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Effect of High-Rate Loading on Anthropomorphic Test Device Pelvises

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12. Abstract

As part of a larger project aimed at gaining a better understanding of factors that affect the quality of test results using anthropomorphic test devices (ATDs), the FAA tested the effects of dynamic loading of an ATD pelvis. The ATDs required in the aviation regulations were initially developed for the automotive crash environment, which does not include a vertical testing component. One of the two dynamic tests is a vertical impact, with the principal measurement being the compressive load in the lumbar spinal column, with a regulatory limit of 1500 lb. The lumbar load cell is mounted to the pelvis, and data collected could be affected by the performance of the ATD pelvis. The ability to define a vertical calibration test could be used to determine if the pelvis is acceptable for initial use or to monitor in-service degradation. Three ATD pelvises were compressed in a high-rate load frame. The peak load and loading rate of the pelvis compression were selected to simulate conditions achieved in transport category aircraft vertical seat testing. The primary test objective was to measure changes to the rubber and foam cover of the metallic pelvis during high cyclic loading. Each pelvis was subjected to over 100 cycles. Static dimensional measurements, based on a manufacturing tolerance evaluation, were collected during testing. The high-cycle testing did not deform the foam and rubber covers enough to exceed the total dimensional tolerance of the pelvises (± 0.120 in.). The appearance of visual damage was closely monitored throughout the testing. Similar visual damage was seen for each pelvis and occurred at low cycles — 15 to 30. Results suggest the appearance of damage minimally changed the dynamic response of the pelvis. Force-deflection data were also collected from each test series. These data showed minimal change during testing, with the deflection at 2000 lb. changing approximately 0.100 in. across the 105 cycles. This value is similar to the manufacturer's tolerance for the height of the pelvis. Based on this, the number of vertical sled tests that would precipitate replacement may be over 100 cycles. Due to the harsh environment of dynamic sled testing, other factors, such as cuts in the foam and rubber due to belt loading, may trigger the removal of an ATD pelvis from service prior to the pelvis reaching a defined number of cycles. Future FAA research will evaluate how this change in pelvis force-deflection affects lumbar load.

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List of Abbreviations

ATD	anthropomorphic test device
AWS	Amazon Web Services
CFR	Code of Federal Regulations
DOI	Digital Object Identifier
DOT	Department of Transportation
FAA	Federal Aviation Administration
FD	force deflection
ft.	feet
GM	General Motors
in.	inches
lb.	pounds (force)
min	minutes
sec	seconds
US	United States

Background

The Federal Aviation Administration (FAA) has regulations that require aircraft seating systems to protect occupants in the event of an emergency landing. These regulations require dynamic testing to substantiate the safety of seating systems. Dynamic testing uses anthropomorphic test devices (ATDs) and sensor sets to collect data in simulated aircraft impacts and crashes to examine potential occupant injury. Due to the severe environment of dynamic testing, reusable parts on the ATDs break down or wear out, and often, this damage cannot be determined by visual inspection. Some ATD parts, such as the head and neck, have evaluation methods outlined in 49 CFR 572 to test specific components to ensure they are acceptable (U.S. Code of Federal Regulations, n.d.). These calibration tests are designed to be conducted before a test series is started and are used to determine when the component is no longer operating within the designed criteria. The criteria allow test engineers and technicians to measure the response of a component and determine the need for component replacement. The ATD regulation does not define a calibration test to determine if the pelvis is acceptable for initial use or to monitor in-service degradation.

Lumbar Load

One of the two dynamic tests required by 14 CFR 2X.562 is a primarily vertical impact with an impact angle of 30° off vertical (U.S. Code of Federal Regulations, n.d.). In this test, the principal measurement is the compressive load in the lumbar spinal column, which has a regulatory limit of 1500 lb. The measured load is a function of the seat deflection (which may reduce the lumbar load), the seat bottom cushion (which amplifies the load), and the rubber and foam of the ATD pelvis (which could increase or decrease the load from a nominal value; see *Figure 1* for the foam and rubber cross-section). Previous testing has shown significant variability in measured lumbar loads that are, in part, attributed to variability in ATD pelvises. (DeWeese et al., 2021; Taylor et al., 2017; DeWeese, 2006). In the attempt to further reduce the variability in this test series, the Hybrid III pelvis was selected due to the tighter manufacturing tolerances compared to those of the Hybrid II pelvis (DeWeese et al., 2021).

Figure 1: Pelvis Foam and Rubber Shell Cross-Section

ATD Calibration

The ATDs required in the aviation regulations were initially developed for the automotive crash environment; both the Hybrid III and FAA Hybrid III use the same pelvis, which does not include a vertical testing component. As a result, 49 CFR 572 does not define a calibration test to determine if the pelvis is acceptable for initial use or to monitor in-service degradation. The required calibration procedures do exist for ATD components such as the head, neck, thorax, lumbar spine, limbs, etc. As an example, the test procedure for the head is a 10-in. drop to a flat plate while measuring the acceleration response. Calibration of ATD components also includes instrumentation, which is defined in SAE International's standard J211-1 (https://www.sae.org/standards/content/j211/1_202208/). The J211-1 provides guidelines and recommendations for the measurements used in dynamic impact testing.

Static Load Test Stand

A test stand is used for checking the manufacturing tolerance for the ATD pelvis (*Figure 2*). Due to the deflection of the foam and rubber, the distance from the H-point to the bottom of the pelvis is measured with a 75-pound (lb.) load applied. A 50th percentile ATD sitting on a flat surface with its feet supported applies approximately 130 lb. to the bottom of the pelvis. This distance is defined as 3.620 in. ± 0.060 in. for the Hybrid III as defined in General Motors (GM) drawing 78051-58 (*Figure 3*). This manufacturing tolerance is evaluated by mounting the pelvis upside down on a 5.362-in. tall pedestal with a 75-lb. static load. Following a 5-minute wait, the distance from the pedestal's top plate inspection surface to the bottom plate inspection surface is recorded. For the Hybrid III pelvis on the test stand, this height range is 10.242 in. and 10.362 in. for the pelvis to be conformed.

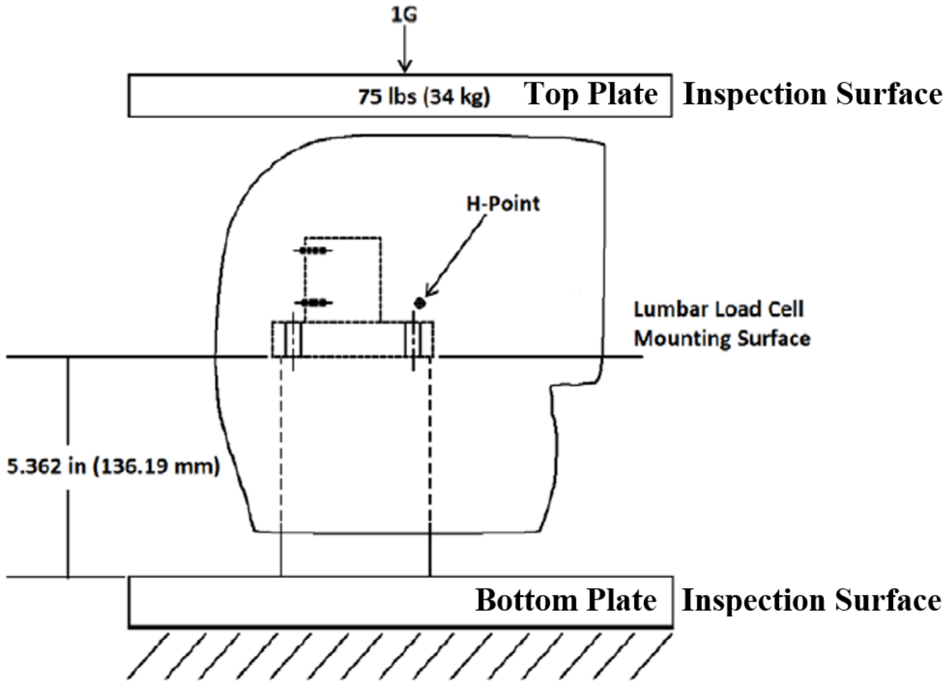

Figure 2: SAE ARP 5765B – Pelvis Compression Illustration

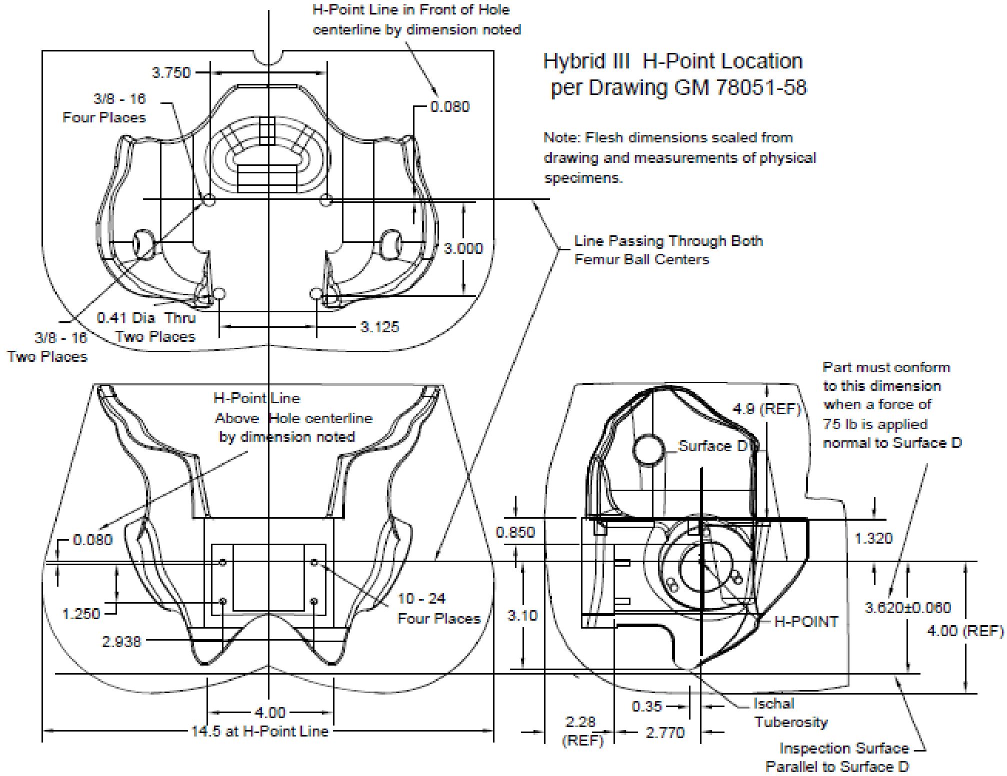

Figure 3: Hybrid III H-Point Location Drawing Based on GM Drawing 78051-58

A yearlong evaluation of pelvis static measurements was conducted by the FAA's Civil Aerospace Medical Institute Biodynamics Research Team (Hellstrom et al., 2023). The testing simulated two types of static ATD pelvis storage methods of the 50th percentile Hybrid III ATD. The objective was to measure changes to the foam and rubber that cover the pelvis. In the first method of storage, no loads were applied to the bottom of the ATD pelvis between measurement dates. The second storage method loaded the bottom of the pelvis with a 125-lb. load between measurement dates. The 125-lb. load was selected because it is the approximate weight applied to a seat pan with a 50th percentile FAA Hybrid III ATD seated in an upright position with the feet supported. The pelvises were removed from storage every 3 months and loaded with 75 lb. to measure the effects of their respective storage methods. At the conclusion of the testing, the unloaded pelvis had virtually no change in measurement over the year of evaluation. The pelvis stored with the static load resulted in the H-point height dimension being outside the minimum tolerance specified in the GM drawing. The pelvis stored with the load had a maximum compression of 0.192 in. Much of the dimension change (~85%) occurred within the first 3 months of storage. The loaded pelvis was then stored unloaded for 6 months after the initial yearlong evaluation was complete. The measurement at the end of the additional 6 months showed the left side rebounded 0.038 in., approximately 20% of the total compression, and the right side rebounded 0.127 in., approximately 65% of the total compression. The effects of long-term loaded storage of an ATD pelvis seem permanent or at least extremely slow to recover. A pelvis that falls outside the manufacturing tolerance could be considered unsuitable for testing. Due to the changes in the pelvis dimensions from static storage, it is imperative that ATDs are stored with no load on the bottom of the pelvis. The “Effect of Pelvic Loading during Anthropomorphic Test Device Storage” report provides details about the static testing and applicable storage methods (https://doi.org/10.21949/1524440).

