A COMPARISON STUDY OF TWO SIDE IMPACT DUMMIES BASED ON THE PROBABILITY OF INJURY RSIK CURVES

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ABSTRACT

In recent years, WorldSID dummy has been continuously developed and investigated to better represent biofidelic ATD as well as a device for replacement of the current existing ES-2 side impact dummy.

In Korea, the side impact type traffic accident is one of the major sever accidents in terms of numbers of accidents and fatality. Since 2003, 50kph 90 degree side crash test has been initiated as a safety standard with ES-1 at the first stage and also same time 55 kph impact speed test has been conducted as a part of KNCAP program. Currently only ES-2 is accepted as a regulatory tool for vehicle certification and KNCAP.

In spite of the introduction of side impact regulation and NCAP test procedures for the protection in lateral collisions during the last 10 years, injuries in this accident type still constitute a significant category of road traffic injuries. The fatality from side impact accidents has not been successfully decreased as expected. The head injury is major sources of fatality in side impact crash accidents in Korea.

In 2009, for further enhancing the protection of side collision, the perpendicular 29 kph pole side impact test with ES-2 dummy has been introduced as an optional test in KNCAP. The main objective of the optional pole side impact test was to promote installation of side curtain airbag in the vehicle fleet as a standard option.

In this study, injury outcome from WorldSID and ES-2 were evaluated with the two different types of vehicle sizes, small and medium size vehicles crash tests. Also, the computer simulations were performed.

In this simulation matrix, impact speeds (50 kph, 55 kph), MDB types (MDB and AE-MDB) were considered as variables.

In fact, WorldSID 50th male dummy's injury risk criteria limits are not finalized yet. Only the injury criteria categories have been just defined in the informal meeting as head injury criteria (HIC36), shoulder performance criteria (shoulder force: Fy), thorax performance criteria (thorax rib deflection), abdominal performance criteria (abdominal rib deflection and T12 resultant acceleration) and pelvis performance criteria (peak pubic symphysis force) Also the injury criteria and dimension of body structures between ES-2 and WorldSID cannot match each other.

In this study, in steads of direct comparison between two dummy's performances, the percentages of injury risk probability were compared with each individual body parts. ES-2 shows higher thoracic rib deflection compared with WorldSID for compact size vehicle. But mid-size case, two dummy's injury risk probability are same levels. The abdomen injuries from two dummies were similar but WorldSID showed lower pelvic injuries. In this study, only 2 different types of vehicles were tested with ES-2 and WorldSID. A small amount of rib deflection from the WorldSID may due to the upper body rotation during the impacts. From this study, the injury patterns are similar between two dummies. However, the probability of injury risk in the thoracic body was not higher than the ES-2 for small size vehicle.

INTRODUCTION

Development of the WorldSID 50th percentile male dummy began in June 1997 with a resolution by the International Organization for Standardization (ISO) ISO/TC22/SC12/WG5 to establish a task group. This task group consisted of many government and industry organizations worldwide. Through this collaboration, the group conducted extensive testing and evaluation, and prepared the drawings and user's manual.

In 2008, the task group finished the biofidelity assessment. They are currently working on risk curves for the injury measures and a practical seating procedure. The WorldSID 50th percentile male dummy has a standing height of 1,753 mm, seating height of 911 mm, and a mass of 77.3 kg. It has symmetrical response (left/right) and is able to be used in side impacts up to ±30° from the pure lateral impact direction.

In terms of global regulatory process, at the 148th session of WP.29 of June 2009, the importance of harmonizing test tools was discussed and there was general agreement to explore opportunities to complete the development of the world side impact dummy (WorldSID) 50th percentile male and 5th percentile female side impact dummies. At the 149th session of WP.29 of November 2009, the representative of the United States of America submitted in an informal document proposing the establishment of an informal group to focus on the development of the two WorldSID dummies. Since the first meeting held in November 2009, the latest meeting, the 11th informal group meeting was in January 2013. Korea has been also regularly participated in this informal group as well as informal group of pole side impact GTR.

WORLDSID VS. ES-2 DUMMIES SIDE IMPACT TEST

The total 4 vehicles were tested according to KMVSS 102 which similar to UN R94 with 2 different dummies, WorldSID 50%tile and ES-2. In the test, two different types of vehicles were selected as mid-size and small compact size vehicle to evaluate structural performances. AE-MDB was used in the test with 50kph impact speed. The test specification was shown in shown figure 1. The Both cars were equipped with thorax and curtain airbags.

