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Washington, DC 20590

# Sled Tests Using the THOR-50M ATD and Quasi-Static Tests of Workstation Tables for Passenger Trains

DOT/FRA/ORD-22/37

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NOTICE



NOTICE

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**14. ABSTRACT**

The industry safety standard for fixed workstation tables on passenger railcars, APTA PR-CS-S-018-13, draft Rev. 2, provides two options for test procedures and requirements when evaluating crashworthy tables for protecting passengers during a collision. MGA Research Corporation performed six dynamic sled table tests per Option A and three dynamic sled tests plus three quasi-static table tests per Option B of the safety standard. Tests on donated workstation tables were performed according to each option of the standard to evaluate the safety equivalency of the options with respect to the risk of injury to the chest and abdomen for a passenger impacted by a table during a rail accident.


**15. SUBJECT TERMS**
Workstation tables, crashworthiness, THOR-50M ATD, H3-50M ATD, abdomen injury, chest injury, energy absorption

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# METRIC/ENGLISH CONVERSION FACTORS

## ENGLISH TO METRIC

### LENGTH (APPROXIMATE)

| | | |
|---|---|---|
| 1 inch (in) | = | 2.5 centimeters (cm) |
| 1 foot (ft) | = | 30 centimeters (cm) |
| 1 yard (yd) | = | 0.9 meter (m) |
| 1 mile (mi) | = | 1.6 kilometers (km) |

### AREA (APPROXIMATE)

| | | |
|---|---|---|
| 1 square inch (sq in, $in^2$) | = | 6.5 square centimeters ($cm^2$) |
| 1 square foot (sq ft, $ft^2$) | = | 0.09 square meter ($m^2$) |
| 1 square yard (sq yd, $yd^2$) | = | 0.8 square meter ($m^2$) |
| 1 square mile (sq mi, $mi^2$) | = | 2.6 square kilometers ($km^2$) |
| 1 acre = 0.4 hectare (he) | = | 4,000 square meters ($m^2$) |

### MASS - WEIGHT (APPROXIMATE)

| | | |
|---|---|---|
| 1 ounce (oz) | = | 28 grams (gm) |
| 1 pound (lb) | = | 0.45 kilogram (kg) |
| 1 short ton = 2,000 pounds (lb) | = | 0.9 tonne (t) |

### VOLUME (APPROXIMATE)

| | | |
|---|---|---|
| 1 teaspoon (tsp) | = | 5 milliliters (ml) |
| 1 tablespoon (tbsp) | = | 15 milliliters (ml) |
| 1 fluid ounce (fl oz) | = | 30 milliliters (ml) |
| 1 cup (c) | = | 0.24 liter (l) |
| 1 pint (pt) | = | 0.47 liter (l) |
| 1 quart (qt) | = | 0.96 liter (l) |
| 1 gallon (gal) | = | 3.8 liters (l) |
| 1 cubic foot (cu ft, $ft^3$) | = | 0.03 cubic meter ($m^3$) |
| 1 cubic yard (cu yd, $yd^3$) | = | 0.76 cubic meter ($m^3$) |

### TEMPERATURE (EXACT)

[(x-32)(5/9)] °F = y °C

## METRIC TO ENGLISH

### LENGTH (APPROXIMATE)

| | | |
|---|---|---|
| 1 millimeter (mm) | = | 0.04 inch (in) |
| 1 centimeter (cm) | = | 0.4 inch (in) |
| 1 meter (m) | = | 3.3 feet (ft) |
| 1 meter (m) | = | 1.1 yards (yd) |
| 1 kilometer (km) | = | 0.6 mile (mi) |

### AREA (APPROXIMATE)

| | | |
|---|---|---|
| 1 square centimeter ($cm^2$) | = | 0.16 square inch (sq in, $in^2$) |
| 1 square meter ($m^2$) | = | 1.2 square yards (sq yd, $yd^2$) |
| 1 square kilometer ($km^2$) | = | 0.4 square mile (sq mi, $mi^2$) |
| 10,000 square meters ($m^2$) | = | 1 hectare (ha) = 2.5 acres |

### MASS - WEIGHT (APPROXIMATE)

| | | |
|---|---|---|
| 1 gram (gm) | = | 0.036 ounce (oz) |
| 1 kilogram (kg) | = | 2.2 pounds (lb) |
| 1 tonne (t) | = | 1,000 kilograms (kg) |
| | = | 1.1 short tons |

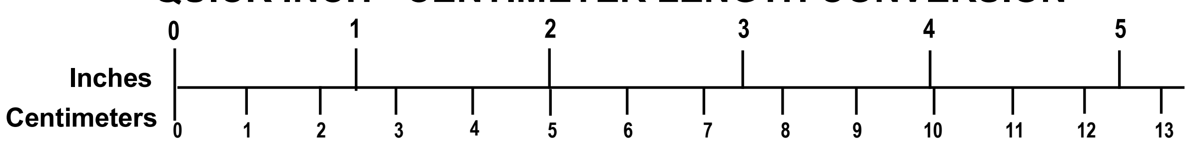
### VOLUME (APPROXIMATE)

| | | |
|---|---|---|
| 1 milliliter (ml) | = | 0.03 fluid ounce (fl oz) |
| 1 liter (l) | = | 2.1 pints (pt) |
| 1 liter (l) | = | 1.06 quarts (qt) |
| 1 liter (l) | = | 0.26 gallon (gal) |
| 1 cubic meter ($m^3$) | = | 36 cubic feet (cu ft, $ft^3$) |
| 1 cubic meter ($m^3$) | = | 1.3 cubic yards (cu yd, $yd^3$) |

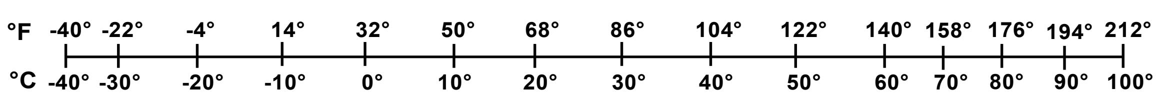
### TEMPERATURE (EXACT)

[(9/5) y + 32] °C = x °F

## QUICK INCH - CENTIMETER LENGTH CONVERSION




## QUICK FAHRENHEIT - CELSIUS TEMPERATURE CONVERSIO




For more exact and or other conversion factors, see NIST Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50 SD Catalog No. C13 10286

Updated 6/17/98

## Acknowledgements

MGA Research Corporation would like to thank the manufacturers who anonymously donated fixed workstation tables, seats, and simulated carbody structures for this test series. The authors would also like to thank Dan Parent, Human Injury Research Division, and Will Millis, Applied Biomechanics Division, at the National Highway Traffic Safety Administration for loaning the THOR-50M ATD.

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# Executive Summary

In 2021, MGA Research Corporation (MGA), located in Greer, South Carolina, performed nine dynamic sled tests and three quasi-static tests with fixed workstation tables. The tests were in accordance with the February 17, 2021 draft of the Fixed Workstation Tables in Passenger Railcars safety standard from the American Public Transportation Association (APTA), APTA-PR-CS-S-018-13, draft Rev. 2 (S-018), which was current at the time of testing. The test results were interpreted in accordance with the May, 2022 balloted version of draft Rev. 2.

Facing seats with a fixed workstation table between them is a common seating configuration on passenger railcars in the U.S. S-018 provides requirements for testing and evaluation of fixed workstation tables used in passenger railcars for the purpose of protecting passengers during a collision.

The objectives of this study:

1. Perform six Option A sled tests according to S-018 requirements utilizing one H3-50M and one THOR-50M.
    - Evaluate table attachment, compartmentalization of anthropomorphic test devices (ATDs), survival space, and human injury criteria per S-018 Option A.
2. Perform three Option B sled tests according to S-018 requirements utilizing two H3-50Ms.
    - Evaluate table attachment, compartmentalization of ATDs, survival space, and human injury criteria per S-018 Option B.
3. Perform three Option B quasi-static tests according to S-018 requirements.
    - Evaluate energy-absorbed by table per S-018 Option B.
4. Determine whether the tables comply with the performance requirements in S-018 and whether Options A and B provide equivalent safety for the tables tested.

MGA technicians dynamically tested five different table designs in accordance with Option A of S-018 (one design was tested twice), for a total of six tests. Three of the five table designs complied with all Option A test requirements (Tables 1, 4, and 5). They also tested three of the five table designs quasi-statically and dynamically in accordance with Option B of S-018. Table 1 met the requirements in Option A but did not meet the requirements in Option B. The discrepancy was attributed to a malfunction of the table's energy-absorption system during the Option B tests. Tables 2 and 3 failed to meet all requirements in both Options A and B.

The Volpe Center supported the FRA in planning the tests and analyzing the results. Volpe researchers presented the results and lessons learned from the tests to the APTA Construction and Structural Working Group and informed discussions in finalizing the draft procedures and requirements in Rev. 2 of S-018.

# 1. Introduction

The Federal Railroad Administration (FRA) Office of Research, Development, and Technology has supported the development of a prototype crashworthy workstation table for passenger trains. It has also supported the development of an industry safety standard with performance requirements for crashworthy tables (American Public Transportation Association [APTA] PR-CS-S-018-13) [1], subsequently referred to as the "table standard" or S-018 in this document. The table standard was developed in conjunction with industry stakeholders, including rail operators, equipment suppliers, and consultants.

Revision 1 of the table standard provides two options for demonstrating table compliance. Option A specifies the use of an advanced anthropomorphic test device (ATD) with bilateral abdomen and chest instrumentation to measure deflection. The Hybrid III Rail Safety (H3-RS) ATD, developed jointly by the Rail Safety Standards Board (RSSB) and the Transport Research Laboratory (TRL), and the Test device for Human Occupant Restraints (THOR-50M) ATD developed by the National Highway Traffic Safety Administration (NHTSA), are the only two advanced ATDs that are equipped to measure bilateral chest and abdomen deflection and permitted for use in the table standard. Option B specifies the use of a standard Hybrid III 50$^{th}$ percentile male ATD (H3-50M) for use in sled testing, which cannot measure bilateral chest and abdomen deflection. In lieu of these critical measurements, Option B also specifies a quasi-static, destructive loading test to evaluate the energy absorption capability of the table without exceeding a defined maximum load. The quasi-static test requirements in Rev. 1 are based on the FRA prototype table design. Options A and B are intended to provide equivalent safety.

Subsequent to the publication of S-018 Rev. 1, commercial table tests and FRA-sponsored finite element analyses indicated that changes to the performance requirements in the table standard may be necessary to achieve safety equivalence in a broader range of table designs and seat/table configurations. Additional tests of commercially developed tables were needed to verify the results of the finite element analyses and to finalize modifications to the performance requirements in draft Rev. 2 of the table standard to improve safety equivalence between Options A and B.

## 1.1 Background

Passenger rail accident investigations motivated FRA research on occupant protection strategies for passengers seated at workstation tables [1, 2]. Its crashworthiness and occupant protection research at the Volpe National Transportation Systems Center (Volpe Center) resulted in the development of a prototype crashworthy table [3, 4], quasi-static and pendulum impact testing of the table [4, 5], full-scale testing of the table in a train-to-train collision with advanced frontal crash ATDs [6], and the recommendation of human injury performance requirements for crashworthy tables [7, 8, 9]. The human injury performance requirements recommended by researchers at the Volpe Center were presented to the APTA Passenger Rail Construction and Structural Working Group and adopted into an industry safety standard (S-018) in 2013.

The original version of APTA S-018 required dynamic testing of fixed workstation tables in passenger railcars with advanced frontal crash ATDs – either a THOR-NT [10, 11] or a modified H3-50M, the Hybrid-III Rail Safety (H3-RS) [12]. The THOR-NT was an older version of the modern THOR-50M [13, 14]. The THOR-NT and H3-RS were seated at prototype crashworthy tables in the train-to-train impact test, and the human injury results from the test, along with accompanying computational modeling [7] from the Volpe Center, were used to develop the performance requirements in APTA S-018 [9].

When the original APTA S-018 was published, there was limited availability of THOR-NT and H3-RS ATDs for dynamic sled testing of crashworthy tables; however, H3-50M ATDs were available for testing. The standard required either a THOR-NT or H3-RS to be seated in the wall-side seat because it generally presents the most severe test condition, and the advanced ATDs are better-equipped to evaluate chest and abdomen injury. However, table manufacturers could not dynamically test their tables if they were unable to find a willing testing lab due to the potential for ATD damage. The Volpe Center conducted occupant protection research to address this limitation, leading to the development of an option (Option B) to test with an H3-50M in both seat positions [15]. The new option required a companion destructive quasi-static test to evaluate the energy-absorption capacity of the table since the H3-50M was limited in its ability to measure chest and abdomen displacements, which can be correlated with injury. The goal of Option B was to be equivalent in safety to Option A by ensuring that the table would have enough energy-absorption capacity at low force levels to arrest the motion of an occupant without inducing severe injury.

In 2014, additional FRA research was performed at the Transport Research Laboratory (TRL) in the U.K. to finalize the design and characterize the biofidelity of the H3-RS with frontal pendulum impact tests [16] and to test donated workstation tables using the H3-RS in 2015 [17]. Additionally, in 2016 the FRA funded Sharma & Associates in Maywood, Illinois, to quasi-statically test two of the donated workstation tables that were tested by TRL [18].

After the H3-RS sled tests were completed, the design of the THOR-50M was finalized. Since the type, location, and number of displacement transducers in the abdomen were changed, Calspan performed research for FRA to evaluate the biofidelity of the THOR-50M [19] using a similar frontal pendulum impact test matrix as the H3-RS testing. The results of the pendulum impact testing indicated that the human injury performance requirements for the THOR-50M should be updated in Revision 2 of APTA S-018 to maintain safety equivalence with the H3-RS ATD. Researchers at the Volpe Center proposed a new abdomen compression limit for the THOR-50M for APTA S-018 based on the results of the pendulum impact testing. Additionally, Volpe researchers found the safety equivalency of Option A and B needed to be improved, as tables which met the energy-absorption requirements in the Option B quasi-static test could fail the human injury performance criteria in a dynamic sled test [20].

This report describes testing to address each of these findings:

1. Dynamically sled test the THOR-50M with donated workstation tables to evaluate the proposed abdomen compression requirement.
2. Test donated workstation tables per the proposed requirements in Option A and B in Revision 2 of APTA S-018 to evaluate the safety equivalence of the options.

Based on the evaluation of all available table test results, Volpe Center researchers also proposed an increase in the THOR-50M chest deflection limit to improve the safety equivalence between the THOR-50M and the H3-50M under S-018 test conditions. The MGA test results reported here have been evaluated for compliance in accordance with the requirements in the February 2022 draft of Revision 2 of APTA S-018.

## 1.2 Objectives

- Perform six sled tests using Option A, three sled tests using Option B, and three quasi-static tests using Option B – all using anonymously donated fixed workstation tables.
- Evaluate the performance of the tables with regards to human injury, compartmentalization, structural integrity, survival space, and energy-absorption, as specified the February 2022 draft of APTA PR-CS-S-018, Rev. 2.

## 1.3 Overall Approach

Anonymous manufacturers provided workstation tables for the test series. The tables were designed to meet the requirements in APTA S-018.

All test setups were approved by a representative from the table manufacturer and a representative from the Volpe Center.

## 1.4 Scope

MGA conducted 12 tests using 5 different workstation table designs as summarized in Table 1. For all tests, the seats and tables were mounted to a simulated carbody structure provided by each manufacturer to resemble the real-world mounting conditions as closely as possible. All seats and tables were positioned as specified by the manufacturer to represent the dimensions intended for service. All seats and tables were attached to the fixtures using fasteners provided by the manufacturers, unless otherwise noted.

**Table 1. Test Summary**

| Test # | Date | MGA Test ID | Table ID | Test Option | Test Type |
|---|---|---|---|---|---|
| 1A† | 05.04.2021 | S21137 | 1 | A | Dynamic |
| 1A* | 05.06.2021 | S21139 | 1 | A | Dynamic |
| 1BD | 06.08.2021 | S21157 | 1 | B | Dynamic |
| 1BQ† | 11.17.2021 | N/A | 1 | B | Quasi-Static |
| 2A | 05.05.2021 | S21138 | 2 | A | Dynamic |
| 2BD | 05.07.2021 | S21140 | 2 | B | Dynamic |
| 2BQ | 07.22.2021 | N/A | 2 | B | Quasi-Static |
| 3A | 05.11.2021 | S21142 | 3 | A | Dynamic |
| 3BD | 05.10.2021 | S21141 | 3 | B | Dynamic |
| 3BQ | 09.01.2021 | N/A | 3 | B | Quasi-Static |
| 4A | 05.12.2021 | S21143 | 4 | A | Dynamic |
| 5A | 06.09.2021 | S21158 | 5 | A | Dynamic |

†Table 1 energy-absorption system malfunctioned due to twisting of wall-side bracket support.
*Table 1 was retested due to energy-absorption system malfunction.

**Legend:**

A = Option A
B = Option B
D = Dynamic
Q = Quasi-static

## 1.5 Organization of the Report

The report is organized as follows:

Section 2: Test Procedure, Conditions, and Pre-test Measurements

An overview of the procedure for the test and all pre-test measurements

Section 3: Test Results and Post-test Measurements

This section contains the results and post-test measurements for each seat type and discusses observation made during the test series.

Section 4: Test Summary

This section contains a brief summary of each test.

Section 5: Conclusion

This section draws conclusions based on the test results.

Section 6: References

This section shows the references used in this report.

Appendix A: Test Data

This section contains full test data.

Appendix B: Survival Space Evaluations

This section contains the survival space evaluations for the dynamic sled tests per Section 5.1.3 of APTA S-018, Revision 2.

Appendix C: Pre- and Post-test Measurements

This section contains all pre- and post-test measurements required by S-108.

## 2. Test Implementation

All tests were executed with MGA's sled and quasi-static systems. MGA's sled system is a pneumatic accelerator sled that uses compressed air to accelerate the sled carriage. The basic operation of the sled involves applying an acceleration force (through the thrust column) to the sled carriage which is initially at rest. The simulated carbody, seats, workstation tables, ATDs, test articles, and other data acquisition components are mounted directly to the carriage assembly. When the carriage is accelerated, the components and ATDs experience a "negative acceleration" similar to the deceleration experienced in an impact (crash) event.

### 2.1 Calibration Pulse

A calibration test was conducted by attaching ballast weight to the sled to simulate the weight of the ATDs and the seats. To help offset the effect of the ATD and seat kinematics during the actual test, additional ballast weight was also used to effectively increase the mass of the sled carriage. Figure 1 is the pre-test calibration pulse, and its corresponding velocity curve shown in Figure 2.

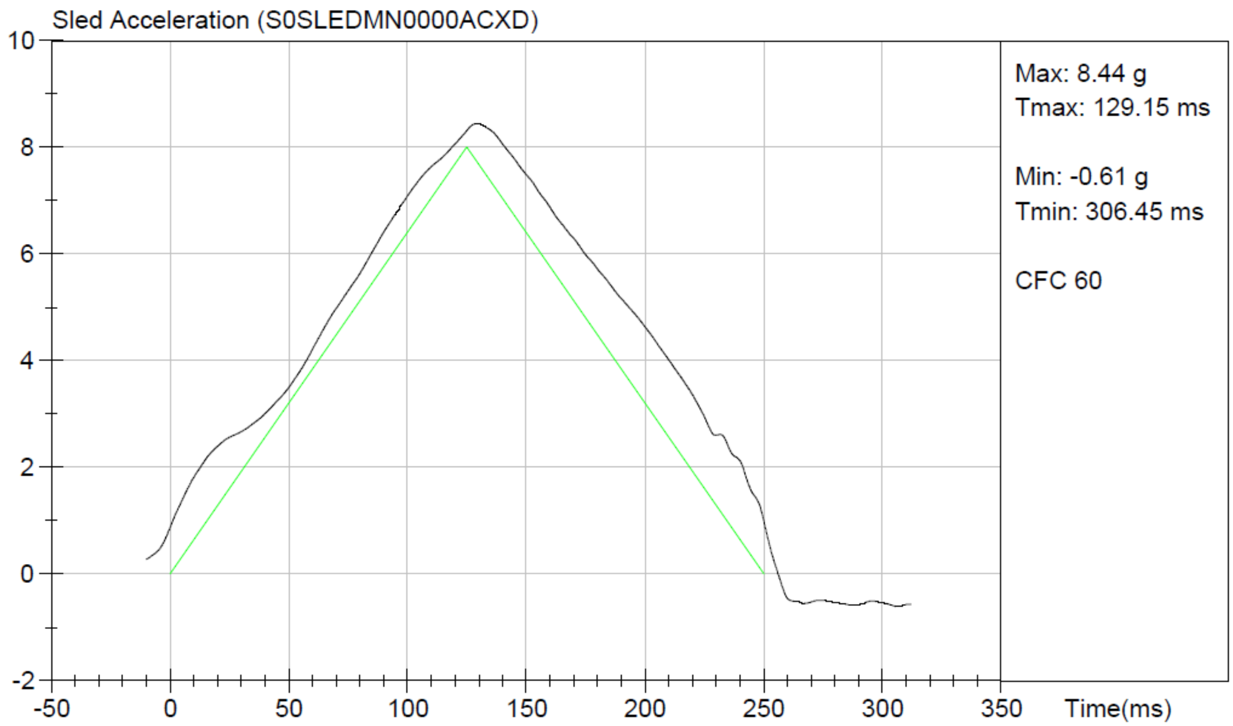



**Figure 1. Pre-test Calibration Acceleration Curve**

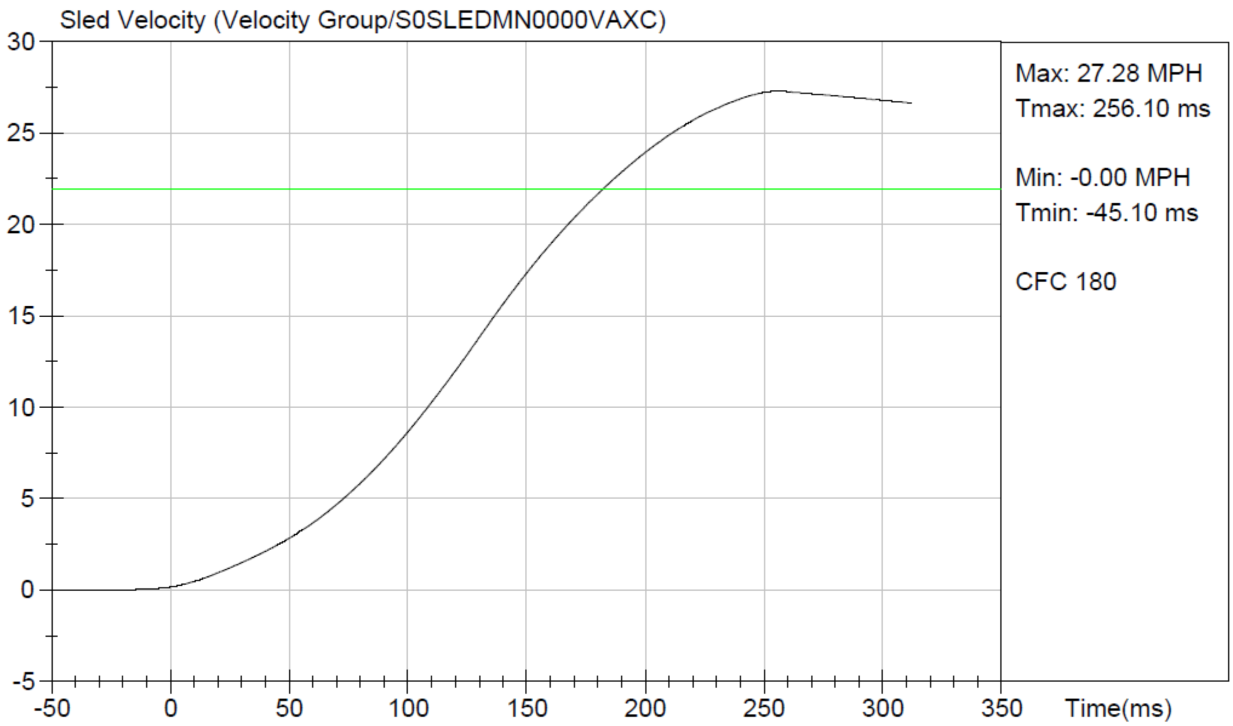



**Figure 2. Pre-test Calibration Velocity Curve**

## 2.2 Pre- and Post-test Measurements

A facing pair of two-person seats and a workstation table were installed in the simulated carbody in the nominal location for their intended rail service. This setup information, provided by each of the donating parties, was documented prior to the execution of the test using calibrated measuring devices. For documentation and verification purposes, photographs were taken of each measurement pre- and post-test. A simulated floor covering was included in the test setup to best replicate the railcar floor covering. Detailed pre- and post-test photographs were taken of the seats and tables to document the seat and table mounting locations and conditions to evaluate any post-test damage. The pre and post-test measurements that were taken are detailed in Figure 3 and Table 2 below. All measurements were taken at the center of each ATD position.

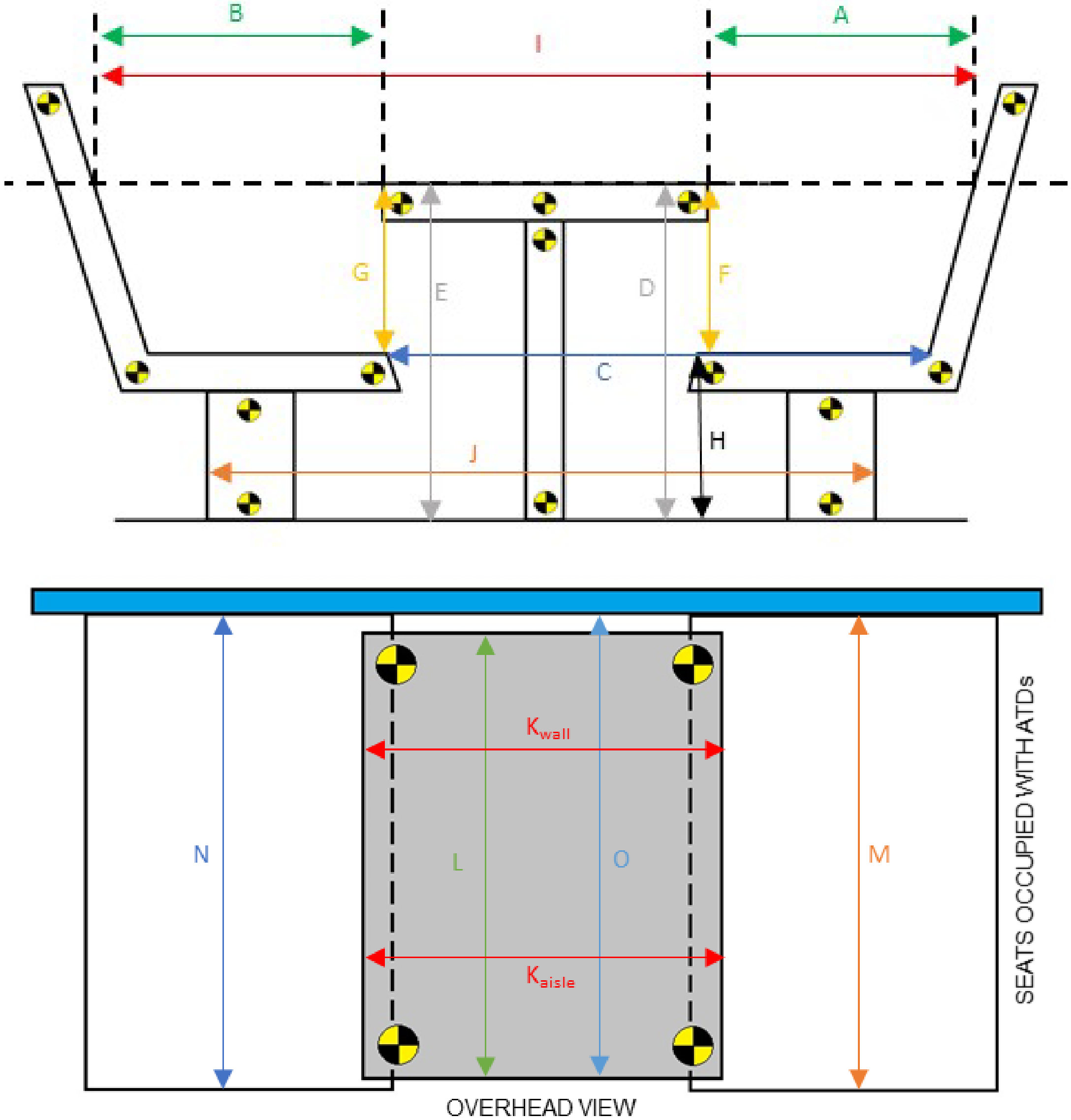



**Figure 3. Schematic of Pre- and Post-test Measurements to Be Recorded**

**Table 2. Pre- and Post-test Measurement Descriptions**

| ID | Description of Measurement |
|---|---|
| A | Longitudinal distance (in a horizontal plane) between tabletop and center of seatback at occupied seating position |
| B | Longitudinal distance (in a horizontal plane) between tabletop and center of seatback at unoccupied seating position |
| C | Longitudinal distance (in a horizontal plane) between seatback cushion of the launch seat(s) and the seat bottom cushion on the side opposite of the table from the ATD, at the height of the front of the seat bottom cushion |
| D | Vertical distance between top of tabletop and the simulated carbody floor measured at occupied seating position |
| $D_1$ | If able, push tabletop down by hand (post-test only) and take Measurement *D* again, at the highest point of the table |
| E | Vertical distance between top of tabletop and the simulated carbody floor measured at unoccupied seating position |
| F | Vertical distance between top of tabletop and the highest point on the seat bottom cushion measured at the center of the occupied seating position |
| G | Vertical distance between top of tabletop and the highest point on the seat bottom cushion measured at the center of the unoccupied seating position |
| H | Vertical distance between the simulated carbody floor and the top of the seat bottom cushion at the center of each occupied seating position |
| I | Longitudinal distance (in a horizontal plane) from seatback cushion of launch seat to seatback cushion of facing seat, measured at the height of the tabletop. |
| J | Longitudinal distance (in a horizontal plane) from the outside edge of the occupied-seat pedestal to the outside edge of the unoccupied-seat pedestal |
| K | Overall width of table being tested measured at the center of each occupant's seating position |
| L | Overall length of table being tested |
| M | Lateral distance (in a horizontal plane) between outside edge of occupied seat and the wall of the simulated carbody |
| N | Lateral distance (in a horizontal plane) between outside edge of unoccupied seat and the wall of the simulated carbody |
| O | Lateral distance (in a horizontal plane) between outside edge of tabletop and the wall of the simulated carbody |

## 2.3 Anthropomorphic Test Devices

The following tests used two H3-50Ms (Option B) or a H3-50M and THOR-50M (Option A) to measure human injury. The ATDs were instrumented with the transducers listed in Table 3. The ATDs' transducers were used to calculate the injury criteria described in Table 4. The requirements for the injury criteria of each ATD are given in Table 5.