Project Scope

While a manufacturing tolerance on the pelvis H-point height provides a conformity check for the pelvis, this alone likely does not provide data that relate to the performance of the component. A vertical calibration test that standardizes the pelvic compressive response and can be used to determine the suitability of the pelvis does not exist. To support the development of a vertical calibration test for the pelvis, the following goals were set for this testing:

- Goal 1: Evaluate if the 75-lb. static evaluation provides adequate data to identify a pelvis’s degradation (e.g., a non-destructive calibration test).
- Goal 2: Identify if visual degradation correlates to the high-rate response of the pelvis.
- Goal 3: Determine if high-rate load frame response correlates to lumbar load measured during a full-scale sled test.
- Goal 4: Determine if a specific number of cycles can be defined for a replacement criterion for the pelvis.

The goal of this project was to simulate a high number of dynamic sled test loading cycles on an ATD pelvis while tracking the change in performance (i.e., force-deflection (FD) response of the pelvis). It is assumed that FD curves will provide insight into the degradation of the Hybrid III pelvis across its service life. The rate of degradation could give insight into the number of cycles until replacement is required. Additionally, the change in the FD curves over the course of the testing could provide insight into how a vertical calibration procedure could be achieved. Prior to this test series, no known data or evaluation information for the service life (number of loading cycles to replacement) for the Hybrid III pelvis was available.

Methods

To evaluate the effect of repeated loading of a pelvis, three pelvises were loaded in a high-rate load frame until the stroke length versus cycles reached an asymptote. Static measurements were recorded prior to the dynamic testing. The pelvises were then loaded over 100 cycles, and the static measurement was repeated. Visual damage to the pelvis was monitored and documented throughout the tests. The temperature and relative humidity of the test area were checked prior to all measurements in accordance with 49 CFR 572 subpart B.

Pelvises

The test series used three brand-new Hybrid III pelvises from two different manufacturers. Two pelvises were from Humanetics Group, Farmington Hills, MI (serial numbers DZ0480 and DZ0498), and one pelvis was from JASTI Company, Limited, Tokyo, Japan (serial number 1203). The pelvises were stored in the shipping box until the start of this test series. Before testing, the H-point was projected and marked on each side of the pelvis with a scribe line and a photometric quad target (Moorcroft et al., 2010). The quad target allowed measurement to the H-point on the rubber surface.

Static Load Test Stand

The test stand consists of three main components: base plate with pedestal, support arm, and top plate with weight mount (*Figure 4*). The base plate served three purposes: ATD pelvis mounting fixture, measurement reference points, and support arm guide. The pelvises were attached to the pedestal using the bolt pattern that connects the lumbar load cell mounting surface to the pelvis. The height of the pedestal used for this project was 5.362 in., including bottom plate thickness. The support arm aligned the guide rods for both the base plate and the top plate to hold the two surface planes of the plates parallel. The top plate served as the weight mount and measurement reference point and distributed the weight evenly over the bottom of the pelvis. The top plate, weighing 25 lb., was designed to hold a maximum of four 25-lb. Olympic-style plate weights. The test stand could apply a load to the pelvis at the nominal weight of an ATD sitting on a flat surface (125 lb.) and the weight used for the manufacturing evaluation (75 lb.). A complete description of the static test stand is available in the pelvis storage evaluation paper (Hellstrom et al., 2023).

The three brand-new pelvises were checked on the static test stand prior to the dynamic testing and at the completion of dynamic testing. The distance from the top inspection surface to the bottom inspection surface was measured as seen in *Figure 2*. The distance was checked on both the right and the left side of the pelvis and the value was averaged. The measurement prior to the dynamic testing was used to determine if the pelvis was within tolerance from the manufacturer (*Figure 3*).

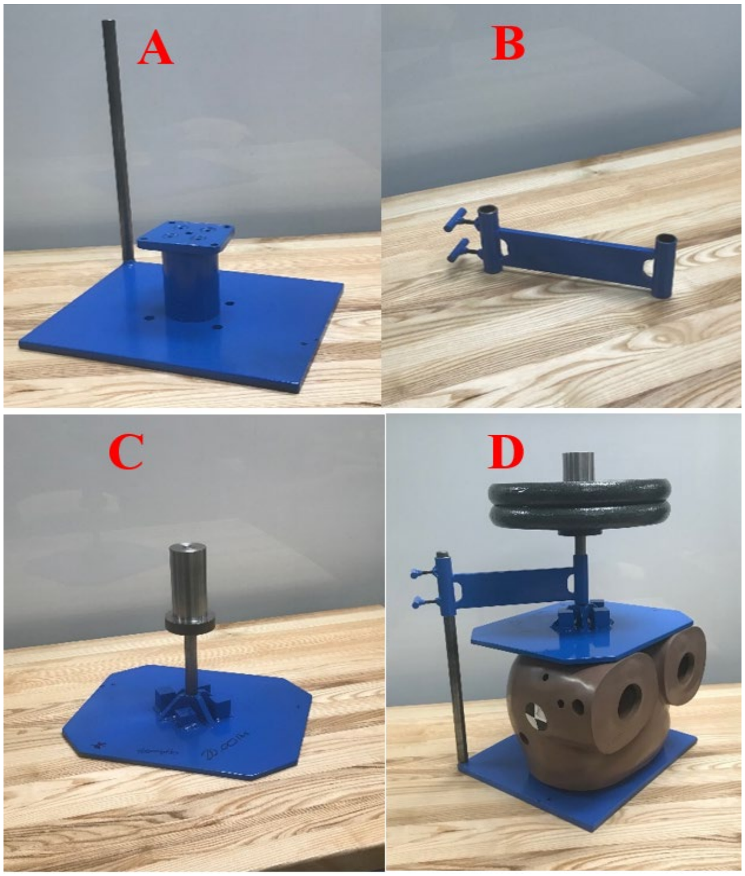

Figure 4: Test Stand Components: (A) Base Plate with Pedestal, (B) Support Arm, (C) Top Plate with Weight Mount, and (D) Complete Assembly with 75-lb. Load

High-Rate Load Frame Setup

To replicate the interaction between the pelvis and an aircraft seat during a dynamic sled test, the pelvises were mounted to a high-rate MTS Landmark load frame and compressed into an aluminum plate. An adapter was designed to interface between the pelvis and the MTS load cell (*Figure 5* and *Figure 6*). An offset of 1.04 in. between the MTS mounting hole and the center of the pelvis' four load cell mounting bolts was necessary to center the pelvis over the MTS ram (*Figure 7*). This offset aligned the ischial tuberosities concentric with the center line of MTS' hydraulic ram; see *Figure 6* and *Figure 8*. The pelvis and ram oriented in a coaxial manner allows the pelvis to be loaded in the same manner, even if the pelvis or the hydraulic ram rotated during a testing cycle. To replicate the interaction between the pelvis and an aircraft seat pan, the test setup utilized an aluminum plate. The plate is rigidly mounted to the top of the hydraulic ram by a single bolt (*Figure 6*). The plate has an 18 in. diameter and is one in. thick. The diameter allowed for ample contact between the plate and the pelvis while minimizing the chance of cutting the foam and rubber cover on the edge of the plate. The circular shape maintains clearance away from the MTS structure due to the ability of the hydraulic ram to rotate unrestrained.

Figure 5: Pelvis to MTS Adapter Mounted on a Pelvis (Top View)

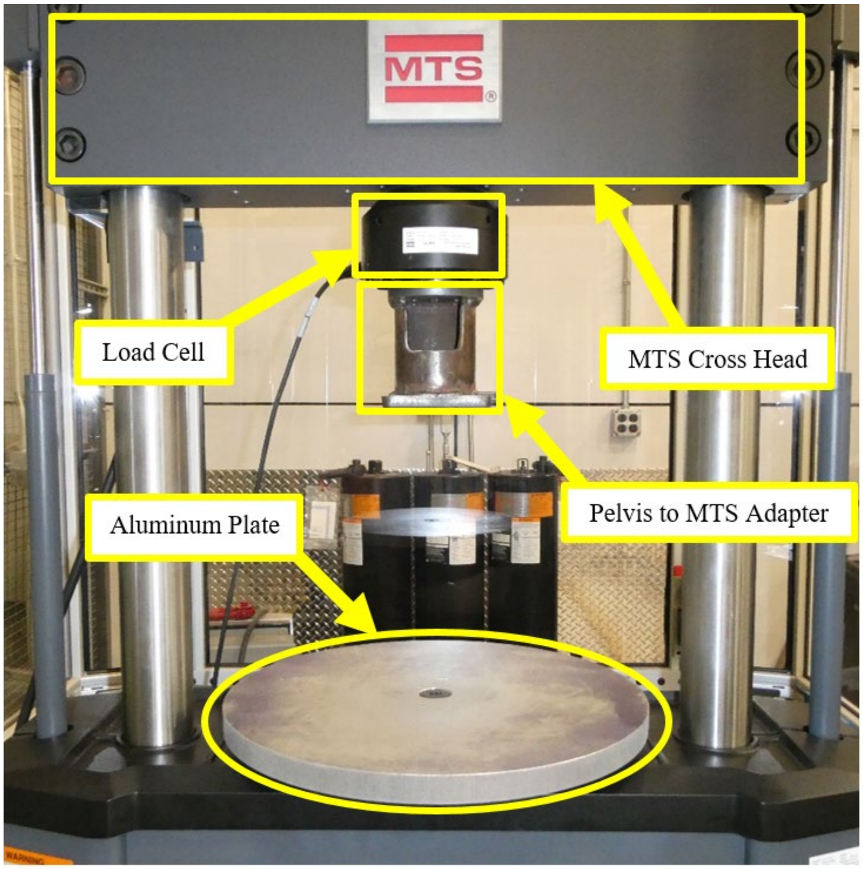

Figure 6: MTS and Test Fixture Components, Ram Below the Plate (Not Pictured)

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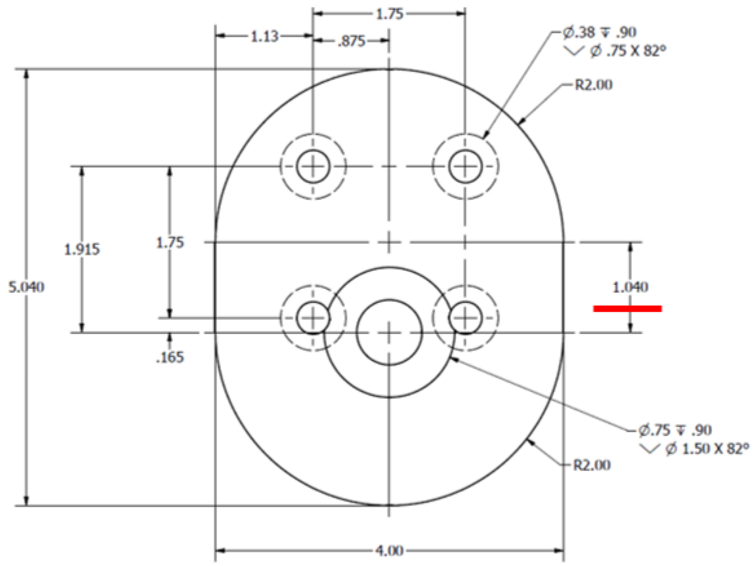

Figure 7: Adapter Top Plate Dimensions, Highlighting the Offset Dimension

Figure 8: Ischial Tuberosities Location on the Bare Metal Hybrid III Pelvis

Loading Profile

The high-rate load frame tests used a loading profile comparable to that seen by the pelvis during a Part 25 vertical dynamic sled test (*Figure 9*). Sled test A12010 had a peak seat pan load of 2898 lb. (tare corrected), with a max loading rate of 4.9 ft./sec based on photometric tracking of the pelvis (Deweese et al., 2021). Based on this information and the results of preliminary load frame tests, a ram velocity of 4 ft./sec was selected for these component tests. *Figure 10* shows the MTS control system's output of the hydraulics ram's stroke distance versus time for a typical test.

The MTS can operate in force control or displacement control; preliminary testing determined that the MTS operated more reliably in displacement control when testing at this speed (Hooper et al., 2005). The MTS' ram stroke distance was adjusted to achieve 3000 lb. ± 500 lb.[1] The goal of 3000 lb. was selected due to the correlation between the seat pan load and the lumbar load. The lumbar load to seat pan load has a ratio of approximately 2:1 (DeWeese, 2005). A load of 3000 lb. would roughly correlate to the lumbar load regulatory limit of 1500 lb. The load applied and measured by the MTS would be equivalent to the load that would be measured at the seat pan load cell in a dynamic sled test (*Figure 9*). The 1500-lb. lumbar load limit ensures that the goal loading is aggressive but within the range that would be practical to see during a certification test.

