofidelity for the purpose of unifying the crash dummies used in side impact tests. Specific research activities for adopting this new dummy in safety assessment testing have been vigorously undertaken in recent years, particularly in Europe and the United States, and these efforts are continuing to gain momentum⁽¹⁾.

A rating system for evaluating the biofidelity of the WorldSID dummy is given in ISO/TR9790.⁽²⁾ Under this system, consistency with the impact response corridors derived from cadaver tests for the head, chest and other regions of the body are rated and the scores are used in evaluating biofidelity. The overall rating reported for the WorldSID dummy under this system is 7.6, compared with a rating of 4.7 for the ES-2 side impact dummy that is

commonly used at present. This higher score indicates the improved biofidelity of the WorldSID dummy. Rhule et al.⁽³⁾ reported a comparison of the biofidelity of WorldSID and ES-2re (ES-2 with a modified rib structure), and their evaluation results are summarized in Table 1.

Table 1. Biofidelity scores for WorldSID and ES-2re

	External Biofidelity		Internal Biofidelity	
	WorldSID	ES-2re	WorldSID	ES-2re
Head	–	–	0.3	1.0
Neck	–	–	0.8	2.2
Shoulder	1.0	2.1	0.9	1.3
Thorax	3.2	3.1	2.0	2.4
Abdomen	1.9	2.7	2.4	n/a
Pelvis	2.7	3.5	1.8	1.5
Overall (with Abdomen)	2.2	2.8	1.4	–
Overall (without Abdomen)	–	–	1.2	1.7

In this ranking system, a lower score means higher biofidelity. The results indicate that the WorldSID dummy exhibits improved biofidelity, as was indicated in the ISO report mentioned above. In order to improve biofidelity, the structure of the WorldSID dummy was substantially changed compared with that of the impact dummies currently used. Hikasa et al.⁽⁴⁾ reported on the basis of their sled tests that the upper body behavior of the WorldSID dummy differs from that of ES-2re mainly because of the different structure of its lumbar vertebrae.

Ootani et al.⁽⁵⁾ mentioned the difference in the structure of the ES-2 and WorldSID dummies and discussed the

difference in kinematics observed in pole side impact crash tests.

Rupp et al.⁽⁶⁾ performed low and high speed sled tests with WorldSID and compared the results with postmortem human subjects (PMHS) test data to elaborate the difference in the different kinematic responses. They mentioned that WorldSID is stiffer than cadavers with respect to the abdomen response and also less sensitive to changes in the impact velocity.

In this study, we used the WorldSID and ES-2 dummies in conducting car-to-pole side impact tests under the same conditions as those of the Euro-NCAP and analyzed the differences in dummy responses.

DUMMIES

Figure 1 shows the typical measurement positions of the WorldSID and ES-2 dummies, and Table 2 compares the injury metrics measurable with each dummy. One major difference is that the force imparted to the abdominal region is measured and evaluated with the ES-2 dummy, whereas abdominal displacement is measured instead with the WorldSID dummy, similar to the measurement of chest displacement. In addition, displacement is measured with a newly adopted displacement sensor called the Infrared Telescoping Rod for Assessment of Chest Compression (IR-TRACC).

Yoganandan et al.⁽⁷⁾ conducted side impact tests to examine the thoracic and abdominal region responses of the WorldSID and ES-2re dummies. They reported that the rib deflection sensors incorporated in the WorldSID dummy are better suited to the measurement of the peak deflections actually generated in the dummy's rib structure. In their study, they measured the actual peak deflection responses of each dummy's rib structure in pendulum and oblique impact tests based on chest band data obtained at every millisecond from the curvature signals of each strain gauge using the RBandPC software. They then compared the "IR-TRACC-type peak deflections" of the WorldSID dummy and the "potentiometer-type peak deflections" of the ES-2re dummy. Their comparison revealed that the rib deflection results of the WorldSID dummy were closer to the peak deflection values, especially for rib deflections in oblique impacts, as measured with a chest band.

