Development of Transfer Functions between ES-2re and SID-IIs Dummies Using Rigid Wall Sled Tests

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Abstract: An understanding of stiffness characteristics of different body regions, such as thorax, abdomen and pelvis of ES-2re and SID-IIs dummies under controlled laboratory test conditions is essential for development of both compatible performance targets for countermeasures and occupant protection strategies to meet the recently updated FMVSS214, LINCAP and IIHS Dynamic Side Impact Test requirements. The primary purpose of this study is to determine the transfer functions between the ES-2re and SID-IIs dummies for different body regions under identical test conditions using flat rigid wall sled tests. The experimental set-up consists of a flat rigid wall with five instrumented load wall plates aligned with dummy's shoulder, thorax, abdomen, pelvis and femur/knee impacting a stationary dummy seated on a rigid low friction seat at a pre-determined velocity. The relative location and orientation of the load wall plates are adjusted relative to the body regions of the ES-2re and SID-IIs dummies respectively. The load wall forces and dummy responses are evaluated by varying four different test parameters to investigate the effects of velocity (initial velocity vs. velocity-time pulse), shoulder engagement (with and without shoulder loadwall plate), initial arm position of the dummy (40 deg. vs. 90 deg), and oblique loading of thorax by rotating the thorax loadwall plate by 15 deg. Cause-and-effect relationships between the input loading conditions and dummy responses are established using linear regression analysis for both the dummies. Subsequently, the transfer functions are developed to establish relationships of responses between the two dummies for each body region. The usefulness of these transfer functions is discussed, and demonstrated.

Keywords: dummies, side impact, SID-IIs, ES-2re, rigid wall, transfer functions

1 Introduction

The impact responses of different body regions (thorax, abdomen and pelvis) of ES-2re and SID-IIs dummies under controlled test conditions were determined using flat rigid wall sled testing. Cause-and-effect relationships between the input loading conditions and dummy responses were established using linear regression analysis. The usefulness and application of results of the regression analysis can be applied to the development of both compatible performance targets for countermeasures and occupant protection strategies. Performance targets for countermeasure development include armrest force-deflection, side air bag (SAB) pressure, shape, and thickness, door trim geometry, pelvis Energy Absorbing (EA) foam properties, etc. The occupant protection considerations include SAB type which may be either thorax or thorax-pelvis combo, depending on distribution of impact forces on thorax, abdomen, pelvis and femur of these two dummies. While there are several studies conducted with rigid and padded wall sled tests for assessing biofidelity of both ES-2/ES-2re and SID-IIs dummies [1-5], results of these studies are limited due to the physical test set-up in which load walls were not aligned with respective dummy body regions. Further, to assess the performance of countermeasures under various loading conditions due to complexity of regulatory and non-regulatory test modes, it is strategically useful to develop a set of transfer functions between the SID-IIs and ES-2re dummies. These transfer functions may aid in the understanding of trade-offs in occupant performance, if any, among various test modes, and may help minimize the amount of iterative testing in different test modes.

The primary purpose of this study was to determine the relationship between the impact responses of the ES-2re and SID-IIs dummies for different body regions (shoulder, thorax, abdomen and pelvis/leg) under identical test conditions, using flat rigid wall test data. The experimental set-up consisted of a flat rigid wall with five instrumented load wall plates aligned with dummy's shoulder, thorax, abdomen, pelvis and upper leg/knee impacting a stationary dummy seated on a rigid seat at a pre-determined velocity. The relative location and orientation of the load wall plates was adjusted relative to the body regions of the ES-2re and SID-IIs dummies respectively. The load wall forces and dummy responses were evaluated by varying four different test parameters to investigate the effects of velocity (initial velocity vs. velocity-time pulse), shoulder engagement (with and without shoulder loadwall plate), initial arm position of the dummy (40 deg. vs. 90 deg), and oblique loading of thorax by rotating the thorax loadwall plate by 15 deg. The transfer functions were then developed to establish relationships of responses between the two dummies for each body region under similar impact conditions. The method for developing the transfer functions is presented and results are discussed below.

2 Method

The experimental set-up consisted of a flat rigid wall impactor with five individual instrumented load walls aligned with the shoulder, thorax, abdomen, pelvis and femur/knee of the dummy. At the start of the test, the dummy was stationary and seated on a rigid seat. The details of the instrumentation, experimental set-up, and test configurations are presented below:

2.1 INSTRUMENTATION

The ES-2re and SID-IIs dummies were instrumented with the transducers in the head, shoulder, thorax, abdomen, pelvis and femur/knee regions as indicated in Table 1. Contact switches were mounted on the dummy to record the time of contact of the rigid wall with different body regions of the dummy. Two six-axis load cells and an accelerometer were mounted behind each load plate (and close to the edge of the load plate) of the impacting rigid wall to measure lateral impact forces and for inertial compensation respectively, per the Test Protocol of ISO TR-9790 for Side Impact Biofidelity Evaluations. Additionally, two (primary and secondary) accelerometers were mounted on the sled to obtain the velocity and displacement time histories of the impacting rigid wall.