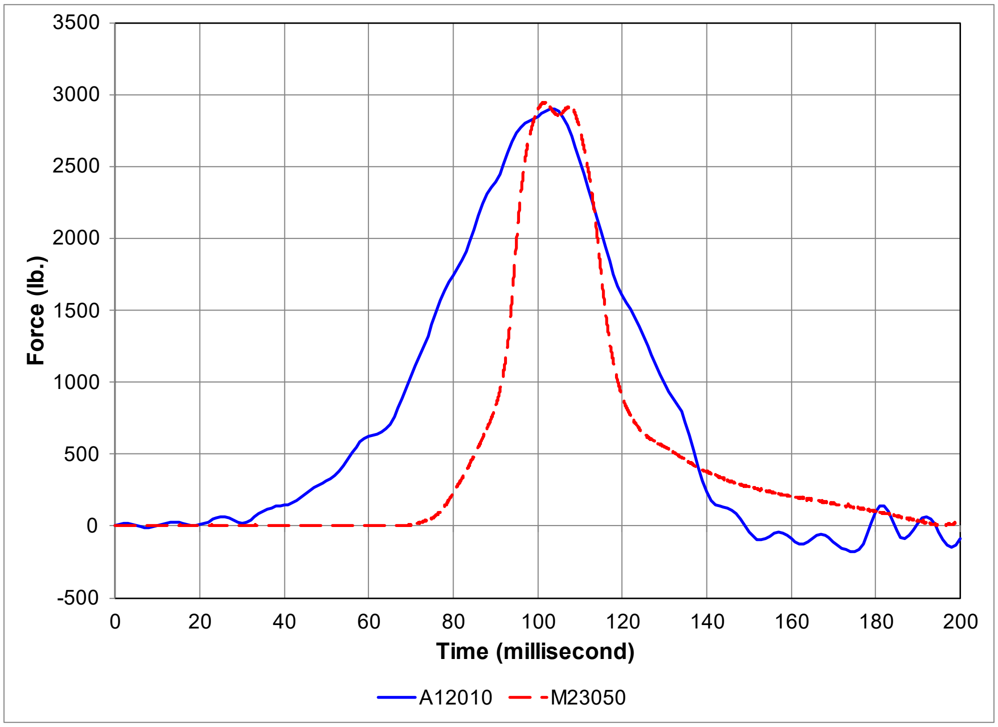

Figure 9: Measured Pan Force from Impact Test A12010 and Measured Force from MTS during Test M23050[2]

[2] Test M23050 shifted to align with the sled test peak for clarity.

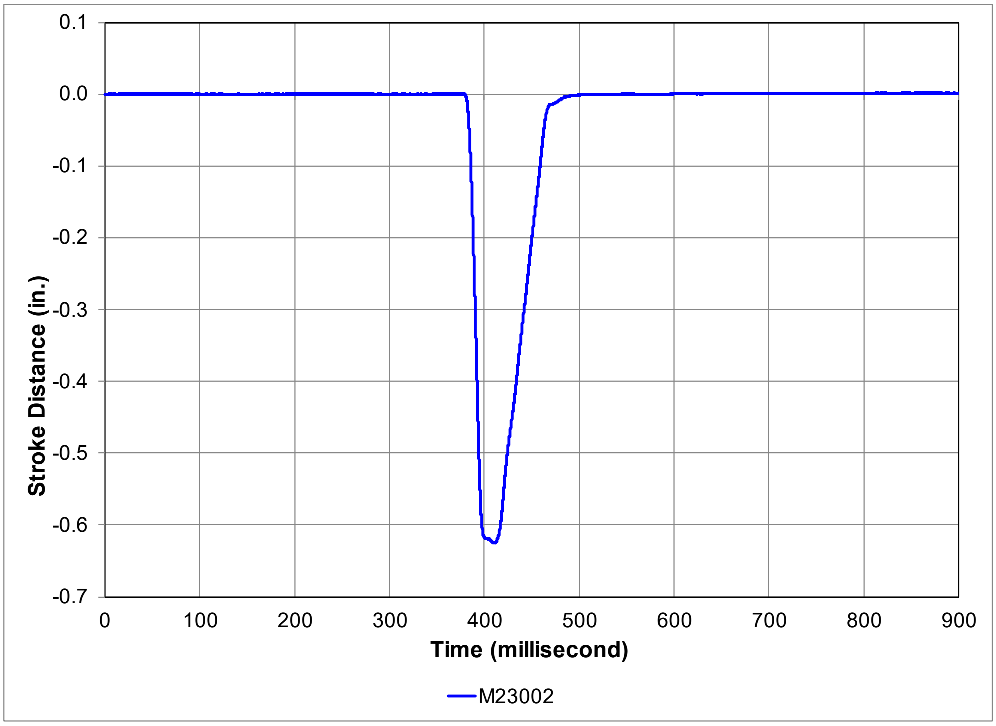

Figure 10: MTS Ram Stroke Distance versus Time (One Cycle)

Procedure

The MTS was cycled for 30 minutes to bring the machine up to operating temperature. The aluminum plate was bolted to the hydraulic ram. The load cell was zeroed on the MTS computer interface. The pelvis and the adapter were bolted together, and then the pair was bolted to the load cell. For the weight of the pelvis and adapter, the load cell would display a reading of approximately 27 lb. The hydraulic ram was raised into position until the aluminum plate contacted the bottom of the pelvis and the load cell read zero. The hydraulic ram's position was zeroed. This position for zero was the starting ram position for every test cycle. Manual measurements were collected from the cross head to the aluminum plate on both the left and right sides of the pelvis. These manually measured values were recorded in case the electrical or the hydraulic power was interrupted to the MTS and the aluminum plate zero distance needed to be re-established. Pretest pictures were taken. The pelvis was compressed to 75 lb., and the loading was maintained for 5 min. At the end of the 5-min compression routine, the ram position was recorded from the computer interface readout, and manual measurements were again collected from the left and right sides of the pelvis, measuring the distance from the MTS cross head and the aluminum plate. The hydraulic ram was then moved back to zero. The MTS compression routine was started, moving the ram up to the programmed distance (procedure stroke length) at 4 ft./sec, then returning to zero (*Figure 10*). The ram was then moved down and off the pelvis. This started the 30-min rest for the pelvis, allowing for post-test pictures to be taken and inspection of visual damage. Data for deflection distance and force were collected at ~24,000 samples per sec. The deflection and force datasets were used to generate the FD graphs for every loading cycle. The data collected were reviewed, and if needed, the routine's stroke length was updated for the next test series to maintain the goal of 3000 lb. ± 500 lb. on the pelvis.[3] The initial exit criterion for the high-rate load frame testing was when the MTS static measurement changed more than 0.060 in. from the first MTS static measurement. This change in static measurements was not achieved, so the exit criterion was changed to end the cyclic testing once the stroke versus cycles reached an asymptote, which ultimately took about 105 cycles for each pelvis.

Test Cycles versus Test Series

A test cycle is defined as loading the pelvis to approximately 3000 lb. and returning to zero (*Figure 9*). Some test cycles were grouped into test series to speed up data collection. The process of moving the ram to zero, compressing the pelvis for 5 min at 75 lb., and then running the test to approximately 3000 lb. at 4 ft./sec was run five times; each cycle was recorded as an individual test series. Cycles 6 through 55 were grouped into five cycle test series. For cycles 56 to 105, the test series consisted of a group of 10 cycles. The run numbers for each test series are based on standard Civil Aerospace Medical Institute naming conventions; high-rate load frame tests are labeled with an 'M,' the year of the run is recorded using two digits, and the next three numbers indicate the chronological order for the run. For example, the first high-rate load frame test for 2023 is labeled M23001. If the test series involved multiple cycles, a hyphen and cycle number are added to the suffix, for example, M23057-3. Appendix A provides the number of cycles associated with each test in *Table 6*, *Table 7*, and *Table 8*.

Results

Static Test Stand Data

All three pelvises were received with an H-point height exceeding the upper limit of the manufacturing tolerance found in the GM drawing. *Table 1* shows the measured dimensions and amount the pelvis was outside the tolerance for both the initial (prior to the start of cyclic testing) and the final (after all cyclic testing is complete) measurements. The initial out-of-tolerance for the pelvises ranged from 0.054 in. to 0.282 in. The final out-of-tolerance for the pelvises ranged from 0.043 in. to 0.272 in.

[3] The first cycle for DZ0480 reached 4500 lb. and was excluded from some subsequent data analyses. Nine cycles were needed to reach the target load for pelvis 1203.

Table 1: Initial Pelvis Dimension and Out-of-Tolerance Values

Pelvis Serial #	Initial Average Distance from Top Inspection Plate to the H-Point (in.)	Value Above the 3.680 Tolerance (in.)	Final Average Distance from Top Inspection Plate to the H-Point (in.)	Value Above the 3.680 Tolerance (in.)
DZ0480	3.760	0.080	3.758	0.078
DZ0498	3.734	0.054	3.724	0.043
1203	3.962	0.282	3.952	0.272

Table 2 contains the initial and final measurements from the static test stand from the top plate inspection surface to the bottom plate inspection surface. The differences across all the tests: for pelvis DZ0480, the difference was 0.002 in.; for pelvis DZ0498, the difference was 0.010 in.; and for pelvis 1203, the difference was 0.009 in.

Table 2: Test Stand Static Measurements, Top Inspection Surface to Bottom Inspection Surface

Pelvis Serial #	Initial Left (in.)	Initial Right (in.)	Initial Average (in.)	Final Left (in.)	Final Right (in.)	Final Average (in.)	Change in Average (in.)
DZ0480	10.402	10.481	10.442	10.514	10.366	10.440	0.002
DZ0498	10.459	10.373	10.416	10.466	10.345	10.406	0.010
1203	10.690	10.597	10.643	10.696	10.572	10.634	0.009

High-Rate Load Frame Data

The test series data can be found in Appendix A in *Table 6*, *Table 7*, and *Table 8*. These data include test series number, date, temperature, humidity, ram distance from zero during the 75-lb. load test, programmed procedure stroke length, and number of cycles in the series.

Three force-deflection (FD) plots were created for each pelvis. The FD curves were created from the 1st, 2nd, 5th, 25th, 55th, and 105th cycles and plotted in *Figure 11*, *Figure 12*, and *Figure 13*. These specific cycle FD curves were selected to show the change in pelvis response as the number of cycles compounded. Pelvis 1203 had an additional nine cycles to program the correct procedure stroke length before the desired peak load was reached. Therefore, these nine tests (M2340 through M23049) will not be used in the total number of cycles. Test series M23050 is treated as the first cycle for pelvis 1203. In combination with the FD plots, the following tables provide the data and calculation for the creep: *Table 3*, *Table 4*, and *Table 5*. All six curves on all three plots cross the 2000-lb. axis. The first data point collected above 2000 lb. was used to evaluate the change in the distance of the curves. The creep was calculated by subtracting the current cycle's ram position at 2000 lb. from the ram position for the first cycle.

Figure 11 shows the FD curves for pelvis DZ0480. The creep is observed between cycles 1 to 2. Cycles 2 and 5 basically overlay until the -2200-lb. axis. The most significant amount of creep comes between cycles 5 and 25, with 0.052 in. at the -2000-lb. axis crossing. Cycles 25 and 55 overlay until the -2200-lb. axis. The creep value is 0.032 in. at the -2000-lb. axis between cycles 55 and 105, which is the same amount of creep as between cycles 1 to 2.