**Table 3. ATD Transducers**

| Body Region | Data Channel |
|---|---|
| Head | Triaxial Head Triaxial Acceleration |
| Chest | Triaxial Chest (Mid-thoracic Spine) Triaxial Acceleration |
| Chest | Sternum Compression (H3-50M) |
| Femur | Axial Left and Right Femur Axial Force |
| Neck | Upper Neck Extension/Flexion Bending Moment |
| Neck | Upper Neck Axial Force |
| Neck | Upper Neck Shear Force |
| Chest | Bilateral Upper and Lower Chest Compression-Time History (THOR-50M) |
| Abdomen | Bilateral Abdominal Compression-Time History (THOR-50M) |

**Table 4. Measured ATD Injury Criteria**

| Body Region | Injury Criteria |
|---|---|
| Head | Head Injury Criterion ($HIC_{15}$) |
| Chest | Resultant Chest Acceleration 3 ms Exceedance |
| Femur | Peak Axial Femur Loads |
| Neck | Upper Neck Axial Tension/Compression Loads |
| Neck | Peak Neck Injury Criterion ($N_{ij}$) |
| Chest | Peak Bilateral Upper and Lower Chest Compression (THOR-50M) or Peak Sternum Compression (H3-50M) |
| Abdomen | Peak Bilateral Abdominal Compression (THOR-50M) |

**Table 5. Injury Criteria Requirements**

| Injury Criterion | H3-50M | H3-RS* | THOR-50M |
|---|---|---|---|
| $HIC_{15}$ | 700 | 700 | 700 |
| $N_{ij}$ | 1.0 | 1.0 | 1.0 |
| $F_z$ (tension) | +938 lbf (+4.17 kN) | +938 lbf (+4.17 kN) | +938 lbf (+4.17 kN) |
| $F_z$ (compression) | −899 lbf (−4 kN) | −899 lbf (−4 kN) | −899 lbf (−4 kN) |
| Chest Acceleration | 60g | 60g | 60g |
| Chest Compression | 2.5 in. (63 mm)† | 2.76 in. (70 mm) | 2.76 in. (70 mm) |
| Abdomen Compression | N/A | 2.64 in. (67 mm) | 3.39 in. (86 mm) |
| Axial Femur Load | ±2250 lbf (±10 kN) | ±2250 lbf (±10 kN) | ±2250 lbf (±10 kN) |

*For information only. The H3-RS ATD was not used in these tests.

### 2.4 Sled Test Procedure

Test procedure for each sled test:

1. Affix the test articles to the test sled:
    a. Verify the proper fasteners and torques with the customer.
    b. Verify the proper floor and carbody attachments are used
2. Inspect the ATD and note any damage prior to the test:
    a. Check the ATDs' clothes and skin for cuts or tears.
    b. Check the tension of all ATD joints.
    c. Every three sled runs, torque the ATDs' lumbar to 11 in/lb ± 1 in/lb and neck column to 12 in/lb ± 2 in/lb.
3. Verify all ATD channels pass calibration and function properly.
4. Using the data acquisition system, perform a sensor check and ATD manipulations (per SAE J211/1).
5. Verify the following requirements as stipulated in APTA S-018 Section 5.1.1:
    a. Back shall be placed against the seat back without clearance.
    b. Knees shall be separated by 6.7 in center-to-center. This is also equivalent to 4 in., inside-to-inside

c. Hands shall be placed on the thighs, palms down,

d. Feet shall be placed on the floor so that the centerlines of the lower legs are approximately parallel.

e. Lower legs shall be placed as close to vertical as possible.

f. Chalk shall be applied to each ATD's face and knees.

g. Tether each ATD such that it will not interfere with the test or the evaluation of compartmentalization but will attempt to mitigate any additional damage on the ATD's rebound. Tether tied around the ATD's waist that is shorter than instrumentation cable slack protects the cables and will prevent the ATD from ultimately being ejected from the sled.

6. Verify all camera cables are well-secured to the sled carriage and booms.
7. Verify lenses are tightened onto camera. Verify F-stop and focus adjustment set screws are tightened.
8. Verify all loose items (tools, parts, etc.) are removed from the sled carriage.
9. Take the pre-test measurements for both ATDs.
10. Create a test setup file using the data acquisition system and ensure the sled accelerometers are the correct serial numbers and are in calibration.
11. ATD data channels collected:
    a. Triaxial head acceleration-time history
    b. Triaxial chest acceleration-time history
    c. Axial left and right femur force-time history
    d. Upper neck extension/flexion bending moment, $M_y$ time history
    e. Upper neck axial force, $F_z$ time history
    f. Upper neck shear force, $F_x$ time history
    g. Longitudinal acceleration-time history of the test sled
    h. Sternum compression-time history (H3-50M)
    i. Bilateral upper and lower chest compression-time history (THOR-50M)
    j. Bilateral abdomen compression-time history (THOR-50M)
12. Take eight pre-test photos. Check with customer or specification to see if additional views are required.
13. Have the customer verify and sign off on the setup.
14. Execute the test.
15. Process and save test data and videos.
16. Inspect the rails and carriage for damage.

17. Take post-test photos to match the pre-test photos, plus any additional views requested by the customer.
18. Inspect the ATD and note any damage after the test.
19. Perform a post-test functionality check of ATD data channels
20. Process the following required ATD injury criteria:
    a. Head injury criterion over any 15 ms interval (HIC15)
    b. 3 ms exceedance chest resultant acceleration
    c. Peak axial femur load
    d. Peak upper neck axial tension/compression loads
    e. Peak neck injury criterion ($N_{ij}$)
    f. Peak sternum compression (H3-50M)
    g. Peak upper and lower bilateral chest compression (THOR-50M)
    h. Peak bilateral abdomen compression (THOR-50M)
21. Evaluate the seat based on the following criteria:
    a. The table and table components shall remain attached to the simulated car structure.
    b. The table shall not penetrate the minimum survival space of 9.7 in (246.4 mm) reserved for occupants in the facing seat at any point during the test
    c. The ATDs shall be compartmentalized.
        i. The ATD must be confined between the impact seat (potentially deformed) and the initially occupied seat until the ATD begins to rebound and move away from the impacted seat.
    d. All injury measurements computed in APTA S-018 Sections 5.1 and 5.2 must meet the requirements defined in Table 5.
22. Take the post-test measurements for both ATD seat positions as described in Table 2.

## 2.5 Quasi-static Test Procedure

Figure 4 shows the test setup for the Option B quasi-static test per Revision 2 of the table standard [21]. In the quasi-static test, the table is simultaneously loaded by rigid body blocks (green blocks in figure) which are typically actuated by hydraulic cylinders (black loading rams).

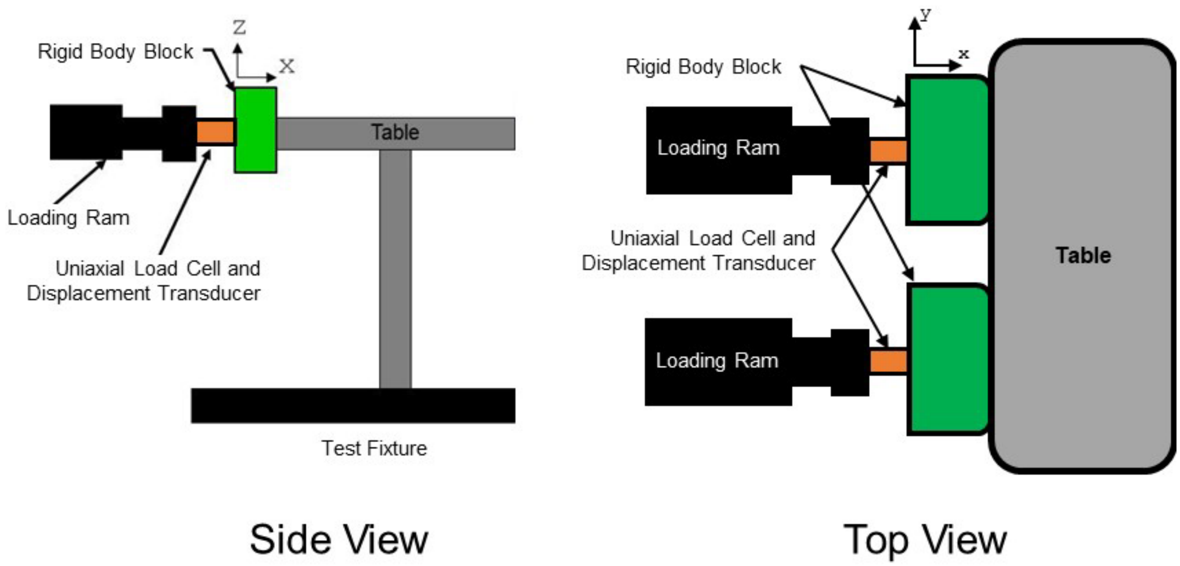



**Figure 4. Quasi-static Test Setup [21]**

Test procedure for each quasi-static test:

1. Install the donated simulated carbody structure to the t-slot floor plates using toe-clamps and ¾-16 Grade 8 fasteners to ensure the simulated carbody structure does not shift.
2. Install the test articles to the simulated carbody structure.
    - Verify the proper fasteners and torques with the customer.
    - Verify the proper floor and carbody attachments are used.
3. Align the two rigid body blocks laterally at the center of each seat position for the intended service.
    - Center the two body blocks vertically on the table edge.
4. Take pre-test photos. Check with customer or specification to see if additional views are required.
5. Actuate the two hydraulic cylinders attached to rigid body blocks at the same time, with the goal of maintaining approximately the same force applied to the table edge at each body block position.
    - Use load control at a rate of approximately 350 lbf (1.3 kN) per minute.
6. Stop the loading of each hydraulic cylinder independently when the applied load at a single seat position reaches 2,250 lbf (10 kN) or when the maximum hydraulic cylinder motion of 250 mm (10 in.) has been achieved.
    - Do not withdraw either body block until both body blocks have reached 2,250 lbf (10 kN) or the maximum stroke of 250 mm (10 in.).
7. Record load and displacement data until both body blocks are completely unloaded by reversing the motion of the loading rams.

For each seat position, if the seat back distance, i.e., measurement *I* in Figure 3, is less than or equal to 57 in. (1448 mm), then the energy absorbed, as calculated above, must be at least 6,250 in-lbf (706.2 J).

For each seat position, if the seat back distance, i.e., measurement *I* in Figure 3, is greater than 57 in. (1448 mm), then the required energy absorption at each seat position is a linear function of *I* according to Equation 1 when *I* is in in and Equation 2 when *I* is in millimeters.

$$Energy \geq \left( 530 \frac{\text{in} - \text{lbf}}{\text{in}} \right) \cdot I - (\, 23{,}960 \text{ in} - \text{lbf} \,) \qquad \text{Equation 1}$$

$$Energy \geq \left( 2.35756 \frac{\text{J}}{\text{mm}} \right) \cdot I - (2707.12 \text{ J} \,) \qquad \text{Equation 2}$$

## 3. Results

Table 6 summarizes the results of the 9 dynamic and 3 quasi-static table tests. Three out of five tables tested per Option A met all requirements. Test 1A was retested due to malfunction of the energy-absorption due to twisting of the wall-side bracket support, and it met the requirements (Test 1A*) after retesting. None of the three tables that were tested per Option B met all requirements. All tables tested per Option B were also tested per Option A, and only Test 1BD met the requirements in Option A, but did not meet the requirements in Option B. The discrepancy was attributed to a malfunction of the table's energy-absorption system.

**Table 6. Test Summary**

| Test # | Date | MGA Test ID | Table ID | Option | Test Type | Met Req't? |
|---|---|---|---|---|---|---|
| 1A | 05.04.2021 | S21137 | 1 | A | Dynamic | **NO**† |
| 1A* | 05.06.2021 | S21139 | 1 | A | Dynamic | **YES** |
| 1BD | 06.08.2021 | S21157 | 1 | B | Dynamic | **NO**† |
| 1BQ | 11.17.2021 | - | 1 | B | Quasi-Static | **NO**† |
| 2A | 05.05.2021 | S21138 | 2 | A | Dynamic | **NO** |
| 2BD | 05.07.2021 | S21140 | 2 | B | Dynamic | **NO** |
| 2BQ | 07.22.2021 | - | 2 | B | Quasi-Static | **NO** |
| 3A | 05.11.2021 | S21142 | 3 | A | Dynamic | **NO** |
| 3BD | 05.10.2021 | S21141 | 3 | B | Dynamic | **NO** |
| 3BQ | 09.01.2021 | - | 3 | B | Quasi-Static | **NO** |
| 4A | 05.12.2021 | S21143 | 4 | A | Dynamic | **YES** |
| 5A | 06.09.2021 | S21158 | 5 | A | Dynamic | **YES** |

†Table 1 energy-absorption system malfunctioned due to wall-side bracket support twisting.
*Table 1 was retested due to energy-absorption system malfunction and use of incorrect seat track.

**Legend:**

A = Option A
B = Option B
D = Dynamic
Q = Quasi-static

### 3.1 Test 1A

A two-person passenger seat was mounted to the test sled. A facing seat was mounted to the test sled on the opposite side of the table at the nominal seat pitch for the intended installation. A fixed workstation table was installed in the middle of the two facing seats. Instrumented ATDs, representative of 50$^{th}$ percentile adult males, were positioned to face the direction of travel. The aisle-side (left passenger) ATD was a H3-50M and the wall-side (right passenger) ATD was a THOR-50M, as specified in Option A of APTA S-018.

Figure 5 shows the setup and Figure 6 shows the post-test outcome for Test 1A.

**Figure 5. Test 1A Lateral Pre-test Photo**

**Figure 6. Test 1A Lateral Post-test Photo**

### *3.1.1 Test 1A: Post-test Observations*

Figure 7. Test 1A Impact Seat

The impact seat pedestal rotated and the seat slid on the track during the event once impacted by the two ATDS.

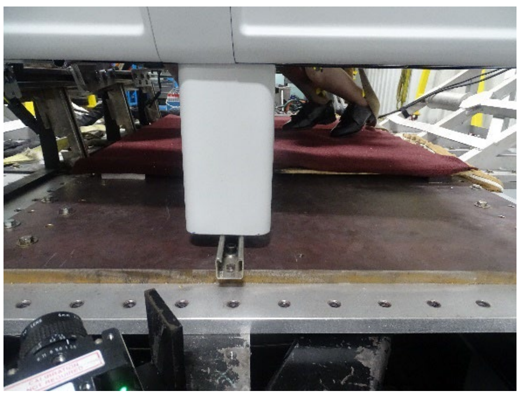


Figure 8. Test 1A Impact Seat Pedestal

The impact seat pedestal mount mildly deformed at the floor mounting location during the event. It was discovered that the wrong seat track was installed, resulting in the impact seat sliding backwards about 2 in. due to impact from the ATDs. All subsequent tests utilized the proper seat track.

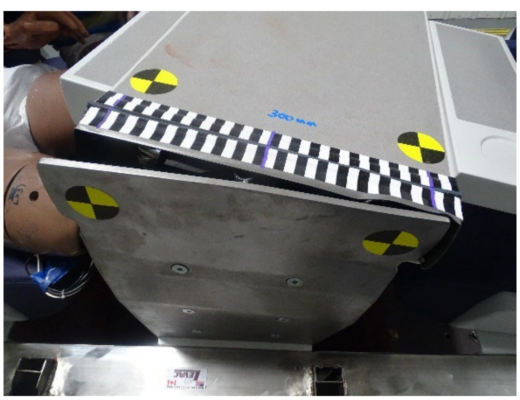
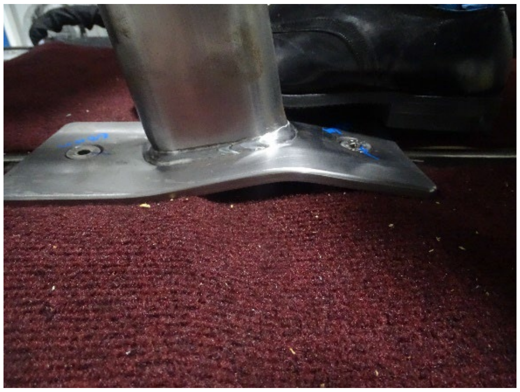


Figure 9. Test 1A Workstation Table Wall Mount

The workstation table translated 3 mm, as observed on the inch tape, and then deformed. The workstation table partially pulled off the wall mount during the event.



The workstation table mount deformed along the track mount during the event.

**Figure 10. Test 1A Workstation Table Floor Mount**

### 3.1.2 Test 1A: Post-test Evaluation

Table 7 below contains the results of the APTA post-test evaluation for Test 1A.

**Table 7. Test 1A APTA Post-test Evaluation**

| APTA Requirement | Assessment |
|---|---|
| The table and all table components must remain attached to the test fixture or simulated railcar structure. | The workstation table partially separated from wall mount during event, but the table and all components remained attached to the test fixture. |
| The table shall not penetrate the minimum survival space of 9.7 in. reserved for occupants in the facing seat, so as not to entrap the facing passengers or prevent egress. | Distance between table and seatback of the seat opposite the ATD measured 12.05 in.; therefore, it did not penetrate survival space. |
| The ATDs shall be compartmentalized between rows of seats. | The ATDs were compartmentalized as defined in S-018. |
| All injury measurements must meet the criteria specified in S-018. | The guide ball on the rotary potentiometer came out of the guide track behind the sternum during the test, so the H3-50M sternum compression measurement was invalid. The THOR-50M lower right chest compression criterion was not met. See Table 8 below. |

### 3.1.3 Test 1A: Human Injury Values

Table 8 below contains the human injury evaluation for Test 1A.

**Table 8. Test 1A Human Injury Requirements**

| Description | APTA PR-CS-S-018-13, Rev. 2 §5.2.1.3 Performance Requirements | H3-50M (Aisle) | THOR-50M (Wall) |
|---|---|---|---|
| Head Injury Criteria | HIC15 ≤ 700 | 21 | 76 |
| Neck Injury Criteria | $N_{IJ}$ Compression/Extension ≤ 1.0 | 0.09 | 0.05 |
| | $N_{IJ}$ Compression/Flexion ≤ 1.0 | 0.08 | 0.10 |
| | $N_{IJ}$ Tension/Extension ≤ 1.0 | 0.24 | 0.40 |
| | $N_{IJ}$ Tension/Flexion ≤ 1.0 | 0.19 | 0.41 |
| Neck Axial Tension | $F_z$ ≤ 4,170 N | 748 | 1,531 |
| Neck Axial Compression | $F_z$ ≤ 4,000 N | 148 | 72 |
| Chest Deceleration | ≤ 60g over a 3ms clip | 20 | 23 |
| Sternum Peak Compression | < 63 mm | NVD†† | |
| Upper-Left Chest Peak Deflection | < 70 mm | | 7 |
| Upper-Right Chest Peak Deflection | < 70 mm | | 12 |
| Lower-Left Chest Peak Deflection | < 70 mm | | 66 |
| Lower-Right Chest Peak Deflection | < 70 mm | | 73† |
| Left Abdomen Peak Deflection | < 86 mm | | 52 |
| Right Abdomen Peak Deflection | < 86 mm | | 62 |
| Femur Load | Left ≤ 10,000 N | 2,398 | 3,066 |
| | Right ≤ 10,000N | 6,805 | 3,092 |

†Table 1 energy-absorption system malfunctioned due to wall-side bracket support twisting.
††No value declared because H3-50M rotary potentiometer dislodged from base.

### *3.1.4 Test 1A: Summary*

In Test 1A, the workstation table failed to translate the length of its intended stroke and instead rotated around the wall mount. This likely influenced the injury results. The table partially separated from the simulated wall mount during the event. There was mild deformation to the pedestal mount. No components separated from the workstation table during the test. The injury criteria were not met due to the THOR-50M lower right chest deflection criteria exceeding the limit. The chest rotary potentiometer in the H3-50M dislodged from the base resulting in an invalid reading. The minimum survival space was preserved during the event.

## 3.2 Test 1A*

A two-person passenger seat was mounted to the test sled. A facing seat was mounted to the test sled on the opposite side of the table at the nominal seat pitch of the intended installation. A fixed workstation table was installed in the middle of the two facing seats. Instrumented ATDs, representative of 50th percentile adult males were positioned to face the direction of travel. The aisle-side (left passenger) ATD was an H3-50M, and the wall-side (right passenger) ATD was a THOR-50M as specified in Option A of APTA S-018.

Figure 11 shows the setup and Figure 12 shows the post-test outcome for Test 1A*.


**Figure 11. Test 1A* Lateral Pre-test Photo**

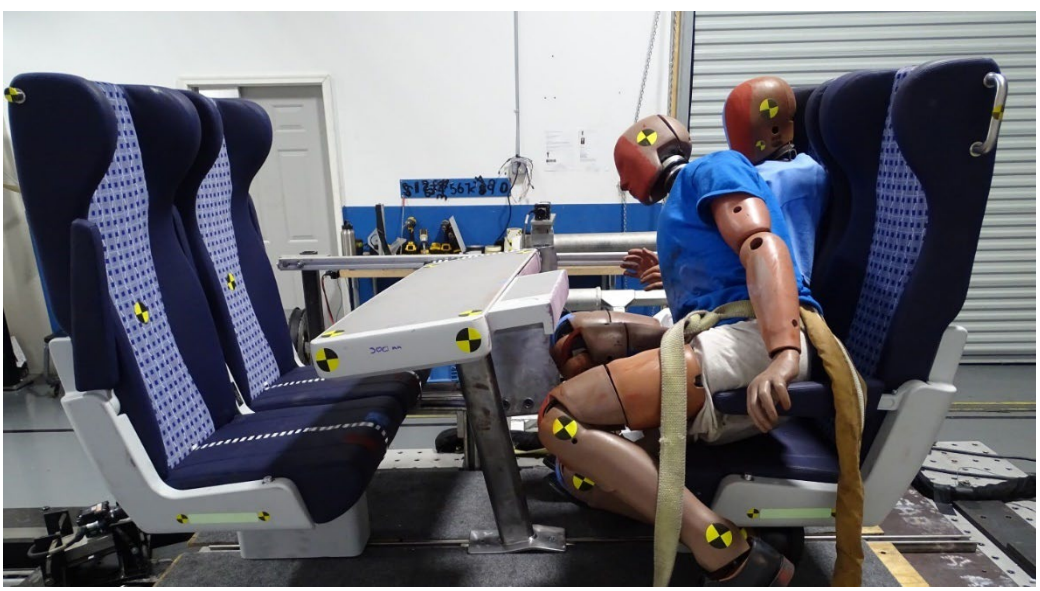


**Figure 12. Test 1A* Lateral Post-test Photo**

### 3.2.1 Test 1A*: Post-test Observations

Figure 13. Test 1A* Impact Seat

The workstation table deformed toward the impact seat during the event.

Figure 14. Test 1A* Impact Seat Pedestal

The workstation table pedestal mount partially deformed during the event. There were no separations of any parts.

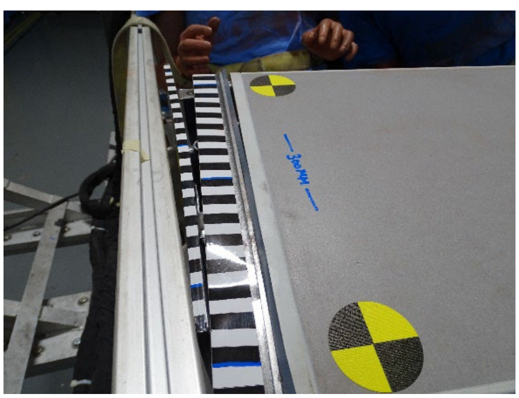


Figure 15. Test 1A* Workstation Table Wall Mount

The workstation table partially pulled off the wall during the event after translating approximately 2 in.

**Figure 16. Test 1A* Workstation Table Floor Mount**

The workstation table floor mount deformed upwards during the event. The table mount remained connected to the simulated floor mount.

### 3.2.2 Test 1A*: Post-test Evaluation

Table 9 contains the results of the APTA post-test evaluation for Test 1A*.

**Table 9. Test 1A* APTA Post-test Evaluation**

| APTA Requirement | Assessment |
|---|---|
| The table and all table components must remain attached to the test fixture or simulated railcar structure. | No table components became loose during the event. |
| The table shall not penetrate the minimum 9.7 in. survival space reserved for occupants in the facing seat, so as not to entrap the facing passengers or prevent egress. | Distance between table and seatback of the seat opposite the ATD measured 13.87 in.; therefore, it did not penetrate survival space. |
| The ATDs shall be compartmentalized between rows of seats. | The ATDs were compartmentalized as defined in S-018. |
| All injury measurements must meet the criteria specified in S-018. | All injury criteria met. See Table 10 below. |

### 3.2.3 Test 1A*: Human Injury Values

Table 10 contains the human injury evaluation for Test 1A*.

**Table 10. Test 1A* Human Injury Measurements**

| Description | APTA PR-CS-S-018-13, Rev. 2 §5.2.1.3 Performance Requirements | H3-50M (Aisle) | THOR-50M (Wall) |
|---|---|---|---|
| Head Injury Criteria | HIC15 ≤ 700 | 21 | 75 |
| Neck Injury Criteria | NIJ Compression/Extension ≤ 1.0 | 0.12 | 0.11 |
| | NIJ Compression/Flexion ≤ 1.0 | 0.04 | 0.11 |
| | NIJ Tension/Extension ≤ 1.0 | 0.27 | 0.30 |
| | NIJ Tension/Flexion ≤ 1.0 | 0.19 | 0.44 |
| Neck Axial Tension | Fz ≤ 4,170 N | 821 | 1,649 |
| Neck Axial Compression | Fz ≤ 4,000 N | 70 | 229 |
| Chest Deceleration | ≤ 60g over a 3ms clip | 25 | 29 |
| Sternum Peak Compression | < 63 mm | 56 | |
| Upper-Left Chest Peak Deflection | < 70 mm | | 6 |
| Upper-Right Chest Peak Deflection | < 70 mm | | 11 |
| Lower-Left Chest Peak Deflection | < 70 mm | | 57 |
| Lower-Right Chest Peak Deflection | < 70 mm | | 68 |
| Left Abdomen Peak Deflection | < 86 mm | | 49 |
| Right Abdomen Peak Deflection | < 86 mm | | 47 |
| Femur Load | Left ≤ 10,000 N | 3,150 | 2,455 |
| | Right ≤ 10,000 N | 3,138 | 2,285 |

### 3.2.4 Test 1A*: Summary

For test 1A*, an additional frame was constructed to simulate a carbody wall to better represent its position in a railcar and to limit rotational movement. The workstation table achieved its full stroke when it translated along the simulated carbody. The impact resulted in mild pedestal deformation and partial separation of the workstation table from the simulated wall mount. There was also minor deformation around the table floor mount. No components separated during the event. All injury criteria requirements were met for both ATDs. The minimum survival space was preserved during the event.

### 3.3 Test 1BD

A two-person passenger seat was mounted to the test sled. A facing seat was mounted to the test sled on the opposite side of the table at the nominal seat pitch for the intended installation. A fixed workstation table was installed in the middle of the two facing seats. Instrumented ATDs, representative of 50th percentile adult males, were positioned to face the direction of travel. Both ATDs were H3-50Ms, as specified in Option B of APTA S-018.

Figure 17 shows the setup and Figure 18 shows the post-test outcome for Test 1BD.

**Figure 17. Test 1BD Lateral Pre-test Photo**

**Figure 18. Test 1BD Lateral Post-test Photo**

### *3.3.1 Test 1BD: Post-test Observations*

**Figure 19. Test 1BD Workstation Table**

The workstation table deformed toward the impact seats upon contact during the event.

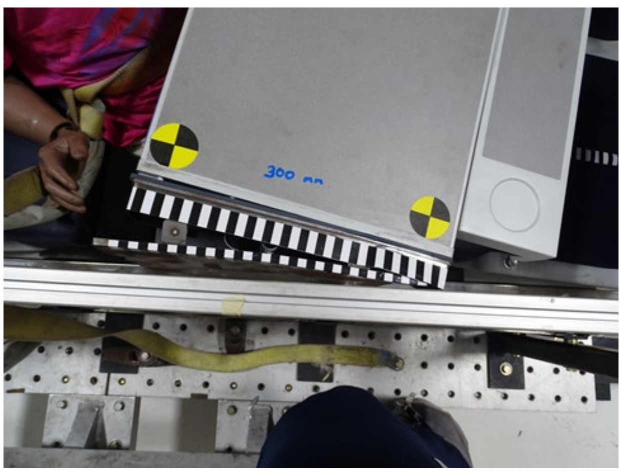


**Figure 20. Test 1BD Workstation Table Wall Mount**

The workstation table translated approximately 10 mm, as observed on the inch tape, and then deformed. The workstation table partially pulled off the simulated wall mount during the event.

**Figure 21. Test 1BD Workstation Table Floor Mount**

The workstation table mount deformed during the event, causing slight separation from the floor track.

### *3.3.2 Test 1BD: Post-test Evaluation*

Table 11 contains the results of the APTA post-test evaluation for Test 1BD.

**Table 11. Test 1BD APTA Post-test Evaluation**

| APTA Requirement | Assessment |
|---|---|
| The table and all table components must remain attached to the test fixture or simulated railcar structure. | The workstation table partially separated from wall mount during the event, but the table and all components remained attached to the test fixture. |
| The table shall not penetrate the minimum survival space of 9.7 in. reserved for occupants in the facing seat, so as not to entrap the facing passengers or prevent egress | Distance between table and seatback of the seat opposite the ATD measures 11.81 in.; therefore, it did not penetrate survival space. |
| The ATDs shall be compartmentalized between rows of seats. | The ATDs were compartmentalized as defined by S-018. |
| All injury measurements must meet the criteria specified in S-018. | The guide ball on the rotary potentiometer came out of the guide track behind the sternum during the test, so the wall-side H3-50M sternum compression measurement was invalid. Aisle-side H3-50M chest compression criteria not met. See Table 12 below. The full stroke of the energy absorbing mechanism was not utilized, which likely influenced the injury results. |

### 3.3.3 Test 1BD: Human Injury Values

Table 12 contains the results of the human injury evaluation for Test 1BD.

**Table 12. Test 1BD Human Injury Measurements**

| Description | APTA PR-CS-S-018-13, Rev. 2 §5.2.1.3 Performance Requirements | H3-50M ATD (Aisle) | H3-50M ATD (Wall) |
|---|---|---|---|
| Head Injury Criteria | HIC15 ≤ 700 | 17 | 42 |
| Neck Injury Criteria | $N_{IJ}$ Compression/Extension ≤ 1.0 | 0.11 | 0.06 |
| | $N_{IJ}$ Compression/Flexion ≤ 1.0 | 0.01 | 0.06 |
| | $N_{IJ}$ Tension/Extension ≤ 1.0 | 0.20 | 0.33 |
| | $N_{IJ}$ Tension/Flexion ≤ 1.0 | 0.15 | 0.32 |
| Neck Axial Tension | $F_z$ ≤ 4,170 N | 723 | 1,087 |
| Neck Axial Compression | $F_z$ ≤ 4,000 N | 345 | 478 |
| Chest Deceleration | ≤ 60g over a 3ms clip | 17 | 28 |
| Sternum Compression | < 63 mm | 74† | NVD†† |
| Femur Load | Left ≤ 10,000 N | 6,878 | 3,461 |
| | Right ≤ 10,000N | 3,082 | 286 |

†Table 1 energy-absorption system malfunctioned due to twisting of wall-side bracket support.
††No value declared because H3-50M rotary potentiometer dislodged from base.

### 3.3.4 Test 1BD: Summary

The workstation table in Test 1BD was designed to translate along the wall mount and absorb energy during impact. In Test 1A, the table failed to translate and instead rotated in a clockwise direction during the event. For Tests 1BD, 1BDQ, and 1A*, an additional longitudinal sidewall frame member was constructed to simulate an interior sheathing and provide additional transverse support to the table bracket. The table partially translated along the simulated carbody, then separated slightly from the wall mount, failing to translate for the full stroke. The table also deformed toward the rear-facing seat upon impact. There was partial separation observed along the impact seat pedestal. The aisle-side H3-50M chest compression criterion was not met. The wall-side H3-50M chest rotary potentiometer dislodged from the base, resulting in an invalid reading. The minimum survival space was preserved during the event.

## 3.4 Test 1BQ

A fixed workstation table and provided simulated car structure was mounted to the rigid t-slot floor plates. The fixed workstation table was attached to the simulated car structure using the same fasteners and attachment mechanisms as intended for service. The hydraulic cylinders and rigid body blocks were aligned laterally at the center of each seating position and centered vertically on the table edge. The table was quasi-statically tested according to the Option B test requirements in Section 5.2.2 of the table standard at a load-controlled rate of 350 lbf/min.