Table 1: Instrumentation for ES-2re and SID-IIs dummies

ES-2re Instrumentation	Channels
Head accelerometers	Ax, Ay, Az
Upper neck load cell	Fx, Fy, Fz, Mx, My, Mz
Shoulder load cell	Fx, Fy, Fz
Rib accelerometers (struck-side)	Ay
Rib deflection potentiometers	Lateral
Upper spine (T1) accelerometers	Ax, Ay, Az
Lower spine (T12) accelerometers	Ax, Ay, Az
Lumbar load cell	Fy, Fz, Mx
T12 load cell	Fy, Fz, Mx
Abdomen load cells-Front/Mid/Rear	Fy
Pelvis accelerometers	Ax, Ay, Az
Pubic symphysis load cell	Fy
Femur load cell	Fx, Fy, Fz, Mx, My, Mz

SID-IIs Instrumentation	Channels
Head accelerometers	Ax, Ay, Az
Upper neck load cell	Fx, Fy, Fz, Mx, My, Mz
Shoulder load cell	Fx, Fy, Fz
Rib accelerometers (struck-side)	Ay
Rib deflection potentiometers	Lateral
Upper spine (T1) accelerometers	Ax, Ay, Az
Lower spine (T12) accelerometers	Ax, Ay, Az
Lumbar load cell	Fx, Fy, Fz, Mx, My, Mz
Pelvis – Iliac loadcell	Fy
Pelvis – Acetabulum loadcell	Fy
Pelvis accelerometers	Ax, Ay, Az
Upper Femur loadcell	Fy
Lower Femur load cell	Fx, Fy, Mx, My

2.2 EXPERIMENTAL SET-UP

The new experimental set-up used in this study consisted of an instrumented flat rigid wall impacting a stationary dummy seated on a rigid low friction seat at a pre-determined velocity. The flat rigid wall used in this study is similar to the Wayne State sled test set-up (WSU loadwall) as stated in the ISO 9790 test protocol for side impact biofidelity evaluations, and consisted of five independent load plates, each aligned with the shoulder, thorax, abdomen, pelvis/femur, and knee regions of the ES-2re and SID-IIs dummies. The configuration of the load plates mounted on the rigid wall is shown in Figure 1. The custom designed aluminum rigid seat on which the dummy is seated has a seat back angle of 19^{o} (with respect to vertical) and a seat pan angle of 16.5^{o} (with respect to horizontal), as shown in Figure 2. The choice of seat back and seat pan angles for the rigid seat were made to be representative of a typical design position of a front seat in a vehicle. Further, the rigid seat is constrained to a translational motion along the direction of impact. A sheet of Teflon was fixed to the seating surface to ensure low friction sliding between the dummy and the seat. The dummy positioning procedure used in this study, where applicable, followed the Test Protocol to Conduct ISO/TR-9790 Sled Tests for Side Impact Biofidelity Evaluations [7]. The ISO 9790 test protocol was used to ensure that the dummy was not rotated about the z-axis in the seat, and the impact side of the knee was at equal distance from the load plates as the impact side of the pelvis; and to record pre-test dummy positioning measurements (head, thorax and pelvis angles, and lateral distances). The repeatability in dummy positioning during the test series was ensured by using a portable high resolution optical 3-D dummy positioning system DPS© which has an accuracy of ±0.1 mm (www.aicon3d.com). The location and orientation of the load plates (on the rigid wall) relative to the respective body regions of the dummy was verified both by means of static pre-test alignment of the dummy and load plates, and dynamically using high speed film coverage (front of the dummy and rigid wall) in practice runs prior to actual test series. A programmable VIA decelerator (VIA Systems, Brighton, MI) was used to control the velocity-time history of the rigid wall.