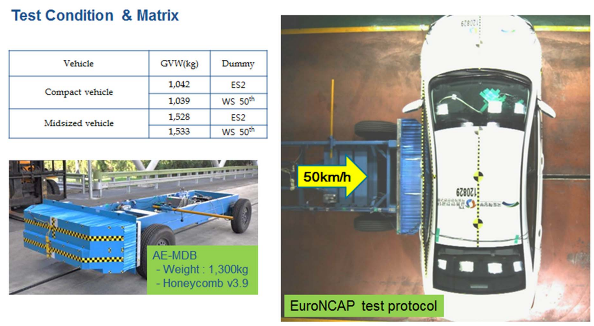


Figure 1. AE-MDB side impact test

In this test, each of dummy was seated in the driver to evaluate dummy kinematics and injury patterns especially thoracic and pelvic parts. The dummies seated in the cars shown in figures 2 and 3.

Figure 2. Dummy seated in the compact size car

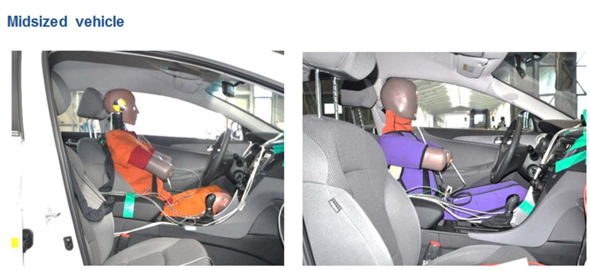


Figure 3. Dummy seated in the mid-size car

The test results are shown in Table 1. In the compact car, the rib defections of WorldSID are significantly lower than those of ES-2 dummies. It may be caused by more rotational behavior in WorldSID than ES-2. In the ES-2 dummy, while the upper rib deflection was the maximum value, the lower rib had a largest deflection in the WorldSID. But reversely, mid-size care case, WorldSID rib deflection is larger than ES-2. The public forces from the WorldSID are lower than ES-2 in both vehicles. The thorax rib deflections and pubic forces are shown in figures 4 and 5.

Table 1. Injury outcomes from side impact tests

			Compact vehicle		Midsized vehicle	
			ES2	WS 50th	ES2	WS 50th
Head	HIC 36	-	84.03	62.93	63.15	96.2
	Peak resultant Acceleration	g	37.33	27.79	26.23	29.33
	3ms	g	29	23.09	25.41	27.05
Shoulder	Shoulder Rib Deflection(1)	mm	-	20.12	-	38.7
Thorax	Upper Rib Deflection(2)	mm	32.4	7.09	12.3	6.13
	Middle Rib Deflection(3)	mm	22.1	7.57	10.0	9.6
	Lower Rib Deflection(4)	mm	22.5	11.89	15.7	18.3
Abdominal & Pelvis	Abdomen Rib1 Deflection(5)	mm	-	16.66	-	20.6
	Abdomen Rib2 Deflection(6)	mm	-	31.03	-	21.9
	Pubic Symphysis Force(Fy)	kN	2.11	1.2	2.48	1.37

