INJURY BIOMECHANICS RESEARCH
Proceedings of the Forty-Sixth International Workshop

Biofidelity of the THOR-05F ATD abdomen in fixed-back belt pull test condition

E.L. Lee[1], J. Stammen[2], R. Ramachandra[3], Y-S Kang[3], and J. Bolte IV[3]
[1]National Highway Traffic Safety Administration, Washington, DC, USA
[2]National Highway Traffic Safety Administration, East Liberty, OH, USA
[3]The Ohio State University, Columbus, OH, USA

ABSTRACT

The biofidelity of the THOR-05F anthropomorphic test device (ATD) was recently presented (Wang et al. 2018). In general, the biofidelity was assessed by comparing the ATD response to target corridors scaled from mid-sized male post mortem human surrogate (PMHS) data, or in some cases, corridors created from small female-specific PMHS data. Where possible, the ATD was tested in the same testing configuration as the PMHS. For the fixed-back belt pull abdomen test condition, the ATD testing did not replicate the input characteristics of the original PMHS study, due to limitations in the test apparatus used. As such, additional work is needed to complete the ATD biofidelity assessment of the abdomen in this test configuration.

The purpose of the current study was to collect data in a fixed-back belt pull test condition on small sized subjects, and to compare the PMHS response to the THOR-05F ATD. Two female and one male PMHS (mean stature 167 cm; mean abdominal depth 17.3 cm) were tested. The subjects were seated upright with a fixed back support. The seatbelt, positioned at the mid-abdomen, was pulled posteriorly using a pneumatic device. Belt force was measured using seat belt load cells and abdomen penetration was measured using a string potentiometer attached to the seatbelt webbing in front of the specimen. The tests were conducted at a sub-injurious level by limiting the abdominal penetration to approximately 27% of the subject's seated abdomen depth. Three THOR-05F ATD tests were conducted using the same setup as the PMHS.

Results demonstrated that the response of the ATD in the fixed back belt pull condition was very repeatable. In addition, the force-displacement response was qualitatively similar to the PMHS response. Future work includes collection of three additional PMHS specimens, which will be tested to injurious levels. At that time, the ATD biofidelity assessment will be updated.

INTRODUCTION

The National Highway Traffic Administration (NHTSA) has been researching advanced frontal anthropomorphic test devices (ATDs) since the early 1980s, beginning with the 50th percentile adult male ATD, and later expanding to the 5th percentile female ATD (Shams et al. 2002; Shams et al., 2003). Between 2005, when the original THOR-05F ATD was built by GESAC, Inc. and delivered to NHTSA, and 2015, significant advancements in biofidelity, durability and usability were made to the THOR-50M ATD (Ridella and Parent, 2001; Parent et al., 2013; Parent et al., 2017), but corresponding updates were not made to the THOR-05F. Thus, in 2015, a project was initiated with Humanetics Innovative Solutions, Inc. to redesign and update the THOR-05F ATD, using knowledge gained throughout the THOR-50M development project and current state-of-the-art biomechanical knowledge.

The biofidelity of the THOR 5th female ATD (THOR-05F) was recently presented (Wang et al., 2018). In general, the biofidelity was assessed by comparing the ATD response to target corridors scaled from mid-sized male post mortem human surrogate (PMHS) data, or in some cases, corridors created from small female-specific PMHS data (Lee et al. 2017). There were 23 test conditions evaluated, covering seven body regions (head, neck, shoulder, thorax, abdomen, knee-thigh-hip, and lower extremity). Where possible, the ATD was tested in the same testing configuration as the PMHS. This was achieved in most tests.

One condition in which the ATD testing did not replicate the input characteristics of the original PMHS study was the fixed-back belt pull abdomen test condition (Lamielle et al., 2008). This was due to limitations in the test apparatus used, which could not replicate the desired belt penetration input of the PMHS tests (Wang et al., 2018). Concurrently with the THOR-05F development project, a separate effort began with Ohio State University (OSU) to collect abdominal data on small sized specimens to support the development of a pressure-based injury risk function for the THOR-05F ATD. Both non-injurious and injurious data were planned. This project yielded data in a fixed-back belt pull condition that exactly replicated the test condition used in the THOR-05F biofidelity testing. While initially targeted for injury criteria development, the test series also presented an opportunity to evaluate the THOR-05F abdominal biofidelity, using matched inputs and small sized specimens. The purpose of the current study was therefore to collect data in a fixed-back belt pull test condition on small sized subjects, and to compare the PMHS response to the THOR-05F ATD. This paper reports only the non-injurious testing results; additional tests intended to be injurious are planned for the near future.

METHODS

Test Fixture

The seatbelt loading device described in Ramachandra et al. (2016) was modified to accommodate a fixed back support to mimic the Lamielle et al. (2008) setup. The Lamielle et al. (2008) setup was targeted because it replicates submarining conditions, and follows the recommendations by Lebarbe et al. (2015), who described a comprehensive set of specifications for assessing the biofidelity of an ATD. The device used a pneumatic piston to pull a seatbelt into the abdomen of the specimen in a controlled manner. The test fixture utilized pressurized nitrogen to propel a piston rearward. This piston was connected to a T-bar mechanism, which also featured attachment points for a standard seatbelt. As the piston pulled the T-bar rearward, the seatbelt was driven into the abdomen of each PMHS.