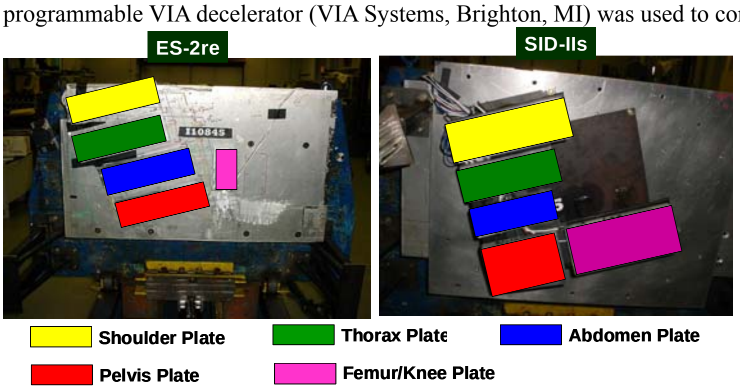

Figure 1: Configuration of the rigid wall load plates

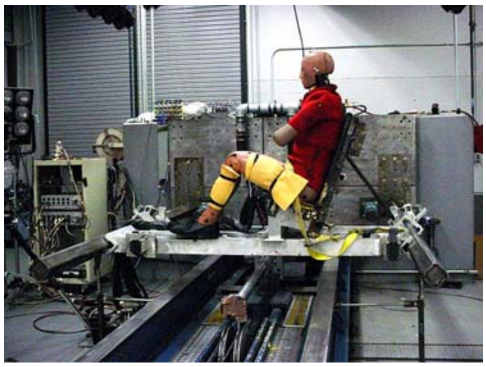
Figure 2: Set-up of the rigid seat with seated dummy

At the start of the test, the dummy was seated on the stationary rigid seat which was allowed to translate, along a linear track in the direction of impact. The rigid wall sled was accelerated to a pre-determined velocity on a sled track (approximately 50 feet or 15 meters in length) and contacted the stationary rigid seat and dummy. The position and orientation of the seat relative to the load plates was designed to avoid direct contact with the load plates of the rigid wall. However, in order to avoid hard contact of the rigid seat with the rigid wall fixture of the sled, aluminum honeycomb (750 psi crush strength) was used in the interface between the seat and the rigid wall (distributed evenly between the top and bottom of the seat) to accelerate the seat, prior to dummy contact with the load plates. Subsequently, upon impact by the rigid wall sled, the seat began to translate prior to dummy contact, i.e., seat slides under the dummy. To minimize the effect of seat-to-rigid wall interaction on the velocity of the rigid wall sled, the mass of the rigid wall sled was chosen to be high (approx. 2645 lbs or 1210 kg) in comparison to the mass of the rigid aluminum seat (approx. 150 lbs or 68 kg). Special care was taken in the design and fabrication of the rigid seat to make it as light as possible, while maintaining durability for the entire test series. The magnitude of velocity drop during the seat interaction with the rigid wall sled was assessed during the practice runs for each velocity condition, and minimized to the extent permissible within the constraints of this test set-up.

2.3 TEST CONFIGURATIONS

The primary objective of this study was to evaluate the responses of ES-2re and SID-IIs dummies under varying initial conditions, with special emphasis on the responses of the shoulder and thorax. Subsequently, the test conditions chosen to asses the dummy responses can be broadly divided into four factors: effect of input velocity to the impacting rigid wall – velocity pulse vs. initial velocity; effect of shoulder engagement with load plate; effect of initial position of dummy's arm – 40^o vs. 90^o (horizontal); and effect of oblique loading to thorax – pure lateral vs. 15^o forward oblique impact. A minimum of two tests were conducted for each test configuration, and in some cases three or more to assess for repeatability (same dummy) and reproducibility (different dummy). The details of each of the four main test conditions are presented below:

2.3.1 Input velocity:

The objective was to evaluate the dummy responses under two different velocity conditions – velocity-time pulse and initial velocity. The intent of the velocity-time pulse was to simulate the MDB loading condition, where the dummy is subjected to a door-velocity time history. The initial velocity condition was used to simulate the loading conditions in a pole test, where the vehicle along with the dummy is propelled into a stationary pole at an initial velocity. The choice of input velocity range for the rigid wall was based on obtaining dummy responses (especially the thorax) in the range required to meet the upgraded FMVSS 214, enhanced side NCAP, ECE 95 and EuroNCAP requirements. Hence, the severity and range of velocities for both the velocity-time pulse and initial velocity for this study was judiciously chosen based on initial MADYMO modeling of the flat rigid wall test set-up to yield peak rib deflections in the range of 22 mm to 44 mm for the ES-2re dummy. The higher range of 44 mm for the peak rib deflection was chosen based on the regulatory requirements to meet NHTSA's upgraded FMVSS 214 in both 33.5 mph MDB and 20 mph Oblique pole test modes with ES-2re dummy in front row outboard seating position on the struck side. The lower range of 22 mm for peak rib deflection was chosen based on the lower limit for peak rib deflection in EuroNCAP requirements as specified in MDB and perpendicular pole tests with ES-2 dummy. As mentioned earlier, a programmable VIA decelerator was used to control the velocity-time history of the rigid wall sled to achieve the target velocity-time pulses.