Figure 22 shows the pre-test setup and Figure 23 shows the post-test outcome for Test 1BQ.

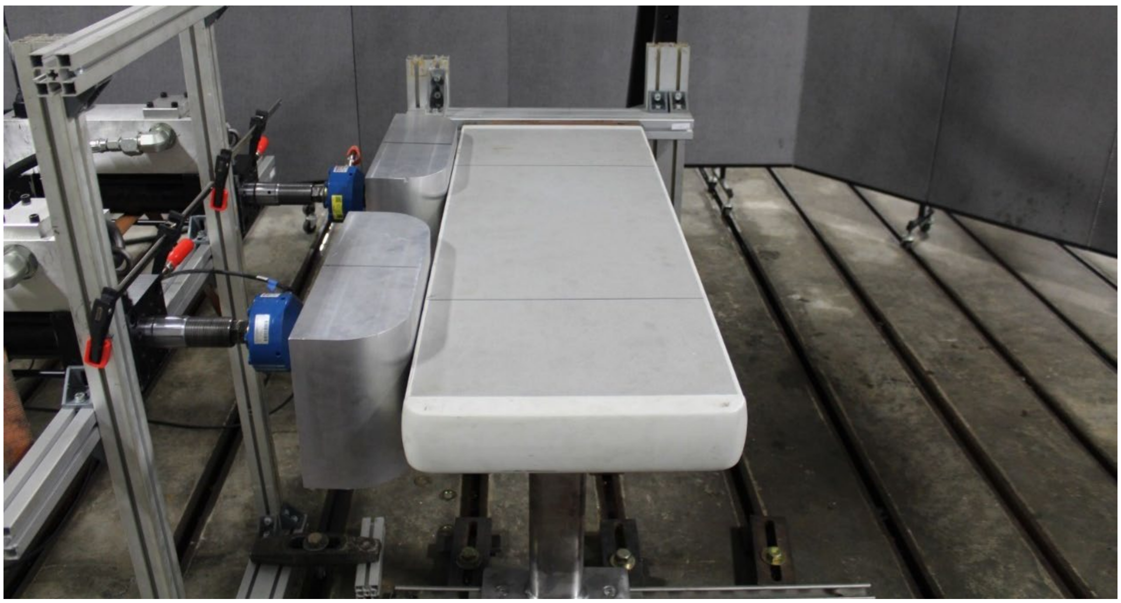


**Figure 22. Test 1BQ Lateral Pre-test Photo**

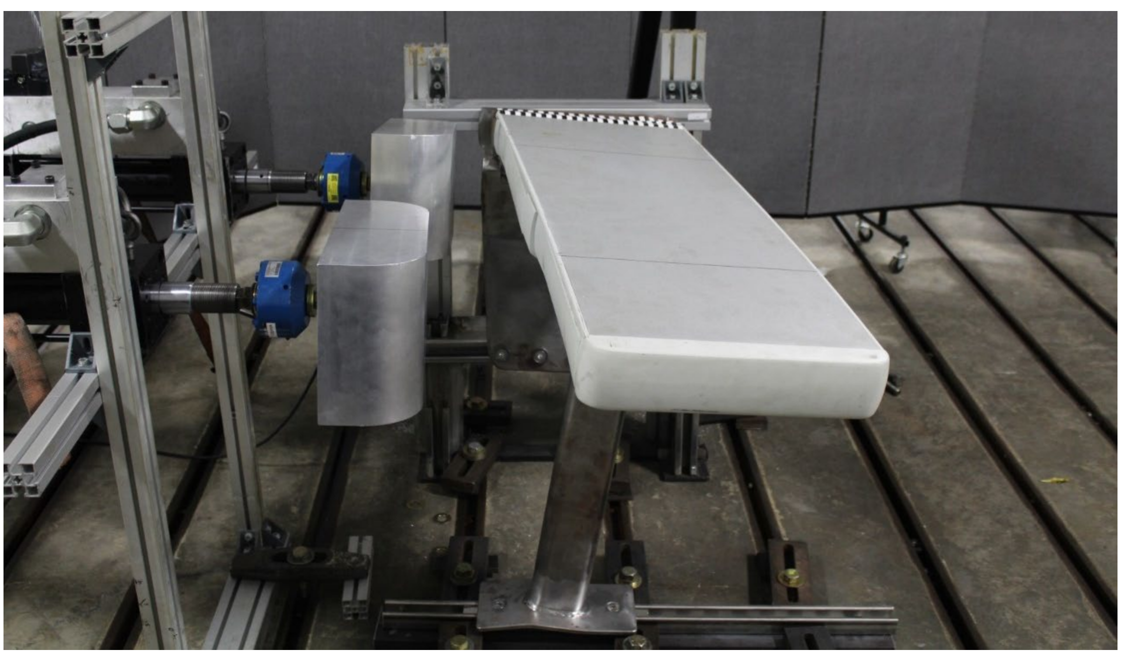


**Figure 23. Test 1BQ Lateral Post-test Photo**

### 3.4.1 Test 1BQ: Post-test Observations

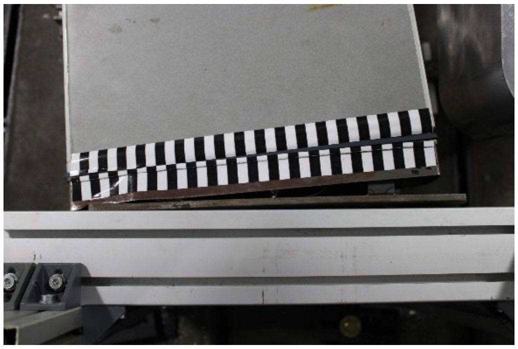


Figure 24. Test 1BQ Workstation Table Overhead

The workstation table translated approximately 25 mm, as observed on the inch tape, along the simulated wall structure. The full stroke of the energy absorbing mechanism was not utilized.

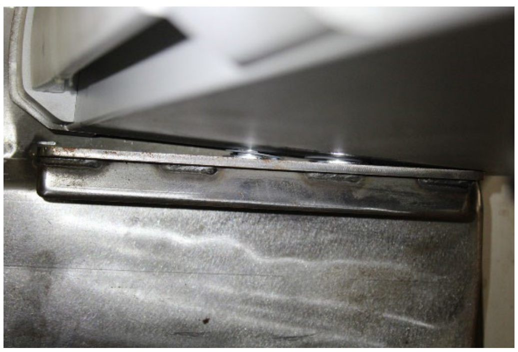


Figure 25. Test 1BQ Workstation Table Wall

The workstation table partially lifted vertically at the wall mount of the structure.

Figure 26. Test 1BQ Pedestal Floor Mount

The pedestal floor mount deformed during the event, causing slight separation from the floor track.

### 3.4.2 Test 1BQ: Post-test Evaluation

Table 13 contains the APTA post-test evaluation for Table 1BQ.

**Table 13. Test 1BQ APTA Post-test Evaluation**

| APTA Requirement | Assessment |
|---|---|
| The table and any table components must remain attached to the test fixture or simulated railcar structure, with the exception of superficial nonstructural components of negligible weight that do not affect the structural integrity of the table. | The workstation table remained secured to the simulated railcar structure with no component separation. |
| For each seat position, if the seat back distance, i.e., measurement *I* in Figure 3, is greater than 57 in. (1448 mm), then the required energy absorption at each seat position is a bilinear function of *I* according to Equation 1 when *I* is in inches and Equation 2 when *I* is in millimeters | The full stroke of the energy absorbing mechanism was not utilized. The workstation table met the energy-absorption requirement at the aisle but not the wall seat position (see Table 14). |
| The allowable load limit is 2,250 lbf if: (1) the vertical distance between top of tabletop and the highest point on the unoccupied seat bottom cushion (depicted as measurement *F* in Figure 3) is greater than 11.6 in. (295 mm); and (2) the chest (sternal) rotary potentiometer in each H3-50M ATD does not malfunction (e.g., dislodge) during the dynamic sled test (Test 3BD). Otherwise, the allowable load limit is 1,800 lbf. | The rotary potentiometers did not dislodge during Test 1BD, and the minimum measurement *F* of the workstation table was approximately 310 mm (Table C3). Therefore, the allowable load limit is 2,250 lbf. |

### 3.4.3 Test 1BQ: Energy-Absorption Calculation

Table 14 contains the APTA energy-absorption evaluation for Table 1BQ.

**Table 14. Test 1BQ Energy-Absorption Calculation**

| Allowed Force [lb] | Measurement I [in.] | APTA PR-CS-S-018-13, Rev. 2 §5.2.2.3 Performance Requirements | Aisle [in.-lbf] | Wall [in.-lbf] |
|---|---|---|---|---|
| 2,250 | 66.9 | ≥ 11,497 in.-lbf | 11,511† | 6,354† |

†Table 1 energy-absorption system malfunctioned due to twisting of the wall-side bracket support.

### 3.4.4 Test 1BQ: Summary

The workstation table in Test 1BQ was designed to translate along the wall mount to the simulated carbody as well as at the top of the table pedestal. In Test 1BQ, only the pedestal translation design achieved full deformation. The wall mount did not. The quasi-static energy-absorption requirements were not met at either seat position.

## 3.5 Test 2A

A two-person passenger seat was mounted to the test sled. A facing seat was mounted to the test sled on the opposite side of the table at the nominal seat pitch for the intended installation. A fixed workstation table was installed in the middle of the two facing seats. Instrumented ATDs, representative of 50th percentile adult males, were positioned to face the direction of travel. The aisle-side (left passenger) ATD was an H3-50M, and the wall-side (right passenger) ATD was a THOR, as specified in Option A of APTA S-018.

Figure 27 shows the setup and Figure 28 shows the post-test outcome for Test 2A.


**Figure 27. Test 2A Lateral Pre-test Photo**

**Figure 28. Test 2A Lateral Post-test Photo**

### 3.5.1 Test 2A: Post-test Observations

Figure 29. Test 2A Impact Seat

The ATDs' knees impacted the opposite seat during the event. No structural issues were observed.

Figure 30. Test 2A Impact Seat Pedestal

The impact seat pedestal mount experienced no deformation. Slight movement was witnessed along the floor track.

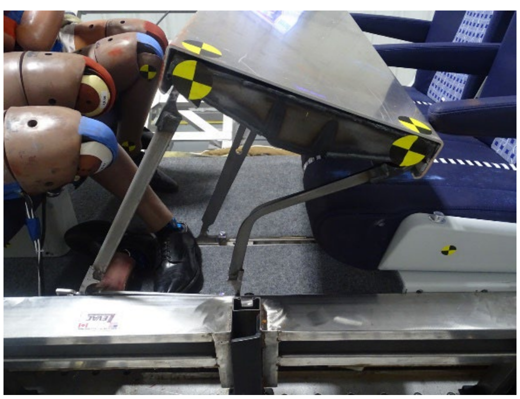


Figure 31. Test 2A Workstation Table Wall Mount

During the event, the THOR-50M tibia was broken.

The workstation table deformed toward the impact seat during impact and remained attached to wall mount.

Figure 32. Test 2A Workstation Table Floor Mount

The workstation table floor mount remained attached to the floor track during the event.

### *3.5.2 Test 2A: Post-test Evaluation*

Table 15 below contains the results of the APTA post-test evaluation for Test 2A.

**Table 15. Test 2A APTA Post-test Evaluation**

| APTA Requirement | Assessment |
|---|---|
| The table and all table components must remain attached to the test fixture or simulated railcar structure. | No table components became loose during the event. |
| The table shall not penetrate the minimum survival space of 9.7 in. reserved for occupants in the facing seat, so as not to entrap the facing passengers or prevent egress. | Distance between table and seatback of the seat opposite the ATD measured 10.40 in.; therefore, it did not penetrate survival space. |
| The ATDs shall be compartmentalized between rows of seats. | The ATDs were compartmentalized as defined in S-018. |
| All injury measurements must meet the criteria specified in S-018. | THOR-50M lower right chest peak deflection criteria not met. See Table 16 below. |

### 3.5.3 Test 2A: Human Injury Values

Table 16 below contains the human injury evaluation for Test 2A.

**Table 16. Test 2A Human Injury Measurements**

| Description | APTA PR-CS-S-018-13, Rev. 2 §5.2.1.3 Performance Requirements | H3-50M ATD (Aisle) | THOR-50M ATD (Wall) |
|---|---|---|---|
| Head Injury Criteria | HIC15 ≤ 700 | 15 | 50 |
| Neck Injury Criteria | $N_{IJ}$ Compression/Extension ≤ 1.0 | 0.01 | 0.05 |
| | $N_{IJ}$ Compression/Flexion ≤ 1.0 | 0.10 | 0.24 |
| | $N_{IJ}$ Tension/Extension ≤ 1.0 | 0.20 | 0.32 |
| | $N_{IJ}$ Tension/Flexion ≤ 1.0 | 0.21 | 0.23 |
| Neck Axial Tension | $F_z$ ≤ 4,170 N | 835 | 1,218 |
| Neck Axial Compression | $F_z$ ≤ 4,000 N | 196 | 614 |
| Chest Deceleration | ≤ 60g over a 3ms clip | 16 | 16 |
| Sternum Peak Compression | < 63 mm | 55 | |
| Upper-Left Chest Peak Deflection | < 70 mm | | 10 |
| Upper-Right Chest Peak Deflection | < 70 mm | | 19 |
| Lower-Left Chest Peak Deflection | < 70 mm | | 61 |
| Lower-Right Chest Peak Deflection | < 70 mm | | 72 |
| Left Abdomen Peak Deflection | < 86 mm | | 30 |
| Right Abdomen Peak Deflection | < 86 mm | | 26 |
| Femur Load | Left ≤ 10,000 N | 2,874 | 3,160 |
| | Right ≤ 10,000N | 7,875 | 1,447 |

### 3.5.4 Test 2A: Summary

The workstation table in Test 2A was designed to bend at the floor mounts and absorb energy through material deformation. After MGA received the table, modifications were made to the table to reduce the bending moment along the wall mount in order to limit contact forces with the ATDs. The pedestal and table mount deformed toward the impact seat during the event. No components separated from the table during the event. Both tibias on the THOR-50M ATD fractured upon impact, and the injury criteria for the lower right chest peak deflection were not met. The minimum survival space was preserved throughout the event.

## 3.6 Test 2BD

A two-person passenger seat was mounted to the test sled. A facing seat was mounted to the test sled on the opposite side of the table at the nominal seat pitch for the intended installation. A fixed workstation table was installed in the middle of the two facing seats. Instrumented ATDs, representative of 50th percentile adult males, were positioned to face the direction of travel. Both ATDs were H3-50Ms, as specified in Option B of APTA S-018.

Figure 33 shows the setup and Figure 34 shows the post-test outcome for Test 2BD.


**Figure 33. Test 2BD Lateral Pre-test Photo**

**Figure 34. Test 2BD Lateral Post-test Photo**

### 3.6.1 Test 2BD: Post-test Observations

Figure 35. Test 2BD Workstation Table

The workstation table deformed toward the impact seats and remained attached to the wall and floor mount.

Figure 36. Test 2BD Workstation Table Front Wall Mount

The workstation table deformed at simulated front wall mount along the table leg frame.

Figure 37. Test 2BD Workstation Table Rear Wall Mount

The workstation table deformed at the rear wall mount near the impact seats.

Figure 38. Test 5 Workstation Table Floor Mount

The workstation table floor mount deformed during the event and remained secured to the floor. No separation was observed.

### 3.6.2 Test 2BD: Post-test Evaluation

Table 17 below contains the results of the APTA post-test evaluation for Test 2BD.

**Table 17. Test 2BD APTA Post-test Evaluation**

| APTA Requirement | Assessment |
|---|---|
| The table and all table components must remain attached to the test fixture or simulated railcar structure. | No table components became loose during the event. |
| The table shall not penetrate the minimum survival space of 9.7 in. reserved for occupants in the facing seat, so as not to entrap the facing passengers or prevent egress | Distance between table and seatback of the seat opposite the ATD measures 10.32 in.; therefore, it did not penetrate the survival space. |
| The ATDs shall be compartmentalized between rows of seats. | The ATDs were compartmentalized as defined in S-018. |
| All injury measurements must meet the criteria specified in S-018. | Wall-side H3-50M chest compression criterion was not met. See Table 18 below. |

### 3.6.3 Test 2BD: Human Injury Values

Table 18 below contains the human injury evaluation for Test 2BD.

**Table 18. Test 2BD Human Injury Measurements**

| Description | APTA PR-CS-S-018-13, Rev. 2 §5.2.1.3 Performance Requirements | H3-50M (Aisle) | H3-50M (Wall) |
|---|---|---|---|
| Head Injury Criteria | HIC15 ≤ 700 | 12 | 22 |
| Neck Injury Criteria | $N_{IJ}$ Compression/Extension ≤ 1.0 | 0.01 | 0.01 |
| | $N_{IJ}$ Compression/Flexion ≤ 1.0 | 0.01 | 0.15 |
| | $N_{IJ}$ Tension/Extension ≤ 1.0 | 0.22 | 0.29 |
| | $N_{IJ}$ Tension/Flexion ≤ 1.0 | 0.19 | 0.20 |
| Neck Axial Tension | $F_Z$ ≤ 4,170 N | 680 | 826 |
| Neck Axial Compression | $F_Z$ ≤ 4,000 N | 47 | 122 |
| Chest Deceleration | ≤ 60g over a 3ms clip | 17 | 19 |
| Sternum Peak Compression | < 63 mm | 45 | 84 |
| Femur Load | Left ≤ 10,000 N | 3,301 | 7,399 |
| | Right ≤ 10,000 N | 5,525 | 3,148 |

### 3.6.4 Test 2BD: Summary

The workstation table in Test 2BD was designed to bend at the table center mount upon impact. Modifications were made to the table to increase the bending moment along the wall mount. The table folded along its mount during the event as intended. After Test 2BD, significant deformation was observed in both the wall mount and table mount. There was no separation of any components during the event. The chest compression criteria for the wall-side H3-50M did not meet the minimum injury criteria. The minimum survival space was preserved during the event.

## 3.7 Test 2BQ

A fixed workstation table and provided simulated car structure was mounted to the rigid t-slot floor plates. The fixed workstation table was attached to the simulated car structure using the same fasteners and attachment mechanisms as intended for service. The hydraulic cylinders and rigid body blocks were aligned laterally at the center of each seating position and centered vertically on the table edge. The table was quasi-statically tested according to the Option B test requirements in Section 5.2.2 of the table standard at a load-controlled rate of 350 lbf/min.

Figure 39 shows the pre-test setup and Figure 40 shows the post-test outcome for Test 2BQ.

**Figure 39. Test 2BQ Lateral Pre-test Photo**

**Figure 40. Test 2BQ Lateral Post-test Photo**

### *3.7.1 Test 2BQ: Post-test Observations*

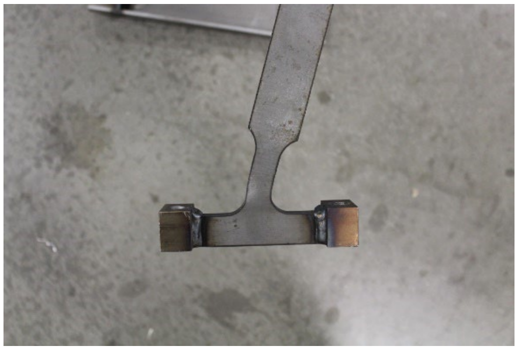


Figure 41. Test 2BQ Workstation Pedestal Floor

Deformation to the pedestal where mounted to the floor rail.

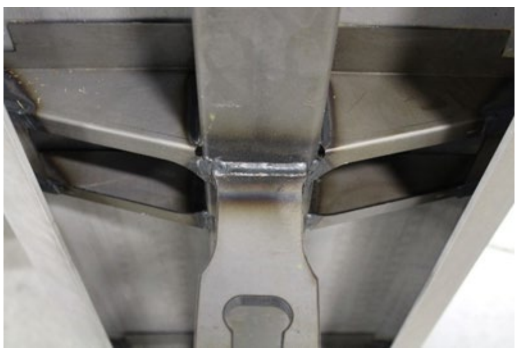


Figure 42. Test 2BQ Workstation Pedestal Table

Minimal deformation to the pedestal at the connection to the table.

Figure 43. Test 2BQ Workstation Table Wall Mount

Deformation to the workstation table where mounted to the simulated wall structure.

Figure 44. Test 2BQ Workstation Table Wall

Deformation to the workstation table where wall mount legs connect to the workstation table base.

### 3.7.2 Test 2BQ: Post-test Evaluation

Table 19 below contains the results of the APTA post-test evaluation for Test 2BQ.

**Table 19. Test 2BQ APTA Post-test Evaluation**

| APTA Requirement | Assessment |
|---|---|
| The table and any table components must remain attached to the test fixture or simulated railcar structure, with the exception of superficial nonstructural components of negligible weight that do not affect the structural integrity of the table. | The workstation table remained secured to the simulated railcar structure with no component separation. |
| For each seat position, if the seat back distance, i.e., measurement *I* in Figure 3, is greater than 57 in. (1448 mm), then the required energy absorption at each seat position is a bilinear function of *I* according to Equation 1 when *I* is in inches and Equation 2 when I is in millimeters | The workstation table did not meet the energy-absorption requirement at the aisle or wall seat position (see Table 20). |
| The allowable load limit is 2,250 lbf if: (1) the vertical distance between top of tabletop and the highest point on the unoccupied seat bottom cushion (depicted as measurement *F* in Figure 3) is greater than 11.6 in. (295 mm); and (2) the chest (sternal) rotary potentiometer in each H3-50M ATD does not malfunction (e.g., dislodge) during the dynamic sled test (Test 3BD). Otherwise, the allowable load limit is 1,800 lbf. | The rotary potentiometers did not dislodge during Test 2BD, and the minimum measurement *F* of the workstation table was approximately 317 mm (Table C5). Therefore, the allowable load limit is 2,250 lbf. |

### 3.7.3 Test 2BQ: Energy-Absorption Calculation

Table 20 contains the APTA energy-absorption evaluation for Table 2BQ.

**Table 20. Test 2BQ Energy-absorption Calculation**

| Allowed Force [lb] | Measurement I [in.] | APTA PR-CS-S-018-13, Rev. 2 §5.2.2.3 Performance Requirements | Aisle [in.-lbf] | Wall [in.-lbf] |
|---|---|---|---|---|
| 2,250 | 67.0 | ≥ 11,550 in.-lbf | 8,262 | 9,209 |

### 3.7.4 Test 2BQ: Summary

The workstation table in Test 2BQ was designed to allow for plastic deformation of the table support legs at both the wall and floor locations to absorb the impact energy of the ATDs. Due to the large amount of translation observed in this design, the hydraulic cylinders used in this test ran out of allowable stroke (250 mm) before the maximum allowable load was achieved. The quasi-static energy-absorption requirements were not met at either seat position.

## 3.8 Test 3A

A two-person passenger seat was mounted to the test sled. A facing seat was mounted to the test sled on the opposite side of the table, at the nominal seat pitch for the intended installation. A fixed workstation table was installed in the middle of the two facing seats. Bolts were used to secure the wall bracket of the table to the wall instead of rivets because the rivets were pulled out in Test 3BD. Instrumented ATDs, representative of $50^{th}$ percentile adult males, were positioned to face the direction of travel. The aisle-side (left passenger) ATD was an H3-50M, and the wall-side (right passenger) ATD was a THOR-50M, as specified in Option A of APTA S-018.

Figure 45 shows the pre-test setup and Figure 46 shows the post-test outcome for Test 3A.

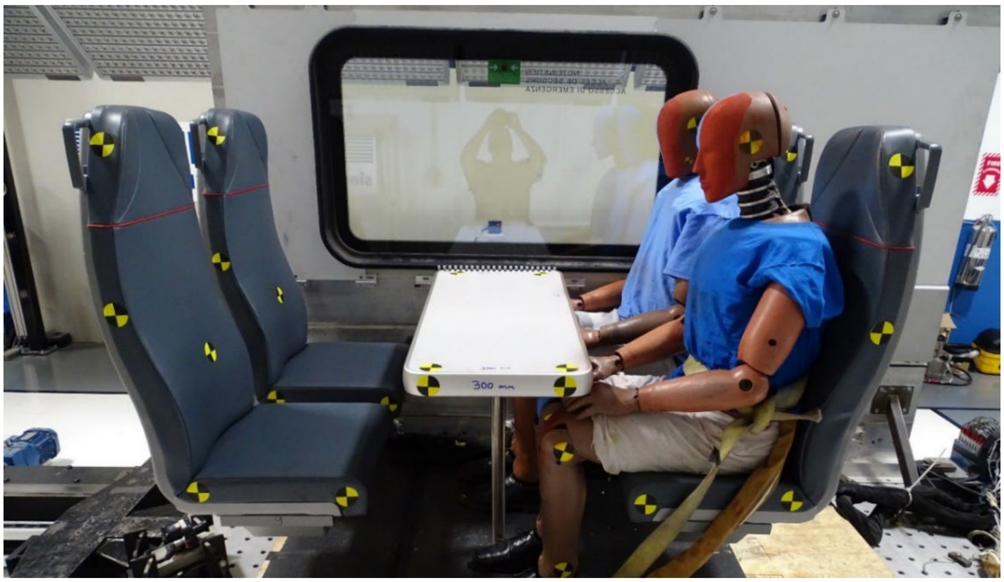


**Figure 45. Test 3A Lateral Pre-test Photo**

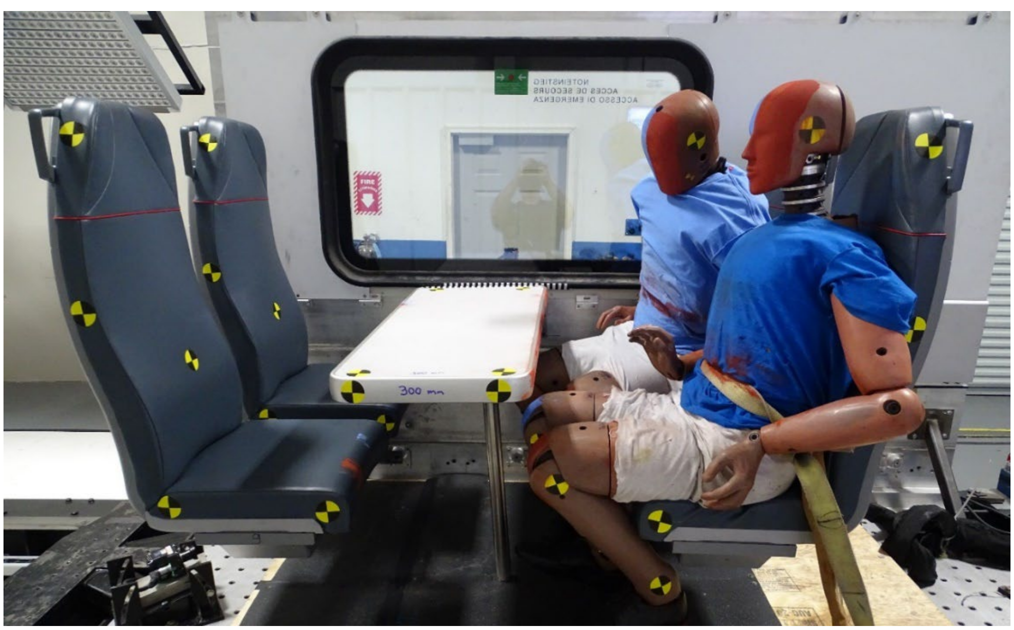


**Figure 46. Test 3A Lateral Post-test Photo**

### *3.8.1 Test 3A: Post-test Observations*


**Figure 47. Test 3A Impact Seat**

There were no structural issues observed on the impact seats during the event.

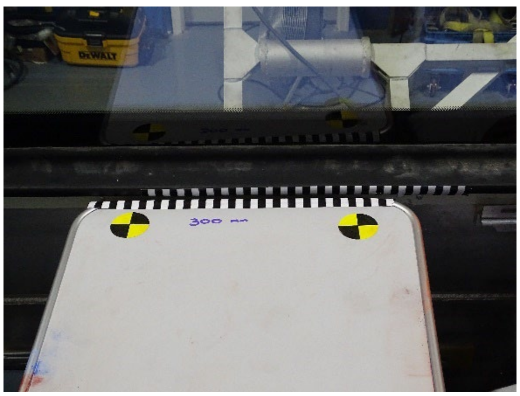



**Figure 48. Test 3A Workstation Table Top**

The workstation table translated approximately 100 mm, as was observed on the inch tape, along the simulated wall mount.

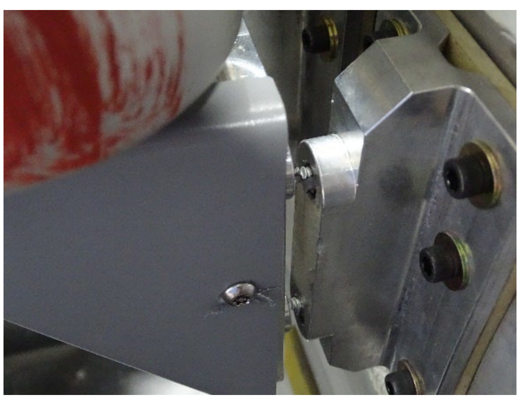


**Figure 49. Test 3A Workstation Table Wall Mount**

The workstation table separated from the simulated wall mount at two separate locations. The wall mount bolts broke off the table mounting locations during the event.

Figure 50. Test 3A Workstation Table Floor Mount

The workstation table floor mount remained attached to the floor mounting position. The workstation table post bent slightly toward the impact seat during the event.

### 3.8.2 Test 3A: Post-test Evaluation

Table 21 below contains the results of the APTA post-test evaluation for Test 3A.

**Table 21. Test 3A APTA Post-test Evaluation**

| APTA Requirement | Assessment |
|---|---|
| The table and all table components must remain attached to the test fixture or simulated railcar structure. | The table detached from wall mounting at two separate locations due to rivets failing at mounting locations, but did not separate from the wall. |
| The table shall not penetrate the minimum survival space of 9.7 in. reserved for occupants in the facing seat, so as not to entrap the facing passengers or prevent egress. | Distance between table and seatback of the seat opposite the ATD measured 10.00 in.; therefore, it did not penetrate survival space. |
| The ATDs shall be compartmentalized between rows of seats. | The ATDs were compartmentalized as defined in S-018. |
| All injury measurements must meet the criteria specified in S-018. | THOR-50M left abdomen peak deflection criteria not met. |

### 3.8.3 Test 3A: Human Injury Values

Table 22 below contains the human injury evaluation for Test 3A.

**Table 22. Test 3A Human Injury Measurements**

| Description | APTA PR-CS-S-018-13, Rev. 2 §5.2.1.3 Performance Requirements | H3-50M (Aisle) | THOR-50M (Wall) |
|---|---|---|---|
| Head Injury Criteria | HIC15 ≤ 700 | 39 | 132 |
| Neck Injury Criteria | $N_{IJ}$ Compression/Extension ≤ 1.0 | 0.2 | 0.01 |
| | $N_{IJ}$ Compression/Flexion ≤ 1.0 | 0.18 | 0.19 |
| | $N_{IJ}$ Tension/Extension ≤ 1.0 | 0.37 | 0.32 |
| | $N_{IJ}$ Tension/Flexion ≤ 1.0 | 0.42 | 0.28 |
| Neck Axial Tension | $F_z$ ≤ 4,170 N | 2,701 | 1,023 |
| Neck Axial Compression | $F_z$ ≤ 4,000 N | 1,147 | 758 |
| Chest Deceleration | ≤ 60g over a 3ms clip | 24 | 20 |
| Sternum Peak Compression | < 63 mm | 18 | |
| Upper-Left Chest Peak Deflection | < 70 mm | | 9 |
| Upper-Right Chest Peak Deflection | < 70 mm | | 3 |
| Lower-Left Chest Peak Deflection | < 70 mm | | 15 |
| Lower-Right Chest Peak Deflection | < 70 mm | | 23 |
| Left Abdomen Peak Deflection | < 86 mm | | 97 |
| Right Abdomen Peak Deflection | < 86 mm | | NVD† |
| Femur Load | Left ≤ 10,000 N | 1,821 | 3,079 |
| | Right ≤ 10,000 N | 2,555 | 1,415 |

†No value declared because right abdomen IR-TRACC was damaged during impact.