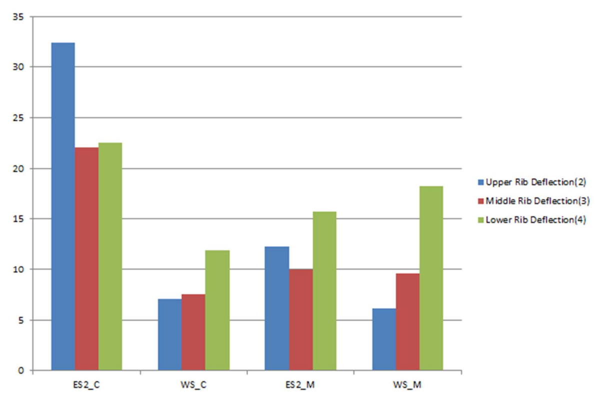


Figure 4. Thorax rib deflections

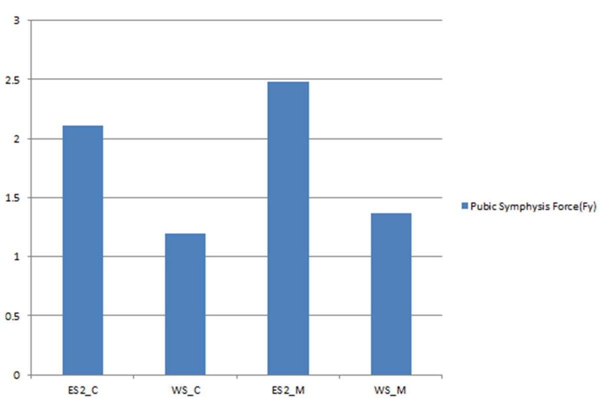


Figure 5. Pubic symphysis forces

However the injury criteria for the WorldSID 50%tile dummy is not finalized yet. In steads of direct comparison, the relative injury risks are examined by IARV's criteria. In general, injury risk curves can be expressed by the logistic regression equations. But in these comparisons, the injury risk rations were simple calculated by the linear relationships. As shown in Table 2, pelvis injury performance, pubic force, are similar in the both dummies. The thorax injury risk ratios for the WorldSID is relatively lower than ES-2.

Table 2. Injury ratios between two dummies in the compact car

Compact Car Injury Performances

ES-2	Injury	Unit	Injury value	IARV's	Ratio
Thorax Ribs	Deflection	mm	32.4	44	73.6%
Pubic	Force	kN	2.11	6.0	35.2%

WorldSID	Injury	Unit	Injury value	IARV's	Ratio
Thorax Ribs	Deflection	mm	11.89	[55.4]	21.5%
Pubic	Force	kN	1.2	[3.365]	35.7%

For the mid-size car, the both thorax and pelvis injury ratios are similar as shown in Table 2.

Table 3. Injury ratios between two dummies in the mid-size car

Mid-size Car Injury Performances

ES-2	Injury	Unit	Injury value	IARV's	Ratio
Thorax Ribs	Deflection	mm	15.7	44	35.7%
Pubic	Force	kN	2.48	6.0	41.3%

WorldSID	Injury	Unit	Injury value	IARV's	Ratio
Thorax Ribs	Deflection	mm	18.3	[55.4]	33.0%
Pubic	Force	kN	1.37	[3.365]	40.7%

A SERIES OF SIMULATIONS RESULTS

Since the side impact tests were limited, the series of the computer simulation were conducted to evaluate two dummies with the different impact speeds and side structural integrities. In the simulation, LS-Dyna with FE WorldSID and ES-2 dummy models were used. The generic mid-size vehicle was modeled without airbags to eliminate effects of airbags.

WorldSID vs. ES-2 Dummies

As a first analysis model, injury outcomes of two dummies were compared with 55 kph impact speed in 1,300 kg AE-MDB. The dummies kinematics and injury results were shown in figure 6 and Table 4.