PMHS Selection and Preparation

A total of three PMHS (Table 1) were obtained through The Ohio State University's Body Donor Program and their use was approved by the Body Donor Program's Advisory Committee. All specimens were screened for infectious diseases, and a dual energy X-ray absorptiometry (DXA) scan was used to exclude specimens with osteoporosis. Specimens were required to have a body mass index (BMI) less than 29.9 (i.e., obese specimens were excluded). Seated abdominal depth between 15-22 cm was targeted as the primary body dimension for inclusion, to assure small sized specimens. Height and weight were considered secondary to BMI and abdomen depth. Specimens that had major abdominal scars or a history of abdominal disease were

also excluded. A computed tomography (CT) scan was done prior to acceptance of each PMHS to check for pre-existing issues such as fractures or artificial implants. Tests ABDSB02 and ABDSB03 were performed within 72 to 120 hours post death, while test ABDSB01 was conducted using a frozen fresh specimen. The specimens were stored in a cooler set at four degree Celsius overnight but were brought up to room temperature of twenty-one degrees Celsius prior to firing. Abdominal measurements such as depth, circumference and width were taken during specimen evaluation (Table 1). The abdominal depth and width measurements were taken again after positioning the subject in order to adjust the belt width and ram stroke. Prior to installing instrumentation, warm saline of around forty degrees Celsius was flushed through both arterial and venous systems to clear all clots from the abdominal aorta and IVC. The bladder and colon were not evacuated.

Table 1. Specimen information (measurements were taken with the specimen in supine position at the time of acceptance)

Test ID	Test Date	Age/ Sex	Mass (kg)	Stature (cm)	Abd Depth (cm)	BMI	L2-L4 BMD (T-Score)	Notes
ABDSB01	07/13/17	38F	54	172.0	16.5	18.3	0.5	
ABDSB02	04/04/18	73M	61	175.0	20.5	21.6	1.4	Aorta-iliac stent
ABDSB03	07/20/18	86F	43	154.5	15.0	18.0	1.5	Plaque in aorta
		Average	*53*	*167.2*	*17.3*	*19.3*		

Instrumentation

Internal instrumentation included pressure transducers (Millar Instruments, TX, Model #SP-524) attached to angiographic catheters routed through Foley catheters. To re-pressurize the abdominal region of each PMHS, Foley balloons in the venous system were inflated between the heart and liver in the IVC and just above the bifurcation of the iliac veins. In the aorta, Foley balloons were inflated around the level of 11th and 12th thoracic vertebrae and just above the bifurcation to iliac arteries. The pressure transducers were then inserted into the vasculature to record pressure during the event. The pressure transducer locations included the superior inferior vena cava (IVC), inferior IVC (intersection of left and right common iliac veins), superior abdominal aorta (celiac trunk) and inferior abdominal aorta (intersection of left and right common iliac arteries). In ABDSB03, the existence of plaque in iliac arteries prevented pressure transducers from being routed into the inferior abdominal aorta via femoral arteries, and therefore no pressure sensor was used in the inferior aorta. However, the iliac arteries were tied off close to the bifurcation of the aorta to keep the vascular system isolated, similar to using the Foley balloon to block fluid from escaping the abdominal vasculature.

Although the spinal motion was arrested for these tests, either a 3aω motion block consisting of three linear accelerometers (Endevco, CA, Model #7264c) and three angular rate sensors (DTS, CA, Model # ARS 8k/ ARS-PRO 18k) or a DTS 6DX PRO (DTS, CA, Model 2k-8k) was attached to the third lumbar vertebra using a bridge mount that rested on the pedicles with one screw drilled though the vertebral body to measure any spinal displacement. ABDSB01 used the 3aω motion block while ABDSB02 and ABDSB03 used the 6 DX motion blocks.

A linear displacement potentiometer (Penny Giles, UK, Model #SLS190) mounted between the moving ram and its stationary frame measured ram displacement. A string potentiometer (Celesco, CA, Model #PT101) attached to the seatbelt webbing in front of the PMHS at the level of the umbilicus measured displacement of the belt with respect to the table. This measurement was also used as the abdomen penetration. In case of failure to obtain measurement from the string potentiometer, a 3aω motion block was installed on

the belt for redundancy. Seatbelt load cells (Denton, Model #5755) were affixed to the belt on the left and right sides of the specimen to measure belt forces. Belt force was calculated as the sum of forces obtained from the two seatbelt load cells. A load cell (Interface, AZ, Model #1210-2K) and a linear accelerometer (Endevco, CA, Model #7264c) were attached behind the ram as a redundant measure to obtain inertially compensated loading data in case the belt load cells failed.

Test Setup

Following instrumentation, a pre-test CT scan was done. The CT scan was used to document the locations of the internal instrumentation and to identify any pre-existing injuries. Figure 1 shows the pre-test position of the PMHS along with the external instrumentation used. Once the instrumentation was complete and subject positioned on the test apparatus, a FARO Arm (FARO Technologies Inc., Florida) was used to document subject position in all three dimensions and locate the initial position of the key landmarks.