### *3.8.4 Test 3A: Summary*

The workstation table in Test 3A was designed to translate while supported by a cantilever attached to a side-wall cutout. A steel bracket was bolted to the simulated carbody wall to hold the wall mounts in position after the rivets failed during Test 3BD. The table translated along the wall mounts during the event. The bolts in two locations along the wall mount broke off from the simulated carbody. No components separated from the workstation table during the event. The THOR-50M left abdominal peak deflection criterion was not met. The THOR-50M sensor for the right abdomen was damaged during the event, resulting in an invalid reading. The minimum survival space remained intact during the event.

## 3.9 Test 3BD

A two-person passenger seat was mounted to the test sled. A facing seat was mounted to the test sled on the opposite side of the table, at the nominal seat pitch for the intended installation. A fixed workstation table was installed in the middle of the two facing seats. Instrumented ATDs, representative of 50th percentile adult males, were positioned to face the direction of travel. Both ATDs were H3-50Ms, as specified in Option B of APTA S-018.

Figure 51 shows the pre-test setup and Figure 52 shows the post-test outcome for Test 3BD.

**Figure 51. Test 3BD Lateral Pre-test Photo**

**Figure 52. Test 3BD Lateral Post-test Photo**

### *3.9.1 Test 3BD: Post-test Observations*

**Figure 53. Test 3BD Workstation Table Wall Mount Brackets**

The wall mount bracket rivets were pulled from the simulated wall mount during the event on the two rearmost brackets. The workstation table translated approximately 90 mm, as was observed on the inch tape, along the simulated wall mount.

**Figure 54. Test 3BD Wall Panel**

The wall panel cracked due to the wall mount brackets being disconnected from the wall.

**Figure 55. Test 3BD Rivet Holes**

The wall panel was removed to show the deformation around the rivet holes of the table mount rivets.

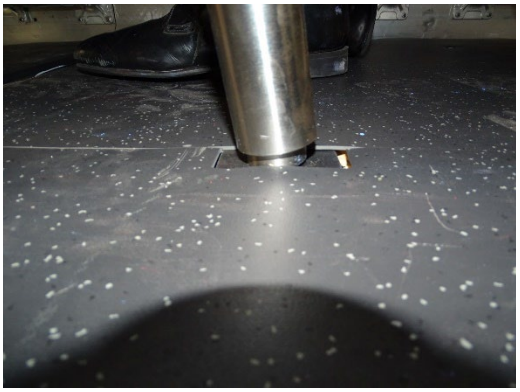


**Figure 56. Test 3BD Workstation Table Floor Mount**

The workstation table floor mount deformed slightly during the event and remained secured to the floor. No separation was observed.

### *3.9.2 Test 3BD: Post-test Evaluation*

Table 23 below contains the results of the APTA post-test evaluation for Test 3BD.

**Table 23. Test 3BD APTA Post-test Evaluation**

| APTA Requirement | Assessment |
|---|---|
| The table and all table components must remain attached to the test fixture or simulated railcar structure. | Two rearmost wall mount brackets were disconnected from wall, but the table did not fully detach from the simulated car structure. |
| The table shall not penetrate the minimum survival space of 9.7 in. reserved for occupants in the facing seat, so as not to entrap the facing passengers or prevent egress. | Distance between table and seatback of the seat opposite the ATD measures 7.8 in.; therefore, it did penetrate survival space. |
| The ATDs shall be compartmentalized between rows of seats. | The ATDs were compartmentalized as defined in S-018. |
| All injury measurements must meet the criteria specified in S-018. | All human injury requirements were met† (see Table 24). |

†Note that the table slid under the ribs of the H3-50Ms and did not engage the chest compression transducers.

### 3.9.3 Test 3BD: Human Injury Values

Table 24 below contains the human injury evaluation for Test 3BD.

**Table 24. Test 3BD Human Injury Measurements**

| Description | APTA PR-CS-S-018-13, Rev. 2 §5.2.1.3 Performance Requirements | H3-50M ATD (Aisle) | H3-50M ATD (Wall) |
|---|---|---|---|
| Head Injury Criteria | HIC15 ≤ 700 | 21 | 46 |
| Neck Injury Criteria | $N_{IJ}$ Compression/Extension ≤ 1.0 | 0.18 | 0.19 |
| | $N_{IJ}$ Compression/Flexion ≤ 1.0 | 0.02 | 0.17 |
| | $N_{IJ}$ Tension/Extension ≤ 1.0 | 0.35 | 0.41 |
| | $N_{IJ}$ Tension/Flexion ≤ 1.0 | 0.30 | 0.39 |
| Neck Axial Tension | $F_z$ ≤ 4,170 N | 2,025 | 2,522 |
| Neck Axial Compression | $F_z$ ≤ 4,000 N | 917 | 1,080 |
| Chest Deceleration | ≤ 60g over a 3ms clip | 22 | 21 |
| Sternum Peak Compression | < 70 mm | 15[†] | 16[†] |
| Femur Load | Left ≤ 10,000 N | 2,717 | 969 |
| | Right ≤ 10,000 N | 1,435 | 606 |

[†]Note that the table slid under the ribs of the H3-50Ms and did not engage the chest compression transducers.

### 3.9.4 Test 3BD: Summary

The workstation table in Test 3BD was designed to translate along the simulated carbody at the wall mount position. Upon impact, the rivets used for the wall mounting brackets failed. Each wall mounting bracket was intended to have six rivets but were installed only using four – which resulted in two brackets pulling off the wall mount. This caused the workstation table to slide underneath the ribs of both H3-50Ms. The injury criteria were met, but there was limited contact with the chest sensors due to the table sliding lower than expected with respect to the ribs. The minimum survival space was not preserved during the test. The table edge on the aisle-side came within 7.8 inches of the opposing seatback during the test.

## 3.10 Test 3BQ

A fixed workstation table and simulated car structure was mounted to the rigid t-slot floor plates. Bolts were used to secure the wall bracket of the table to the wall instead of rivets because the rivets pulled out in Test 3BD. The hydraulic cylinders and rigid body blocks were aligned laterally at the center of each seating position and centered vertically on the table edge. The table was quasi-statically tested according to the Option B test requirements in Section 5.2.2 of the table standard at a load-controlled rate of 350 lbf/min.

Figure 57 shows the pre-test setup and Figure 58 shows the post-test outcome for Test 3BQ.

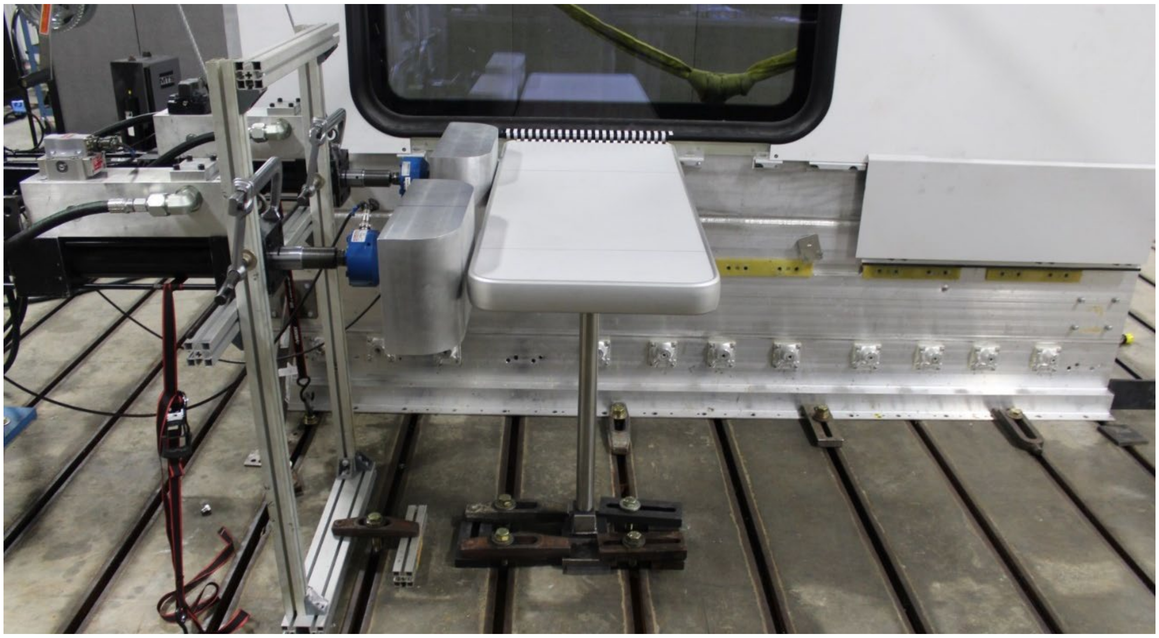


**Figure 57. Test 3BQ Lateral Pre-test Photo**

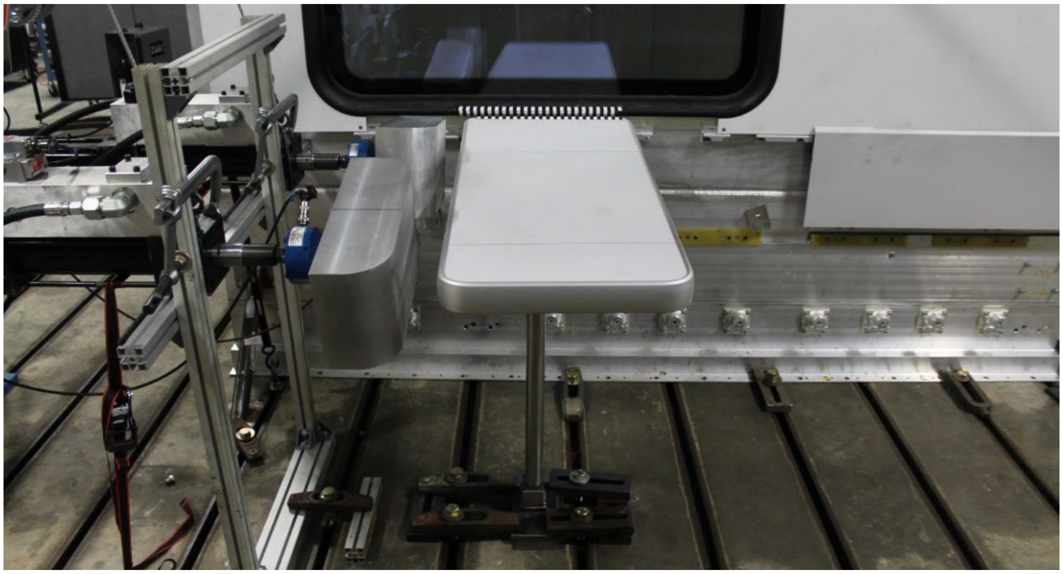


**Figure 58. Test 3BQ Lateral Post-test Photo**

### *3.10.1 Test 3BQ: Post-test Observations*

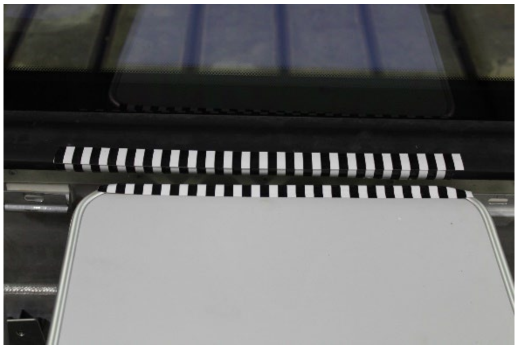


Figure 59. Test 3BQ Workstation Table Overhead

The workstation table translated approximately 20 mm, as was observed on the inch tape, along the simulated wall structure.

Figure 60. Test 3BQ Workstation Table Below

The workstation table translated as designed in the direction of loading.

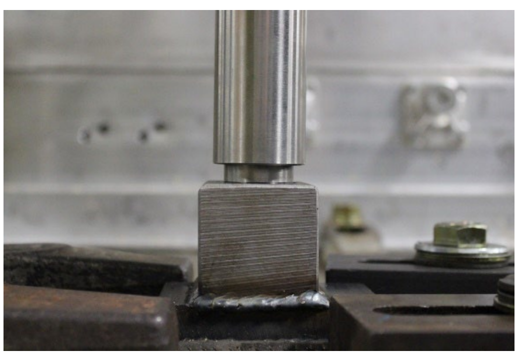


Figure 61. Test 3BQ Pedestal Floor Mount

The pedestal floor mount had minimal deformation following loading.

### *3.10.2 Test 3BQ: Post-test Evaluation*

Table 25 below contains the results of the APTA post-test evaluation for Test 3BQ.

**Table 25. Test 3BQ APTA Post-test Evaluation**

| APTA Requirement | Assessment |
|---|---|
| The table and all table components must remain attached to the test fixture or simulated railcar structure, with the exception of superficial nonstructural components of negligible weight that do not affect the structural integrity of the table. | The workstation table remained secured to the simulated railcar structure with no component separation. |
| For each seat position, if the seat back distance, i.e., measurement *I* in Figure 3 is less than or equal to 57 in. (1448 mm), then the energy absorbed, as calculated above, must be at least 6250 in.-lbf (706.2 J). | The workstation table did not meet the energy-absorption requirement at the aisle or wall seat position (see Table 26). |
| The allowable load limit is 2,250 lbf if: (1) the vertical distance between top of tabletop and the highest point on the unoccupied seat bottom cushion (depicted as measurement *F* in Figure 3) is greater than 11.6 in. (295 mm); and (2) the chest (sternal) rotary potentiometer in each H3-50M ATD does not malfunction (e.g., dislodge) during the dynamic sled test (Test 3BD). Otherwise, the allowable load limit is 1,800 lbf. | The rotary potentiometers did not dislodge during Test 3BD; however, the minimum measurement *F* of the workstation table was approximately 253 mm (Table C7). Therefore, the allowable load limit is 1,800 lbf. |

### *3.10.3 Test 3BQ: Energy-Absorption Calculation*

Table 26 contains the APTA energy-absorption evaluation for Table 1BQ.

**Table 26. Test 3BQ Energy-absorption Calculation**

| Allowed Force [lbf] | Measurement I [in.] | APTA PR-CS-S-018-13, Rev. 2 §5.2.2.3 Performance Requirements | Aisle [in.-lbf] | Wall [in.-lbf] |
|---|---|---|---|---|
| 1,800 | 56.4 | ≥ 6,250 in.-lbf | 2,842 | 1,788 |

### *3.10.4 Test 3BQ: Summary*

The workstation table in Test 3BQ was designed to translate while supported by a wall-mounted cantilever. The table achieved less than half its designed stroke before the maximum allowable load (8,000 N) was achieved at each seat position. Due to the limited amount of displacement of this table, the quasi-static energy-absorption requirements were not met at either seat position.

## 3.11 Test 4A

A two-person passenger seat was mounted to the test sled. A facing seat was mounted to the test sled on the opposite side of the table, at the nominal seat pitch for the intended installation. A fixed workstation table was installed in the middle of the two facing seats. Instrumented ATDs, representative of 50th percentile adult males, were positioned to face the direction of travel. The aisle-side (left passenger) ATD was an H3-50M, and the wall-side (right passenger) ATD was a THOR-50M as specified in Option A of APTA S-018.

Figure 62 shows the pre-test setup and Figure 63 shows the post-test outcome for Test 4A.

**Figure 62. Test 4A Lateral Pre-test Photo**

**Figure 63. Test 4A Lateral Post-test Photo**

### *3.11.1 Test 4A: Post-test Observations*

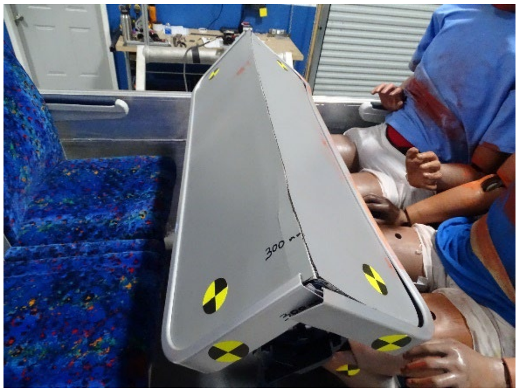


Figure 64. Test 4A Workstation Table

The workstation table folded upwards along the mid-table line upon impact during the event. Fractures were observed in tabletop post-test.

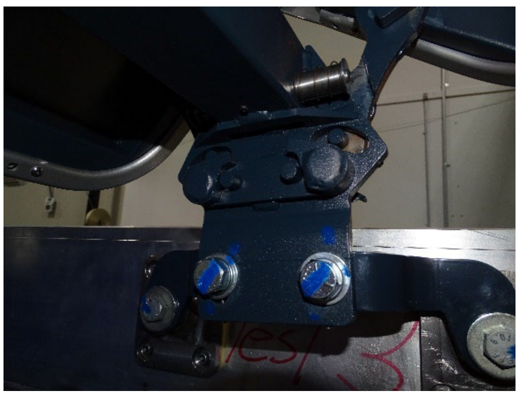


Figure 65. Test 4A Workstation Table Floor Mount

The bolts that attached the workstation table to the wall mounting bracket rotated partially during event.

Figure 66. Test 4A Workstation Table Floor Mount

There were no structural issues observed with the workstation table floor mount.

### 3.11.2 Test 4A: Post-test Evaluation

Table 27 below contains the results of the APTA post-test evaluation.

**Table 27. Test 4A APTA Post-test Evaluation**

| APTA Requirement | Assessment |
|---|---|
| The table and all table components must remain attached to the test fixture or simulated railcar structure. | No table components became loose during the event. |
| The table shall not penetrate the minimum survival space of 9.7 in. reserved for occupants in the facing seat, so as not to entrap the facing passengers or prevent egress. | Distance between table and seatback of the seat opposite the ATD measures 17.72 in.; therefore, it did not penetrate survival space. |
| The ATDs shall be compartmentalized between rows of seats. | The ATDs were compartmentalized as defined in S-018. |
| All injury measurements must meet the criteria specified in S-018. | All human injury requirements were met (see Table 28). Note that the results from the aisle-side H3-50M chest potentiometer looked like it had a pinched wire, so the authors excluded that portion of test data from the evaluation. Also note that the right abdomen IR-TRACC on the THOR-50M malfunctioned during the test. |

### 3.11.3 Test 4A: Human Injury Values

Table 28 below contains the human injury evaluation for Test 4A.

**Table 28. Test 4A Human Injury Requirements**

| Description | APTA PR-CS-S-018-13, Rev. 2 §5.2.1.3 Performance Requirements | H3-50M (Aisle) | THOR-50M (Wall) |
|---|---|---|---|
| Head Injury Criteria | HIC15 ≤ 700 | 79 | 86 |
| Neck Injury Criteria | $N_{IJ}$ Compression/Extension ≤ 1.0 | 0.09 | 0.13 |
| | $N_{IJ}$ Compression/Flexion ≤ 1.0 | 0.11 | 0.31 |
| | $N_{IJ}$ Tension/Extension ≤ 1.0 | 0.52 | 0.50 |
| | $N_{IJ}$ Tension/Flexion ≤ 1.0 | 0.25 | 0.35 |
| Neck Axial Tension | $F_z$ ≤ 4,170 N | 1,196 | 1,698 |
| Neck Axial Compression | $F_z$ ≤ 4,000 N | 578 | 437 |
| Chest Deceleration | ≤ 60g over a 3ms clip | 21 | 31 |
| Sternum Peak Compression | < 63 mm | 55† | |
| Upper-Left Chest Peak Deflection | < 70 mm | | 41 |
| Upper-Right Chest Peak Deflection | < 70 mm | | 45 |
| Lower-Left Chest Peak Deflection | < 70 mm | | 51 |
| Lower-Right Chest Peak Deflection | < 70 mm | | 66 |
| Left Abdomen Peak Deflection | < 86 mm | | 34 |
| Right Abdomen Peak Deflection | < 86 mm | | NVD†† |
| Femur Load | Left ≤ 10,000 N | 3,362 | 4,269 |
| | Right ≤ 10,000 N | 5,512 | 3,207 |

†H3-50M sternum rotary potentiometer had a pinched wire before actual peak compression that was excluded from evaluation.
††No value declared because right abdomen IR-TRACC malfunctioned.

### *3.11.4 Test 4A: Summary*

The table developed for Test 10 was designed to fold along the length of the table to absorb the impact of the passengers. The table folded on impact as designed. No structural issues were observed. All injury criteria requirements were met for both occupants. The wire for the H3-50M rotary chest potentiometer was pinched during the event and that portion of the test data was excluded from the evaluation because it did not occur during peak compression.

### 3.12 Test 5A

A two-person passenger seat was mounted to the test sled. A facing seat was mounted to the test sled on the opposite side of the table, at the nominal seat pitch for the intended installation. A fixed workstation table was installed in the middle of the two facing seats. Instrumented ATDs, representative of 50th percentile adult males, were positioned to face the direction of travel. The aisle-side (left passenger) ATD was an H3-50M, and the wall-side (right passenger) ATD was a THOR-50M, as specified in Option A of APTA S-018.

Figure 67 shows the pre-test setup and Figure 68 shows the post-test outcome for Test 5A.

**Figure 67. Test 5A Lateral Pre-test Photo**

**Figure 68. Test 5A Lateral Post-test Photo**

### *3.12.1 Test 5A: Post-test Observations*

**Figure 69. Test 5A Impact Seat**

Only the aisle-side ATD's knees contacted the impact seat during the event. No structural issues were observed.

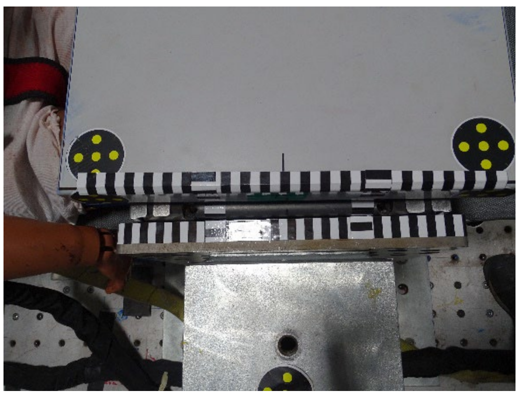


**Figure 70. Test 5A Workstation Table Wall Mount**

No structural issues were observed along the simulated wall mount of the workstation table.

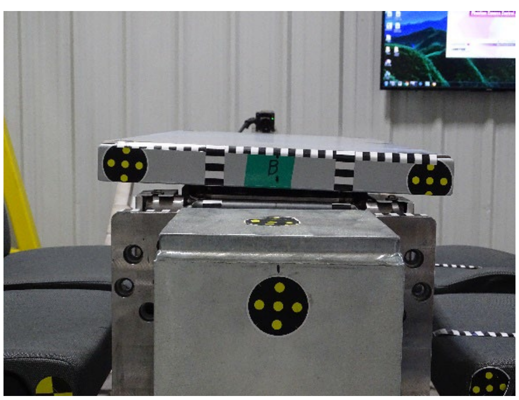


**Figure 71. Test 5A Workstation Table**

The workstation table became slightly deformed during the event. The table was angled slightly toward the impact seat post-test.

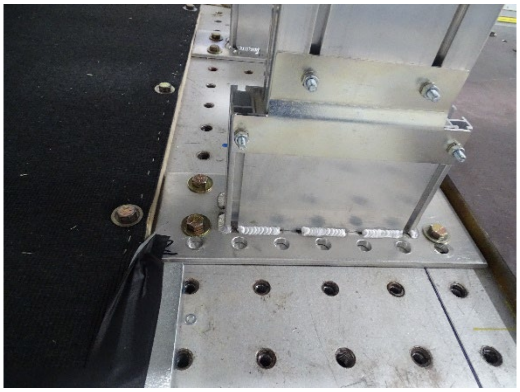


Figure 72. Test 5A Impact Seat Pedestal

No structural issues were observed along the impact seat pedestal.

### *3.12.2 Test 5A: Post-test Evaluation*

Table 29 below contains the results of the APTA post-test evaluation.

**Table 29. Test 5A APTA Post-test Evaluation**

| APTA Requirement | Assessment |
|---|---|
| The table and all table components must remain attached to the test fixture or simulated railcar structure. | No table components became loose during the event. |
| The table shall not penetrate the minimum survival space of 9.7 in. reserved for occupants in the facing seat, so as not to entrap the facing passengers or prevent egress. | Distance between table and seatback of the seat opposite the ATD measures 11.81 in.; therefore, it did not penetrate survival space. |
| The ATDs shall be compartmentalized between rows of seats. | The ATDs were compartmentalized as defined in S-018. |
| All injury measurements must meet the criteria specified in S-018. | The guide ball on the rotary potentiometer came out of the guide track behind the sternum during the test, so the H3-50M sternum compression measurement is invalid. All human injury requirements were met (see Table 30). |

### 3.12.3 Test 5A: Human Injury Values

Table 30 below contains the human injury evaluation for Test 5A.

**Table 30. Test 5A Human Injury Measurements**

| Description | APTA PR-CS-S-018-13, Rev. 2 §5.2.1.3 Performance Requirements | H3-50M (Aisle) | THOR-50M (Wall) |
|---|---|---|---|
| Head Injury Criteria | HIC15 ≤ 700 | 44 | 548 |
| Neck Injury Criteria | $N_{IJ}$ Compression/Extension ≤ 1.0 | 0.01 | 0.14 |
| | $N_{IJ}$ Compression/Flexion ≤ 1.0 | 0.08 | 0.20 |
| | $N_{IJ}$ Tension/Extension ≤ 1.0 | 0.24 | 0.32 |
| | $N_{IJ}$ Tension/Flexion ≤ 1.0 | 0.22 | 0.31 |
| Neck Axial Tension | $F_z$ ≤ 4,170 N | 1,101 | 1,055 |
| Neck Axial Compression | $F_z$ ≤ 4,000 N | 255 | 1,006 |
| Chest Deceleration | ≤ 60g over a 3ms clip | 32 | 33 |
| Sternum Peak Compression | < 63 mm | NVD† | |
| Upper-Left Chest Peak Deflection | < 70 mm | | 18 |
| Upper-Right Chest Peak Deflection | < 70 mm | | 23 |
| Lower-Left Chest Peak Deflection | < 70 mm | | 49 |
| Lower-Right Chest Peak Deflection | < 70 mm | | 57 |
| Left Abdomen Peak Deflection | < 86 mm | | 83 |
| Right Abdomen Peak Deflection | < 86 mm | | 84 |
| Femur Load | Left ≤ 10,000 N | 2,615 | 3,166 |
| | Right ≤ 10,000 N | 4,177 | 2,176 |

†No value declared because H3-50M rotary potentiometer had a pinched wire, and the guide ball dislodged from the track.

### 3.12.4 Test 5A: Summary

The workstation table developed for Test 11 was designed to translate along the simulated carbody at the wall mount position. The table translated as designed upon impact by the ATDs. As the ATDs rebounded, the table returned to its original position. No structural issues were observed during the event. The human injury criteria were met for the THOR-50M and H3-50M, but the H3-50M rotary chest potentiometer malfunctioned when the radial arm dislodged from the base, resulting in an invalid reading.

# 4. Discussion

Table 31 summarizes the compliance of each table design for Options A and B of the table standard. Table 1 met the requirements in Option A but not B. It is possible that Table 1 could also meet the requirements for Options B – if consistent function of the wall mount energy-absorption system could be achieved. Tables 2 and 3 did not fully meet the requirements of Options A or B. Table 4 was the only table design tested per Options A and B that met all requirements; however, the Table 4 Option B test results presented below in Table 31 were not performed as part of this test series and were shared by the manufacturer. Table 5 met the requirements of Option A but could not be tested per Option B due to limitations of the quasi-static test procedure.

**Table 31. APTA S-018 Compliance Matrix for Table Designs**

| Table Design | Option A & B | Option A Dynamic | Option B Dynamic | Option B Quasi-Static |
|---|---|---|---|---|
| **Table 1** | No | Yes | No | No |
| **Table 2** | No | No | No | No |
| **Table 3** | No | No | No | No |
| **Table 4** | Yes | Yes | Yes | Yes |
| **Table 5** | N/A | Yes | N/A | N/A |

Table 1 was dynamically tested 3 times but only passed in Test 1A* because the wall mount of the table failed to translate in Test 1A and Test 1BD. In comparing the pre- and post-test measurements for the distance between the rear-facing wall seat and the tabletop (wall-side measurement B in Figure 3), the table translated 121, 292, and 133 mm in Tests 1A, 1A*, and 1BD, respectively. Therefore, the authors concluded the table only fully engaged the wall bracket energy-absorption system in Test 1A* where it was able to translate more than double the distance measured post-test at the wall seat position for the other two tests. The table manufacturer has advised that the complete side wall assembly, including the thermoplastic side wall covering, may be necessary for the energy absorption system to consistently perform as intended.

Table 32 shows normalized Option A injury criteria and Option B quasi-static energy-absorption for the three table designs tested per Option A and B in this test series. Since Table 1 malfunctioned during its first Option A test (Test 1A), the results from the second test are shown (Test 1A*). Option B quasi-static energy-absorption was normalized at each seat position by dividing the measured peak energy-absorption (up to the allowable load) by the required energy-absorption. Option A injury criteria were normalized for the H3-50M (aisle) by dividing the allowable sternum compression by the measured peak sternum compression. For the THOR-50M (wall), the sensor location with the highest injury criterion was identified and its peak value was used to divide the allowable limit (i.e., 70 mm for a chest sensor and 86 mm for an abdomen sensor). Thus, any normalized value greater than or equal to 1.0 met the requirements, and conversely, any normalized value less than 1.0 did not meet the requirements.

**Table 32. Normalized Option A Injury Criteria and Option B Quasi-static Energy Absorptions**

| Table Design | Aisle | Aisle | Wall | Wall |
|---|---|---|---|---|
| | Option A Injury Criteria | Option B Energy-Absorption | Option A Injury Criteria | Option B Energy-Absorption |
| **Table 1** | 1.13 | 1.00† | 1.03 | 0.55† |
| **Table 2** | 1.15 | 0.72 | 0.97 | 0.80 |
| **Table 3** | 3.5 | 0.45 | 0.72 | 0.29 |

†Table 1 energy-absorption system malfunctioned during quasi-static test due to wall-side bracket support twisting.

The H3-50M in the aisle seat did not exceed any injury criteria in the three Option A tests shown above. This was likely a result of the occupant in the aisle seat experiencing lower contact forces from the table, since tables are typically stiffer at the wall seat position closer to the wall bracket. Also, the H3-50M has only a single deflection sensor in the chest and abdomen (located at the sternum), whereas the THOR-50M has four deflection sensors in the chest and two deflection sensors in the abdomen. Tables which impact far from the sternum (i.e., low tables) typically result in low peak sternum compression. Table 3 is an example of this situation, where the peak sternum compression of the H3-50M as only 18 mm, but the peak abdomen compression for the THOR-50M was 97 mm. This discrepancy in measured injury from the two ATDs demonstrates the need for a quasi-static energy-absorption evaluation when testing exclusively with H3-50M ATDs.

The results of the test series indicate an improvement in the safety equivalency between Options A and B in Revision 2 of the table standard over Revision 1, which was evaluated previously [15, 17, 18]. In testing anonymously donated tables per Revision 1 of the table standard, none of the tables met all requirements for Option A, even when some tables met the Option B quasi-static requirements. By increasing the energy-absorption requirements in Revision 2 of the standard, tables are less likely to pass Option B, but fail Option A. This was desirable for the APTA Construction & Structural Working Group because Option A directly evaluates chest and abdomen injury criteria at more anatomic locations with advanced frontal crash ATDs (i.e., H3-RS or THOR-50M) while Option B is limited to sternal compression (H3-50M). When more H3-RS and THOR-50M ATDs are available for table sled tests, current working group members intend to remove Option B.