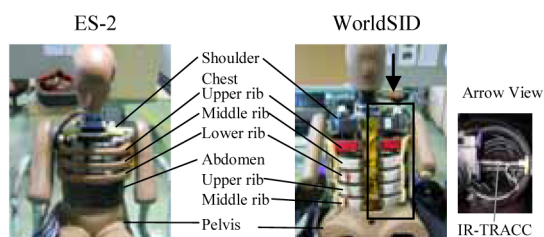


Figure 1. Injury measurement regions of ES-2 and WorldSID

Table 2. Comparison of injury metrics of ES-2 and WorldSID

		ES-2	WorldSID	
Shoulder		–	Displacement & Force	
Chest	Upper	Displacement	Displacement	
	Mid			
	Lower			
Abdomen		Force	Upper Lower	Displacement
Pubic		Force	Force	

Table 3 shows the widths of the ES-2 and WorldSID dummies as measured from the center to the edge of the dummy body in each region. These measurements were obtained from CAD drawings of the dummies. The data indicate that the WorldSID dummy has narrower shoulders but a wider chest, abdomen and pelvis than the ES-2 dummy.

Table 3. Difference in width of ES-2 and WorldSID from dummy center

	ES-2	WorldSID	Difference [mm]
Shoulder	246	237	–9
Chest	164	180	16
Abdomen	140	180	40
Pelvis	180	207	27

TEST CONDITIONS

The test conditions of the two pole side impact experiments using the ES-2 and WorldSID dummies in this study are tabulated in Table 4. The same mid-size SUV was used in both cases. The same P-T(pelvis-thorax type) side air bag was used with the same TTF(time-to-fire) for air bag deployment.

The pole size, angle of impact and impact velocity were the same as the Euro-NCAP conditions. The dummies were seated in the driver's seat. The WorldSID dummy was seated according to the procedure specified by the ISO's WorldSID Task Group. According to this seating procedure, the seat is positioned 20 mm rearward of the center of the seat's sliding range. Therefore, the WorldSID dummy was sitting 20 mm further rearward compared with the ES-2 dummy that was positioned in the center of the seat's sliding range. Owing to that difference, the position of the pole was adjusted accordingly so that it impacted the center of each dummy's head as shown in Figure 2a.

In Figure 2b, the superimposed position of two dummies show the difference in G-sensor positions and the impacting pole with respect to the vehicle reference frame. The prescribed seating positions of the dummies were slightly different as stipulated in Euro-NCAP protocol. The same was true for the corresponding positions of the G-sensors. In other words, the following discussion and analysis of the test data are based on the exact protocol procedures without adjusting the seating and the sensor positions for two different dummies. Sensor T1 of ES-2 and sensor T4 of WorldSID

were chosen for a comparison of upper thorax accelerations and the kinematics of the respective dummies. G-sensors at T12 and the pelvis were chosen for a comparison of the kinematics of the abdomen and the pelvis.

Table 5 shows the relative difference in vertical and horizontal positions of the respective G-sensors of ES-2 and WorldSID dummies. The position of the center lines of the two dummies was identical.

Table 4. Crash test conditions

Test Number	1	2
Dummy	ES-2	WorldSID
Longitudinal seat position	Neutral	Neutral -20 mm(rearward)
Vehicle type	Mid-size SUV	
Side airbag	Pelvis-thorax type	
Angle of impact	90 deg	
Velocity	29.5 km/h	