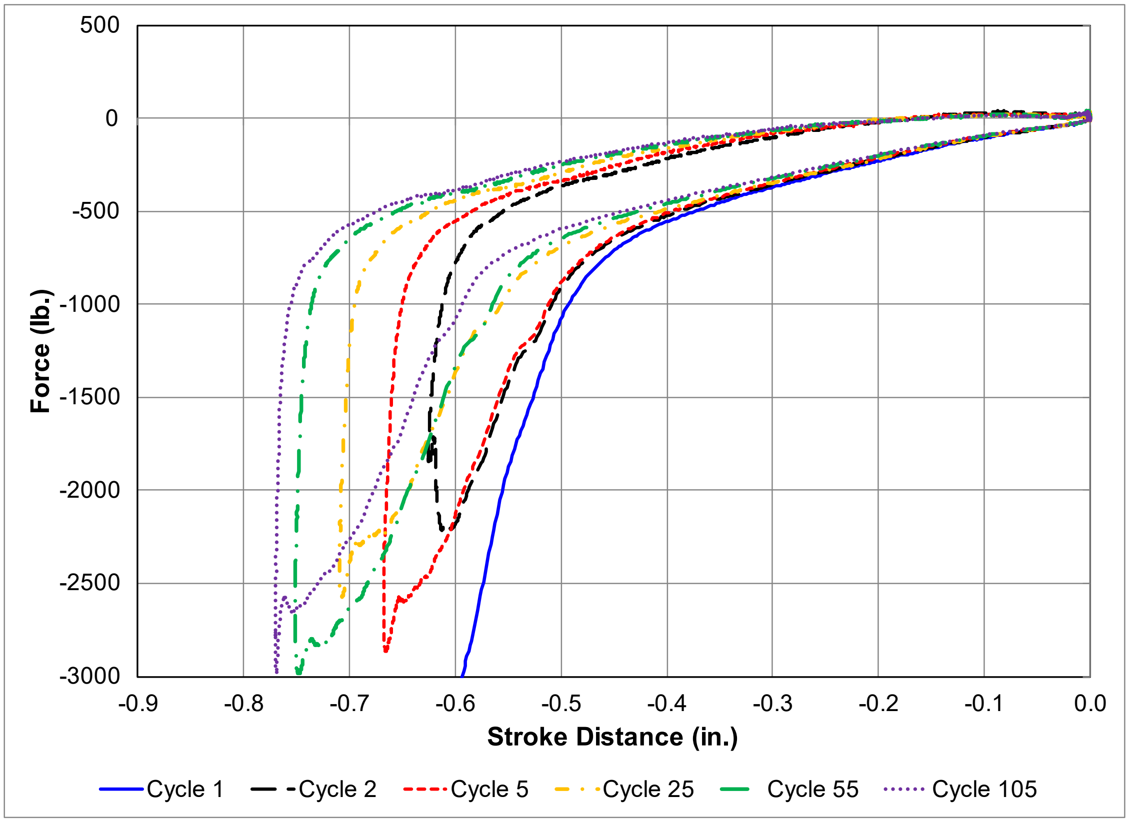

Figure 11: Pelvis DZ0480 Force Deflections at Cycles 1, 2, 5, 25, 55, and 105[4]

[4] The Y-axis minimum force value is limited to -3000 lb. for clarity; test series M23001 exceeded -4500 lb.

Table 3: Pelvis DZ0480 Data and Calculated Values for Creep at -2000 lb.

Test Number	Cycle	Time to Reach 2000 lb. (sec)	Stroke Distance (in.)	Force (lb.)	Creep (in.)
M23001	1	0.397	-0.556	-2009	0.000
M23002	2	0.397	-0.588	-2005	-0.032
M23005	5	0.397	-0.593	-2008	-0.037
M23009-5	25	0.398	-0.644	-2009	-0.089
M23015-5	55	0.398	-0.646	-2007	-0.090
M23020-10	105	0.399	-0.678	-2013	-0.122

Figure 12 has the FD curves for pelvis DZ0498. Cycles 1, 2, and 5 overlay up to -2500 lb. Similar to the trend observed with pelvis DZ0480, the most significant shift comes between cycles 5 and 25 with 0.052 in. of creep at the -2000-lb. axis. Cycles 25 and 55 overlay until -2500 lb. The amount of creep between cycles 55 and 105 was 0.023 in., which is nearly half of the creep calculated between cycles 5 and 25.

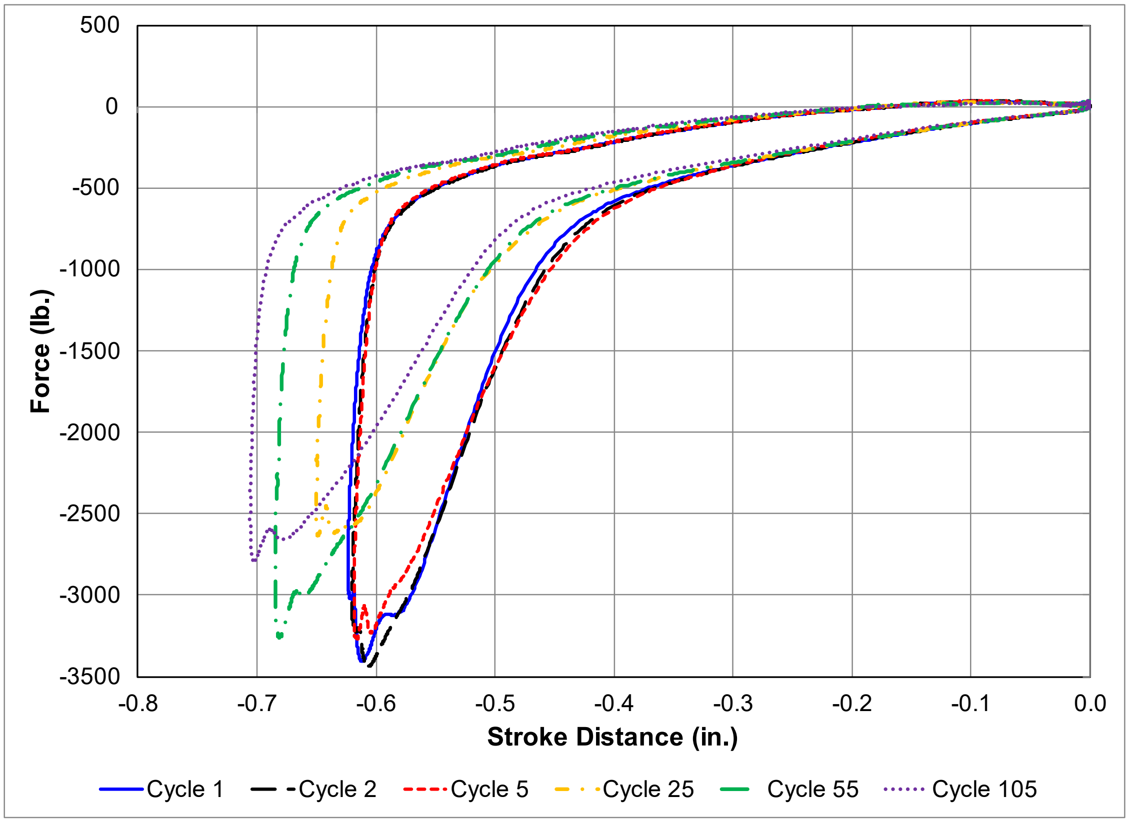

Figure 12: Pelvis DZ0498 Force Deflections at Cycles 1, 2, 5, 25, 55, and 105

Table 4: Pelvis DZ0498 Data and Calculated Values for Creep at -2000 lb.

Test Number	Cycle	Time to Reach 2000 lb. (sec)	Stroke Distance (in.)	Force (lb.)	Creep (in.)
M23021	1	0.397	-0.525	-2015	0.000
M23022	2	0.395	-0.522	-2016	0.003
M23025	5	0.395	-0.524	-2000	0.001
M23029-5	25	0.397	-0.578	-2018	-0.053
M23035-5	55	0.396	-0.580	-2013	-0.056
M23040-10	105	0.397	-0.603	-2010	-0.079

Figure 13 shows the FD curves for pelvis 1203. There are observable shifts in creep between cycles 1, 2, and 5, with 0.033 in. of creep between cycles 1 and 5. Again, the most significant amount of creep comes between cycles 5 and 25, with 0.053 in. at the -2000-lb. axis. There is also observable creep between cycles 25 and 55 of 0.011 in. at the -2000-lb. axis. Between cycles 55 and 105, the amount of creep observed at the -2000-lb. axis was 0.034 in., which is almost the same amount calculated between cycles 1 and 5.

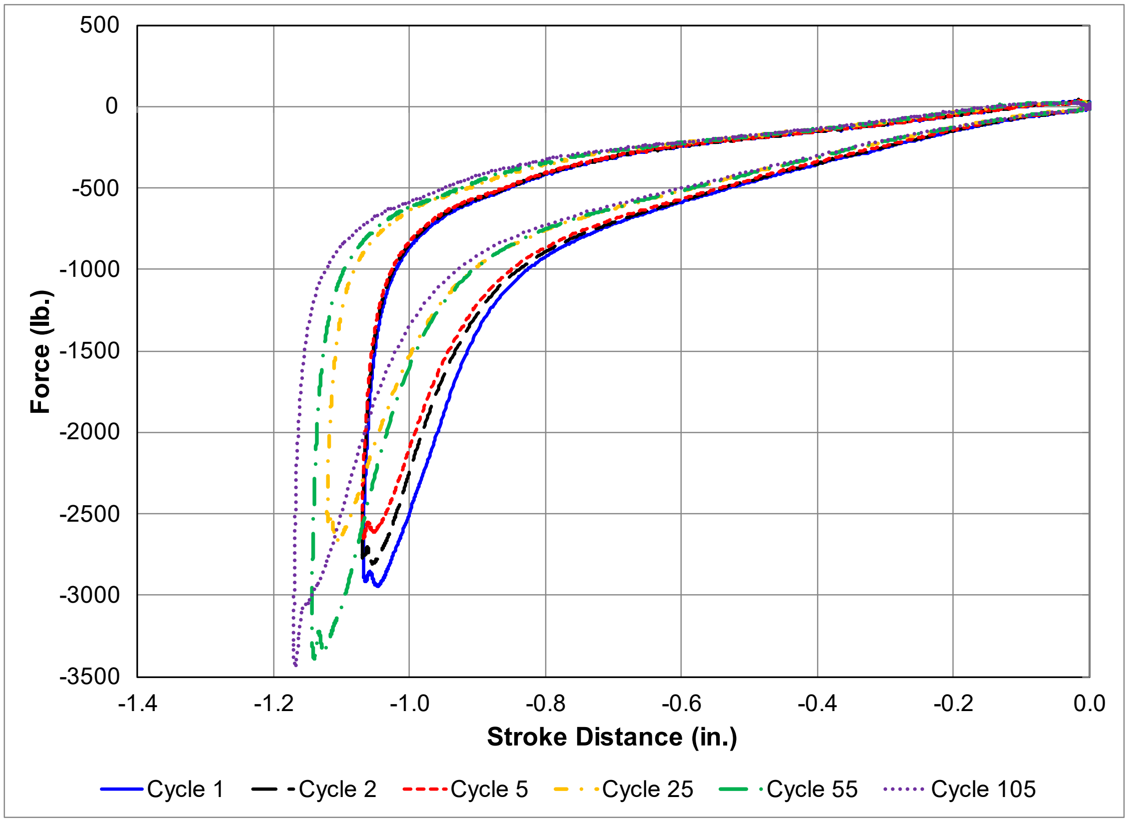

Figure 13: Pelvis 1203 Force Deflections at Cycles 1, 2, 5, 25, 55, and 105

Table 5: Pelvis 1203 Data and Calculated Values for Creep at -2000 lb.

Test Number	Cycle	Time to Reach 2000 lb. (sec)	Stroke Distance (in.)	Force (lb.)	Creep (in.)
M23050	1	0.405	-0.959	-2004	0.000
M23051	2	0.405	-0.981	-2005	-0.022
M23054	5	0.406	-0.993	-2004	-0.033
M23058-5	25	0.407	-1.046	-2010	-0.086
M23064-5	55	0.407	-1.034	-2007	-0.075
M23069-10	105	0.407	-1.068	-2018	-0.109

The procedure stroke length is the operator-programmed distance that the MTS' ram moved to achieve the goal of 3000 lb. ± 500 lb. *Figure 14* shows the plots of the procedure stroke length versus the number of cycles for the three pelvises. These plots were used to confirm that the required change in procedure stroke length was becoming asymptotic (minimal change in stroke length) as the testing continued. Pelvis DZ0480 had a total change in procedure stroke of 0.155 in. for all tests. A ~25% change in procedure stroke length was programmed at cycle 4, a ~50% percent change at cycle 16, and a ~75% change at cycle 36. Pelvis DZ0498 had a total change in procedure stroke of 0.090 in. for all tests. A ~25% percent change in procedure stroke length was programmed at cycle 11, ~50% percent change at cycle 36, and ~75% change at cycle 51. Pelvis 1203 had a total change in procedure stroke of 0.110 in. for all tests. A ~25% percent change in procedure stroke length was programmed at cycle 11, ~50% percent change at cycle 26, and ~75% change at cycle 86.