## 4.1 Survival Space Evaluation

The authors evaluated the survival space in the nine sled tests after having conducted all of the sled tests. After the sled tests, the authors realized that a post-test review of the overhead camera footage would have been improved had the reference markers (placed at the center of each seatback at tabletop height) been placed at the left and right sides of each seatback, since the sides of the seats extend closer to the table than the center. A side-view camera from the aisle would have been an even better option, as the aisle side of the table almost always experiences the greatest survival space impingement. While there were side-view cameras in all of the sled tests, they were centered on the table and not on the survival space. Since the side-view cameras were not centered on the survival space (i.e., the gap between the rear-facing seat and table), they could not be used to evaluate survival space reliably without distortion effects from the lens. In future testing, the authors recommend positioning a camera centered on the survival space at the height of the tabletop, with a reference-length scale in the plane of the outboard edge of the table near the height of the tabletop. In most cases, inch-tape (or something similar) could be placed on the outboard edge of the tabletop or on the aisle armrest.

# 5. Conclusion

This series tested the structural integrity of passenger railcar interior equipment, the compartmentalization of occupant ATDs, the energy absorption capabilities of crashworthy workstation tables, and the injury criteria resulting from dynamic impacts. The objective of this test series was to conduct dynamic and quasi-static workstation table tests according to APTA PR-CS-S-018-13, Rev. 2 and compare the safety equivalency of Options A and B in the revised standard. Of the five table designs tested, three designs met the requirements in either Option A or B of the revised standard. Of those five table designs, three table designs were tested to both Option A and B and none of them met all the requirements in both options. However, Table 4, tested only to Option A in this test series, is known to have passed Option B in testing performed by the manufacturer. Also, Table 1 may have passed Option B had it not malfunctioned during the dynamic and quasi-static Option B tests.

The authors conclude that Options A and B in Revision 2 of the table standard are closer to being equivalent than in Revision 1. Additional testing could be undertaken to further refine the performance requirements and improve the safety equivalency of both options; however, it is expected that Option A will become the preferred option for testing now that the H3-RS and THOR-50M ATDs are more widely available for workstation table testing. When the APTA Construction & Structural Working Group feels that the availability of the advanced frontal crash ATDs is acceptable, the authors recommend removing Option B so that (1) the safety equivalency of the options is now longer of concern, and (2) abdomen injury criteria can be directly evaluated using the advanced ATDs.

# 6. References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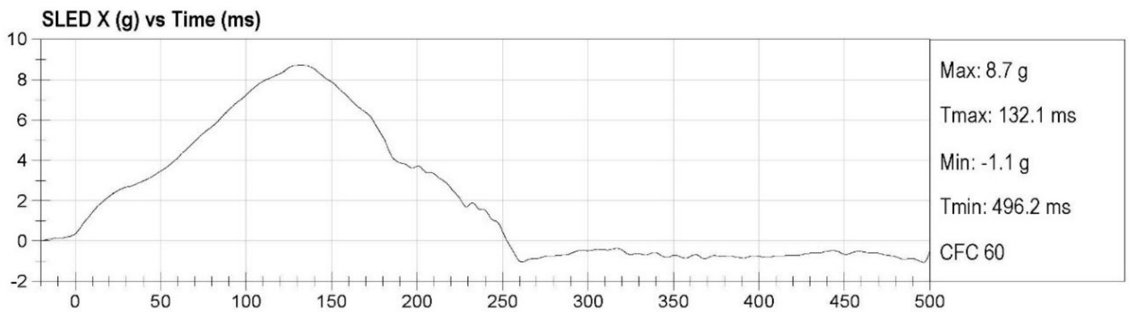
# Appendix A. Test Data

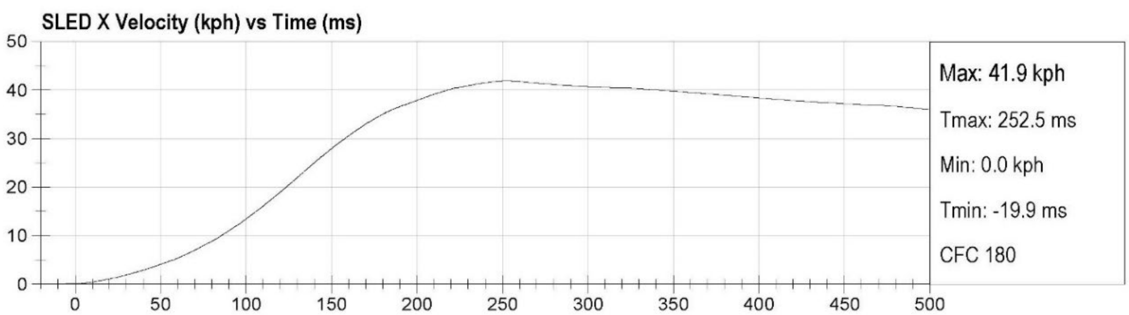
The following contains the full test data for the reported sled and quasi-static tests. Left Rail Passenger (LRP) refers to the ATD in the aisle-side seat. Right Rail Passenger (RRP) refers to the ATD in the wall-side seat.

## A.1: Test 1A Data

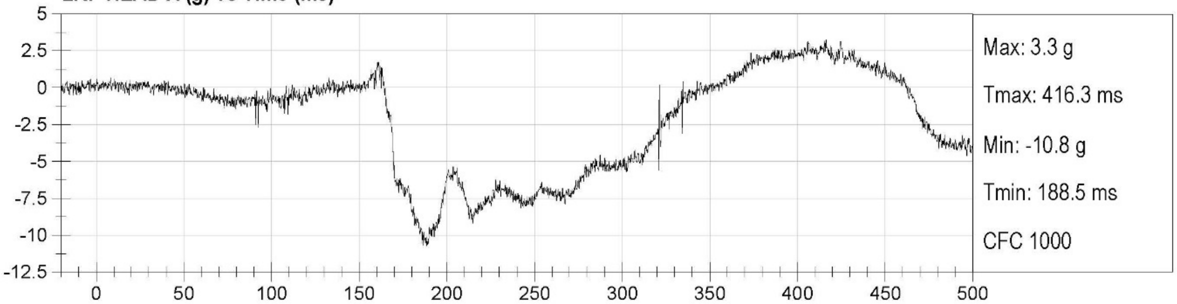
Test Date: 05/04/2021

MGA Test ID: S21137

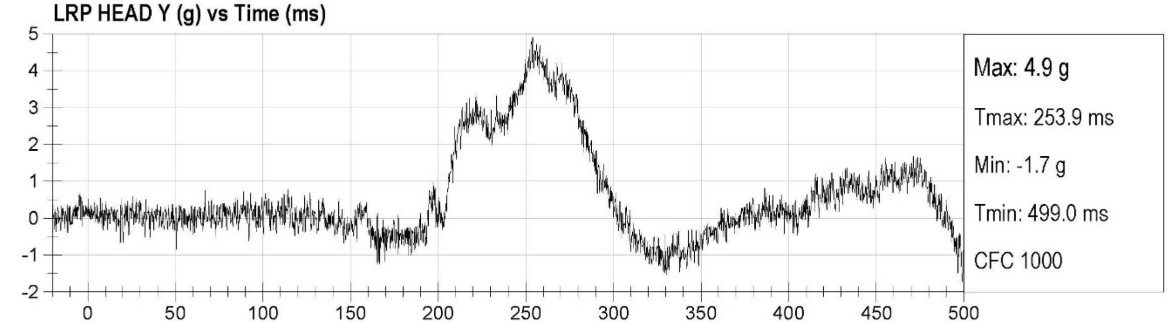


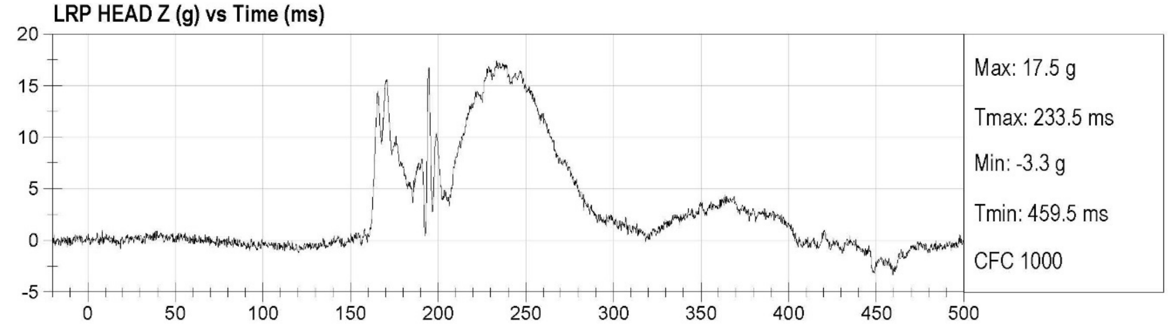
LRP HEAD X (g) vs Time (ms)



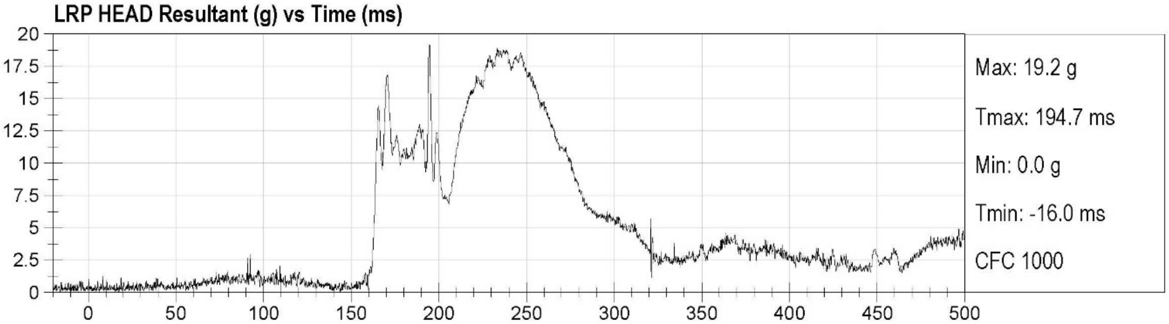

LRP HEAD Y (g) vs Time (ms)



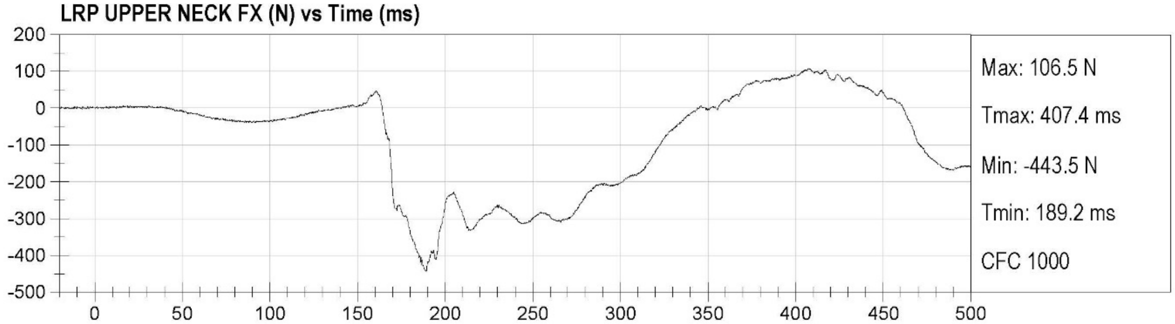

LRP HEAD Z (g) vs Time (ms)




LRP HEAD Resultant (g) vs Time (ms)



LRP UPPER NECK FX (N) vs Time (ms)

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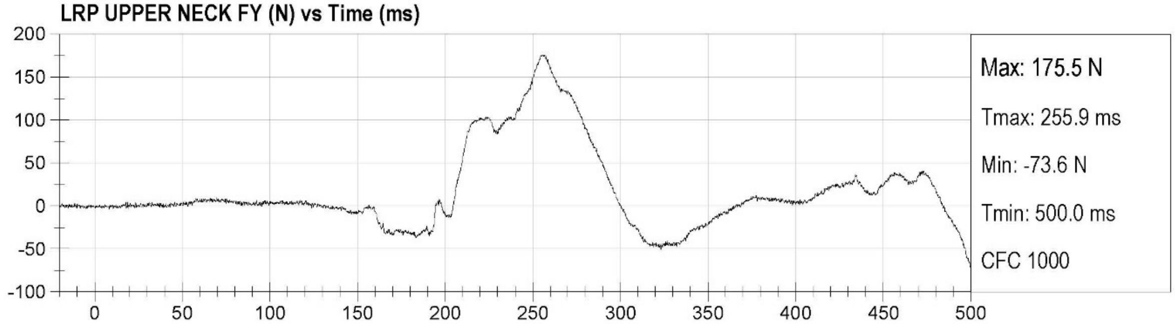
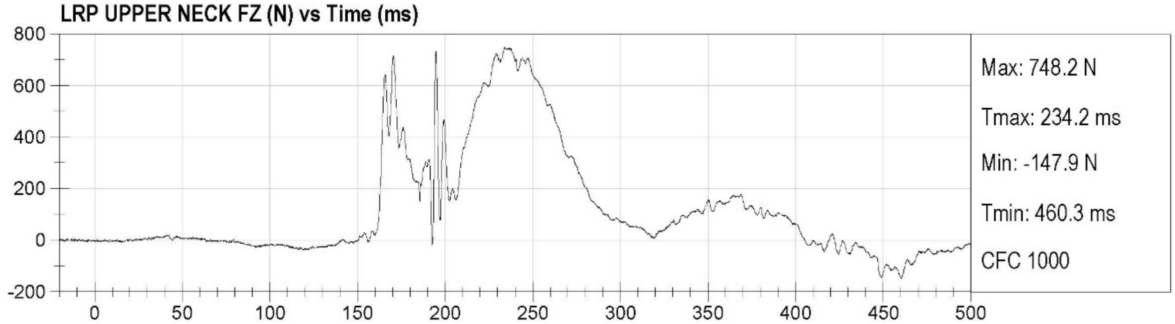
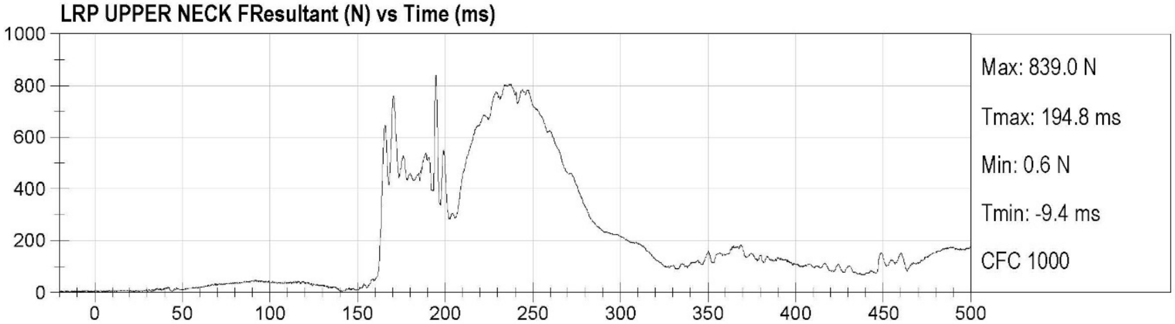


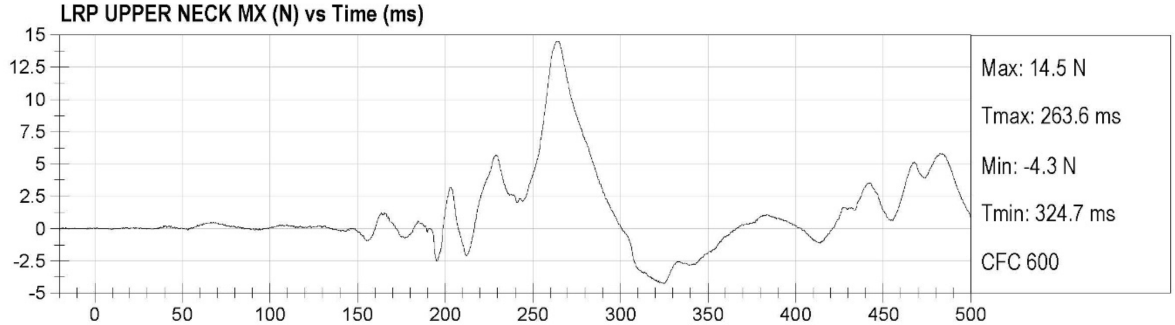

LRP UPPER NECK FZ (N) vs Time (ms)



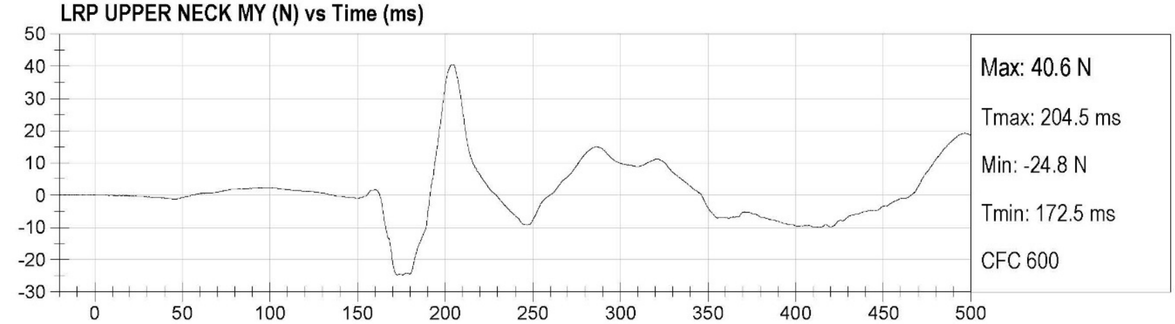

LRP UPPER NECK FResultant (N) vs Time (ms)



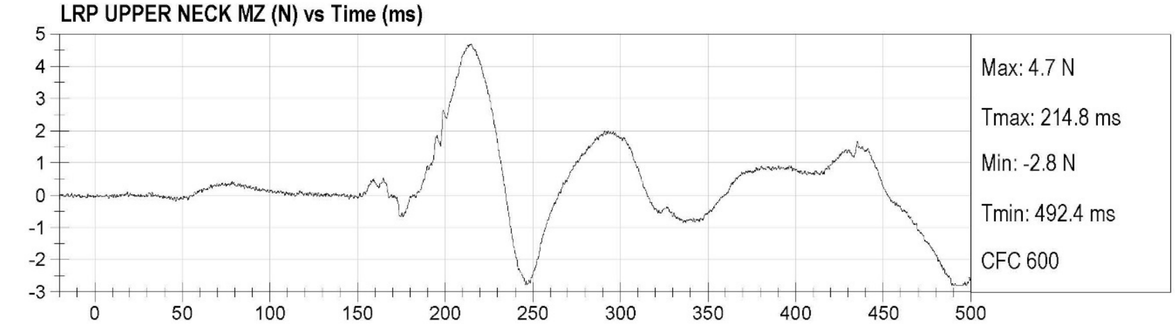
LRP UPPER NECK MX (N) vs Time (ms)



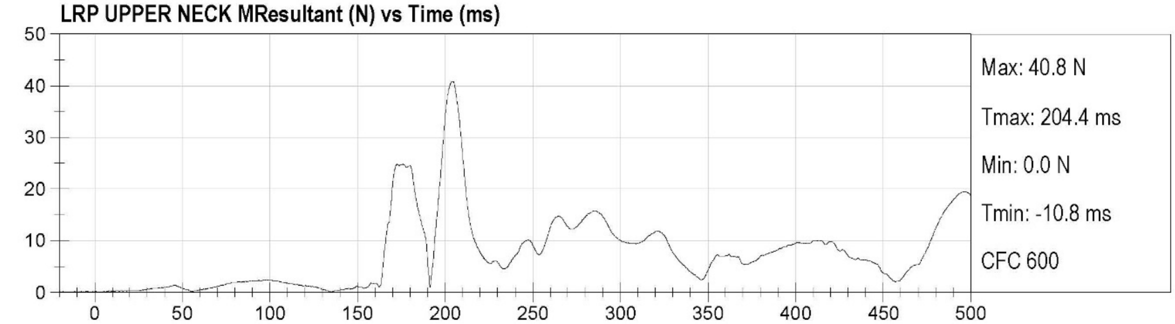

LRP UPPER NECK MY (N) vs Time (ms)

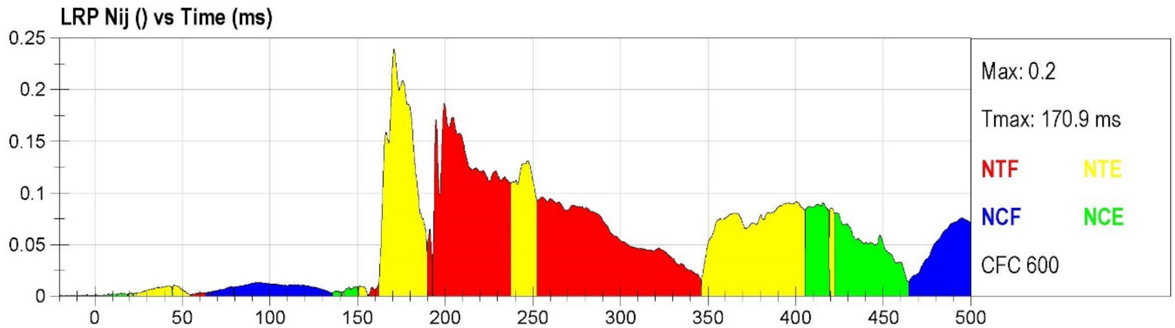



LRP UPPER NECK MZ (N) vs Time (ms)




LRP UPPER NECK MResultant (N) vs Time (ms)




LRP Nij () vs Time (ms)
Max: 0.2
Tmax: 170.9 ms
NTF
NTE
NCF
NCE
CFC 600
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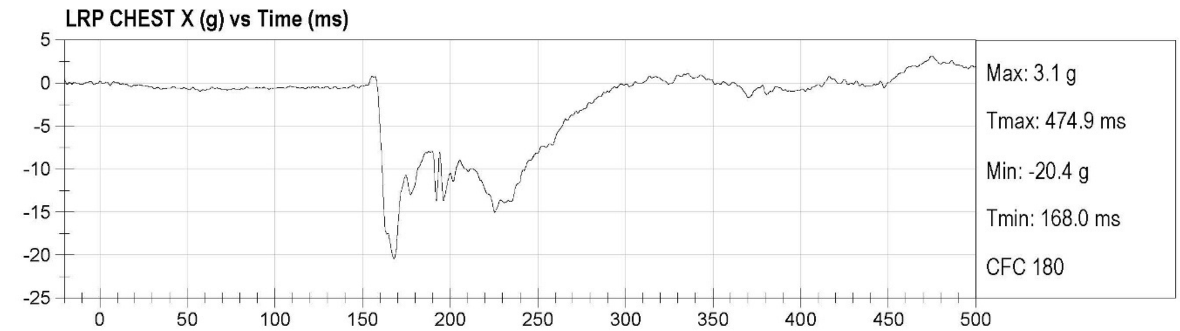
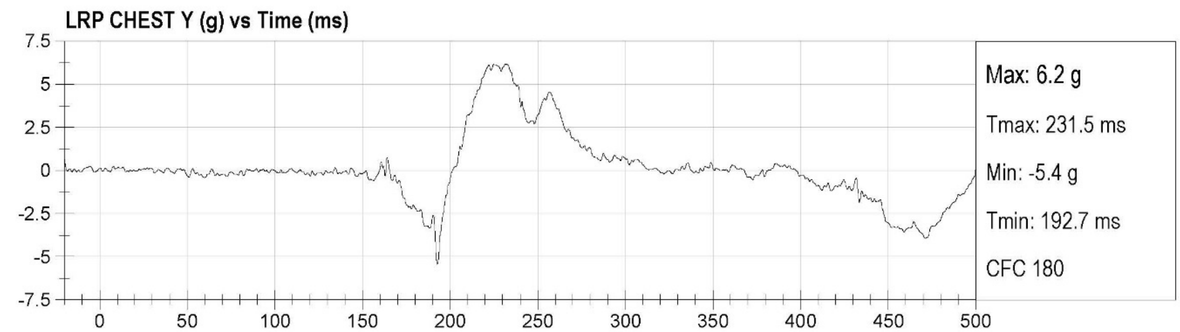
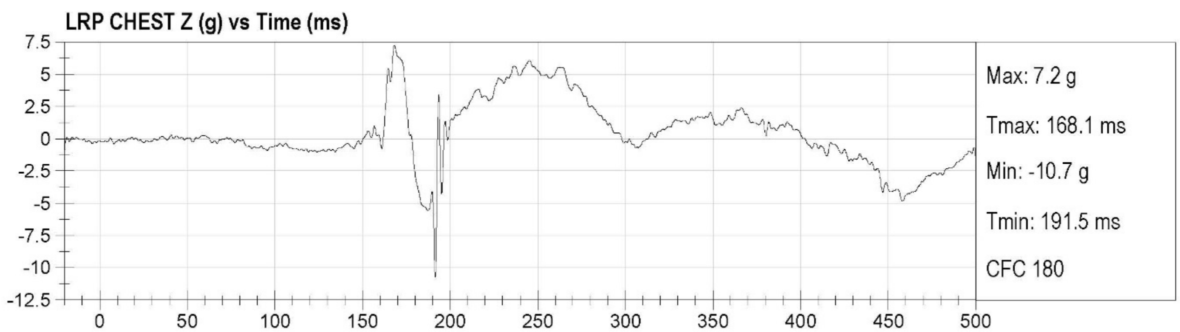
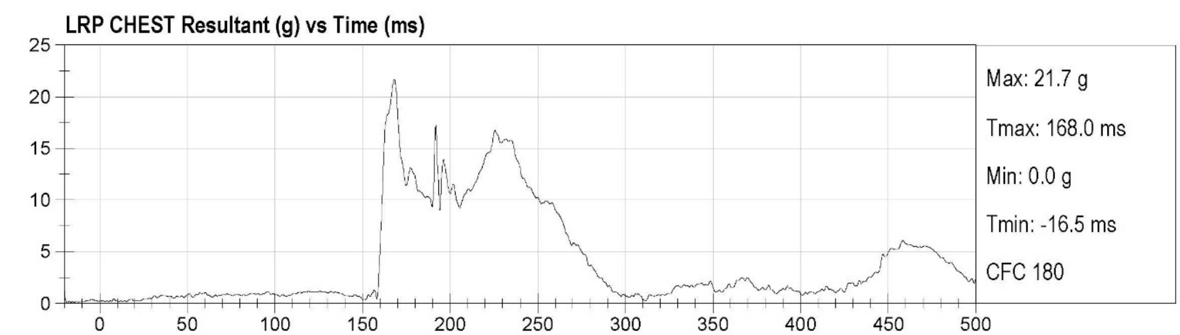
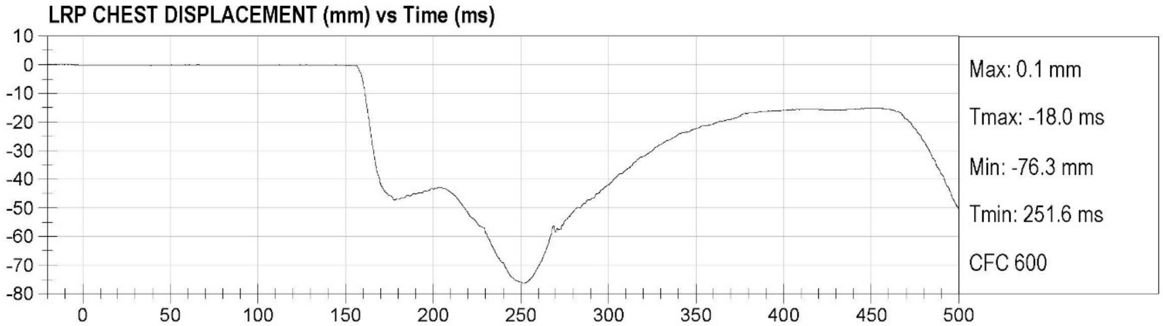
0.05
0
0
50
100
150
200
250
300
350
400
450
500

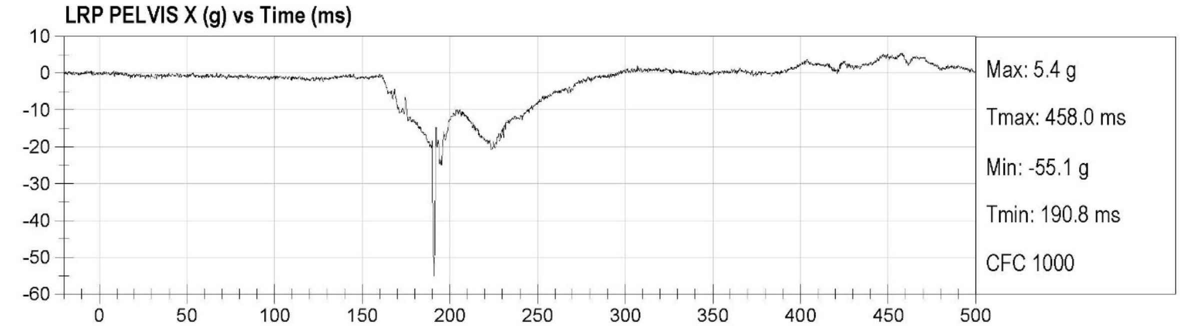

LRP CHEST X (g) vs Time (ms)
Max: 3.1 g
Tmax: 474.9 ms
Min: -20.4 g
Tmin: 168.0 ms
CFC 180

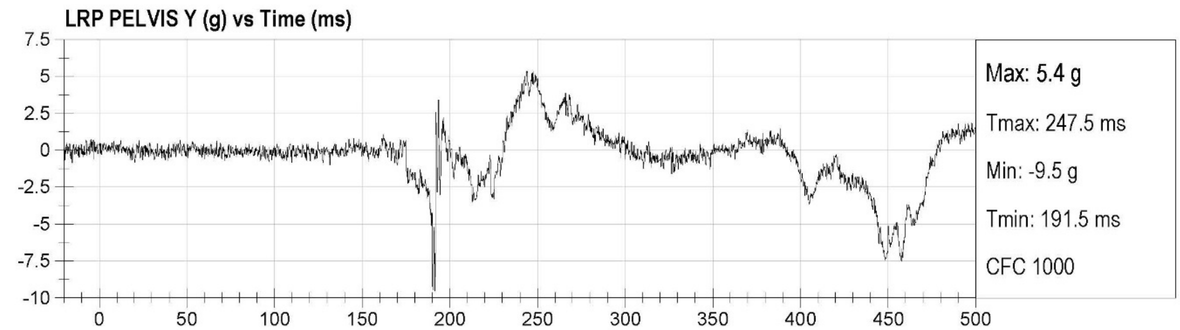

LRP CHEST Y (g) vs Time (ms)
Max: 6.2 g
Tmax: 231.5 ms
Min: -5.4 g
Tmin: 192.7 ms
CFC 180

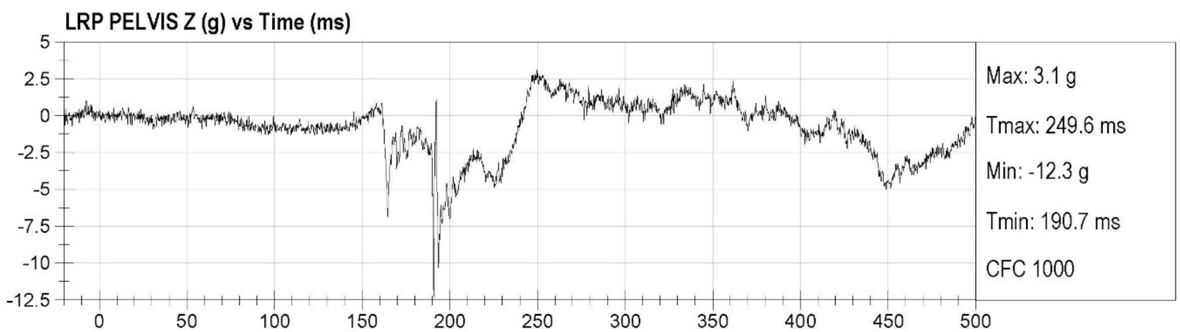

LRP CHEST Z (g) vs Time (ms)
Max: 7.2 g
Tmax: 168.1 ms
Min: -10.7 g
Tmin: 191.5 ms
CFC 180