Prior to impact, the arms were lifted to shoulder level to ensure that they would not interfere with the movement of the PMHS. The lumbar spine was positioned to be upright without any slouch and the posterior aspect of the PMHS was maintained flush against the back plates. This limited spinal flexion/extension during impact providing a true abdominal response. The legs splayed slightly outward in a natural seated position.

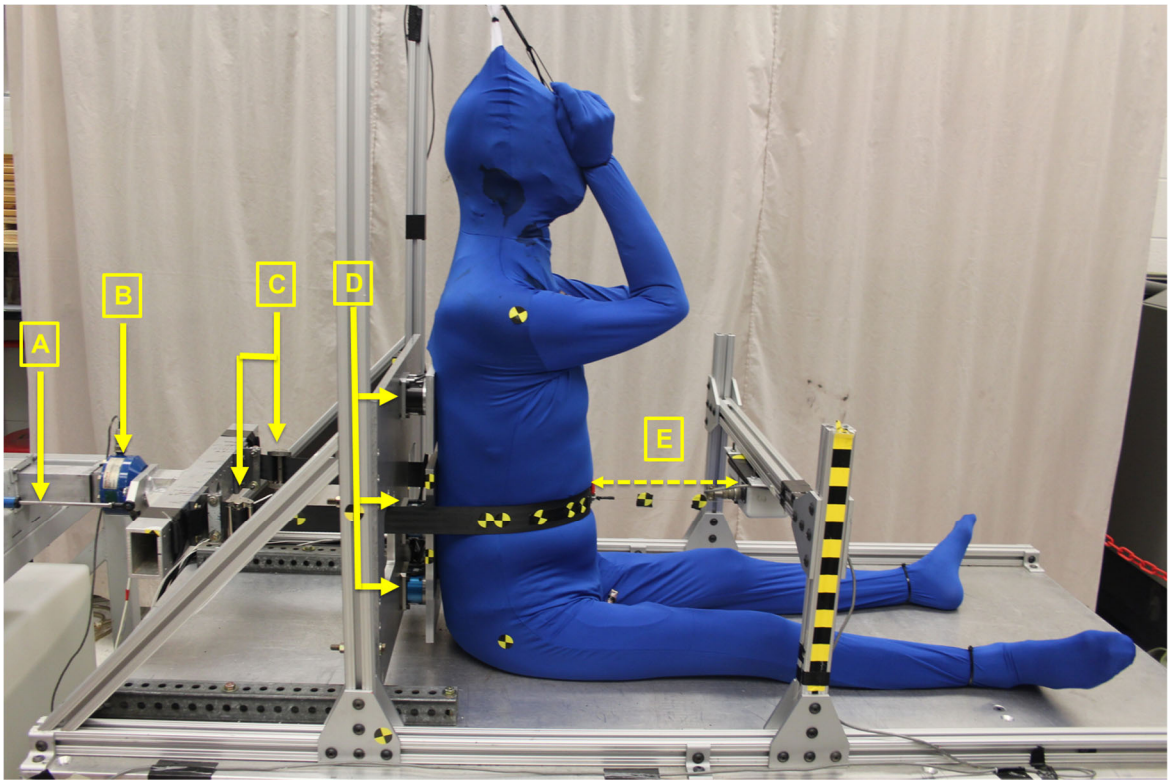

Figure 1. Pre-test positioning of PMHS (ABDSB02 shown) on the seatbelt test device (A: Linear potentiometer on ram; B: Force transducer on ram; C: Seatbelt load cells; D: Load cells attached to thoracic and lumbar back plates; and E: String potentiometer attached to seatbelt).

The PMHS were kept in the seated position using a head halter connected via a ratchet strap to the frame of the fixture. The seatbelt was positioned to wrap around the anterior and lateral aspects of the PMHS abdomen at the mid-abdomen level. Anteriorly, this position corresponded to the umbilicus of the specimen. The initial belt tension was adjusted so that each belt load cell measured 10-20 N, to ensure repeatable initial position of the belt with respect to each PMHS and remove any slack. Both arterial and venous systems in the abdomen were re-pressurized using saline before each test to approximate physiological levels (14.0 kPa in the

aorta and 0.9 kPa in the IVC).

The abdominal region of each specimen was loaded by the seatbelt at a nominal velocity of 3.7 $\pm$ 0.5 m/s. As noted by Wang et al. (2018), the only significant different between the test condition used here from that of the Lamielle et al. (2008) was the achieved belt penetration velocity input (similar nominal peak velocity but longer duration). The tests were intended to be non-injurious, and therefore penetration was limited to approximately 27% of seated abdominal depth (Table 2) measured just prior to wrapping the seatbelt after final positioning. The seated abdomen depth varied between initial acceptance and just prior to firing the ram for the same specimen due to the perfusion of organs and vasculature. The 27% compression target was derived from the Lamielle et al. (2008) test outcomes below which there were no injuries reported. Each test was captured using high-speed cameras (Vision Research Inc., NJ, Phantom at 1000fps) placed laterally and oblique to the specimen.

Table 2: Abdominal measurements taken for belt width placement and restricting ram stroke

Test ID	Abd Width (cm)	Abd Depth (cm)
ABDSB01	27.5	21.8
ABDSB02	28.0	26.5
ABDSB03	27.0	21.2

PMHS Injury Assessment

Following the test performed on each PMHS, a post-test CT scan was taken to document the change in locations of the internal instrumentation as well as any damage that occurred. An anatomical dissection was then conducted to note all damage in detail. Injuries were coded using the Abbreviated Injury Scale 2005 – update 2008 (Gennarelli et al. 2008).