2.3.2 Shoulder engagement:

The objective of this test configuration was to evaluate the effect of shoulder engagement and loading on dummy responses, especially the shoulder and thorax of the upper torso. This configuration was used to represent the variation in full-vehicle test conditions with the dummy, where the shoulder may be above or below the window sill (door beltline), depending on the seating height of the dummy relative to the door. If the shoulder is above the window sill, the shoulder will not be directly loaded and vice-versa. In this study, to simulate the effect of loading where the shoulder is above the window sill, the shoulder load plate was removed to avoid direct loading or engagement of the shoulder. Similarly, the shoulder load plate was retained to simulate the effect of shoulder engagement, where the shoulder is below the window sill.

2.3.3 Initial arm position:

The objective of this test configuration was to assess the influence of dummy's arm position on thorax responses. This was achieved by varying the initial position of the dummy's arm between nominal (arm at 40^o detent) and horizontal (arm at 90^o angle or perpendicular to thorax) positions. The horizontal arm position eliminated arm interaction with the thorax. A recent study [6] investigating the influence of arm position on thoracic response in human cadavers using low energy (72 Joules) non-destructive pendulum impacts, showed an increase in both scaled peak impactor force and scaled average peak rib deflection when the arm was placed at 90^o to the thorax, compared to arm at 45^o. The low impactor force and average rib deflection with arm at 45^o, was due to the inertial response of the shoulder and arm, which has a low inertial mass compared to the thorax [6]. Subsequently, for those test configurations with horizontal arm position in this study, the shoulder load plate was always removed in order to evaluate the response of the thorax without the influence of arm and loading to the shoulder. For the nominal arm position, the test configurations were chosen to evaluate dummy responses with and without shoulder load plate.

For the SID-IIs dummy, the test set-up was modified due to the construction of the dummy thorax. When the arm was set at 40^o or 90^o angle, the thorax upper rib was covered by the arm, exposing only the middle and lower thorax ribs to thorax load plate, while the upper rib was aligned with the shoulder load plate. To account for this, for the tests conducted with 40^o or 90^o arm positions, the height of thorax load plate was reduced to cover only the middle and lower thorax ribs. Needless to mention, even when the arm was set at 90^o, there was upper rib loading by the arm. Further, to eliminate influence of arm on thorax response completely, the dummy's arm was removed in three test conditions, and test set-up was modified with a longer thorax load plate covering all the three thorax ribs. Figure 3 shows the initial arm positions for the SID-IIs dummy in this study.

Arm @ 40 deg

Arm @ 90 deg

Arm Removed

Figure 3: Initial arm positions for SID-IIs dummy

2.3.4 Oblique loading to thorax:

The objective of this test configuration was to assess the effect of oblique loading on the thorax responses. This test configuration represents the loading condition in an FMVSS 214 full-vehicle oblique pole test with the dummy in front row seat, where the vehicle is oriented at 75° to the pole whose centerline is aligned with the head CG of the dummy. The vehicle along with the dummy is propelled side ways into the stationary pole at an initial velocity of 20 mph (8.9 m/s). During the crash event, the side structure of the vehicle (mainly the front door and B-pillar) intruding into the occupant compartment presents an oblique loading surface for the dummy. The extent of oblique loading depends on the door curvature due to intrusion, door-to-dummy initial gap, vehicle lateral stiffness among others [8]. To simulate this loading condition, the thorax load plate was rotated 15° forward of lateral (in z-axis about the CG of the load plate) while the other load plates remained in the pure lateral position. Based on the biofidelity evaluations of the ES-2re dummy thorax, the sensitivity of peak rib deflections to rearward oblique impacts (at 15° and 30° rear of lateral) were not significant when compared to forward oblique impacts [5]. Hence, in this study, only the 15° forward oblique loading was considered, besides the pure lateral loading condition. Further, since the intent of the forward oblique impact was to simulate the full-vehicle oblique pole test, all forward oblique impacts were carried out with constant velocity inputs, and the effect of oblique loading with velocity-time pulse was not evaluated in this study.

Table 2 summarizes the test conditions including four main factors and their levels used in the rigid wall sled tests. Figure 4 summarizes the initial test conditions for the ES-2re dummy.