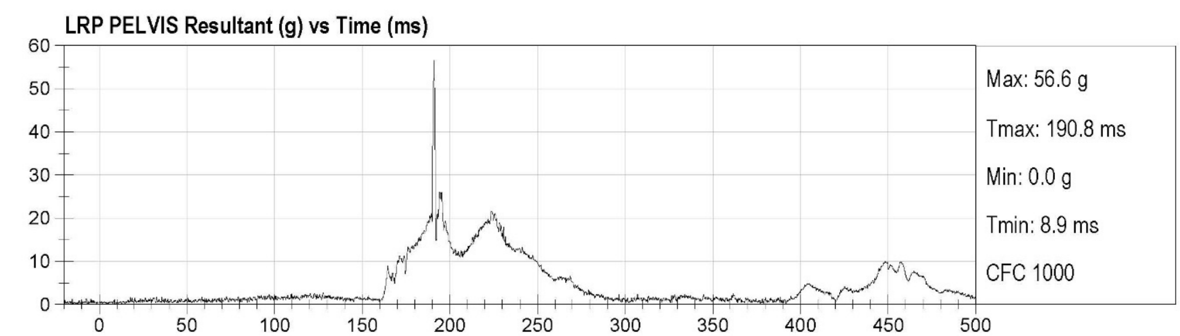

LRP CHEST Resultant (g) vs Time (ms)
Max: 21.7 g
Tmax: 168.0 ms
Min: 0.0 g
Tmin: -16.5 ms
CFC 180

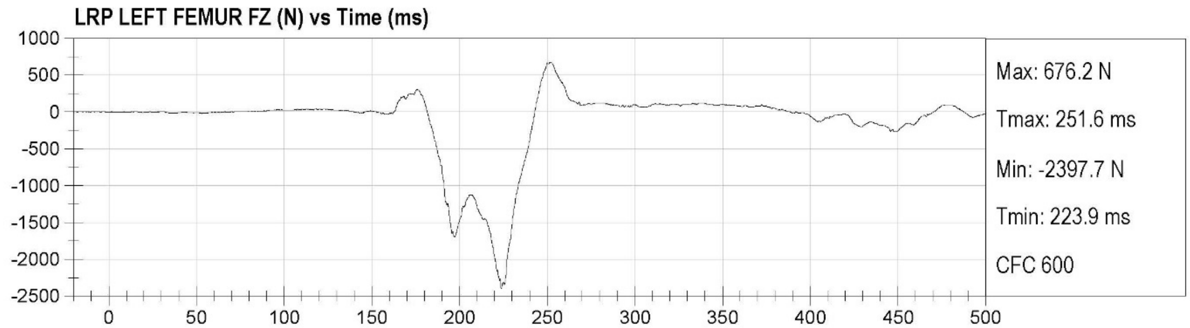

LRP CHEST DISPLACEMENT (mm) vs Time (ms)
Max: 0.1 mm
Tmax: -18.0 ms
Min: -76.3 mm
Tmin: 251.6 ms
CFC 600

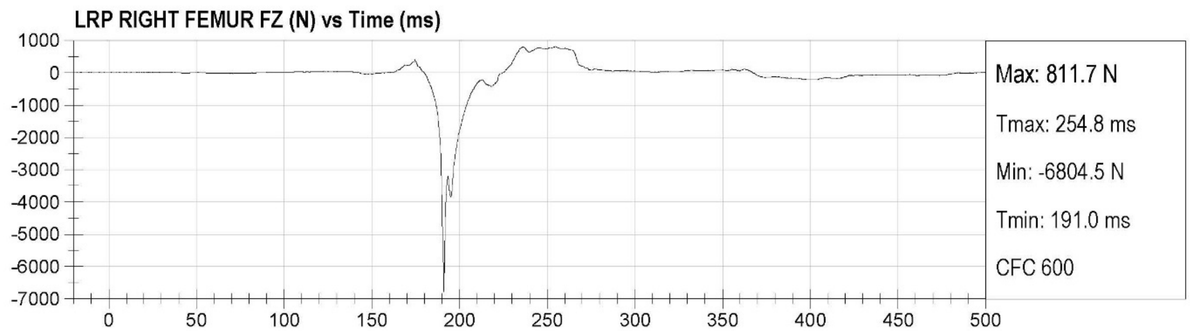

LRP PELVIS X (g) vs Time (ms)
Max: 5.4 g
Tmax: 458.0 ms
Min: -55.1 g
Tmin: 190.8 ms
CFC 1000

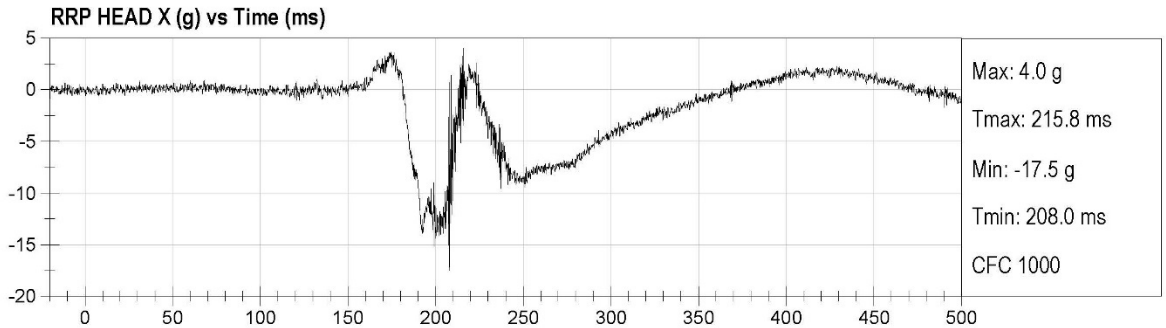

LRP PELVIS Y (g) vs Time (ms)
Max: 5.4 g
Tmax: 247.5 ms
Min: -9.5 g
Tmin: 191.5 ms
CFC 1000

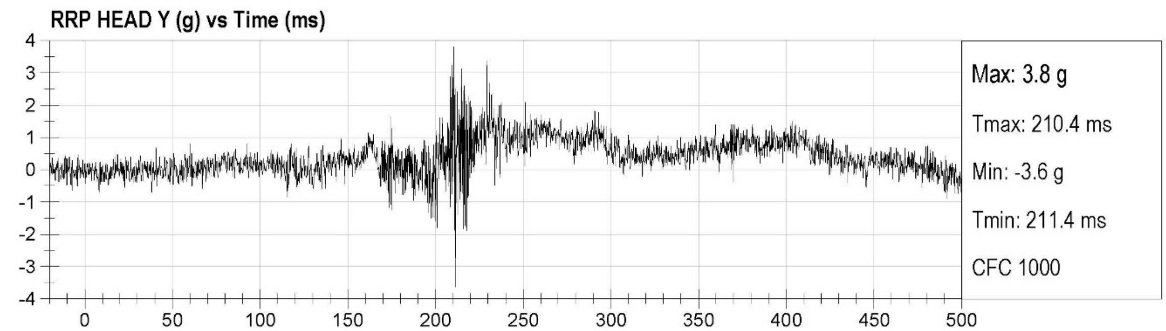

LRP PELVIS Z (g) vs Time (ms)
Max: 3.1 g
Tmax: 249.6 ms
Min: -12.3 g
Tmin: 190.7 ms
CFC 1000

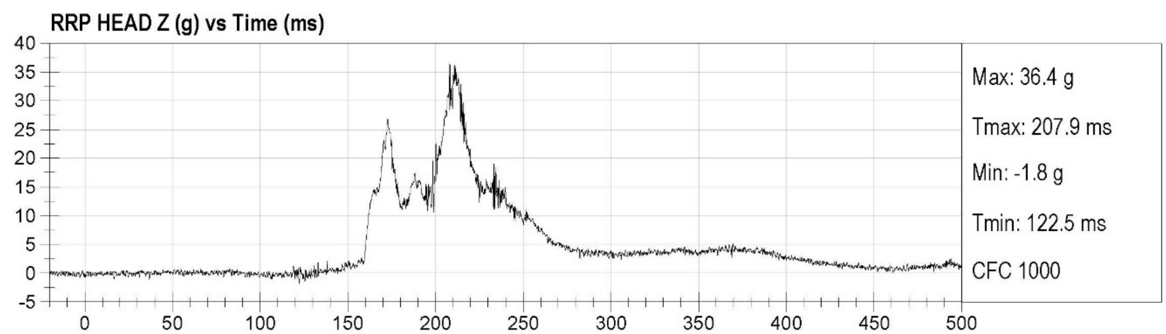

LRP PELVIS Resultant (g) vs Time (ms)
Max: 56.6 g
Tmax: 190.8 ms
Min: 0.0 g
Tmin: 8.9 ms
CFC 1000

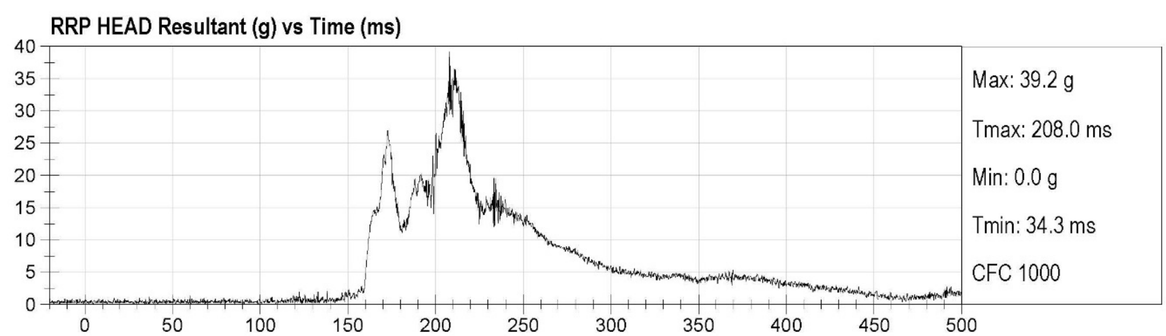

LRP LEFT FEMUR FZ (N) vs Time (ms)
Max: 676.2 N
Tmax: 251.6 ms
Min: -2397.7 N
Tmin: 223.9 ms
CFC 600

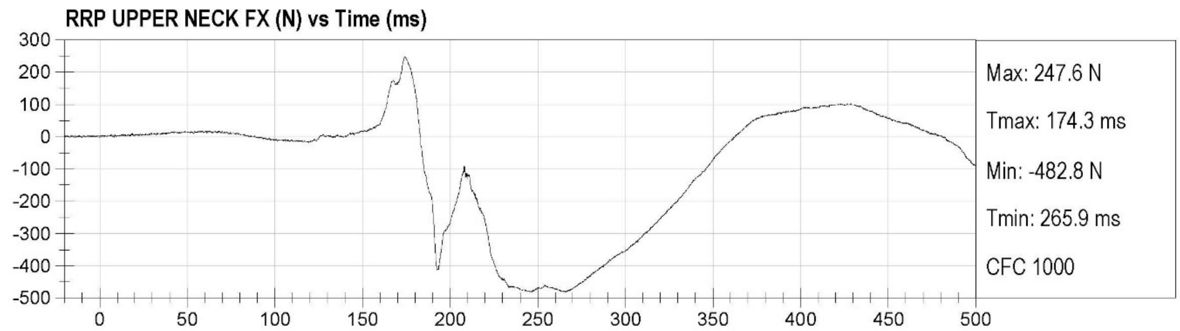

LRP RIGHT FEMUR FZ (N) vs Time (ms)
Max: 811.7 N
Tmax: 254.8 ms
Min: -6804.5 N
Tmin: 191.0 ms
CFC 600

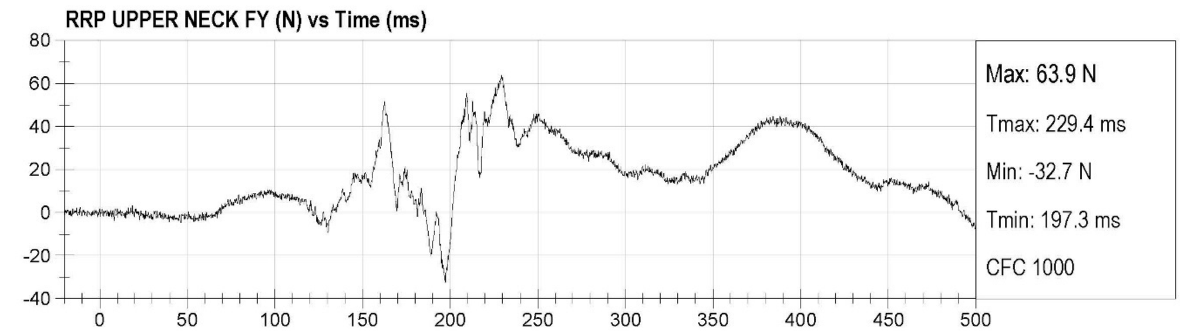

RRP HEAD X (g) vs Time (ms)
Max: 4.0 g
Tmax: 215.8 ms
Min: -17.5 g
Tmin: 208.0 ms
CFC 1000

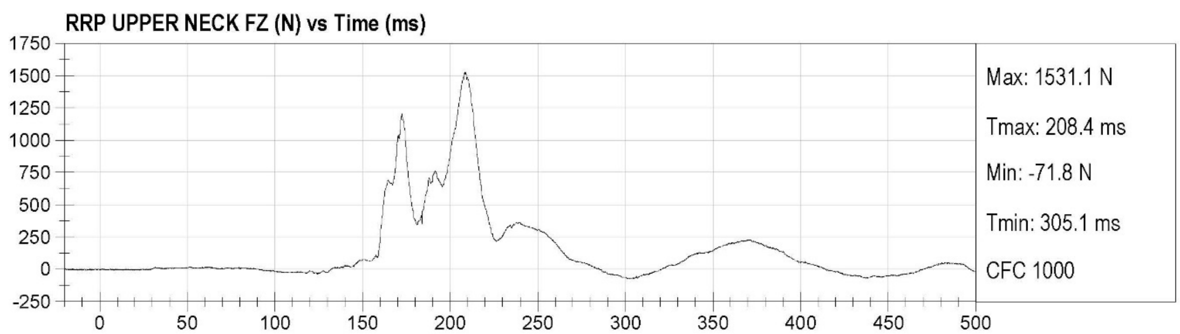

RRP HEAD Y (g) vs Time (ms)
Max: 3.8 g
Tmax: 210.4 ms
Min: -3.6 g
Tmin: 211.4 ms
CFC 1000

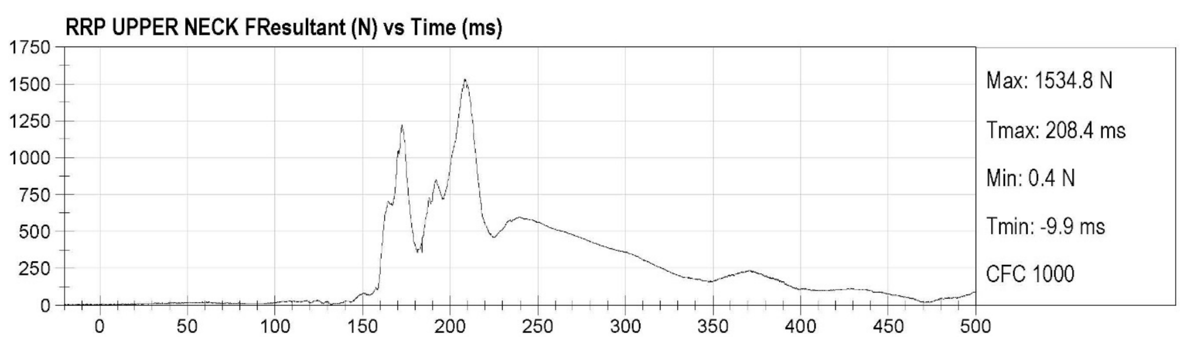

RRP HEAD Z (g) vs Time (ms)
Max: 36.4 g
Tmax: 207.9 ms
Min: -1.8 g
Tmin: 122.5 ms
CFC 1000


RRP HEAD Resultant (g) vs Time (ms)
Max: 39.2 g
Tmax: 208.0 ms
Min: 0.0 g
Tmin: 34.3 ms
CFC 1000

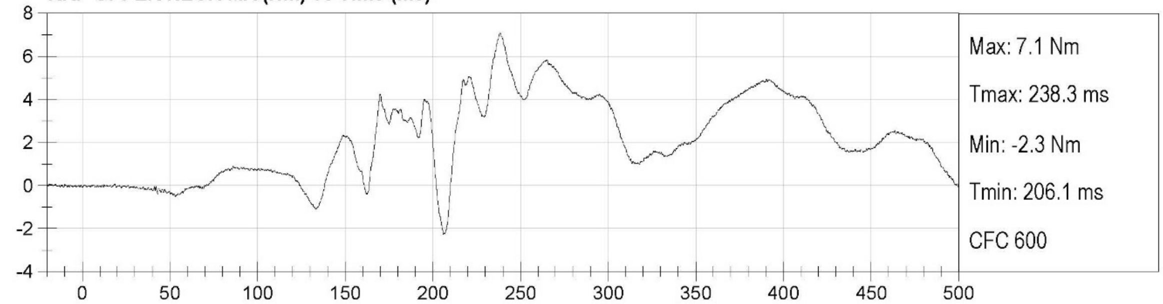

RRP UPPER NECK FX (N) vs Time (ms)
Max: 247.6 N
Tmax: 174.3 ms
Min: -482.8 N
Tmin: 265.9 ms
CFC 1000


RRP UPPER NECK FY (N) vs Time (ms)
Max: 63.9 N
Tmax: 229.4 ms
Min: -32.7 N
Tmin: 197.3 ms
CFC 1000

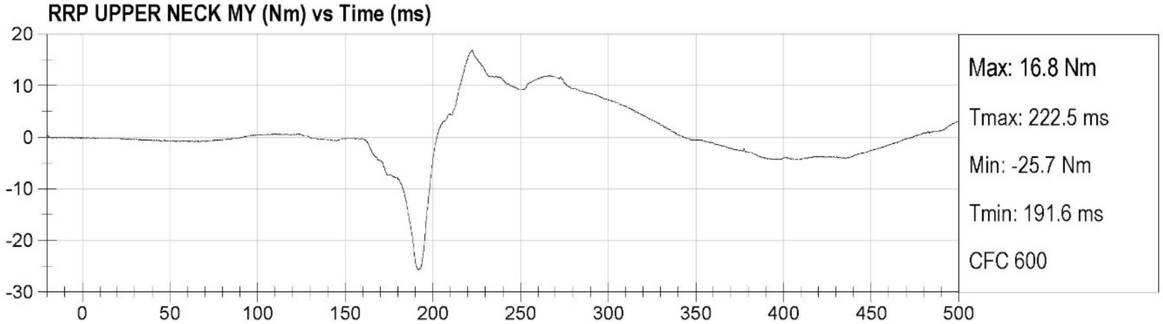

RRP UPPER NECK FZ (N) vs Time (ms)
Max: 1531.1 N
Tmax: 208.4 ms
Min: -71.8 N
Tmin: 305.1 ms
CFC 1000


RRP UPPER NECK FResultant (N) vs Time (ms)
Max: 1534.8 N
Tmax: 208.4 ms
Min: 0.4 N
Tmin: -9.9 ms
CFC 1000

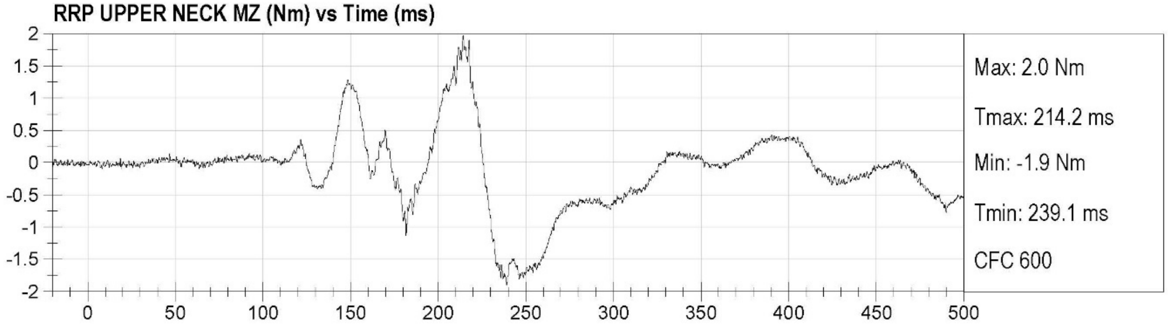
RRP UPPER NECK MX (Nm) vs Time (ms)



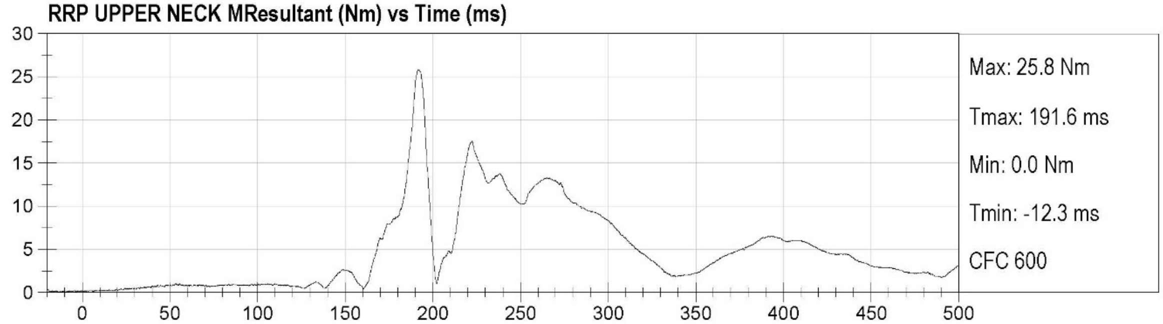

RRP UPPER NECK MY (Nm) vs Time (ms)

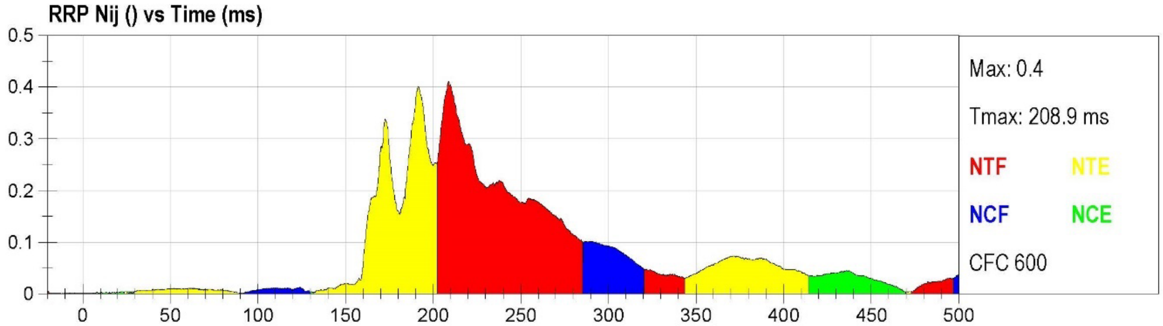


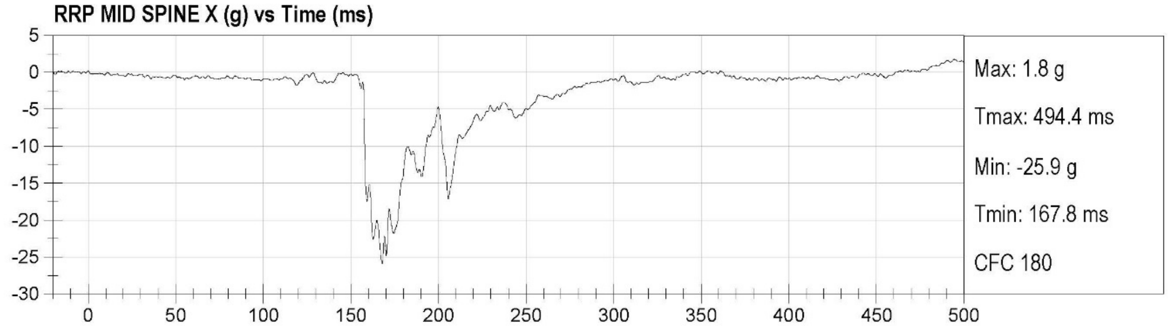

RRP UPPER NECK MZ (Nm) vs Time (ms)

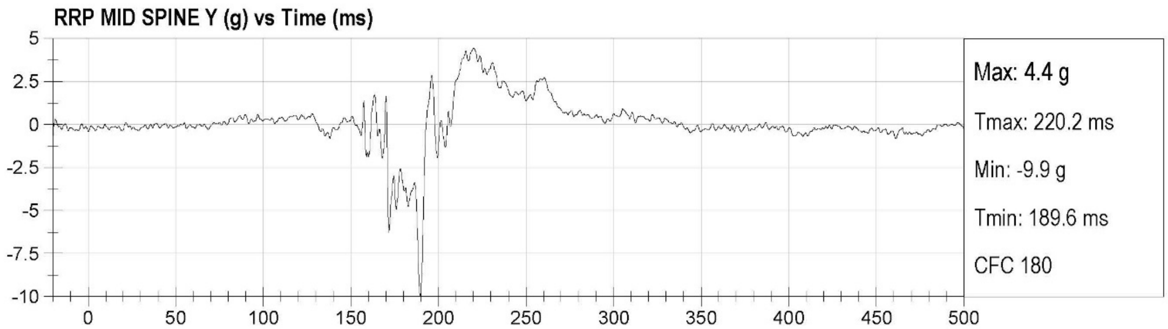


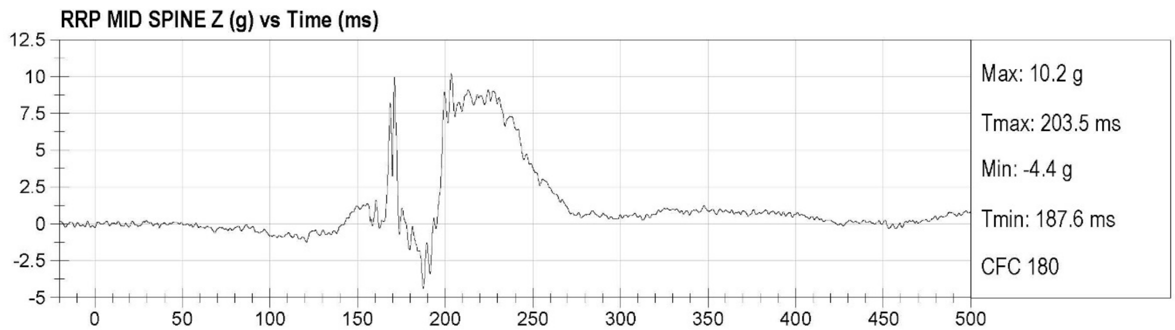

RRP UPPER NECK MResultant (Nm) vs Time (ms)

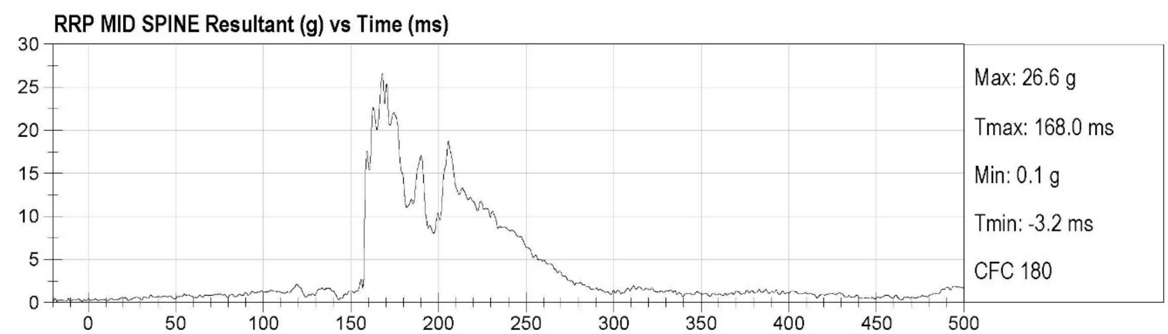


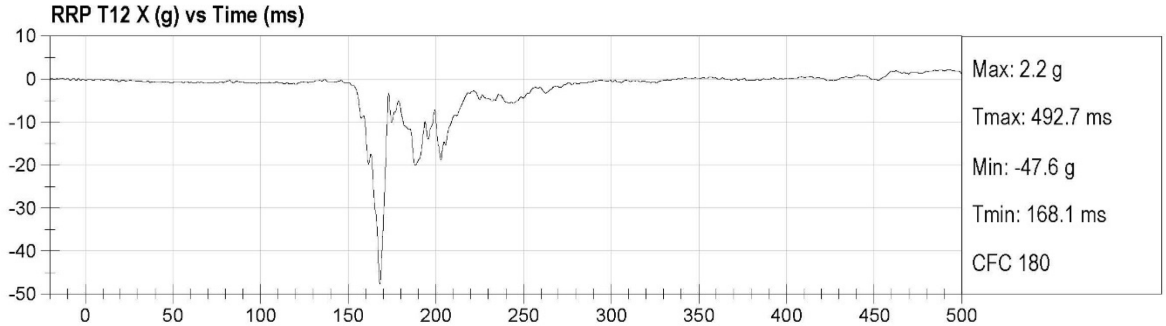

RRP Nij () vs Time (ms)
0.5
0.4
0.3
0.2
0.1
0
0
50
100
150
200
250
300
350
400
450
500
Max: 0.4
Tmax: 208.9 ms
NTF
NTE
NCF
NCE
CFC 600

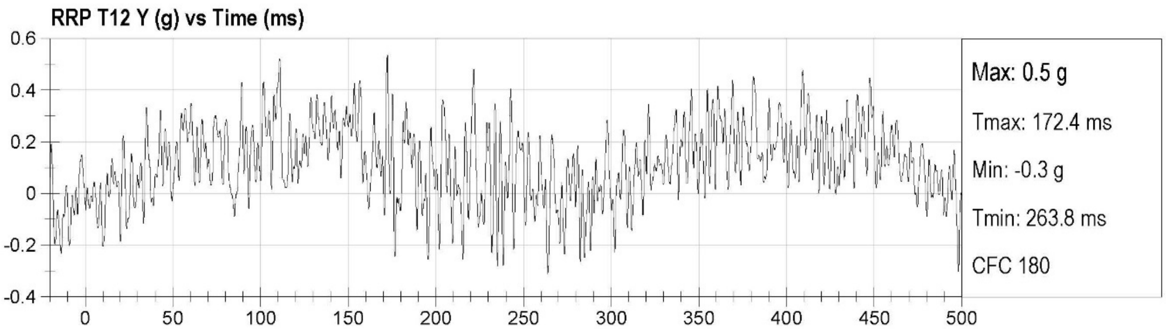

RRP MID SPINE X (g) vs Time (ms)
Max: 1.8 g
Tmax: 494.4 ms
Min: -25.9 g
Tmin: 167.8 ms
CFC 180