ATD Tests

For the three ATD tests, the test setup was kept as close to the PMHS test setup as possible. The same external instrumentation was used (linear potentiometer, seatbelt load cells, and fixture instrumentation). The pre-test position of the THOR-05F, along with the external instrumentation used, is shown in Figure 2. Abdomen pressure was recorded using the ATD's internal instrumentation, namely two Abdomen Pressure Twin Sensors (APTS, Transpolis, Inc.). These are two soft cylindrical polyurethane bladders closed by aluminum caps and filled with liquid. The pressure in the fluid is measured by a pressure cell implanted in the cap.

The lumbar spine was positioned to be upright without any slouch and the lower thoracic spine was adjusted such that the T12 tilt sensor read 0° about the Y-axis and 0 ± 1° laterally about the X-axis. This minimized spinal flexion/extension during impact providing a true abdominal response. Prior to impact, the arms were lifted to shoulder level to ensure that they would not interfere with the movement of the ATD. The legs splayed slightly outward in a natural seated position. The seatbelt was positioned to wrap around the anterior and lateral aspects of the ATD abdomen at the mid-abdomen level. Anteriorly, this position corresponded to the belly-button mark on the one-piece abdomen visible when the jacket was removed. The initial belt tension was adjusted so that each belt load cell measured 15-20 N, to ensure repeatable initial position of the belt with respect to each ATD and remove any slack. For all the trials, the chest jacket was used for accurate ATD representation and to account for the influence of outer flesh/skin on the abdominal response. The penetration limit was targeted at approximately 27% of seated abdominal depth, to match the PMHS tests. The seated abdominal depth of THOR-05F measured just prior to testing was 225 mm.

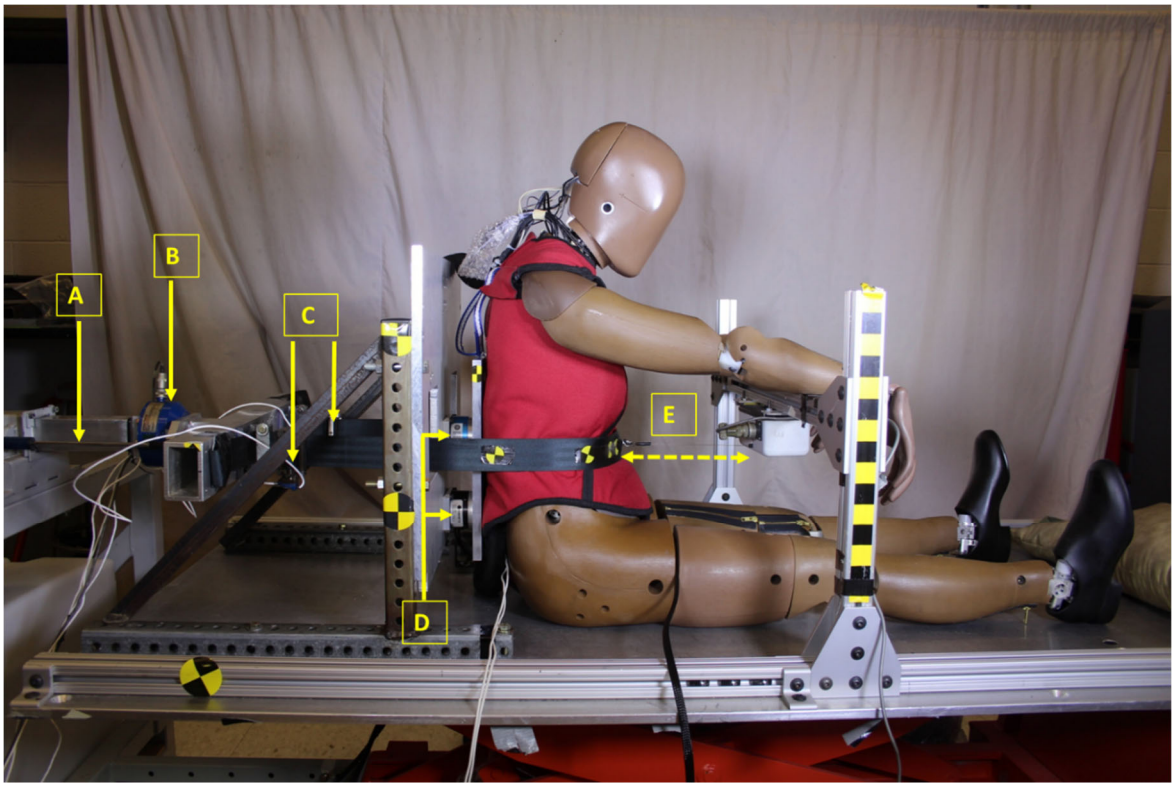

Figure 2. Pre-test positioning of THOR-05F on the seatbelt test device (A: Linear potentiometer on ram; B: Force transducer on ram; C: Seatbelt load cells; D: Load cells attached to lumbar back plate; and E: String potentiometer attached to seatbelt).