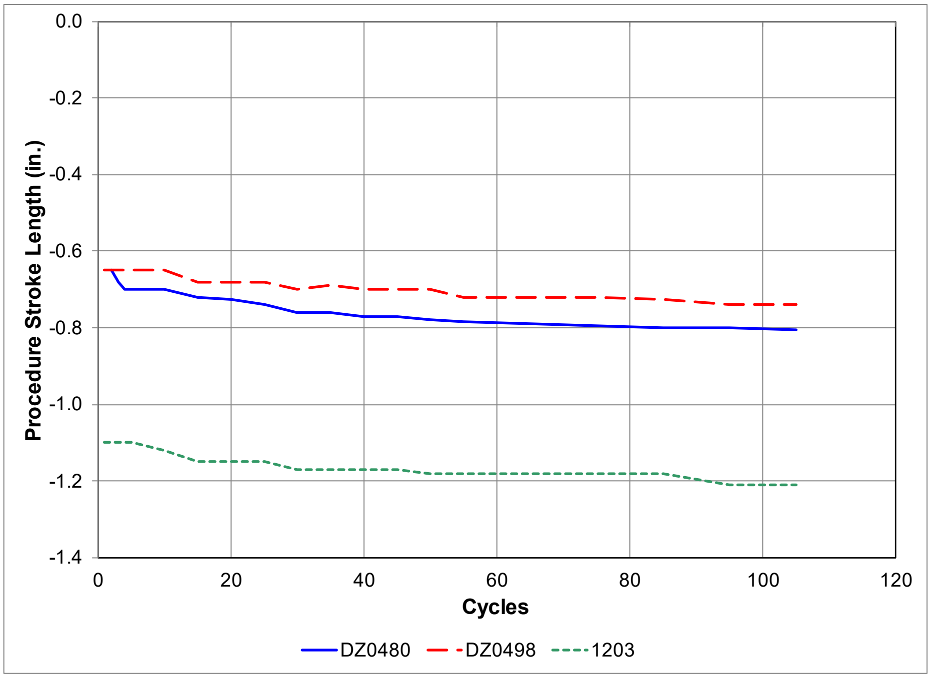

Figure 14: Procedure Stroke Length versus Cycles[5]

Discussion

Goal 1: Evaluation of 75-lb. Static Measurement

All three of the pelvises tested in this project were received from their manufacturers with the H-point outside the upper limit of the tolerance called out in the GM drawing. The two pelvises in the year-long static testing project were also taller and outside the tolerance (Hellstrom et al., 2023).

Static measurements were taken on the static test stand at the start and completion of the dynamic testing. All three pelvises were dynamically loaded to 3000 lb. ± 500 lb. over 100 times. The repeated dynamic loading minimally changed the static measurement. Across the three pelvises, the maximum change in the static measurement was 0.010 in. for pelvis DZ0498. The change in the foam and rubber due to the cyclic loading was less than the manufacturer's total tolerance. The repeated dynamic loading effects are significantly smaller than the effects of static long-term loading (Hellstrom et al., 2023). In that test series, continual static load on the bottom of the pelvis replicating an ATD seated on a chair was simulated for 1 year. The change in H-point height (as much as 0.324 in.) was greater than the effect of dynamically loading the pelvis over 100 times.

Static measurements with the 75-lb. load were also taken at the start of every test series using the MTS position and force readouts. Pelvis DZ0480 had a maximum difference in MTS static

[5] Test M23001, cycle 1 is omitted since the input stroke length exceeded the -3500 lb. goal.

reading of 0.031 in. across the test series. This value is a quarter of the allowable total tolerance of 0.120 in. ± 0.060 in. defined in the GM drawing for the distance from the H-point to the inspection surface (*Figure 2*). Pelvis DZ0498 had a maximum difference in the MTS readings across all the tests of 0.039 in, a third of the allowable 0.120 in. Pelvis 1203 had a maximum difference in the MTS readings across all the tests of 0.046 in., a little more than 3/8ths of the allowable 0.120 in. The tolerance range of 0.120 in. is approximately the thickness of three stacked credit cards. The change in the static measurements for all three pelvis heights was approximately the thickness of a single credit card. *Figure 15* uses pelvis DZ0480 to illustrate the minimal change in static measurements over the course of the testing. The full set of static measurements is contained in *Table 6*, *Table 7*, and *Table 8* in Appendix A.

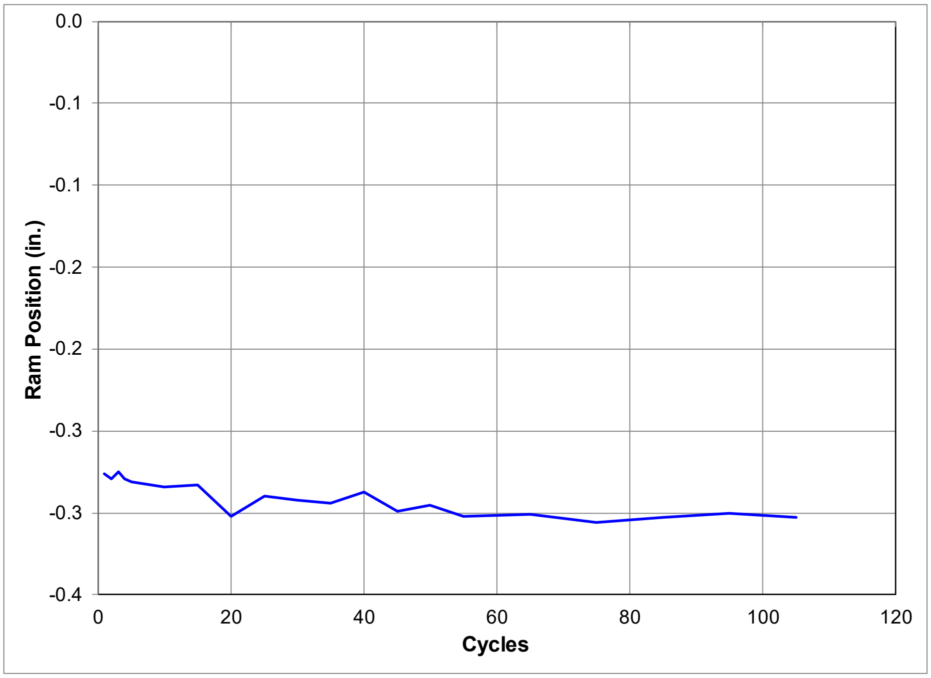

Figure 15: Pelvis DZ0480 MTS Static Measurement with 75-lb. Load versus Cycles

Change in MTS Static Reading and Change in Procedure Stroke Length

The change in MTS procedure stroke length (dynamic loading) was compared to the MTS hydraulic ram position during the 75-lb. static loading. *Figure 16*, *Figure 17*, and *Figure 18* show the change in stroke length versus cycles and the change in static position reading versus cycles. The first test for each pelvis provided the initial values for the stroke length and the MTS position reading (except pelvis DZ0480, which used the second cycle since the first cycle exceeded the load limit). The values for pelvises DZ0498 and 1203 were calculated by subtracting the current cycle value from the first cycle value. Due to the high load achieved on the first cycle for pelvis DZ0480, the values for that pelvis were calculated by subtracting the current cycle from the second cycle value.

As the testing advanced, the increase in the procedure stroke length did not directly correlate with a change in the MTS static readings. The change in static measurements based on cyclic testing does not correlate to the pelvis usage, damage, or response. The ratio of change in slope of the stroke length to the MTS static reading varied greatly between the pelvises and does not provide a trend in results between the pelvises. For pelvis DZ0480, the stroke length trendline slope value was six times higher than the static MTS trendline value across all tests. For pelvis DZ0498, the stroke length trendline slope was approximately three times the static MTS trendline slope value. Finally, for pelvis 1203, the stroke length to MTS reading value was approximately doubled. Based on the results of the static test stand data and the static measurement taken on the high-rate load frame, the 75-lb. manufacturing tolerance check does not appear to provide data sufficient to determine if a pelvis is acceptable for use in a dynamic certification sled test.

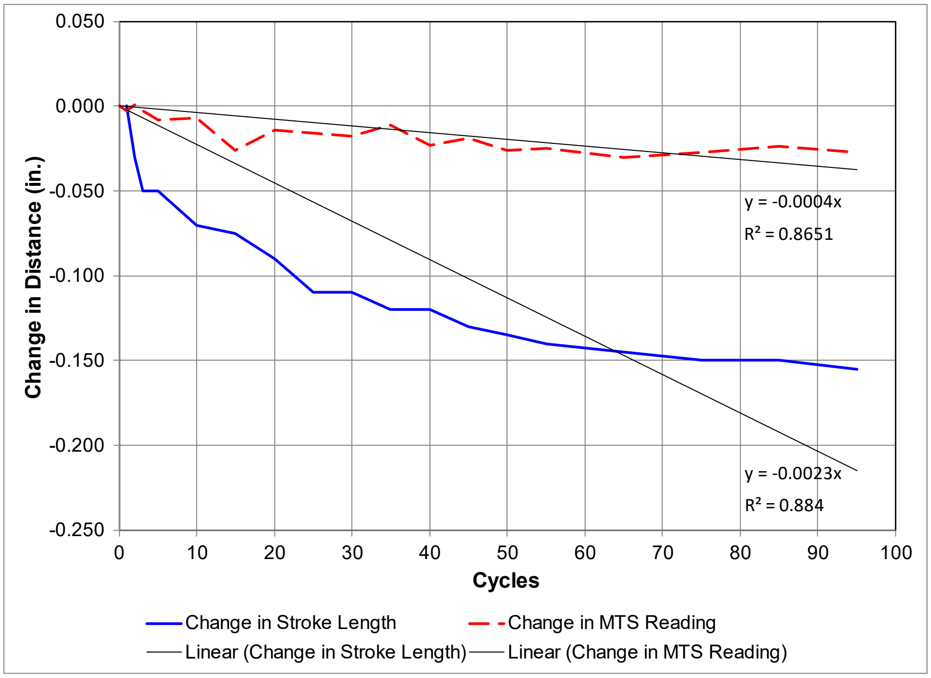

Figure 16: Pelvis DZ0480 Cycles versus Change in MTS Static Reading and Change in Procedure Stroke Length

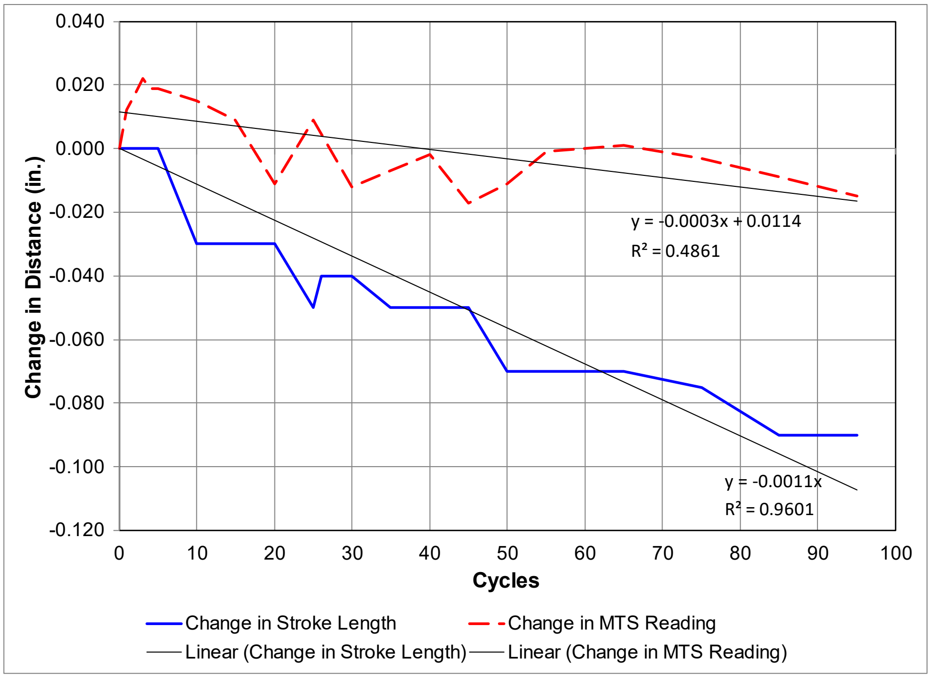

Figure 17: Pelvis DZ0498 Test Series versus Change in MTS Static Reading and Change in Procedure Stroke Length