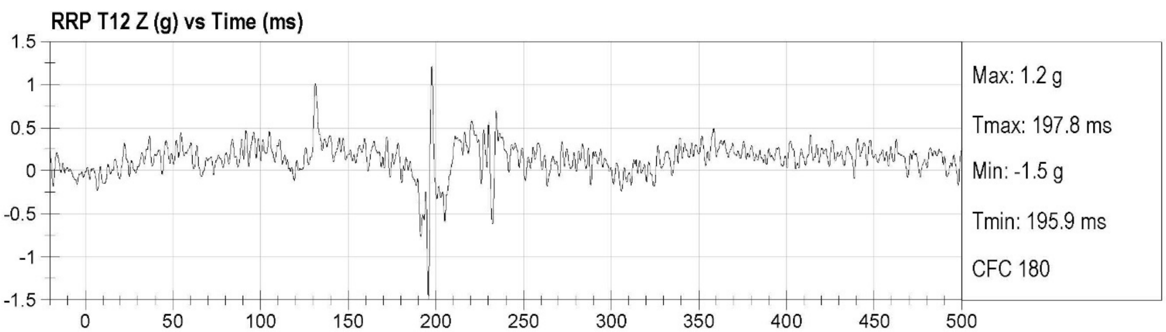

RRP MID SPINE Y (g) vs Time (ms)
Max: 4.4 g
Tmax: 220.2 ms
Min: -9.9 g
Tmin: 189.6 ms
CFC 180


RRP MID SPINE Z (g) vs Time (ms)
Max: 10.2 g
Tmax: 203.5 ms
Min: -4.4 g
Tmin: 187.6 ms
CFC 180


RRP MID SPINE Resultant (g) vs Time (ms)
Max: 26.6 g
Tmax: 168.0 ms
Min: 0.1 g
Tmin: -3.2 ms
CFC 180

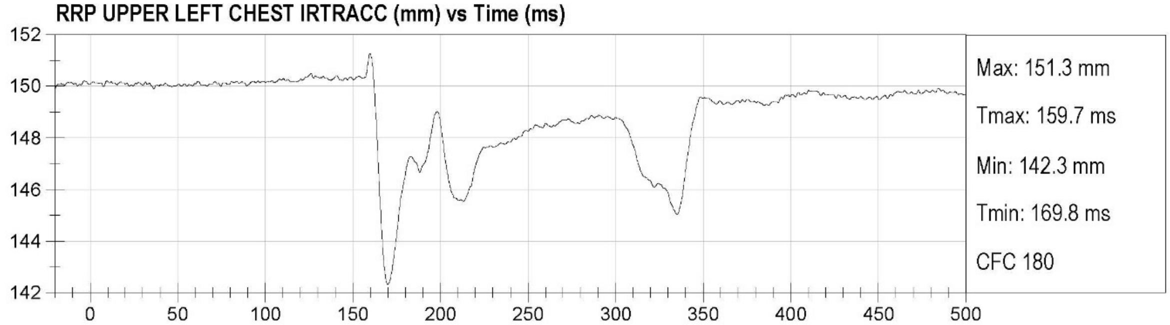

RRP T12 X (g) vs Time (ms)
Max: 2.2 g
Tmax: 492.7 ms
Min: -47.6 g
Tmin: 168.1 ms
CFC 180


RRP T12 Y (g) vs Time (ms)
Max: 0.5 g
Tmax: 172.4 ms
Min: -0.3 g
Tmin: 263.8 ms
CFC 180

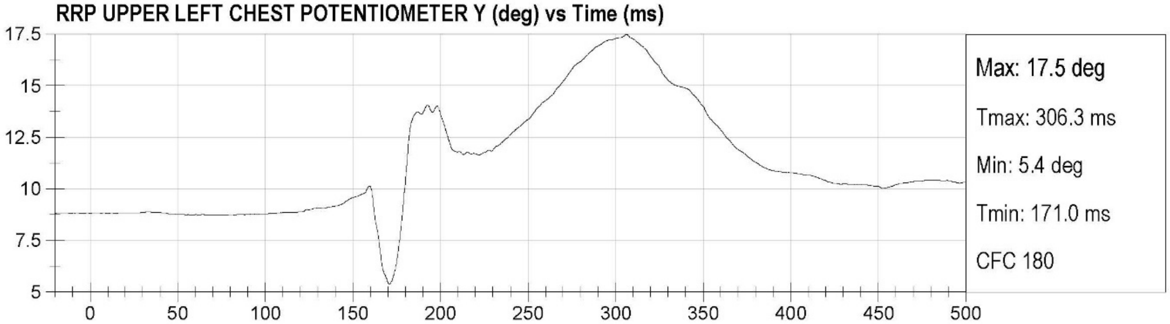

RRP T12 Z (g) vs Time (ms)
Max: 1.2 g
Tmax: 197.8 ms
Min: -1.5 g
Tmin: 195.9 ms
CFC 180


RRP T12 Resultant (g) vs Time (ms)
Max: 47.6 g
Tmax: 168.1 ms
Min: 0.0 g
Tmin: -10.6 ms
CFC 180

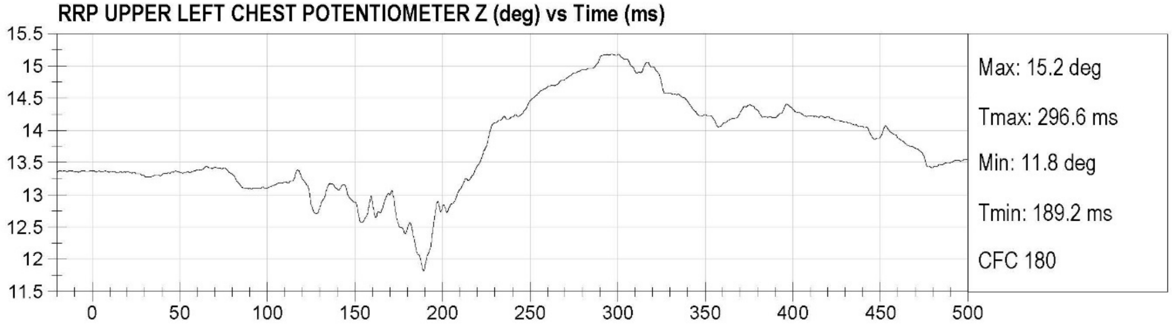
RRP UPPER LEFT CHEST IRTRACC (mm) vs Time (ms)

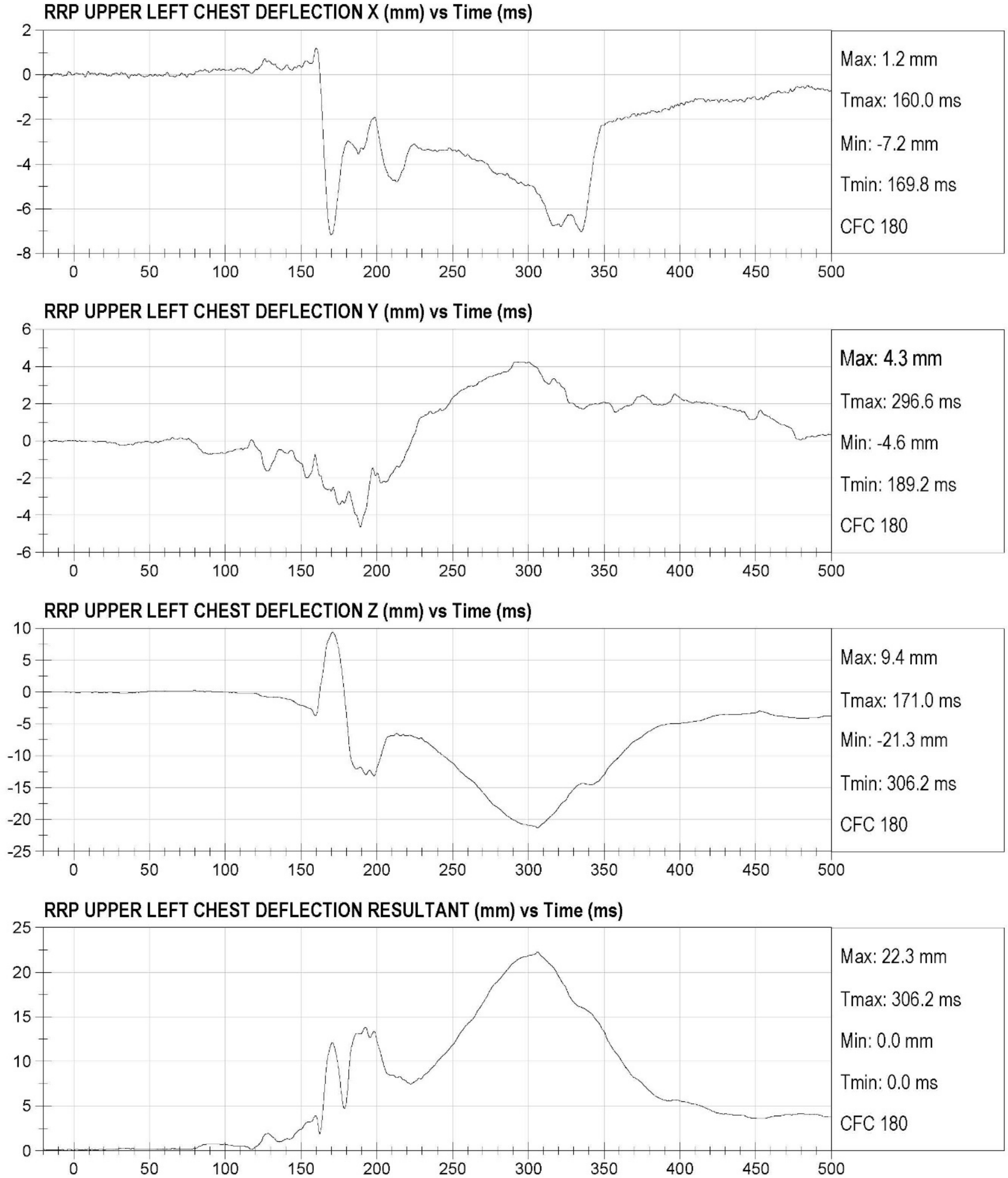



RRP UPPER LEFT CHEST POTENTIOMETER Y (deg) vs Time (ms)

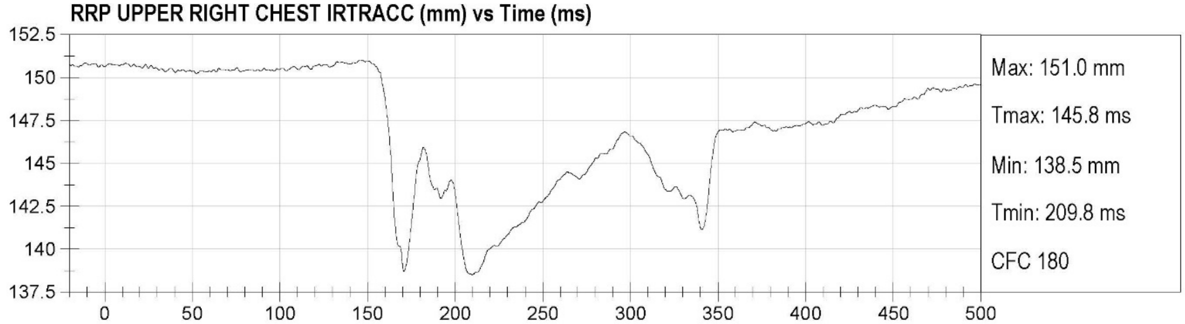



RRP UPPER LEFT CHEST POTENTIOMETER Z (deg) vs Time (ms)

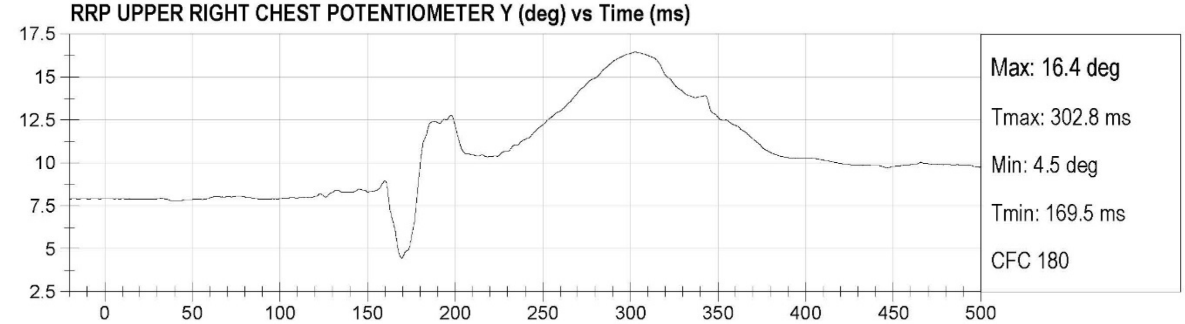



RRP UPPER LEFT CHEST DEFLECTION X (mm) vs Time (ms)
Max: 1.2 mm
Tmax: 160.0 ms
Min: -7.2 mm
Tmin: 169.8 ms
CFC 180
RRP UPPER LEFT CHEST DEFLECTION Y (mm) vs Time (ms)
Max: 4.3 mm
Tmax: 296.6 ms
Min: -4.6 mm
Tmin: 189.2 ms
CFC 180
RRP UPPER LEFT CHEST DEFLECTION Z (mm) vs Time (ms)
Max: 9.4 mm
Tmax: 171.0 ms
Min: -21.3 mm
Tmin: 306.2 ms
CFC 180
RRP UPPER LEFT CHEST DEFLECTION RESULTANT (mm) vs Time (ms)
Max: 22.3 mm
Tmax: 306.2 ms
Min: 0.0 mm
Tmin: 0.0 ms
CFC 180

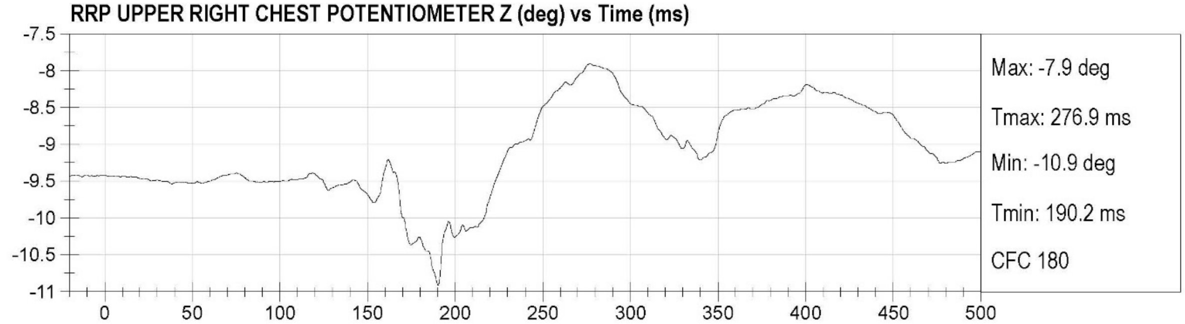
RRP UPPER RIGHT CHEST IRTRACC (mm) vs Time (ms)

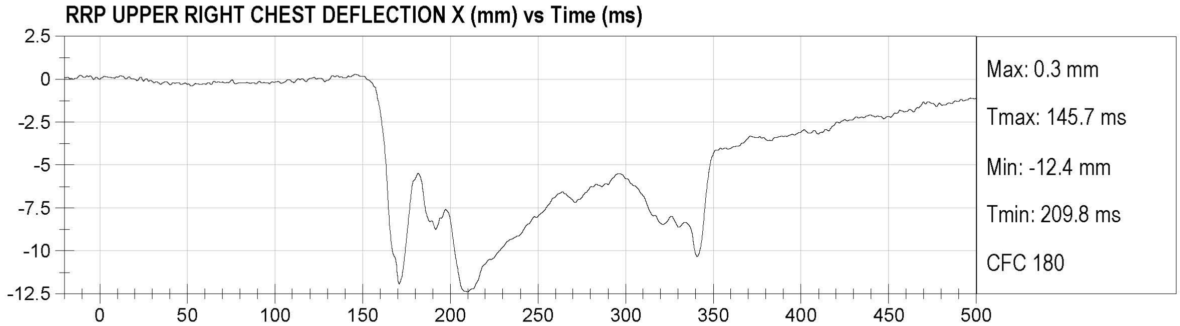


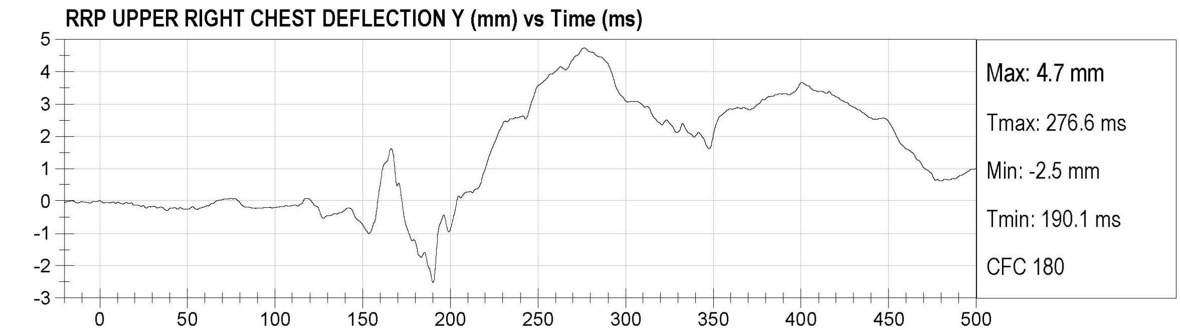

RRP UPPER RIGHT CHEST POTENTIOMETER Y (deg) vs Time (ms)

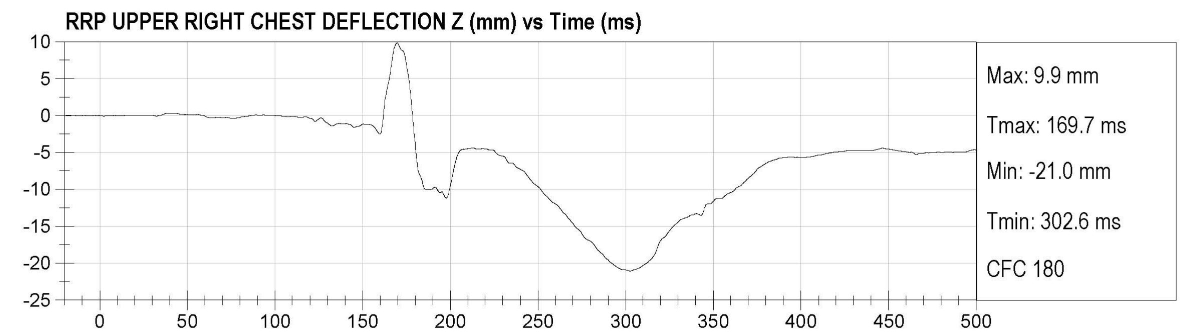


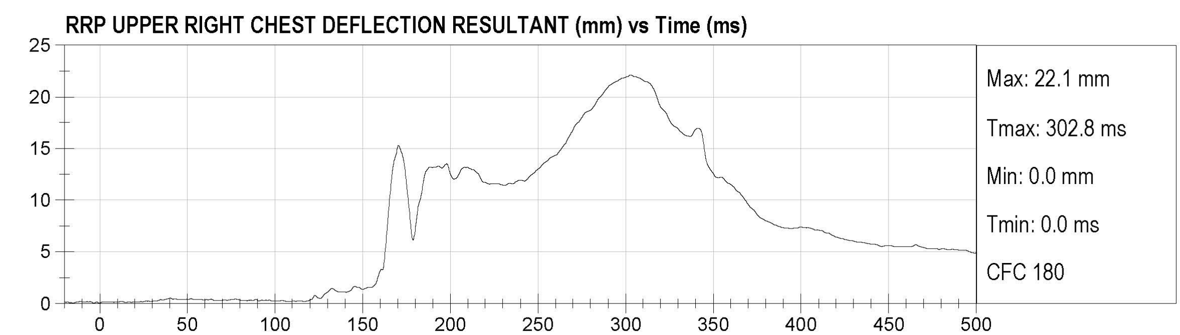

RRP UPPER RIGHT CHEST POTENTIOMETER Z (deg) vs Time (ms)

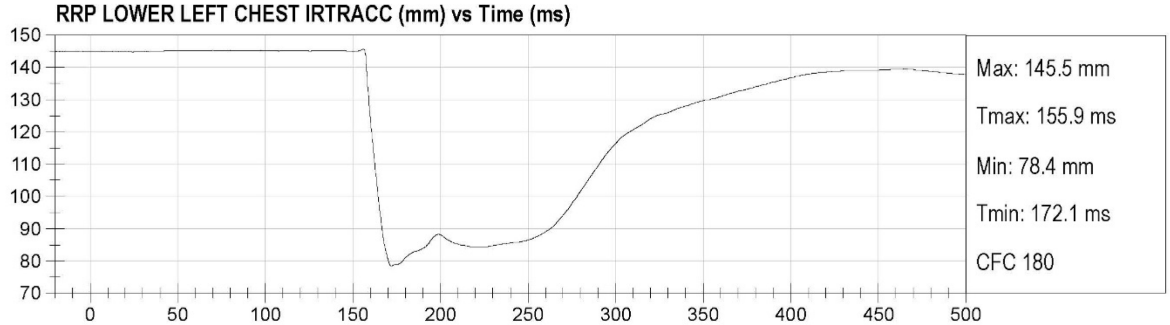


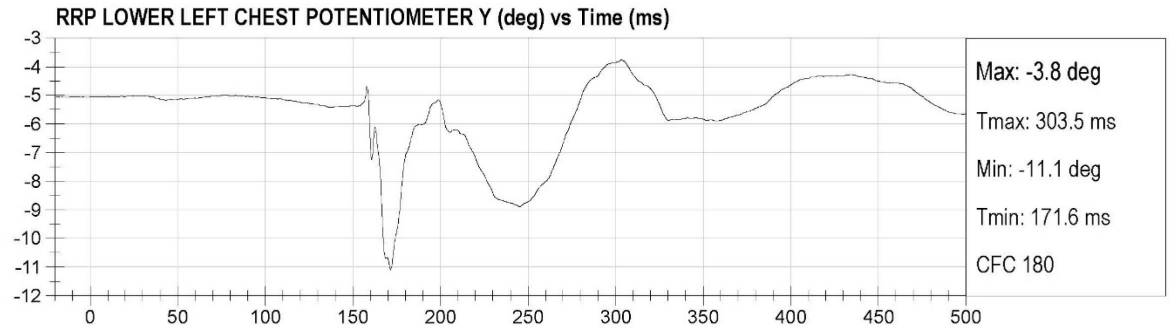

RRP UPPER RIGHT CHEST DEFLECTION X (mm) vs Time (ms)
2.5
0
-2.5
-5
-7.5
-10
-12.5
0
50
100
150
200
250
300
350
400
450
500
Max: 0.3 mm
Tmax: 145.7 ms
Min: -12.4 mm
Tmin: 209.8 ms
CFC 180

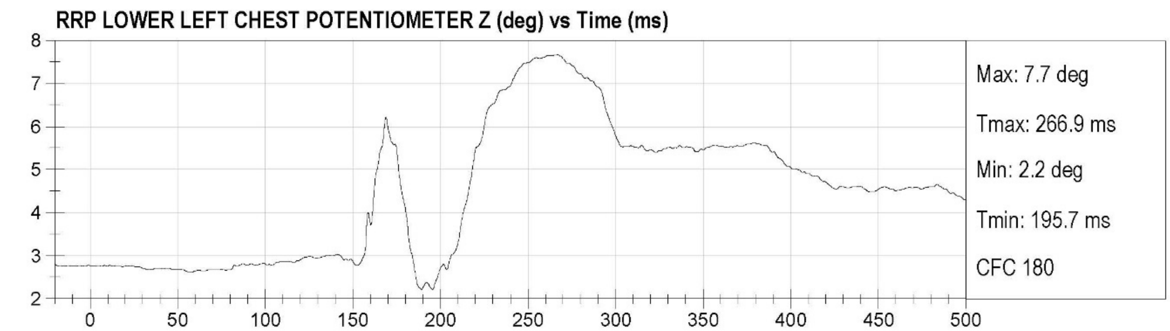

RRP UPPER RIGHT CHEST DEFLECTION Y (mm) vs Time (ms)
5
4
3
2
1
0
-1
-2
-3
0
50
100
150
200
250
300
350
400
450
500
Max: 4.7 mm
Tmax: 276.6 ms
Min: -2.5 mm
Tmin: 190.1 ms
CFC 180

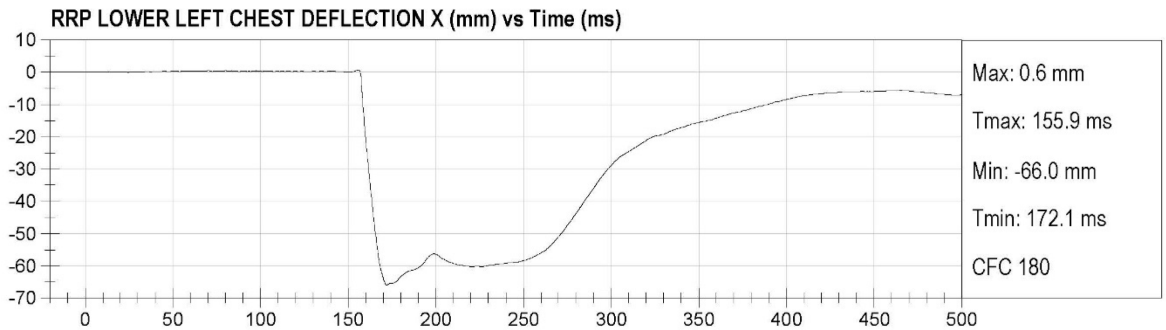

RRP UPPER RIGHT CHEST DEFLECTION Z (mm) vs Time (ms)
10
5
0
-5
-10
-15
-20
-25
0
50
100
150
200
250
300
350
400
450
500
Max: 9.9 mm
Tmax: 169.7 ms
Min: -21.0 mm
Tmin: 302.6 ms
CFC 180

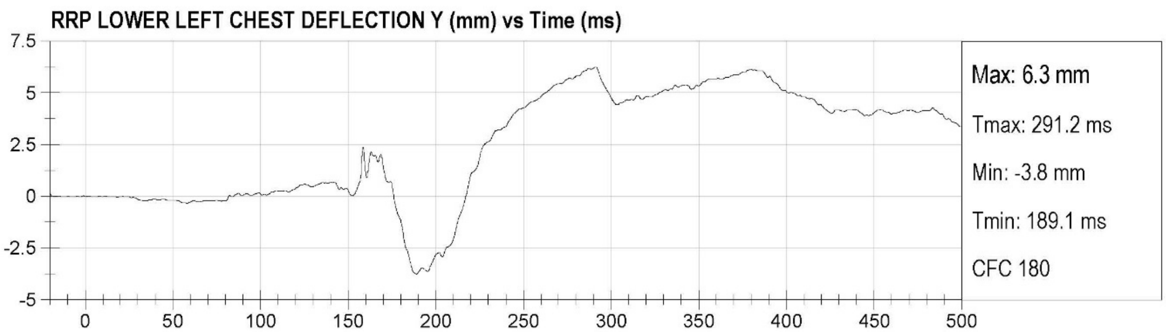

RRP UPPER RIGHT CHEST DEFLECTION RESULTANT (mm) vs Time (ms)
25
20
15
10
5
0
0
50
100
150
200
250
300
350
400
450
500
Max: 22.1 mm
Tmax: 302.8 ms
Min: 0.0 mm
Tmin: 0.0 ms
CFC 180

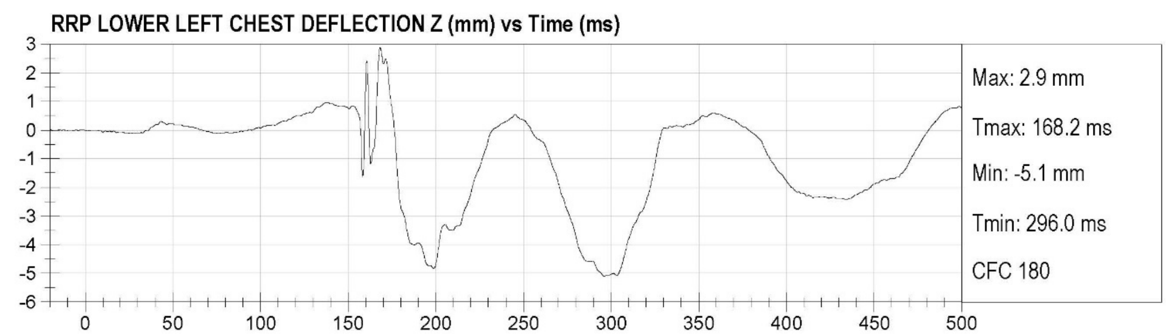

RRP LOWER LEFT CHEST IRTRACC (mm) vs Time (ms)
Max: 145.5 mm
Tmax: 155.9 ms
Min: 78.4 mm
Tmin: 172.1 ms
CFC 180

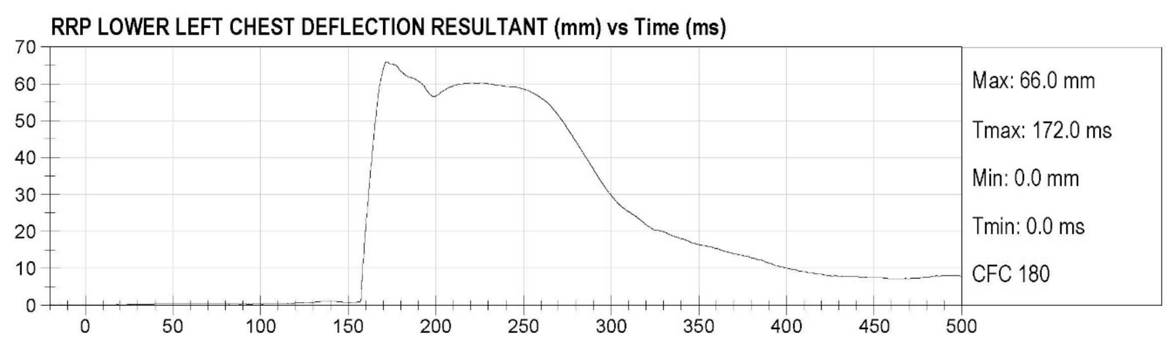

RRP LOWER LEFT CHEST POTENTIOMETER Y (deg) vs Time (ms)
Max: -3.8 deg
Tmax: 303.5 ms
Min: -11.1 deg
Tmin: 171.6 ms
CFC 180

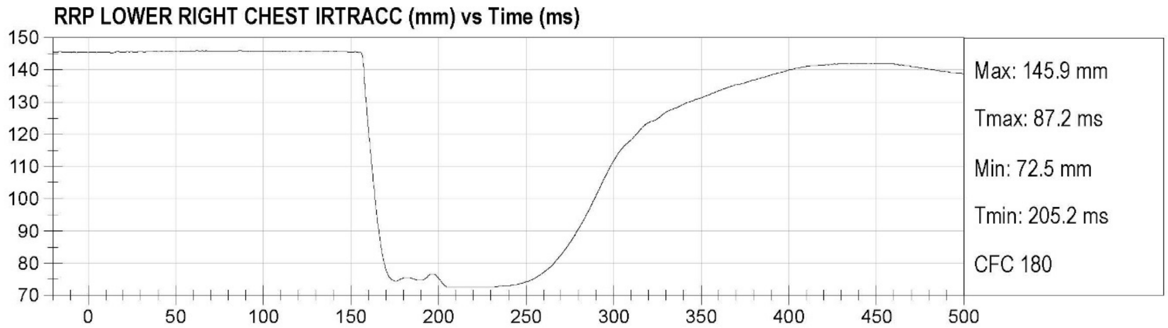

RRP LOWER LEFT CHEST POTENTIOMETER Z (deg) vs Time (ms)
Max: 7.7 deg
Tmax: 266.9 ms
Min: 2.2 deg
Tmin: 195.7 ms
CFC 180