Table 2: Summary of test configurations in the rigid wall sled tests

No.	Main Factors	No. of levels	Description of levels
1	Velocity input	5	Velocity-time pulse: 1) 7 m/s to 4 m/s in 25 milliseconds 2) 9 m/s to 6 m/s in 25 milliseconds Constant velocity: 3) 4.47 m/s (10 mph) 4) 6.7 m/s (15 mph) 5) 8.0 m/s (18 mph)
2	Shoulder engagement	2	1) With and 2) Without shoulder plate
3	Initial position of arm relative to thorax	2	1) 40° and 2) 90°
4	Orientation of thorax plate	2	1) 0° (pure lateral) 2) 15° forward of lateral (oblique)

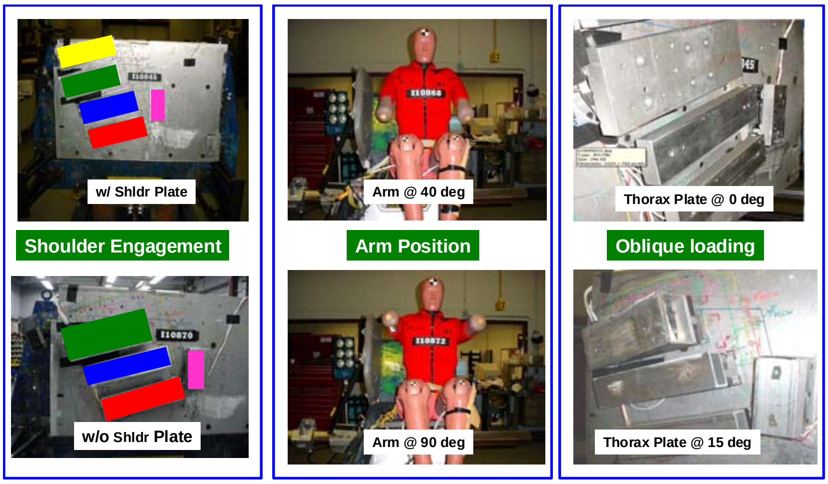

Figure 4: Summary of initial test configurations (ES-2re dummy shown as an example)

2.4 DATA ACQUISITION

Data from the load cells and accelerometers were recorded at a sampling frequency of 12.5 kHz. The soak time for the dummy between tests was at least half-hour. Post-test visual inspection of the dummy was carried out after every run to check for damage. The dummies were either changed or re-calibrated after twelve runs. Four high speed digital cameras (1000 frames per second) were used to capture the dummy kinematics. These include two front views for covering overall and close-up of the dummy and load plates, one overall rear view covering seat-to-rigid wall and dummy-to-load plate, and one overhead view. Contact switches mounted to the thorax, abdomen, pelvis, femur and knee of the dummy were used to record the time of load plate contact with the dummy. The initial velocity of the rigid wall sled was obtained using a laser timing trap just prior to seat/dummy contact. All the data from the dummy was filtered per SAE J211 procedure. The force-time history data from the two individual load cells was summed to obtain the total impactor force for each load plate of the rigid wall. The load plate impactor forces were filtered to CFC180.

2.5 TRANSFER FUNCTIONS METHODOLOGY

To derive the required transfer functions, five similar test conditions were chosen from the list of test conditions for both ES-2re and SID-IIs dummies. Table 3 summarizes the five identical test conditions with unique test configurations along with the reference test conditions for both ES-2re and SID-IIs dummies. Due to the severity of impact that may damage the dummy parts, the velocities for SID-IIs dummy were limited to lower severity pulse of 7m/s to 4m/s and an initial velocity of 4.5 m/s, in this study. Subsequently, the ES-2re dummy was subjected to the same velocity conditions to permit comparison of dummy responses for development of transfer functions.

To establish the transfer functions between the two dummies, a linear regression analysis was conducted using dummy responses obtained from the five test conditions. The correlation was deemed acceptable if the correlation co-efficient (R^2) was ≥ 0.7. The linear regression was conducted for all dummy and loadwall responses that were mutually permissible with available test data.

Table 3: Summary of identical rigid wall test conditions for ES-2re and SID-IIs dummies

No.	Velocity Input	Shoulder Load Plate (With/Without)	Initial Arm Position (deg)	Thorax Load Plate Angle (deg)	ES-2re ReferenceTest Condition	SID-IIs ReferenceTest Condition
1	7 m/s to 4 m/s	With	40°	0°	S1	V1
2	7 m/s to 4 m/s	Without	40°	0°	S2	V2
3	4.5 m/s	With	40°	0°	V2	V1
4	4.5 m/s	With	40°	15°	V3	O1
5	7 m/s to 4 m/s	Without	90°	0°	A1	A1

3 Results and Discussion

Five identical rigid flat wall test conditions with unique configurations were chosen for the development of transfer functions between ES-2re and SID-IIs dummies. Though the linear regression analysis was carried out for all permissible dummy and loadwall responses, only the results of those regressions which yielded a $R^2 \geq 0.7$ were used for the development of transfer functions. Hence, the results of the regression analysis will be presented for the following responses:

- Shoulder Fy and deflection,
- Peak and average thorax rib,
- Peak and average T12-Ay,
- Peak and average pelvis-Ay,
- Pelvis load Fy,
- Pelvis impactor force from loadwall,
- Sum of loadwall forces from shoulder, thorax and abdomen, and
- Sum of loadwall forces from shoulder, thorax, abdomen, pelvis and knee

Next, the results of the regression analysis will be presented. Wherever possible, the usefulness of the regression in understanding transfer functions between ES-2re and SID-IIs dummies will be illustrated. Figures 5(a) and (b) present the regressions for shoulder Fy and deflection, respectively, exhibiting good correlations. From Figure 5(b), the ES-2re shoulder Fy corresponding to a SID-IIs shoulder deflection of 50 mm (IIHS Side Impact target) can be determined and evaluated for potential conflict or trade-off, if any, in design of countermeasures that enable both dummy responses to meet performance for safety standard test requirements and/or public test protocols.

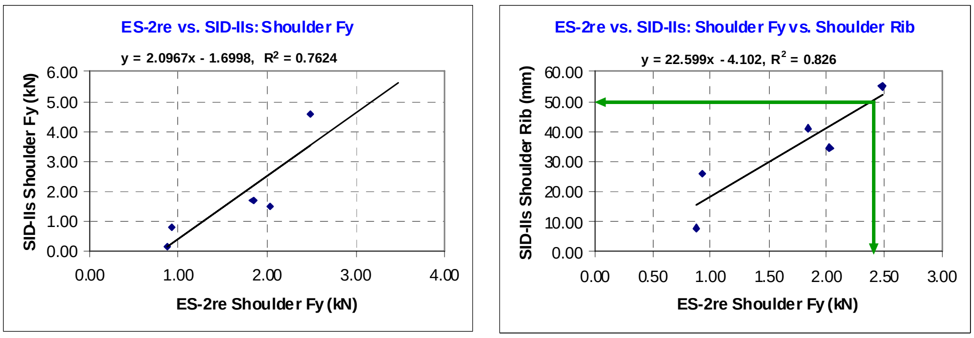

Figure 5: Correlation of ES-2re shoulder Fy with (a) SID-IIs shoulder Fy and (b) SID-IIs shoulder deflection

The correlation for peak and average thorax ribs is presented in Figures 6 (a), (b) and (c). The SID-IIs peak rib deflection corresponding to an ES-2re peak rib deflection target of 25 mm, is 34 mm. This is less than peak rib deflection target of 51 mm specified in the IIHS Side impact test protocol. Also, the SID-IIs average thorax rib deflection of 25 mm corresponds to an ES-2re peak rib deflection target of 25 mm, thus indicating compatibility between the targets. The correlation for abdomen is presented in Figure 7. The SID-IIs average abdomen rib deflection corresponding to an ES-2 peak abdomen load target of 1 kN for 'good' in EuroNCAP side impact (assuming the abdomen responses between ES-2 and ES-2re are similar, since there is no difference in construction of abdomen and pelvis), is 20.4 mm.. The peak abdomen rib deflection of SID-IIs dummy is 24.4 mm. From Figure 8, the SID-IIs average rib deflection target for a ES-2re peak rib deflection of 25 mm (LINCAP/EuroNCAP test modes) is approximately 20 mm, which is less than the average rib deflection target of 34 mm for 'good' torso rating in IIHS side impact test.