Data Analysis

Data were acquired at a sampling frequency of 20,000 Hz and in the laboratory coordinate system (LCS), with the positive x-axis directed from posterior to anterior, positive y-axis directed from left to right, and positive z-axis directed from superior to inferior, per standard SAE-J211. Time zero was defined as the time at which the ram acceleration exceeded 0.5 g's.

Abdomen penetration was defined as the deflection of the abdomen versus time, where the deflection is measured at the point anterior to the abdomen at the sagittal midline using a string potentiometer attached to the belt. Compression of the abdomen was defined as the percentage of penetration, calculated by dividing the abdominal penetration by initial abdominal depth measured just prior to firing each test. Abdomen penetration speed was found by differentiating abdomen penetration.

Pressure readings in the abdominal aorta and IVC were recorded during each PMHS test. A fast Fourier transform (FFT) analysis of the pressure signals was performed followed by filtering at CFC60. In the PMHS, the peak rates of pressure change, $\dot{P}_{max}$, were calculated for IVC and compared with Ramachandra et al. (2016), where a value of 9.3 kPa/ms would correspond to a 50% risk of AIS 3+ abdominal injury.

RESULTS

The anatomical dissection performed following each test revealed no damage to any of the abdominal organs after careful examination. Test ABDSB02 resulted in fractures to rib 10 on both left and right sides. Test ABDSB03 resulted in fractures to rib 10 on right side and ribs 10 and 11 on right side. These instances of skeletal damage are not considered relevant for pressure based injury prediction since the risk function is based upon soft tissue damage in the abdomen and not related to skeletal damage.

Table 3: Damage summary (Abbreviated Injury Scale 2005 - Update 2008)

Test ID	Abdominal Injury	Abdominal AIS	Skeletal	Skeletal AIS
ABDSB01	None	0	None	0
ABDSB02	None	0	Rib fractures: R 10th; L 10th	450202.2
ABDSB03	None	0	Rib fractures: R 10th; L 10th and 11th	450203.3

Force-Penetration Response

The force-time and penetration-time histories for the PMHS and THOR-05F tests are shown in Figure 3. Peak seatbelt forces ranged from 1.9 to 2.6 kN for the PMHS. The peak penetrations ranged from 68 to 94 mm for the PMHS. Note that because the target penetration was limited to approximately 27% of each subject's seated abdominal depth, the actual time over which the ram acted on each subject differed slightly. Actual peak compression of the abdomen ranged from 23 to 28% in the PMHS subjects, with a mean compression of 25.5% among the three tests. Peak compression achieved in the THOR-05F tests was approximately 33%. Figure 4 shows belt force vs. abdomen penetration responses.

In all tests, it was noticed that the seatbelt string potentiometer continued to displace beyond peak force due to a combination of inertial effects even after belt slack upon ram stop and additional spool out of the string potentiometer. The over-spooling occurs after the loading event concluded and beyond the point of interest, and hence the data may be considered realistic at least until the peak abdominal penetration speed is measured. The point at which ram displacement stopped for each PMHS test (and overspooling began) is indicated by a star of the appropriate color in Figure 3Figure 4.

The response of the THOR-05F fell within the range of the PMHS responses, indicating qualitatively good biofidelity. Quantitative biofidelity assessment is desired, and has been reported in other body regions by Wang et al. (2018), but would require a corridor to be created using the mean and standard deviation of the PMHS data. While a biofidelity corridor could be constructed using the available PMHS data, it would be limited by the lowest amount of compression measured in the PMHS test series (meaning the corridor could be constructed only up to 23% compression). Three additional PMHS tests are planned in the near future, using higher levels of compression (targeting injurious conditions). Therefore, quantitative biofidelity assessment may be performed once those additional specimens are available. The data presented here is thus limited to a qualitative comparison.