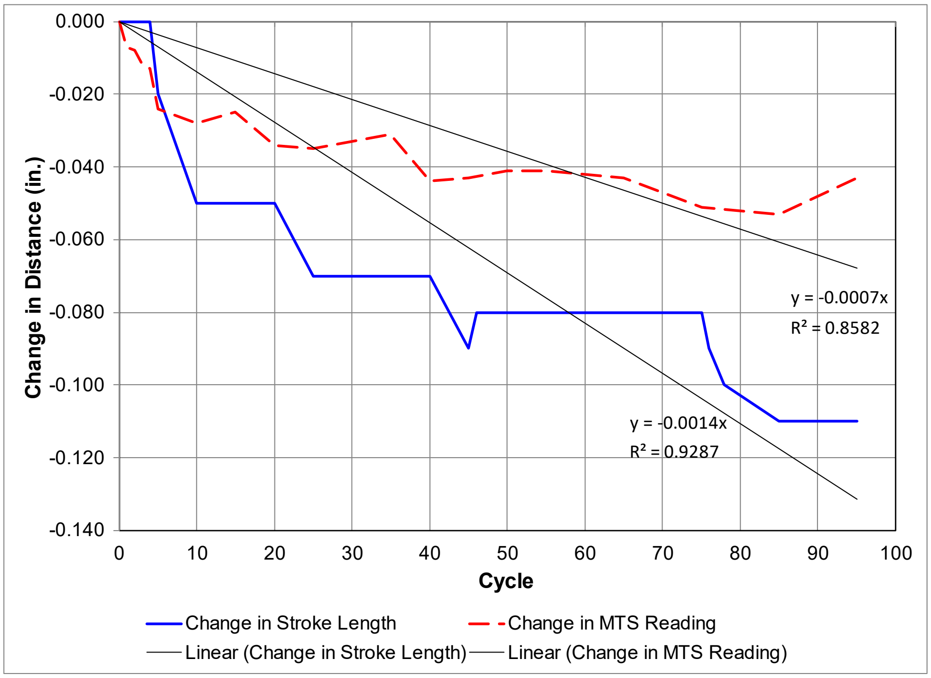

Figure 18: Pelvis 1203 Test Series versus Change in MTS Reading and Change in Procedure Stroke Length

Goal 2: Visible Pelvis Damage and Correlation to Change in Pelvis Response

The region of the pelvis that was contacting the aluminum plate is visible in *Figure 19*. Breakthrough damage during the testing was contained to the small regions directly under the ischial tuberosities (*Figure 19* A). The compression region (*Figure 19* B) illustrates that most of the area on the pelvis bottom was interacting with the aluminum plate. Pelvis DZ0480 achieved breakthrough of the foam and rubber directly below the ischial tuberosities between cycles 15 and 20. It is worth noting that the very first cycle for this pelvis generated a load of ~4500 lb. Pelvis DZ0498 achieved breakthrough between cycles 25 and 30. Pelvis 1203 showed visual damage between cycles 21 and 25 below the right ischial tuberosity. After 105 cycles, the JASTI pelvis (1203) only achieved breakthrough on the right side. With all the variations noted in the testing of the three pelvises, breakthrough was achieved within a relatively narrow range of cycles (15-30). *Figure 11*, *Figure 12*, and *Figure 13* show that all three pelvises had approximately 0.052 in. of creep on the -2000-lb. axis on the FD curves between cycles 5 and 25. The change in stroke distance for achieving the desired forces followed the same trend when breakthrough occurred for all three pelvises. *Figure 20* shows the breakthrough time on the procedure stroke length versus cycles for DZ0480. The logarithmic trend in change of stroke length versus cycle was consistent from cycles 6 to 105 (coefficient of determination, $r^2 = 0.98$). *Figure 21* and *Figure 22* show the breakthrough time on the procedure stroke length versus cycles plot of DZ0498 and 1203, respectively. Based on these results, minor damage to the ATD skin on the underside of the pelvis does not appear to provide data sufficient to determine if a pelvis is acceptable for use in a dynamic certification test.

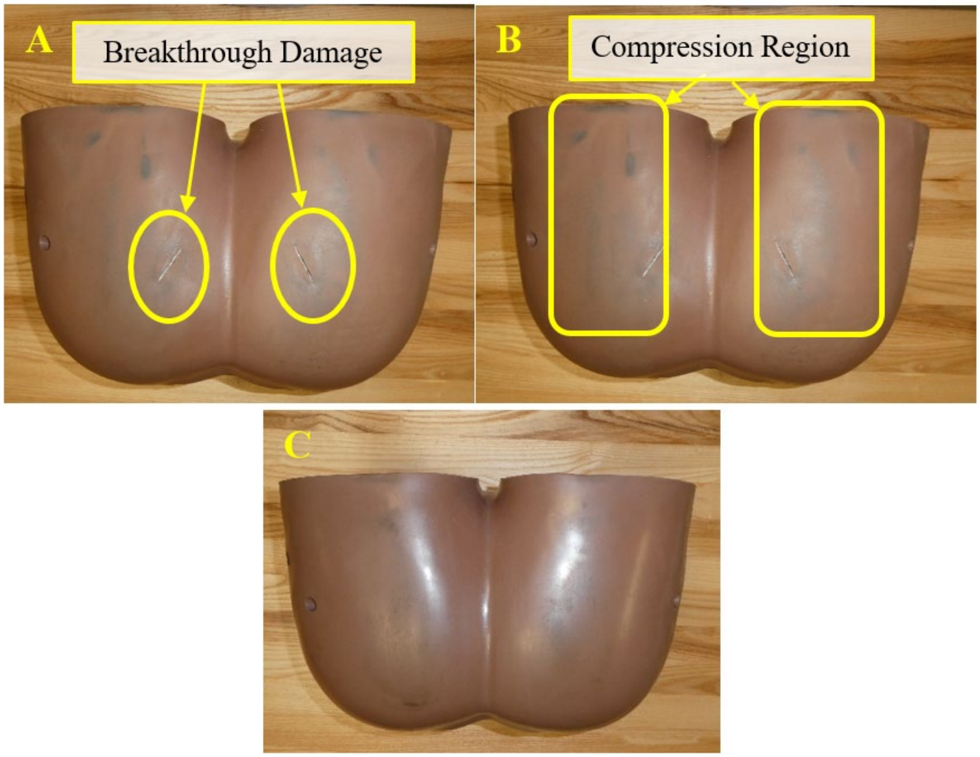

Figure 19: A) Pelvis DZ0480 Showing Areas of Breakthrough, B) Pelvis DZ0480 Showing Area of Contact/Compression Region, and C) Brand New Pelvis

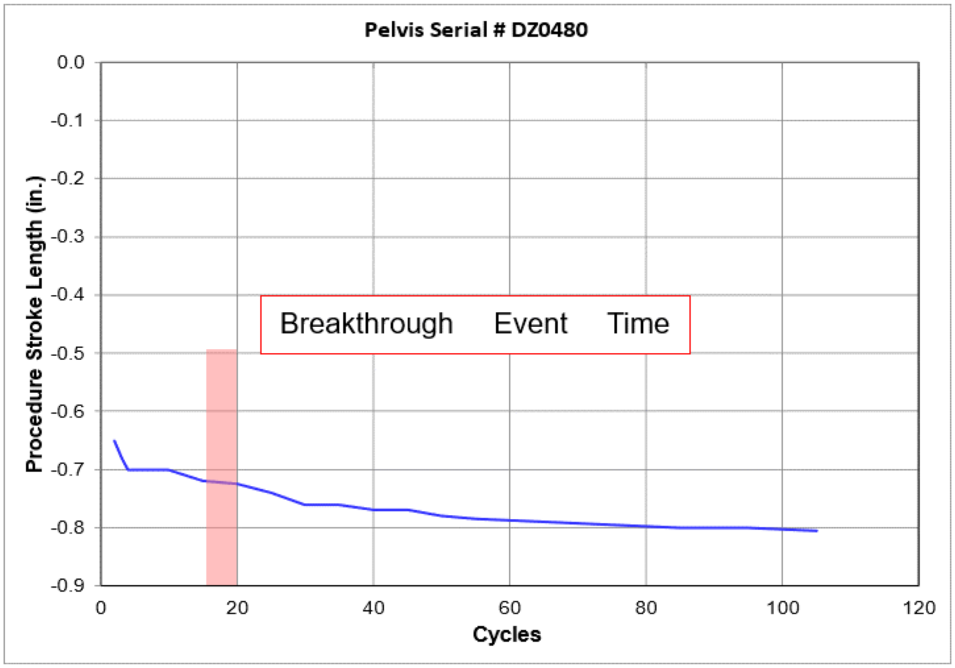

Figure 20: Pelvis DZ0480 Breakthrough Time Frame

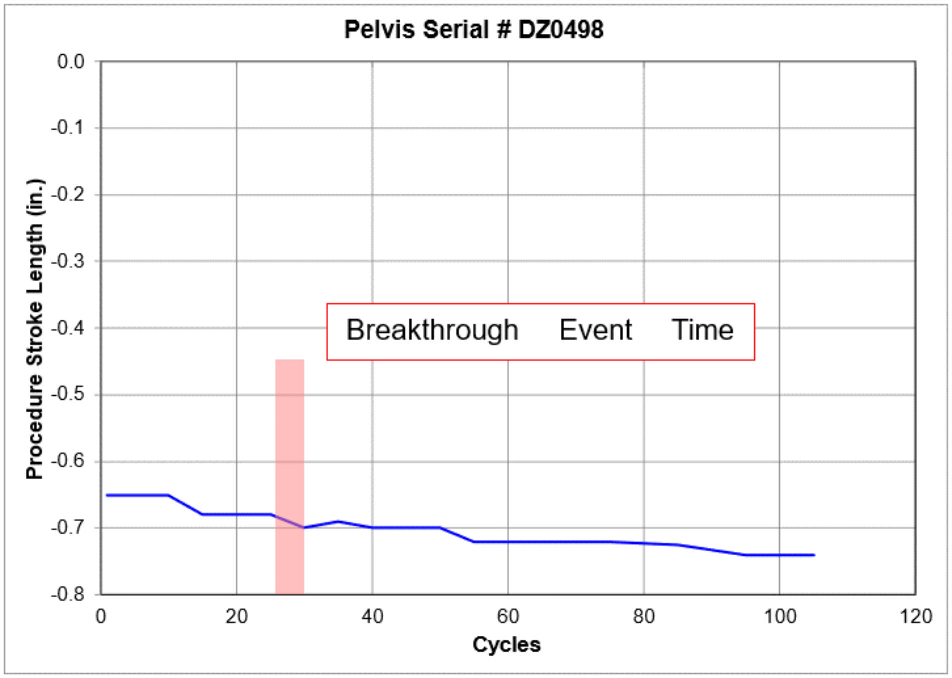

Figure 21: Pelvis DZ0498 Breakthrough Time Frame

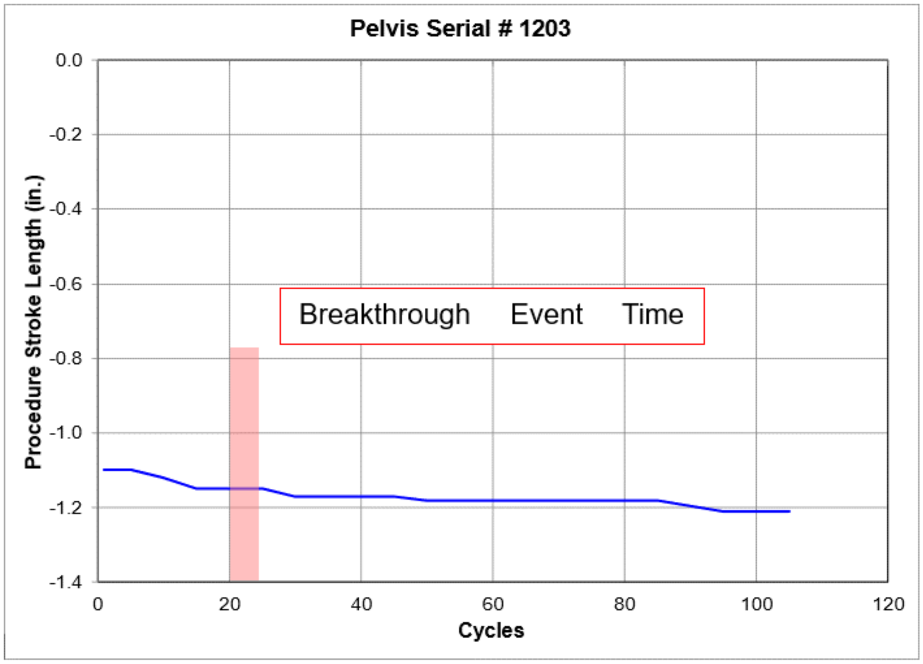

Figure 22: Pelvis 1203 Breakthrough Time Frame

Goal 3: Does a High-Rate Load Frame Response Correlate to Lumbar Load Measurement in Full-Scale Sled Tests?