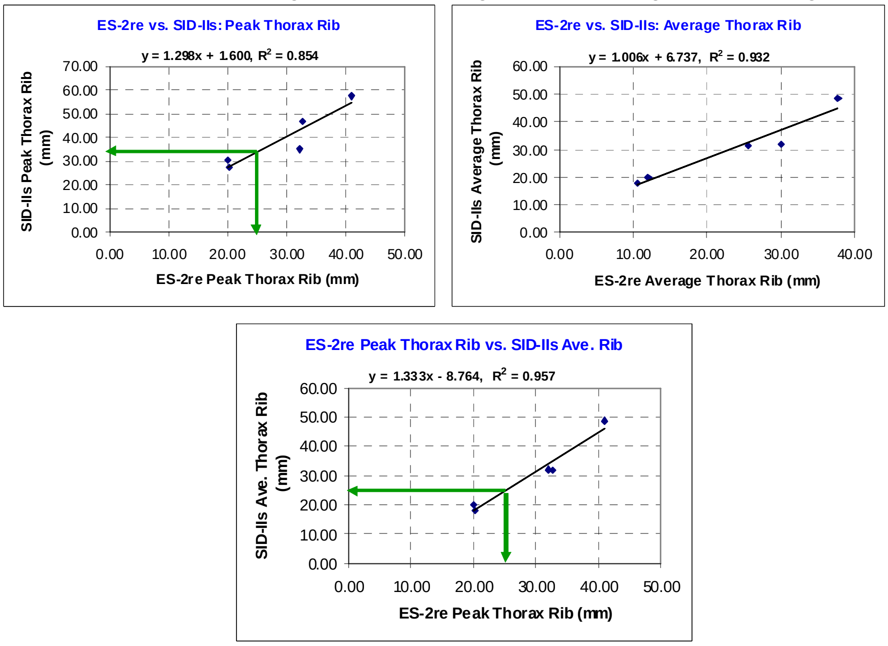

Figure 6: Correlation of (a) ES-2re and SID-IIs peak thorax rib, (b) ES-2re and SID-IIs average thorax rib and (c) ES-2re peak thorax rib and SID-II average rib

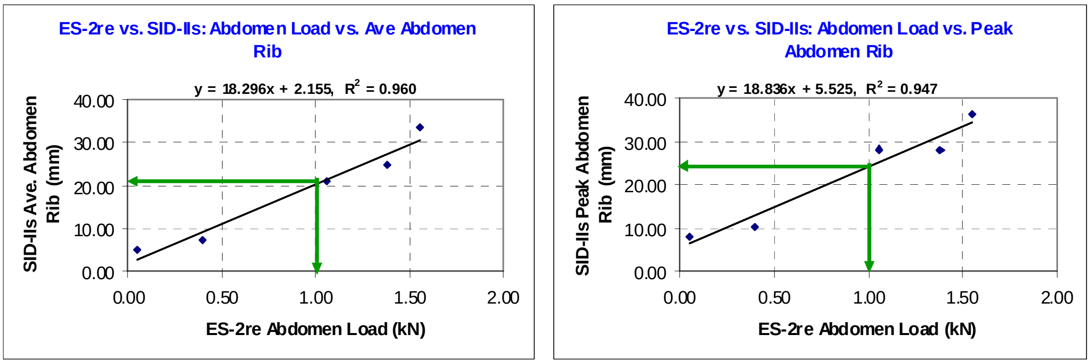

Figure 7: Correlation of ES-2re abdomen load with (a) SID-IIs average abdomen rib and (b) SID-IIs peak abdomen rib

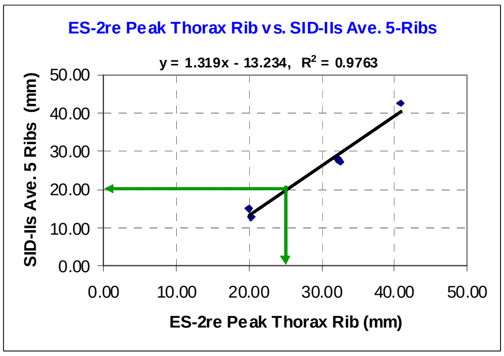

Figure 8: Correlation of ES-2re peak rib with (a) SID-IIs average thorax and abdomen ribs

Figure 9 shows the correlations for peak and average T12-Ay between the two dummies. From Figure 9 (a), the limit for ES-2re peak T12-Ay can be found to be approximately 60g that corresponds to a target of 65g for SID-IIs. The correlation for peak pelvis load, pelvis loadwall force, and peak pelvis-Ay is shown in Figures 10(a), (b) and (c), respectively. It is noted that the target for a good rating for combined iliac and acetabulum load in IIHS side impact test with SID-IIs is 5.1 kN. From Figure 10(a), the ES-2re pubic load corresponding to a SID-IIs combined pelvis load of 4 kN, is 2.4 kN. Based on the flat rigid wall sled tests with SID-IIs, the input pelvis loadwall force target corresponding to a combined pelvis load target of 4 kN is 5.6 kN. From Figure 10 (b), which shows the results of regression analysis of the pelvis load wall force between ES-2re and SID-IIs dummies, an ES-2re input load wall force (pelvis and femur) of 12.5 kN corresponds to a SID-IIs pelvis input load wall force of 5.6 kN.