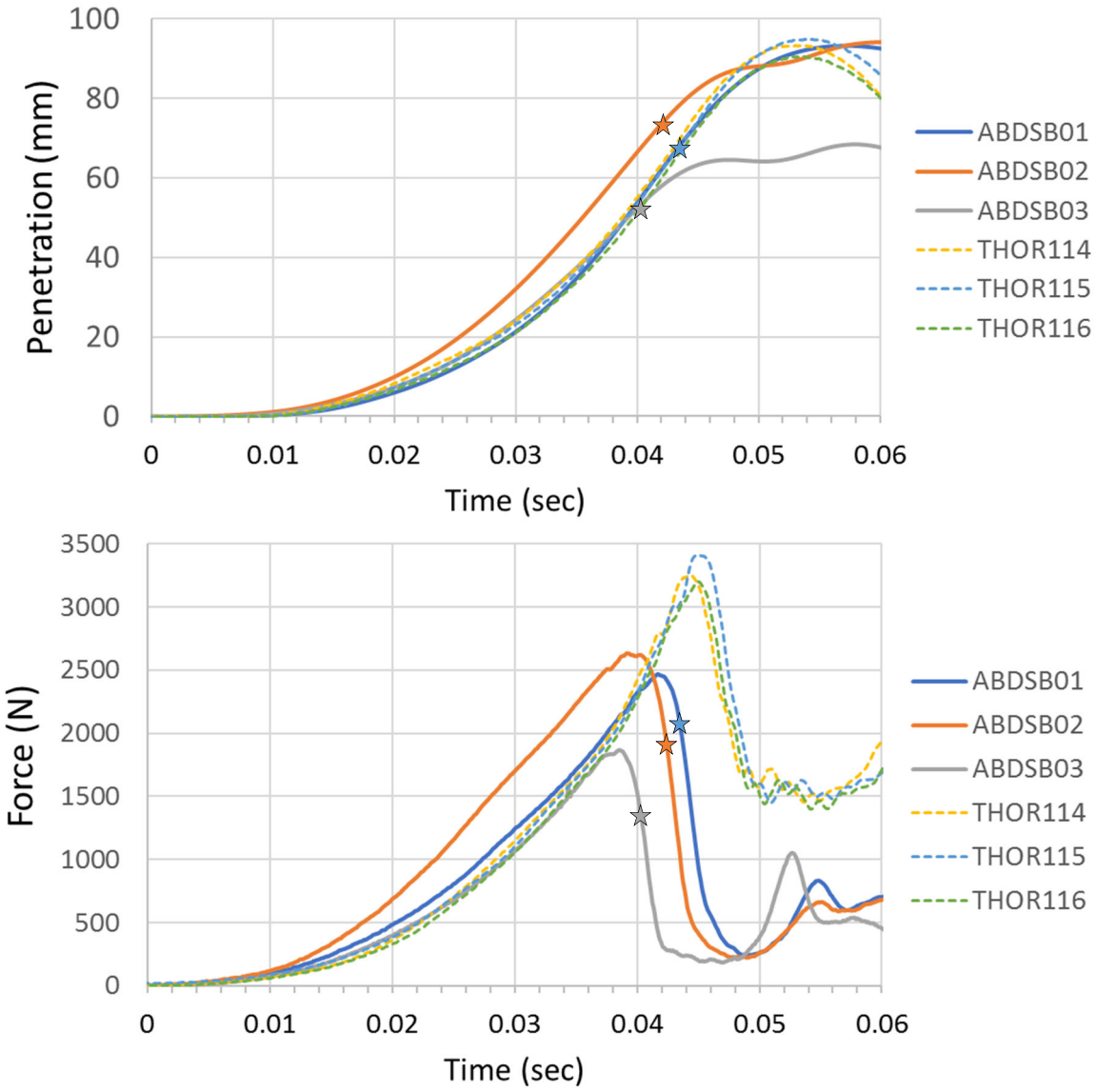

Figure 3. Force-time and penetration-time responses from the PMHS and ATD tests. The point at which the ram displacement stopped for each PMHS test is indicated by a star.

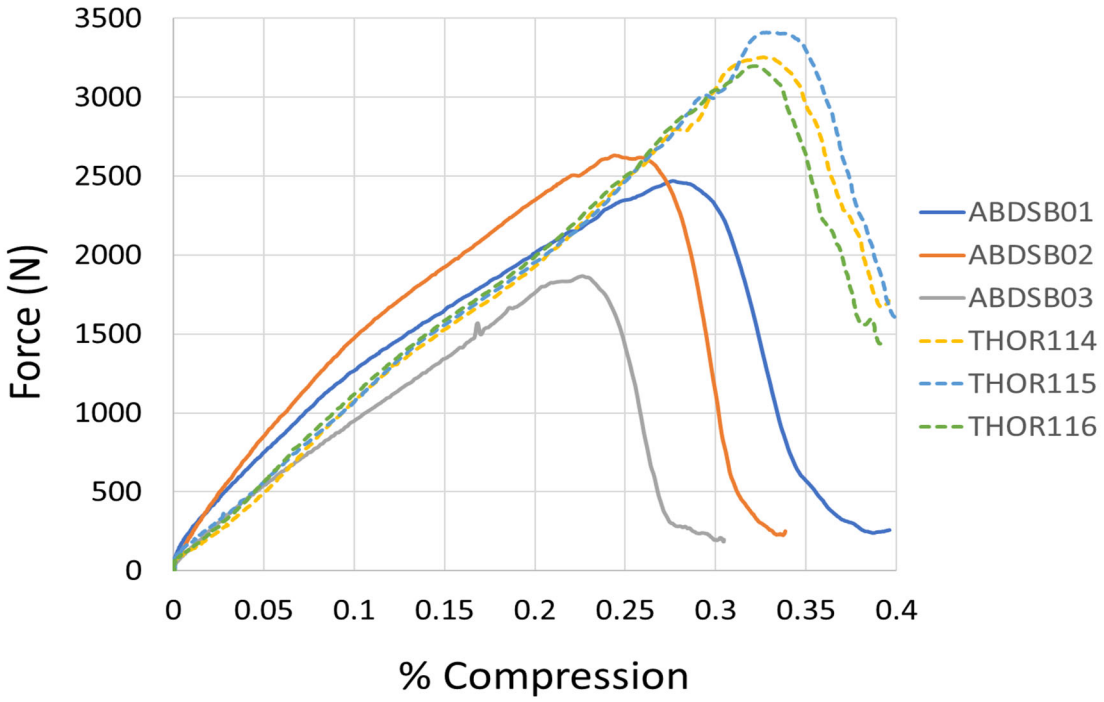

Figure 4. Force-compression responses from the PMHS and ATD tests.