The shapes of the FD curves for all three pelvises are similar at the start of testing and at the end of testing. To illustrate the similarity of the FD curves, the final cycle was shifted by the change in the procedure stroke length at 2000 lb. for the respective pelvis (*Figure 23*, *Figure 24*, and *Figure 25*). *Figure 23* (pelvis DZ0480) was shifted based on the second cycle since the first cycle overshot the loading goal; both the first and second cycles are included in the figure. The final cycle was shifted to the left by 0.100 in. for pelvises DZ0480 and 1203 (*Figure 23* and *Figure 25*). For pelvis DZ0498 (*Figure 24*), the final cycle was shifted by 0.090 in. All three plots show minimal change in the shape of the FD curves across the 105 cycles tested. It was assumed that degraded foam would provide little to no resistance during the compression portion of the FD curve. This anticipated FD curve, after a high number of cycles, would show the loading portion of the curve overlay the unloading curve. This was not seen or achieved across the 105 cycles in rigid fixturing for all three pelvises. Therefore, based on these data, it is not possible to identify when a pelvis has reached its operational limit based on reviewing the FD curve.

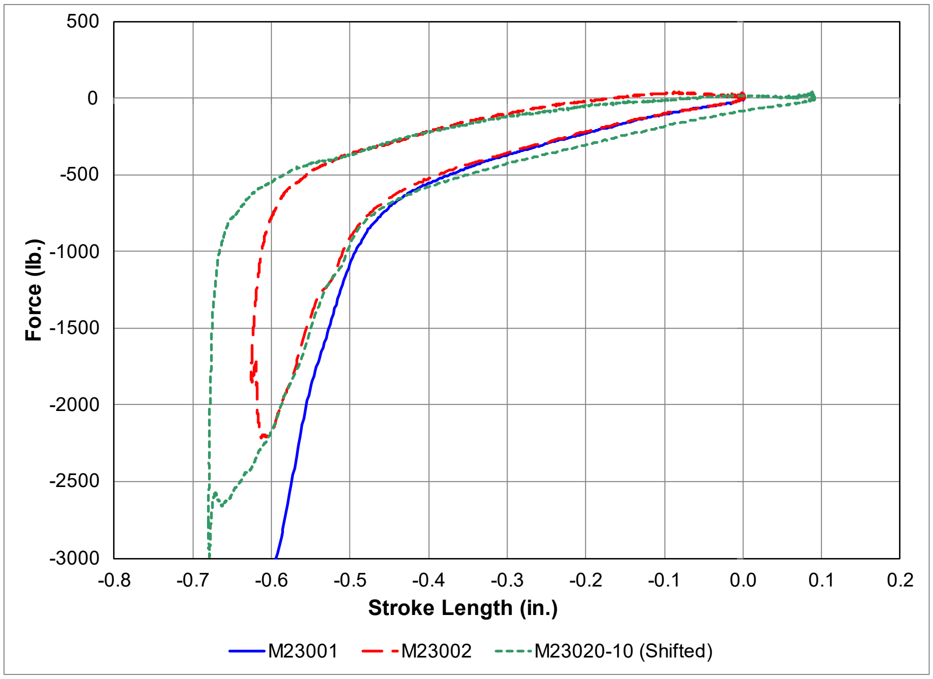

Figure 23: Pelvis DZ0480 First, Second, and Last Cycles (Cycle 105 Shifted by 0.10 in.)[6]

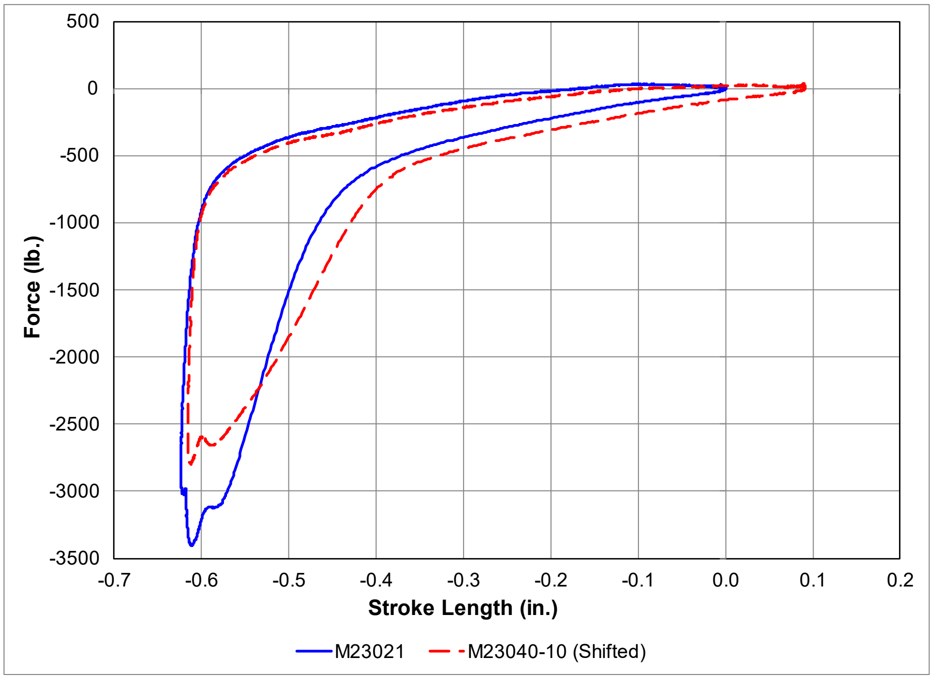

Figure 24: Pelvis DZ0498 First and Last Cycle Force Deflection Plots (Cycle 105 Shifted by 0.09 in.)

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[6] The Y-axis minimum force axis value is limited to -3000 lb. for clarity; test series M23001 had values exceeding -4500 lb.

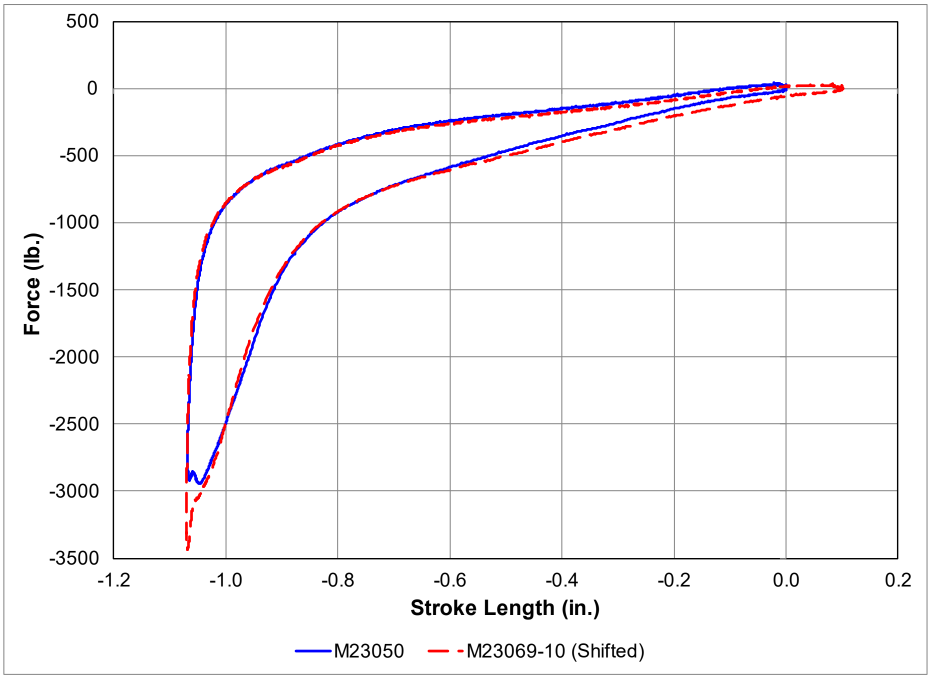

Figure 25: Pelvis 1203 First Cycle and Last Cycle Force Deflection Plots (Cycle 105 Shifted by 0.10 in.)

One aspect of this project was to determine a vertical calibration procedure for the pelvis. However, the data collected in this test series were insufficient to develop a calibration procedure. There is a need to analyze the effects of the 0.090 in. to 0.100 in. shift of the FD curves. The high-rate load frame testing did not provide insight into how the FD curve shift affects the lumbar load response of a fully assembled ATD. Sled tests or computer modeling could be used to determine if there are changes with the occupant and seat loading due to the additional displacement of the rubber and rubber cover. One option to be considered in future testing would be to run tests using a subset of ATD components. One subset of components to be considered would include all the components between the thorax and the pelvis (Waagmeester et al., 2002).

A vertical calibration procedure for the ATD pelvis would expand the scope of the ATD conformity requirements and increase consistency in certification testing. In certification testing, for a test series to be conformed, many aspects of the test setup need to be defined in advance. For example, the seat is required to conform to the submittal drawing, and the ATD is required to be calibrated and within the manufacturer's dimensional tolerances. A newly defined vertical calibration procedure would verify that a pelvis conforms and its response is within an acceptable range.

Goal 4: Number of Loading Cycles for Replacement

The test setup and high-rate load frame fixture provided a very aggressive environment for the pelvis. On the load frame, each pelvis was loaded at the same angle, same location, and without a seat cushion for 105 cycles. While the loading conditions are similar to certification testing (i.e., rise-time, velocity, and peak load), the fixture rigidity may have accelerated the rate of damage to the pelvis. Also, testing with a cushion and a flexible seat pan may extend the life cycle of the ATD pelvis. As previously discussed, there was a ~0.100 in. change in the procedure stroke length for all three pelvises. This is less than the manufacturer's tolerance (0.120 in.). Based on these data, it is reasonable to expect a pelvis to last for more than 100 cycles. However, the effect of this change is not known without additional research. If future research reveals a change in occupant response due to the additional compression of the foam and rubber, then a range of allowable changes in occupant response could be established. An established range could be used to determine the cycles to failure. It has been observed that a pelvis utilized in certification testing, particularly in the horizontal test condition, will often be damaged by other factors (i.e., cuts from seat belts, damage from external sources). This external damage may take a pelvis out of service prior to achieving vertical degradation of the foam, as observed in this test series.

Conclusion

ATDs are used to predict occupant injury in dynamic tests required by FAA regulations to substantiate the safety of seating systems. The ATD pelvis does not have a set of calibration tests to determine if the component is acceptable for initial use or to monitor degradation to determine the need to remove components from service. The manufacturing drawings for the Hybrid III ATD require the H-point to be a certain height when loaded by a 75-lb. plate with a tolerance (3.620 in. ± 0.060 in.). Three ATD pelvises underwent component-level testing that simulated conditions comparable to a primarily vertical impact test. To evaluate the effect of repeated loading on a pelvis, the pelvises were loaded in a high-rate load frame until the stroke length versus cycles reached an asymptote. Static measurements were recorded prior to the dynamic testing. The pelvises were then repeatedly loaded until the exit criterion was reached. Static measurements were repeated at the end of the dynamic testing. Visual damage to the pelvis was monitored and documented throughout the tests. The goal of this project was to simulate the number of cycles to failure for an ATD pelvis while tracking the change in performance (i.e., FD response of the pelvis).

When comparing the initial (prior to the start of cyclic testing) and the final (after all 105 cyclic tests were complete) static measurements, the maximum change for any pelvis tested was 0.010 in. With the manufacturer's tolerance being 0.120 in., a change of less than 10% of the tolerance can be considered negligible. The change in procedure stroke length compared to the static measurements collected on the high-rate load was also evaluated. This ratio showed there was no consistency for the three pelvises. The results show that under these test conditions, an in-service check of the pelvis height under the 75-lb. static load will not give an engineer/technician any indication of the dynamics response of the pelvis.