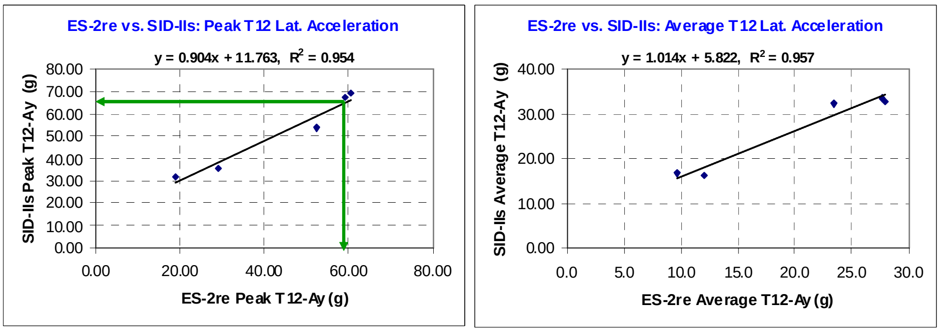

Figure 9: Correlation of (a) peak T12-Ay and (b) average T12-Ay between ES-2re & SID-IIs

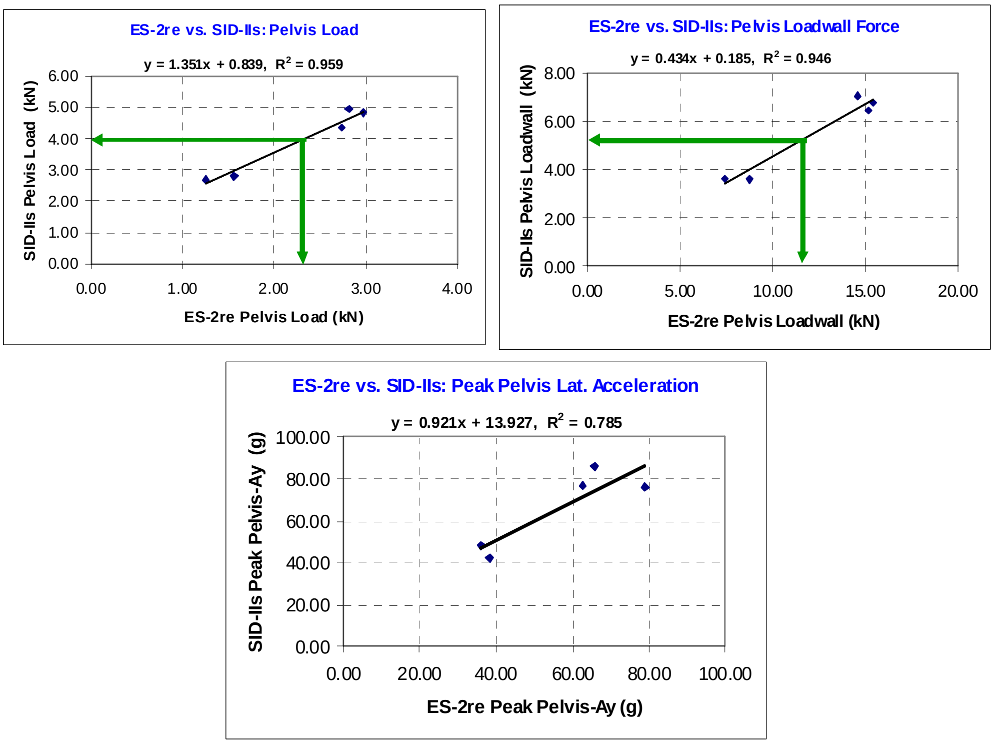

Figure 10: Correlation of (a) peak pelvis load, (b) pelvis loadwall force, and (c) peak pelvis acceleration for ES-2re and SID-IIs

4 Conclusions

The current study attempted to develop the transfer functions between ES-2re and SID-IIS dummies using flat rigid wall sled test data. To accomplish this, five identical test conditions with these two dummies were used. A regression analysis was conducted to develop the transfer functions that related the responses of each body region between these two dummies. Based on the results and findings from the study, following conclusions were made:

- The results of the regression analysis yielded good correlation for the following dummy responses - Shoulder Fy and deflection, Peak and average thorax rib, Peak and average T12-Ay, Peak and average pelvis-Ay, Pelvis load Fy, Pelvis impactor force from loadwall, Sum of loadwall forces from shoulder, thorax and abdomen, and Sum of loadwall forces from shoulder, thorax, abdomen, pelvis and knee. The transfer functions for these responses were presented along with illustrative examples and/or the interpretation of the results.
- The transfer functions developed between the two dummies permit comparison of ES-2re and SID-IIs dummy responses in different test modes (IIHS, FMVSS 214/LINCAP, and EuroNCAP), for comparable impact severity. The results of this analysis can be readily applied to assess performance trade-offs, if any, between these two dummies. Additionally, the transfer functions can potentially aid in the initial target setting for intended performance of countermeasures (SAB, door trim, EA foams, etc.) that are compatible with both dummies.

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