Pressure Response

While comparison of external response was the primary goal of this study, future work will investigate a pressure-based injury risk function specific to the THOR-05F. This is expected to involve a matched pair analysis and development of a transfer function, as it is unlikely that THOR-05F pressure response will be directly comparable to PMHS vasculature pressure. Thus, while pressures for both PMHS and ATD are reported here, they likely cannot be directly compared.

For the PMHS perfusion pressure data, the pressure transducer with the highest peak (positive maximum) pressure was defined as P_{max}. P_{max} in the IVC ranged from 17.5 to 99.2 kPa (Figure 5). Data from the pressure transducers were used to calculate the positive maximum rate of pressure change ($\dot{P}_{max}$) during the event up to P_{max}. The $\dot{P}_{max}$ calculated in the IVC ranged from 0.84 to 8.02 kPa/ms. The calculated IVC $\dot{P}_{max}$ from all tests were less than 9.3 kPa/ms, which was the 50% abdominal injury risk value suggested by Ramachandra et al (2016).

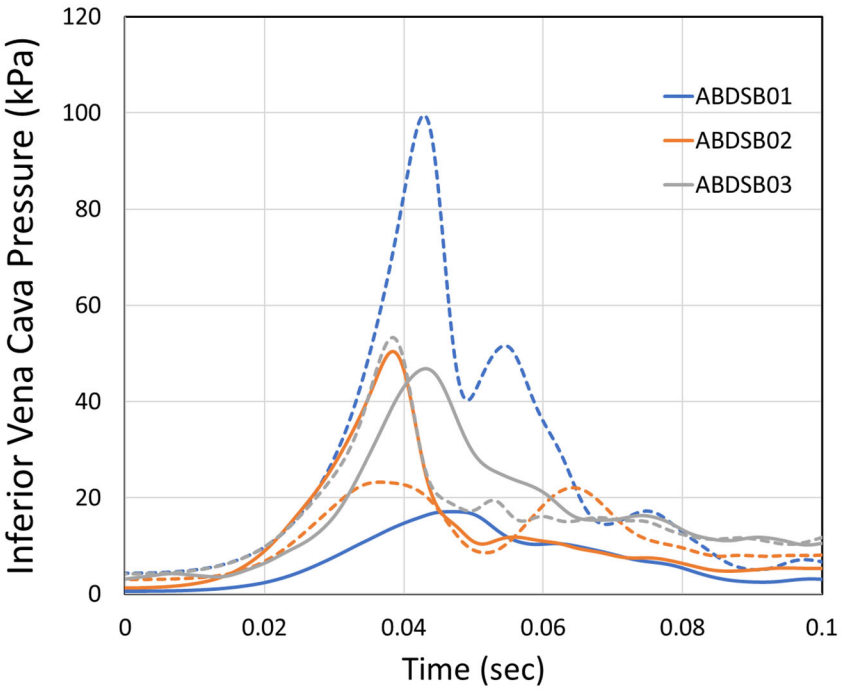

Figure 5. Inferior vena cava pressure traces from each test (solid line is superior IVC; dashed line is inferior IVC)

For the THOR-05F, peak pressures ranged from 71 to 80 kPa in the right APTS, and 140 to 150 kPa in the left APTS (Figure 6). This left-right difference was unexpected, as the sensors are oriented symmetrically in the sagittal plane and care was taken to position the ATD symmetrically during the test. The initial belt tension in the left and right load cells were within 5-10 N of each other. The issue may be related to inconsistencies in the abdomen foam density or structural differences between the right and left side of the ATD, posterior to the abdomen insert. The issue is currently under further investigation. In the future, the abdomen qualification test will be used detect such a discrepancy.

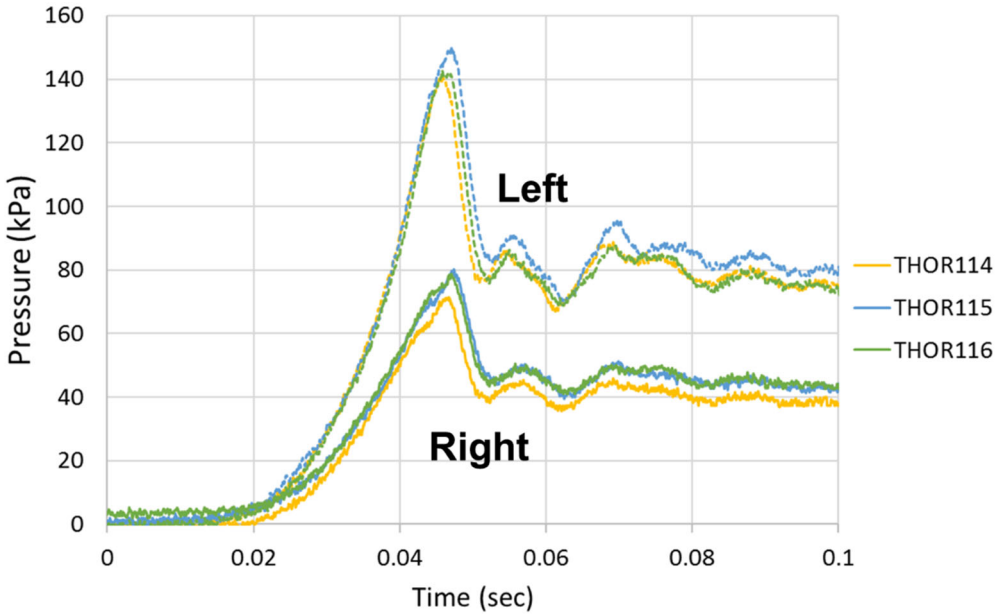

Figure 6. APTS pressure traces in three THOR-05F tests. Differences between left and right pressure sensors are under further investigation