The high-rate load frame testing was to achieve seat pan forces that correlate to the lumbar load regulatory compression limit (1500 lb.) and hydraulic ram speed near values achieved during Part 25 tests (~4 ft./sec). Each pelvis underwent the loading procedure on a high-rate load frame for 105 cycles. All three pelvises achieved visible damage under the ischial tuberosities between 15 and 30 cycles. When visual damage appeared, the FD curves were checked at the cycles prior to and after the damage appeared. There were no notable shifts in the FD curves across the cycles at the time of visual damage. As a result, visual damage cannot be used as a reliable indicator of any degradation in the pelvis's dynamic performance.

Data from the high-rate load frame testing were utilized to monitor the change in the FD curves over the course of the test series. However, there was very little change in the shape of the FD curves across all the test cycles. There was noticeable creep in the FD curves as the testing progressed. The biggest change in creep came between cycles 5 and 25, with about 0.052 in. for all three pelvises. At the end of testing, the total creep for all three pelvises ranged between 0.090 in. and 0.100 in. Additional research would be required to evaluate the effect of the ~0.100 in. change in the pelvis foam and rubber with a complete ATD and seat system in a dynamic test condition.

While the number of cycles to replacement cannot be derived from this testing alone, the dynamic response of the pelvis minimally changed over the course of the testing. Therefore, the number of vertical sled tests that would precipitate replacement may be over 100 cycles. Due to the harsh environment of dynamic sled testing, other factors, such as cuts in the foam and rubber due to belt loading, may trigger the removal of an ATD pelvis from service prior to the pelvis reaching a defined number of cycles.

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Appendix A: Test Setup Data

Table 6: Humanetics Pelvis DZ0480

Test Number	Date	Temperature (°F)	Relative Humidity (%)	Pretest MTS Reading During 75-lb Static Test (in.)	Procedure Stroke Length (in.)	Cycles
M23001	2/16/2023	68.5	23.8	-0.276	-0.710	1
M23002	2/16/2023	68.5	22.2	-0.279	-0.650	2
M23003	2/16/2023	68.5	22.1	-0.275	-0.680	3
M23004	2/16/2023	69.0	27.6	-0.279	-0.700	4
M23005	2/16/2023	69.0	28.3	-0.281	-0.700	5
M23006	2/16/2023	69.0	28.5	-0.284	-0.700	6-10
M23007	2/16/2023	68.1	26.6	-0.283	-0.720	11-15
M23008	2/17/2023	68.3	26.1	-0.302	-0.725	16-20
M23009	2/17/2023	68.3	22.8	-0.29	-0.740	21-25
M23010	2/17/2023	68.5	20.5	-0.292	-0.760	26-30
M23011	3/22/2023	70.3	61.0	-0.294	-0.760	31-35
M23012	3/22/2023	70.3	59.7	-0.287	-0.770	36-40
M23013	3/23/2023	70.5	67.4	-0.299	-0.770	41-45
M23014	3/23/2023	71.0	55.1	-0.295	-0.780	46-50
M23015	3/23/2023	71.2	50.5	-0.302	-0.785	51-55
M23016	3/23/2023	71.3	46.1	-0.301	-0.790	56-65
M23017	3/23/2023	71.3	41.0	-0.306	-0.795	66-75
M23018	3/24/2023	70.0	40.6	-0.303	-0.800	76-85
M23019	3/24/2023	70.1	40.9	-0.300	-0.800	86-95
M23020	3/24/2023	70.5	45.2	-0.303	-0.805	96-105

Table 7: Humanetics Pelvis DZ0498

Test Number	Date	Temperature (°F)	Relative Humidity (%)	Pretest MTS Reading During 75-lb Static Test (in.)	Procedure Stroke Length (in.)	Cycles
M23021	5/23/2023	68.7	68.6	-0.300	-0.650	1
M23022	5/23/2023	68.7	69.2	-0.288	-0.650	2
M23023	5/23/2023	69.0	69.8	-0.283	-0.650	3
M23024	5/23/2023	68.7	69.8	-0.278	-0.650	4
M23025	5/23/2023	68.7	69.3	-0.281	-0.650	5
M23026	5/23/2023	68.9	67.1	-0.281	-0.650	6-10
M23027	5/23/2023	69.0	66.2	-0.285	-0.680	11-15
M23028	5/23/2023	69.6	65.1	-0.291	-0.680	16-20
M23029	5/24/2023	69.0	67.1	-0.311	-0.680	21-25
M23030	5/24/2023	69.8	64.4	-0.291	-0.690[7]	26-30
M23031	5/31/2023	69.0	69.7	-0.312	-0.690	31-35
M23032	5/31/2023	69.2	68.7	-0.307	-0.700	36-40
M23033	5/31/2023	69.6	68.2	-0.302	-0.700	41-45
M23034	6/1/2023	69.4	65.6	-0.317	-0.700	46-50
M23035	6/1/2023	69.0	67.8	-0.311	-0.720	51-55
M23036	6/1/2023	69.2	67.1	-0.301	-0.720	56-65
M23037	6/1/2023	68.7	68.7	-0.299	-0.720	66-75
M23038	6/1/2023	69.0	68.5	-0.303	-0.725	76-85
M23039	6/1/2023	69.2	69.1	-0.309	-0.740	86-95
M23040	6/1/2023	69.4	69.1	-0.315	-0.740	96-105

[7] Cycle M23030-1 exceeded limit (>3500 lb.) at -0.700 in of stroke. Reduced stroke to -0.690 in. of stroke for M23030-2 through M23030-5.

Table 8: JASTI Pelvis 1203

Test Number	Date	Temperature (°F)	Relative Humidity (%)	Pretest MTS Reading During 75-lb Static Test (in.)	Procedure Stroke Length (in.)	Cycles
M23041	6/2/2023	68.9	69.4	-0.170	-0.520	0
M23042	6/2/2023	68.9	69.5	-0.163	-0.570	0
M23043	6/2/2023	69.2	69.8	-0.165	0.630	0
M23044	6/2/2023	69.4	69.4	-0.158	0.700	0
M23045	6/2/2023	69.4	69.4	-0.161	-0.770	0
M23046	6/2/2023	69.9	68.2	-0.161	-0.830	0
M23047	6/5/2023	68.7	67.2	-0.178	-0.880	0
M23048	6/5/2023	68.9	67.1	-0.168	-0.930	0
M23049	6/5/2023	69.0	67.0	-0.170	-0.980	0
M23050	6/5/2023	69.0	66.7	-0.169	-1.100	1
M23051	6/5/2023	68.9	66.4	-0.176	-1.100	2
M23052	6/5/2023	69.0	67.7	-0.177	-1.100	3
M23053	6/5/2023	69.6	66.6	-0.181	-1.100	4
M23054	6/5/2023	70.8	65.9	-0.182	-1.100	5
M23055	6/13/2023	66.6	69.1	-0.193	-1.120	6-10
M23056	6/13/2023	66.6	69.2	-0.197	-1.150	11-15
M23057	6/13/2023	67.0	68.8	-0.194	-1.150	16-20
M23058	6/15/2023	67.6	64.6	-0.203	-1.150	21-25
M23059	6/15/2023	67.5	65.8	-0.204	-1.170	26-30
M23060	6/15/2023	68.2	65.5	-0.202	-1.170	31-35
M23061	6/15/2023	67.8	66.9	-0.200	-1.170	36-40
M23062	6/16/2023	67.6	67.7	-0.213	-1.170	41-45
M23063	6/16/2023	67.9	67.9	-0.212	-1.180[8]	46-50
M23064	6/16/2023	67.7	68.1	-0.210	-1.180	51-55
M23065	6/16/2023	67.7	68.3	-0.210	-1.180	56-65
M23066	6/16/2023	67.8	68.2	-0.212	-1.180	66-75
M23067	6/23/2023	67.1	65.4	-0.220	-1.180[9]	76-85
M23068	6/23/2023	67.2	66.4	-0.222	-1.210	86-95
M23069	6/23/2023	67.4	68.6	-0.212	-1.210	96-105

[8] Cycle M23063-1 exceeded limit (>3500 lb.) at -1.190 in. of stroke. Reduced stroke to -1.180 in. of stroke for M23063-2 through M23063-5.
[9] Cycle M23067-1 exceeded limit (<2500 lb.) at -1.180 in of stroke. Increased stroke to -1.190 in. of stroke for cycles M23067-2 and M23067-3, then increased stroke to -1.120 in. for M23067-4 through M23067-10.

Appendix B: Data Management Plan

Dataset and Contact Information

Title: Effect of High-Rate Loading on Anthropomorphic Test Device Pelvis

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https://www.faa.gov/about/office_org/headquarters_offices/avs/offices/aam/cami/

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Recommended Citation: Hellstrom, I., Moorcroft, D., Carroll, W. (2024). Effect of High-Rate Loading on Anthropomorphic Test Device Pelvis [datasets]. U.S. Department of Transportation, Federal Aviation Administration. https://doi.org/10.21949/1529669

Project Abstract

As part of a larger project aimed at gaining a better understanding of factors that affect the quality of test results using Anthropomorphic Test Devices (ATDs), the FAA tested the effects of dynamic loading of ATD pelvis. This project was completed by compressing an ATD pelvis in a high-rate load frame to simulate dynamic seat certification testing conditions. The load and rate of the pelvis compression were programmed to simulate conditions achieved in transport aircraft vertical seat testing. The primary test objective was to measure changes to the rubber and foam cover of the metallic pelvis during high cyclic loading. Each pelvis was subjected to over 100 cycles. Similar visual damage was seen for each pelvis, which occurred at low cycles, 15 to 30. The appearance of visual damage was closely monitored throughout the testing. Results suggest the appearance of damage minimally changed the dynamic response of the pelvis. Static dimensional measurements were collected during testing. Force-deflection data were also collected from each test series. The force-deflection data make up the primary dataset from this project. Dimensional tolerances for the pelvis are defined federal regulations. The high-cycle testing did not deform the foam and rubber covers enough to exceed the total dimensional tolerance of the pelvises.

Project start date: 10-23-2020

Project end date: 01-31-2025

Data Description

This dataset contains test data of anthropomorphic test device pelvises mounted vertically in rigid fixtures on a high-rate load frame. These data are created by physical experiments. Sensors include a load cell and a linear variable differential transducer. Data also include photos from still cameras. The tests were conducted in 2023. No existing data were used for this test series.

It is anticipated that aircraft seat manufacturers and test laboratories will benefit from access to this data as they design and test real aircraft seats and restraints. This dataset will also provide a public record to support potential rulemaking.

Roles & Responsibilities

The FAA Aerospace Medical Research Division (see Contact Information) is responsible for generating the data and is responsible for managing the data initially. This division is responsible for managing the internal project management processes to ensure adherence to the published data management plan (DMP). This process requires management review and sign-off at project start and close-out.

Standards Used

The data files collected here are saved in the ubiquitous and common .csv file format.

Documentation will include this data management plan and the metadata and readme files created in 2024.

Access Policies

These data files are in the public domain and can be shared without restriction. The data files contain no sensitive information.

Sensitive Data Policies

The data files contain no sensitive information.

Sharing Policies

The data are in the public domain and may be re-used without restriction. Citation of the data is appreciated. Please use the following recommended citation: Hellstrom, I., Moorcroft, D., Carroll, W. (2024). Effect of High-Rate Loading on Anthropomorphic Test Device Pelvis [datasets]. U.S. Department of Transportation, Federal Aviation Administration. https://doi.org/10.21949/1529669

Archiving and Preservation Plans

Prior to archiving, the data are stored on the secured FAA networks and drives, which are backed up nightly. The United States (US) Department of Transportation (DOT) systems are secured from outside users and backed up daily. Files in ROSA P are backed up in NTL drives at US DOT, daily; at the Centers for Disease Control, the repository managing facility, daily; and in Amazon Web Service Cloud servers in Virginia and Oregon daily.

The dataset will be retained in perpetuity.

The Digital Object Identifiers (DOIs) associated with this dataset include: https://doi.org/10.21949/1529669.

The assigned DOI resolves to the repository landing page for the “Effect of High-Rate Loading on Anthropomorphic Test Device Pelvis” dataset, so that users may locate associated metadata and supporting files. The Biomechanics Test Database meets all the criteria outlined on the “Guidelines for Evaluating Repositories for Conformance with the DOT Public Access Plan” page: https://ntl.bts.gov/ntl/public-access/guidelines-evaluating-repositories.

Applicable Laws and Policies

This data management plan was created to meet the requirements enumerated in the U.S. Department of Transportation's 'Plan to Increase Public Access to the Results of Federally-Funded Scientific Research' Version 1.1 https://doi.org/10.21949/1529668 and guidelines suggested by the DOT Public Access website https://doi.org/10.21949/1529669, in effect and current as of April 29, 2024.