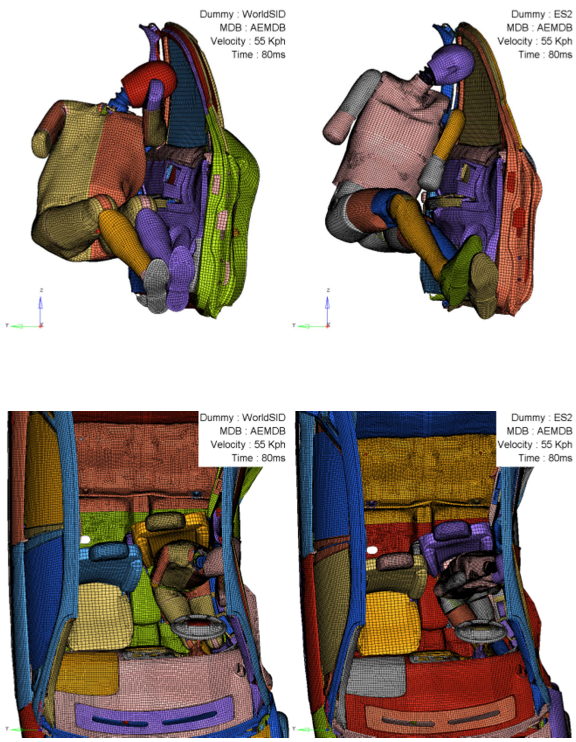


Figure 6. WS and ES-2 kinematics

Table 4. Injuries between two dummies in the mid-size car simulations

WorldSID				ES2			
Shoulder (KN)		-1.29		Clavicle (KN)		-0.46	
Rib def. (mm) /acc. (G)	U	Ax	107.6	Rib def. (mm) /acc. (G)	U	Ay	172.0
		Ay	274.5				
		Az	111.2			def.	-45.2
		def.	-28.1				
	M	Ax	108.9		M	Ay	183.3
		Ay	192.7				
		Az	60.6			def.	-49.7
		def.	-23.6				
	L	Ax	54.8		L	Ay	110.9
		Ay	149.7				
		Az.	56.8			def.	-53.7
		def.	-13.6				
T12 (G)		Ay	68.6	Lower spine acc. (G)		Ay	6.64
		AR	69.1				
Pubic symphysis Shear-s (KN)		1.68		Pubic symphysis Shear-s (KN)		3.25	
Abdominal def. (mm)		Upper	-12.1				
		Lower	-59.2				

As indicated in figures and Table 4, the rib deflections of WorldSID are lower than ES-2. It can be due to the rotation of dummy during the impact. In the ES-2 dummy, x, z directions rib acceleration sensors are not available. However, in WorldSID, as shown in Table 4, x, y directional acceleration values are significant. It means that the deformation of rib cage is influenced by x, z directional forces and generating acceleration in these directions.

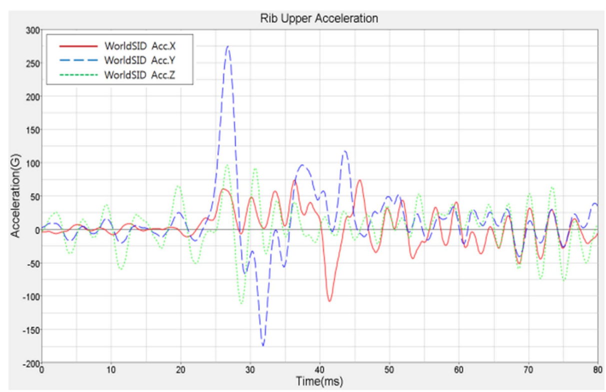


Figure 7. WS50 upper rib accelerations (x, y, z)

In figure 7, it displays the rotation of rib cage. Each individual rib can be deformed and rotated independently. But in the ES-2, whole rib cage is moved as one part as shown in figure 8.

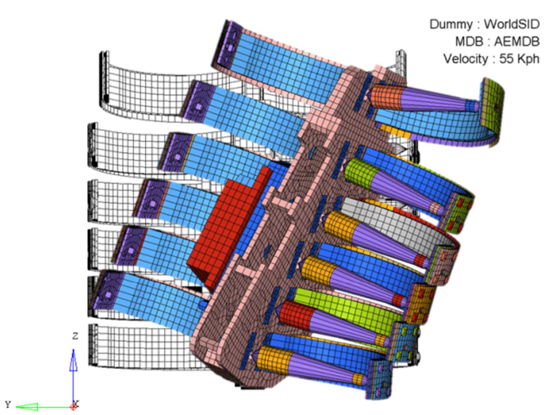


Figure 7. Deformation shape of WordlSID

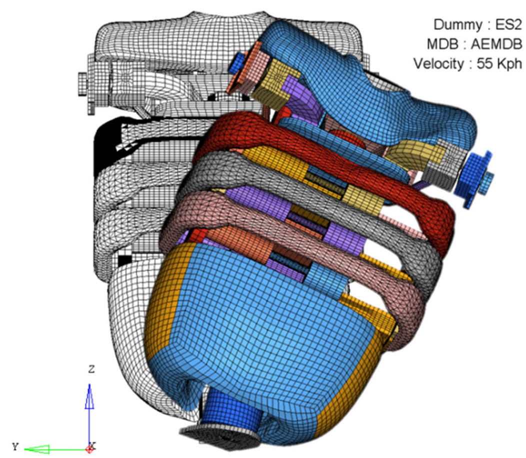


Figure 8. Deformation shape of ES-2

AE-MDB vs. R95 MDB in WorldSID and ES-2

Results from two different MDBs, the injury levels are similar in WS 50 and ES-2 dummies as shown in Table 5 and 6. The impact speed was 55 kph in both cases.