CONCLUSIONS

The general intent of this study was to load the abdomen of small sized PMHS in a non-injurious manner and obtain matched data using the THOR-05F ATD. A total of three abdominal belt pull tests were conducted on three relatively small PMHS. Three matched tests were conducted on the THOR-05F ATD. No abdominal organ injury occurred in any of the PMHS tests in this series, and the values of peak rate of vascular pressure change were consistent with the threshold of serious abdominal injuries as reported by Ramachandra et al. (2016). The THOR-05F response in force-time, penetration-time and force-compression closely matched that of the PMHS. Future work will entail collection of additional PMHS data at higher levels of compression, biofidelity corridor construction and quantitative biofidelity assessment of the THOR-05F in this condition.

ACKNOWLEDGEMENTS

The THOR-05F testing was conducted under contract DTNH2213D00301L/0045. The post mortem human surrogate testing was conducted under contract DTNH2217F00157. Special thanks also go out to Heather Rhule and Kevin Moorhouse of the National Highway Traffic Safety Administration.

REFERENCES

GENNARELLI, T.A., WODZIN, E. (2008). Abbreviated injury scale 2005: update 2008.

LAMIELLE, S., VEZIN, P., VERRIEST, J. P., PETIT, P., TROSIELLE, X., VALLANCIEN, G. (2008). 3D Deformation and dynamics of the human cadaver abdomen under seatbelt loading. Stapp Car Crash Journal, Vol. 50. SAE Paper #2008-22-0011.

LEBARBÉ, M., DONNELLY, B., PETIT, P. AND MOORHOUSE, K., 2015. A frontal response specification for assessing the biofidelity of an anthropometric test dummy; Part 1-Upper body. Proceedings of 2015 IRCOBI Conference. Paper #IRC-15-58.

LEE, E., PARENT, D.P., CRAIG, M.J., MCFADDEN, J. AND MOORHOUSE, K. (2017). Biomechanical response requirements manual: THOR 5th percentile female NHTSA advanced frontal dummy. DOT HS 812 370

PARENT, D., CRAIG, M., RIDELLA, S., MCFADDEN, J. (2013). Thoracic biofidelity assessment of the THOR Mod Kit ATD. In: Proceedings of the 23rd ESV Conference, Paper No. 13-0327.

PARENT, D., CRAIG, M., MOORHOUSE, K. (2017). Biofidelity evaluation of the THOR and Hybrid III 50th percentile male frontal impact anthropomorphic test devices. Stapp Car Crash Journal, Vol. 61. pp. 227-76.

RAMACHANDRA, R., KANG, Y-S., BOLTE IV, J.H., HAGEDORN, A., HERRIOTT, R., STAMMEN, J.A., MOORHOUSE, K. (2016) Biomechanical responses of PMHS subjected to abdominal seatbelt loading. Stapp Car Crash Journal, Vol. 60. pp. 59-87.

RIDELLA, S., PARENT, D. (2011). Modifications to improve the durability, usability, and biofidelity of the THOR-NT dummy. In: Proceedings of the 22nd ESV Conference, Paper No. 11-0312.

SHAMS, T., HUANG, T.J., RANGARAJAN, N., HAFFNER, M. (2003). Design requirements for a fifth percentile female version of the THOR ATD. In: Proceedings of the 18th International Technical Conference on the Enhanced Safety of Vehicles, Nagoya, Japan.

SHAMS, T., BEACH, D., HUANG, T., RANGARAJAN, N., HAFFNER, M. (2002). Development of THOR-FLx: A biofidelic lower extremity for use with 5th percentile female crash test dummies. Stapp Car Crash Journal, Vol. 46. SAE Paper #2002-22-0014

WANG, Z.J., LEE, E., BOLTE, J., BELOW, J. LOEBER, B., RAMACHANDRA, R., GREENLEES, B., GUCK, D. (2018). Biofidelity evaluation of THOR 5th percentile female ATD. In: Proceedings of the 2018 IRCOBI Conference. Paper #18-88.

All Authors' full name, affiliation, address, phone and e-mail

1. Ellen Lee
   National Highway Traffic Safety Administration
   1200 New Jersey Ave., SE, Washington DC 20590
   (202) 266-1435
   Ellen.lee@dot.gov

2. Jason Stammen
   National Highway Traffic Safety Administration
   (937) 666-3319
   Jason.stammen@dot.gov

3. Rakshit Ramanchandra
   The Ohio State University
   (614) 366-7767
   Rakshit.Ramachandra@osumc.edu

4. Yun-Seok Kang
   The Ohio State University
   (614) 366-7584
   YunSeok.Kang@osumc.edu

5. John Bolte IV
   The Ohio State University
   (614) 688-4015
   John.Bolte@osumc.edu