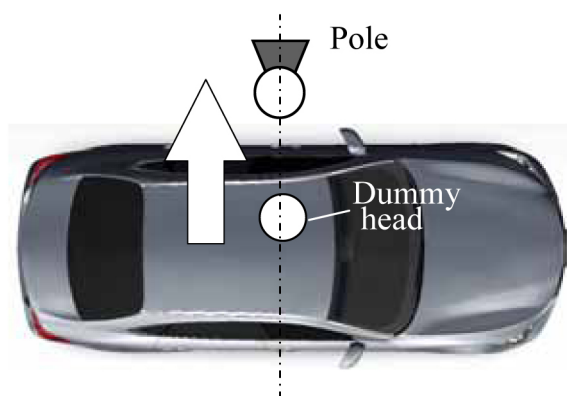


Figure 2a. Crash test overview

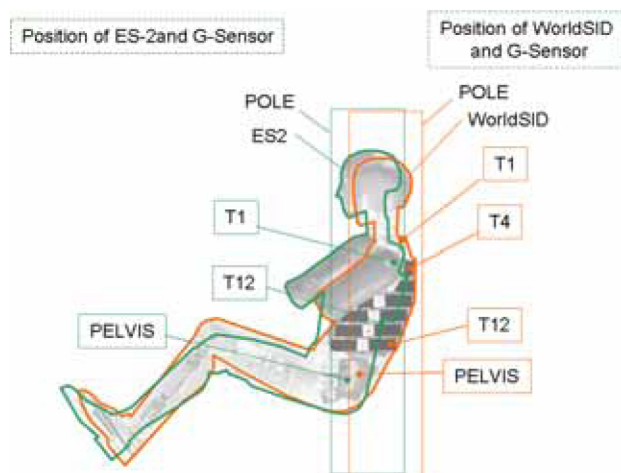


Figure 2b. Positions of each dummy and G-sensors relative to the same mid-size SUV

Table 5. Relative positions of G-sensors and pole

Position of ES-2		Position of WorldSID	
T1	w.r.t.	T4	60.3 mm rearward 4.4 mm downward
T12	w.r.t.	T12	73.9 mm rearward 34.0 mm downward
Pelvis	w.r.t.	Pelvis	68.7 mm rearward 45.3 mm downward
Pole	w.r.t.	Pole	64.9 mm rearward

TEST RESULTS AND DISCUSSION

Comparison of Resultant Dummy Acceleration

The accelerations generated in the direction of impact in the thoracic, abdominal and pelvic regions of each dummy were compared in order to analyze their behavior and responses. Figure 3 shows the locations of the G-sensors attached to the two seated dummies. The acceleration values measured for each region were integrated to calculate the outboard movement of the dummy toward the door. The relationship between the measured acceleration and amount of lateral movement of the two dummies is shown in Figure 4 for the ES-2 dummy and in Figure 5 for the WorldSID dummy.

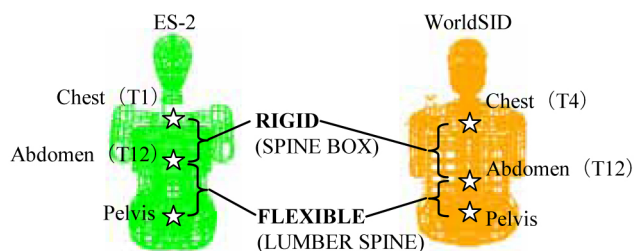


Figure 3. Locations of chest, abdomen, and pelvis G-sensors on ES-2 and WorldSID

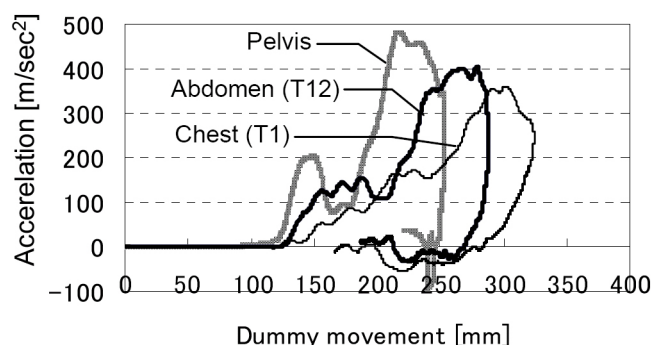


Figure 4. Chest, abdomen, pelvis responses of ES-2