Table 5. Injury comparison with AE-MDB and R95 MDB in WS50 dummy

	MDB	
	AEMDB	R95
Shoulder load cell (KN)	-1.29	-1.63
Thorax rib upper displacement (mm)	-28.06	-30.60
Thorax rib middle displacement (mm)	-23.60	-22.46
Thorax rib lower displacement (mm)	-13.59	-13.51
Abdomen rib upper displacement (mm)	-12.07	-16.36
Abdomen rib lower displacement (mm)	-59.22	-60.70
Abdomen T12 resultant accel. (G)	69.09	82.76
Pubic load cell (KN)	-0.63	-0.67

Table 6. Injury comparison with AE-MDB and R95 MDB in ES-2 dummy

	MDB	
	AEMDB	R95
Clavicle load cell (KN)	-0.46	-0.64
Thorax rib upper (mm)	-45.18	-41.03
Thorax rib middle (mm)	-49.72	-42.36
Thorax rib lower (mm)	-49.72	46.00
Pubic load cell (KN)	5.75	7.45

50 kph vs. 55 kph impact with AE-MDB in WorldSID and ES-2

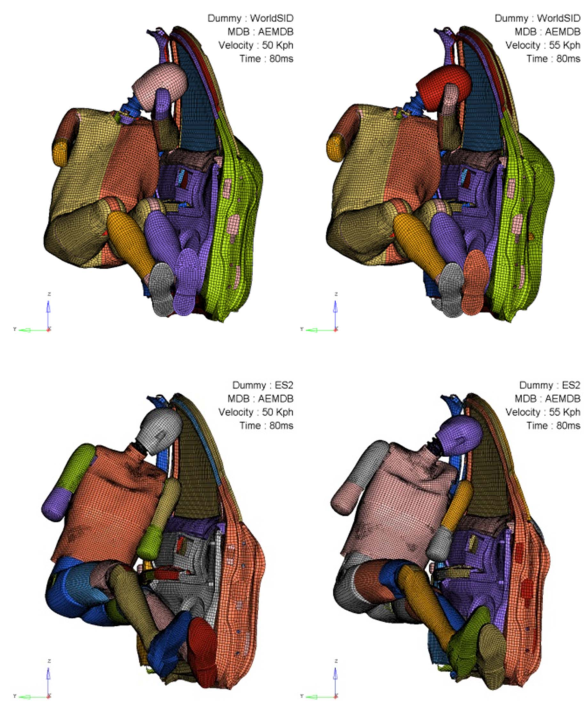


Figure 8. Kinematics of WS50 and ES-2

As shown in figure 8-9 and Table 7-8, the higher impact speed increased injury values in both two dummies. But the difference is not significant for WS50 dummy. For the 50 kph case, the maximum rib deflection was 23.46 mm at the upper rib. Increasing impact speed to 55 kph, the maximum rib deflection is increased 19.6%, 28.06 mm. The following figures represent upper rib deflection, lower abdomen deflection and pubic force comparisons.

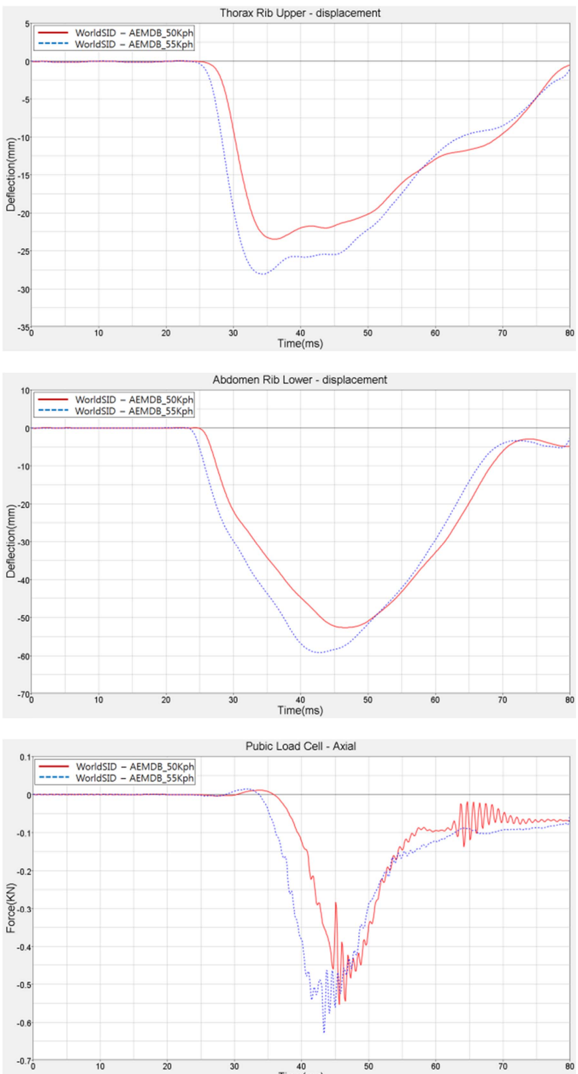


Figure 8. Injury comparison 50, 55 kph in WS50

Table 7. WS50 Injury comparison with different impact speeds, 50, 55 kph

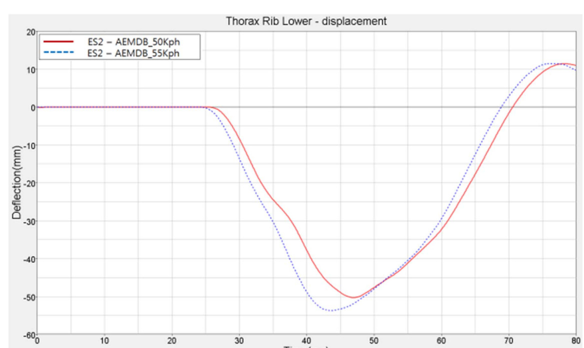
WS 50 /AE-MDB	Velocity (Km/h)	
	50Kph	55Kph
Shoulder load cell (KN)	-1.16	-1.29
Thorax rib upper displacement (mm)	-23.46	-28.06
Thorax rib middle displacement (mm)	-18.10	-23.60
Thorax rib lower displacement (mm)	-11.16	-13.59
Abdomen rib upper displacement (mm)	-9.31	-12.07
Abdomen rib lower displacement (mm)	-52.64	-59.22
Abdomen T12 resultant accel. (G)	57.95	69.09
Pubic load cell (KN)	-0.55	-0.63

For the ES-2 dummy, increasing impact speed to 55 kph, the maximum rib deflection is increased only 6.7%, 53.67 mm. The following figures represent lower rib deflection, and pubic force comparisons.

9.6%

Table 8. ES-2 Injury comparison with different impact speeds, 50, 55 kph

	Velocity (Km/h)	
	50Kph	55Kph
Clavicle load cell (KN)	-0.63	-0.46
Thorax rib upper displacement (mm)	-43.35	-46.18
Thorax rib middle displacement (mm)	-45.35	-49.72
Thorax rib lower displacement (mm)	-50.26	-53.67
Pubic load cell (KN)	4.34	5.75



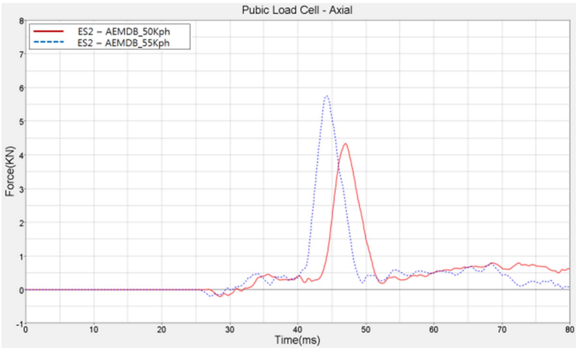


Figure 9. Injury comparison 50, 55 kph in ES-2

CONCLUSIONS

With impact tests and computer simulations, two different side impact dummies, WS50 and ES-2 have been evaluated in terms of dummy kinematic and injury outcomes. In general, WS50 dummy shows lower thorax rib deflection than ES-2. It may be caused by rotational behaviors in WS50 dummy. Since WS50 dummy is designed for ability to be used in side impacts up to ±30° from the pure lateral impact direction. Also, the way of construction of rib cage which more flexible and independently movable each rib part. Therefore, the resultant deflection of WS rib and abdomen should be counted in steads of only y directional deflection to consider rotational behavior of dummy.

Since injury criteria for WS50 is not established yet, IARV's values of each dummy were compared. In general, injury risk curves can be expressed by the logistic regression equations. But in these comparisons, the injury risk rations were simple calculated by the linear relationships. The pelvis injury performances, pubic force, are similar in the both dummies. The thorax injury risk ratios for the WorldSID is relatively lower than ES-2.

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