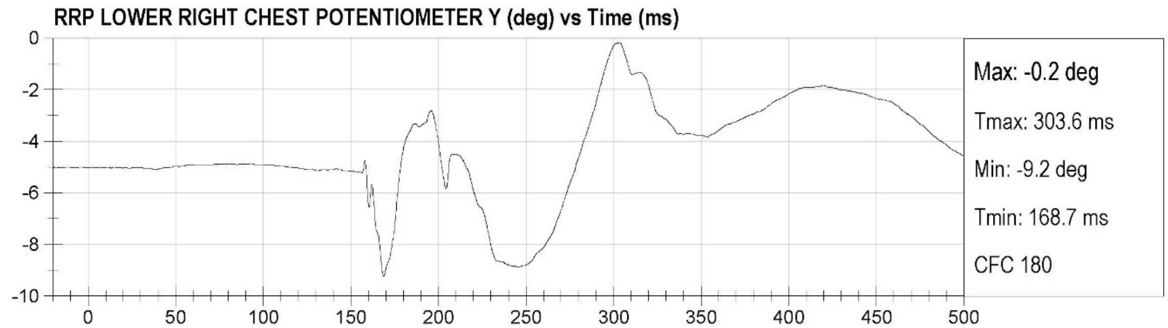

RRP LOWER LEFT CHEST DEFLECTION X (mm) vs Time (ms)
10
0
-10
-20
-30
-40
-50
-60
-70
0
50
100
150
200
250
300
350
400
450
500
Max: 0.6 mm
Tmax: 155.9 ms
Min: -66.0 mm
Tmin: 172.1 ms
CFC 180

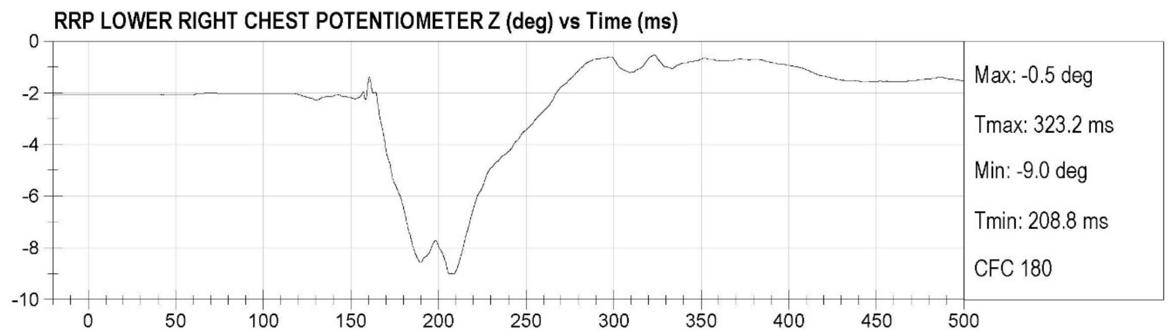

RRP LOWER LEFT CHEST DEFLECTION Y (mm) vs Time (ms)
7.5
5
2.5
0
-2.5
-5
0
50
100
150
200
250
300
350
400
450
500
Max: 6.3 mm
Tmax: 291.2 ms
Min: -3.8 mm
Tmin: 189.1 ms
CFC 180


RRP LOWER LEFT CHEST DEFLECTION Z (mm) vs Time (ms)
3
2
1
0
-1
-2
-3
-4
-5
-6
0
50
100
150
200
250
300
350
400
450
500
Max: 2.9 mm
Tmax: 168.2 ms
Min: -5.1 mm
Tmin: 296.0 ms
CFC 180

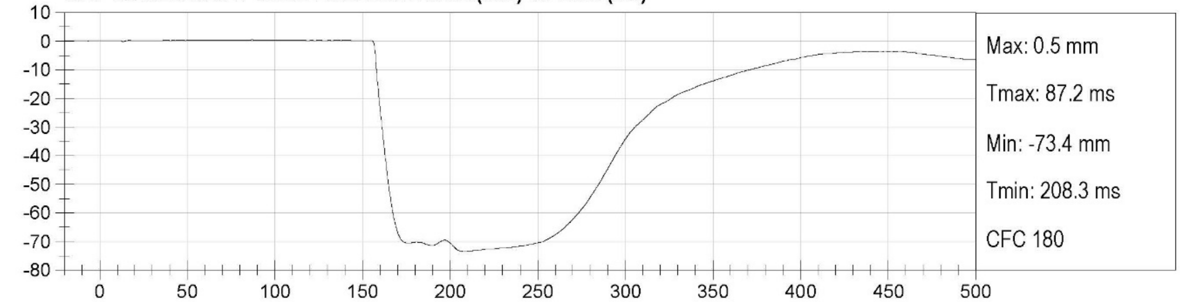

RRP LOWER LEFT CHEST DEFLECTION RESULTANT (mm) vs Time (ms)
70
60
50
40
30
20
10
0
0
50
100
150
200
250
300
350
400
450
500
Max: 66.0 mm
Tmax: 172.0 ms
Min: 0.0 mm
Tmin: 0.0 ms
CFC 180


RRP LOWER RIGHT CHEST IRTRACC (mm) vs Time (ms)
Max: 145.9 mm
Tmax: 87.2 ms
Min: 72.5 mm
Tmin: 205.2 ms
CFC 180

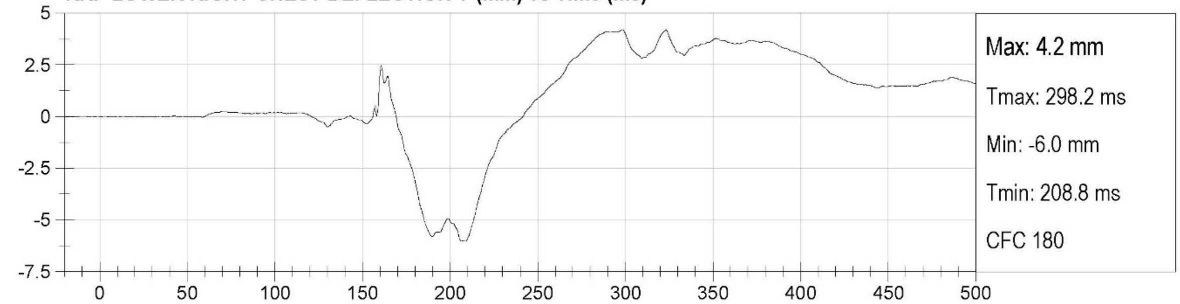

RRP LOWER RIGHT CHEST POTENTIOMETER Y (deg) vs Time (ms)
Max: -0.2 deg
Tmax: 303.6 ms
Min: -9.2 deg
Tmin: 168.7 ms
CFC 180


RRP LOWER RIGHT CHEST POTENTIOMETER Z (deg) vs Time (ms)
Max: -0.5 deg
Tmax: 323.2 ms
Min: -9.0 deg
Tmin: 208.8 ms
CFC 180

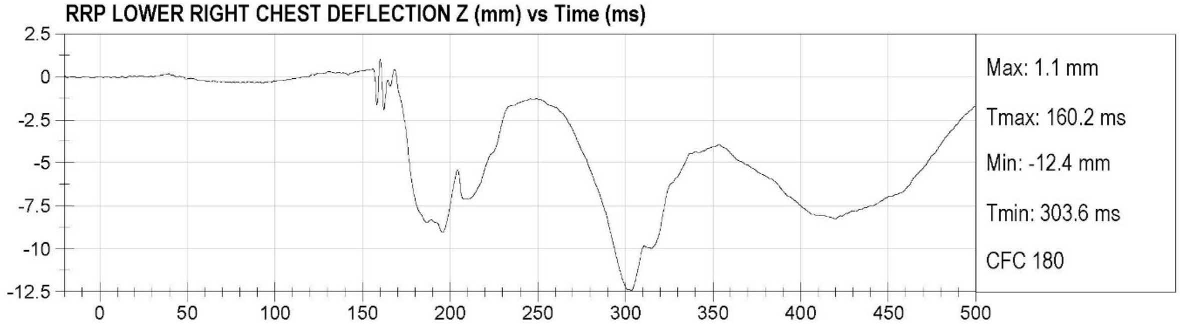
RRP LOWER RIGHT CHEST DEFLECTION X (mm) vs Time (ms)



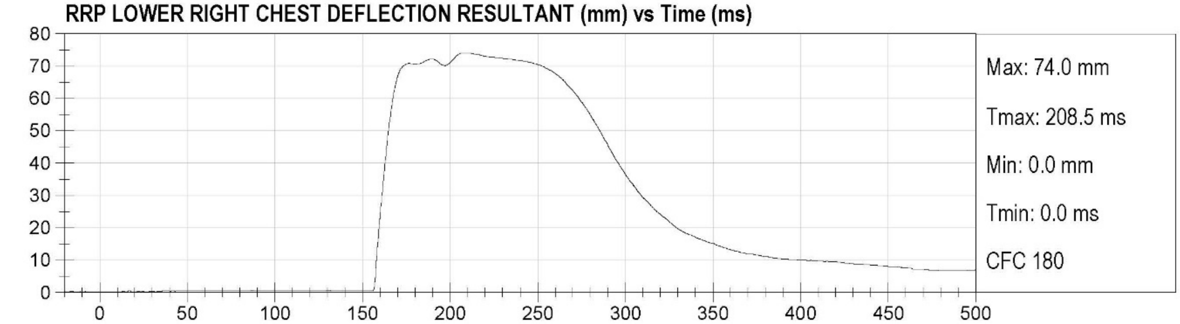

RRP LOWER RIGHT CHEST DEFLECTION Y (mm) vs Time (ms)

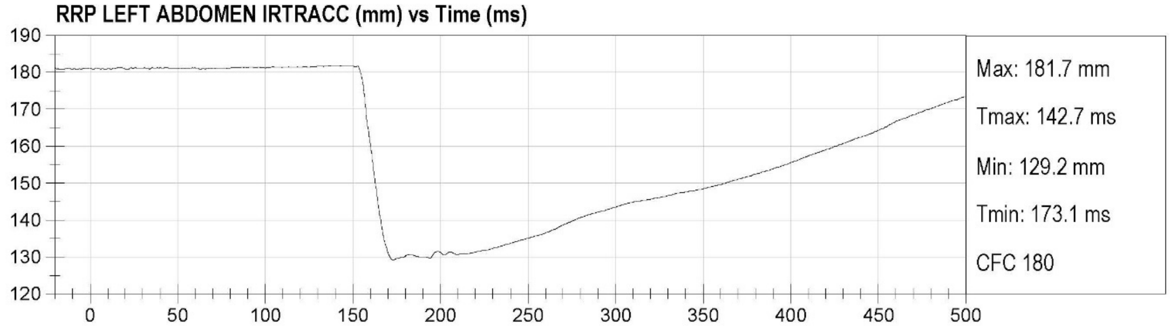


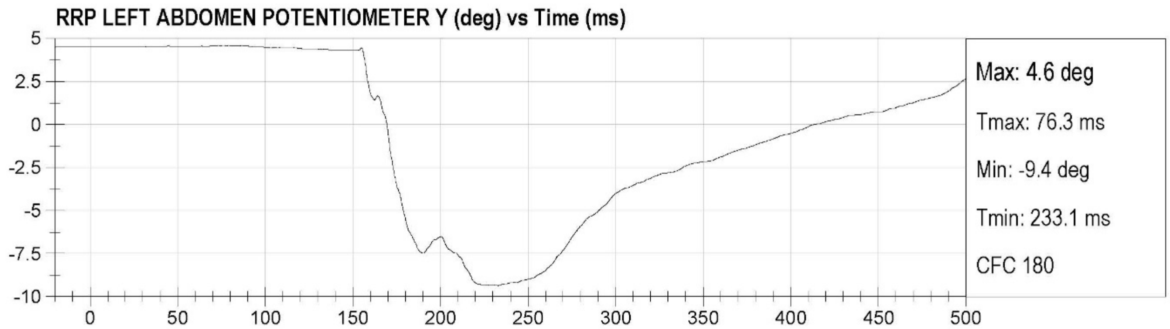

RRP LOWER RIGHT CHEST DEFLECTION Z (mm) vs Time (ms)

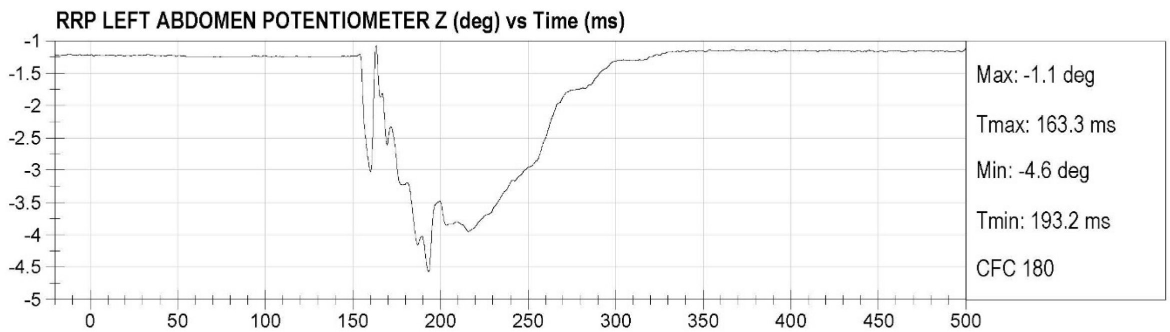


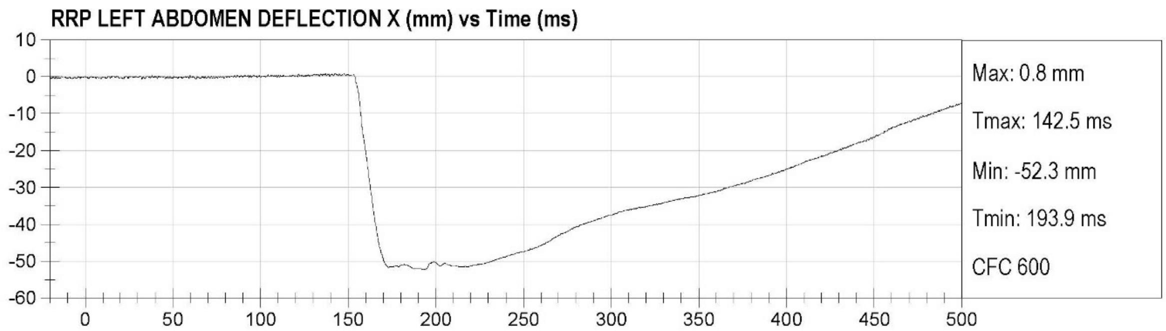

RRP LOWER RIGHT CHEST DEFLECTION RESULTANT (mm) vs Time (ms)

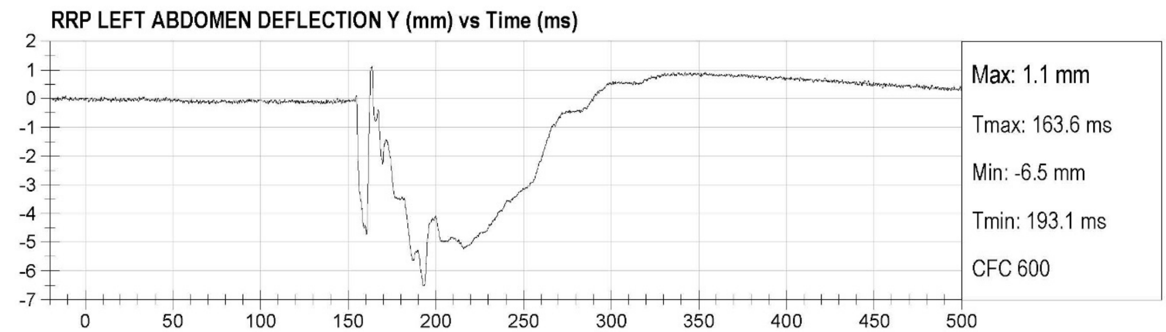


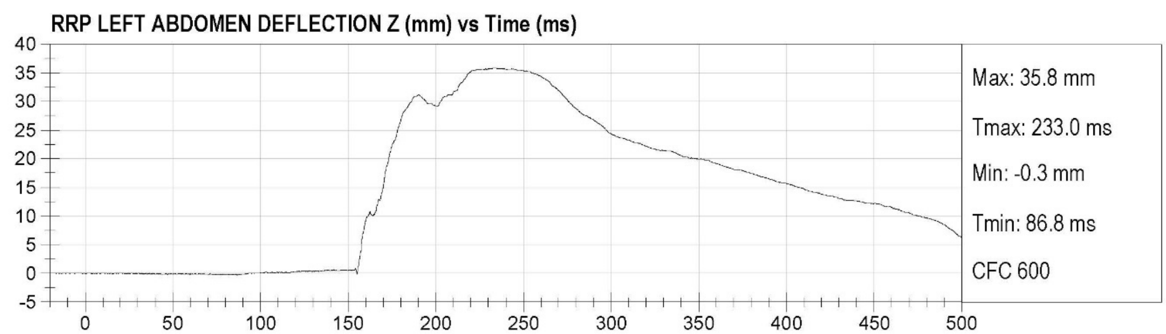

RRP LEFT ABDOMEN IRTRACC (mm) vs Time (ms)
190
180
170
160
150
140
130
120
0
50
100
150
200
250
300
350
400
450
500
Max: 181.7 mm
Tmax: 142.7 ms
Min: 129.2 mm
Tmin: 173.1 ms
CFC 180

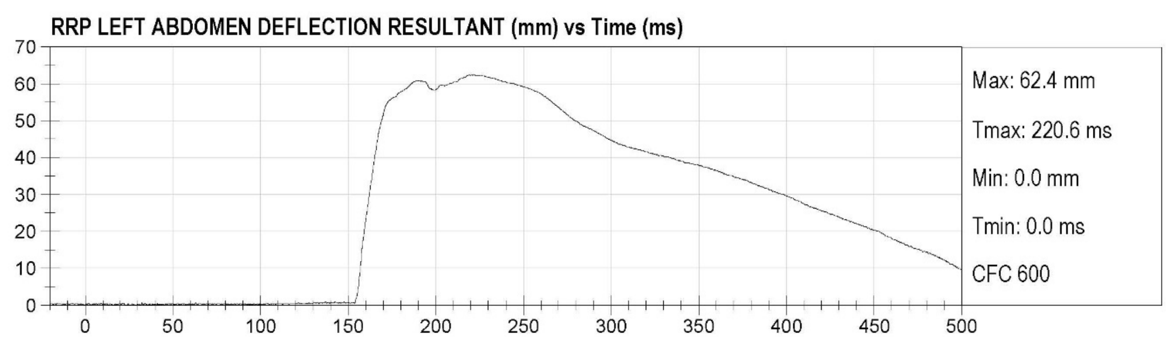

RRP LEFT ABDOMEN POTENTIOMETER Y (deg) vs Time (ms)
5
2.5
0
-2.5
-5
-7.5
-10
0
50
100
150
200
250
300
350
400
450
500
Max: 4.6 deg
Tmax: 76.3 ms
Min: -9.4 deg
Tmin: 233.1 ms
CFC 180


RRP LEFT ABDOMEN POTENTIOMETER Z (deg) vs Time (ms)
-1
-1.5
-2
-2.5
-3
-3.5
-4
-4.5
-5
0
50
100
150
200
250
300
350
400
450
500
Max: -1.1 deg
Tmax: 163.3 ms
Min: -4.6 deg
Tmin: 193.2 ms
CFC 180

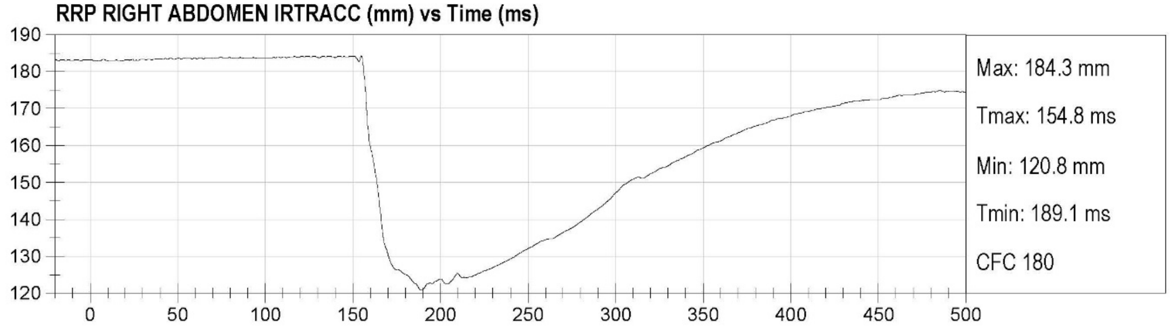

RRP LEFT ABDOMEN DEFLECTION X (mm) vs Time (ms)
Max: 0.8 mm
Tmax: 142.5 ms
Min: -52.3 mm
Tmin: 193.9 ms
CFC 600


RRP LEFT ABDOMEN DEFLECTION Y (mm) vs Time (ms)
Max: 1.1 mm
Tmax: 163.6 ms
Min: -6.5 mm
Tmin: 193.1 ms
CFC 600

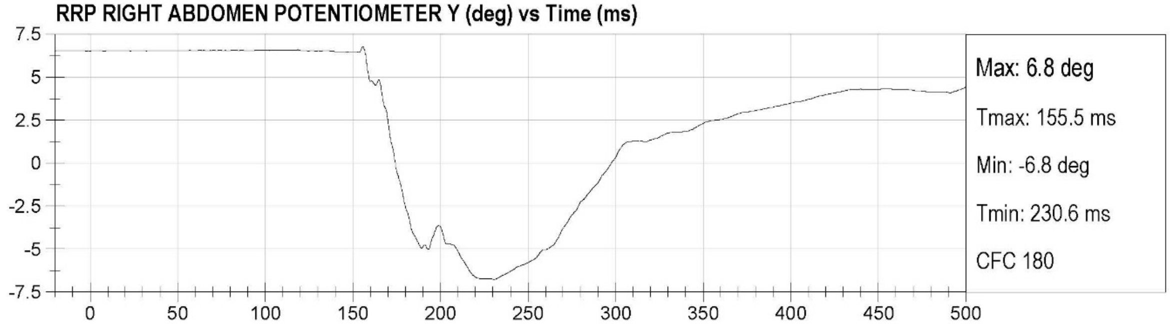

RRP LEFT ABDOMEN DEFLECTION Z (mm) vs Time (ms)
Max: 35.8 mm
Tmax: 233.0 ms
Min: -0.3 mm
Tmin: 86.8 ms
CFC 600


RRP LEFT ABDOMEN DEFLECTION RESULTANT (mm) vs Time (ms)
Max: 62.4 mm
Tmax: 220.6 ms
Min: 0.0 mm
Tmin: 0.0 ms
CFC 600

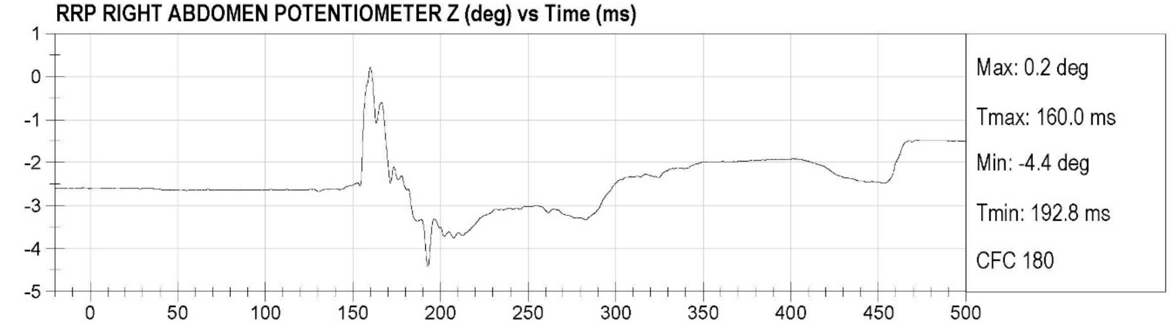
RRP RIGHT ABDOMEN IRTRACC (mm) vs Time (ms)



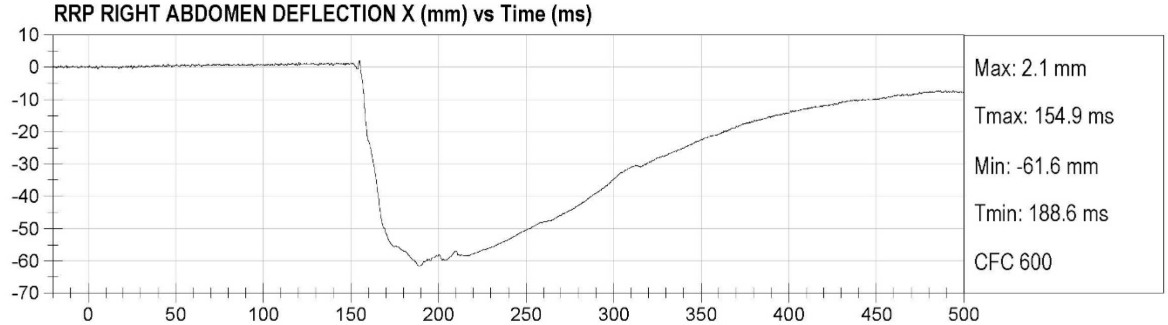

RRP RIGHT ABDOMEN POTENTIOMETER Y (deg) vs Time (ms)



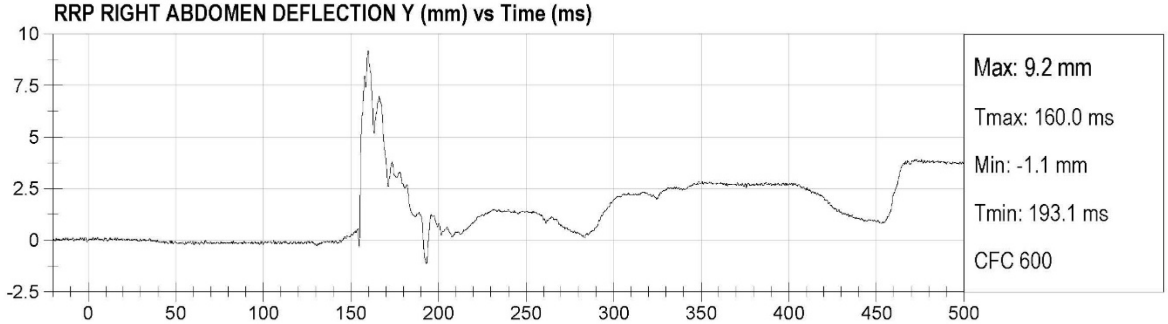

RRP RIGHT ABDOMEN POTENTIOMETER Z (deg) vs Time (ms)



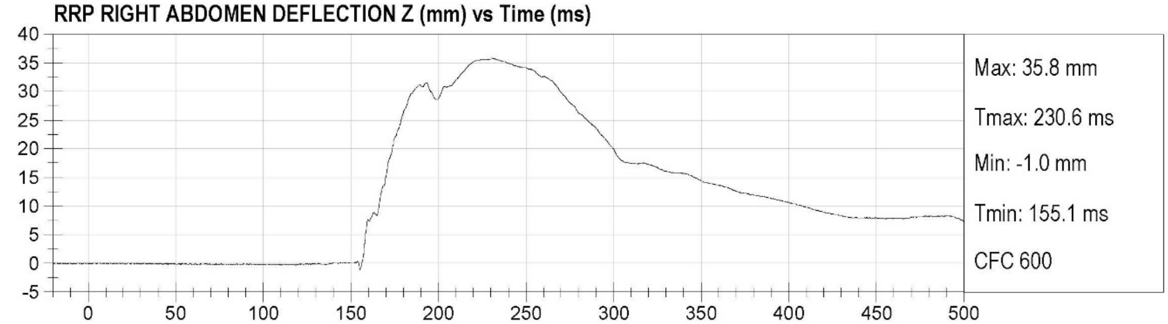
RRP RIGHT ABDOMEN DEFLECTION X (mm) vs Time (ms)



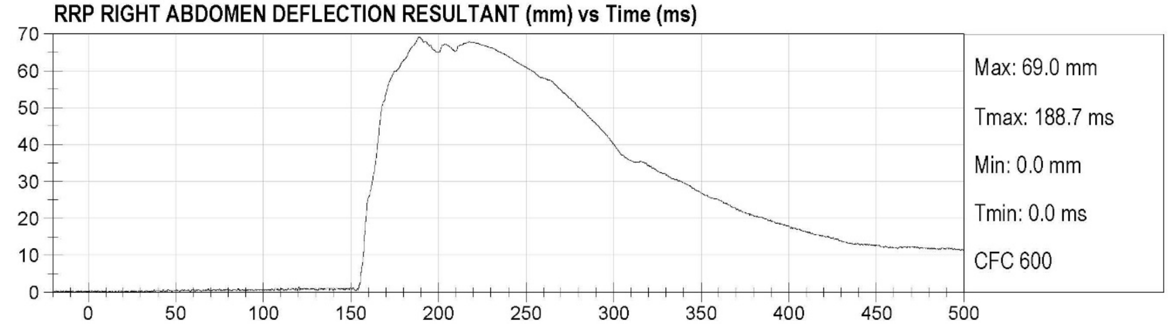

RRP RIGHT ABDOMEN DEFLECTION Y (mm) vs Time (ms)

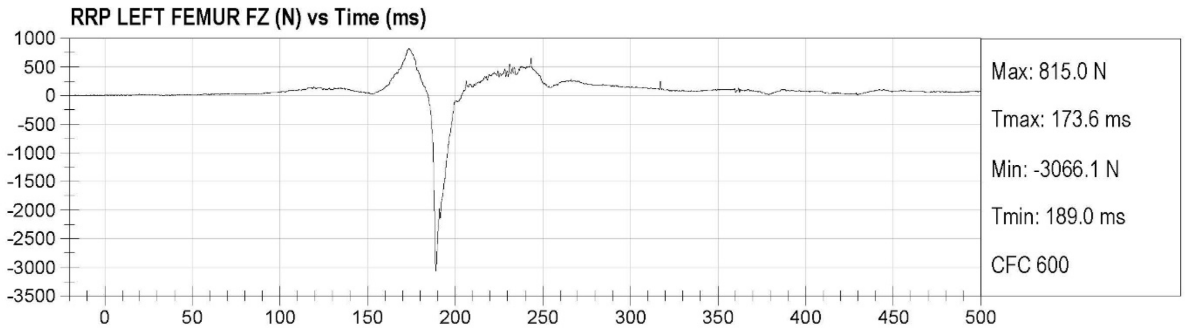


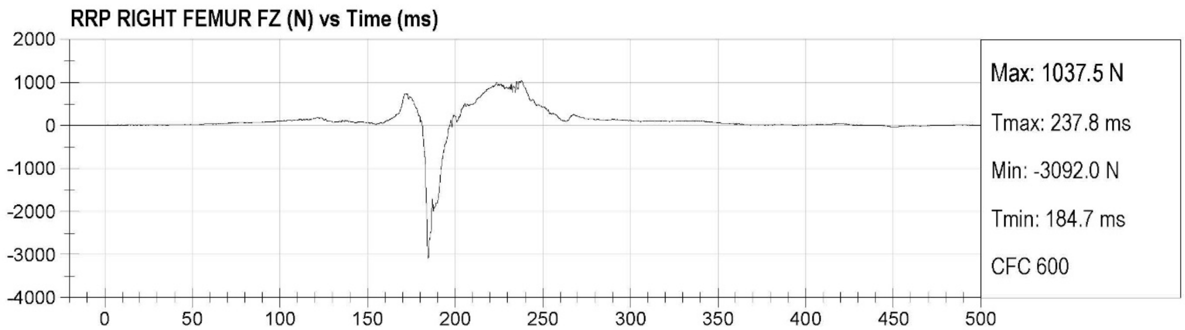

RRP RIGHT ABDOMEN DEFLECTION Z (mm) vs Time (ms)




RRP RIGHT ABDOMEN DEFLECTION RESULTANT (mm) vs Time (ms)



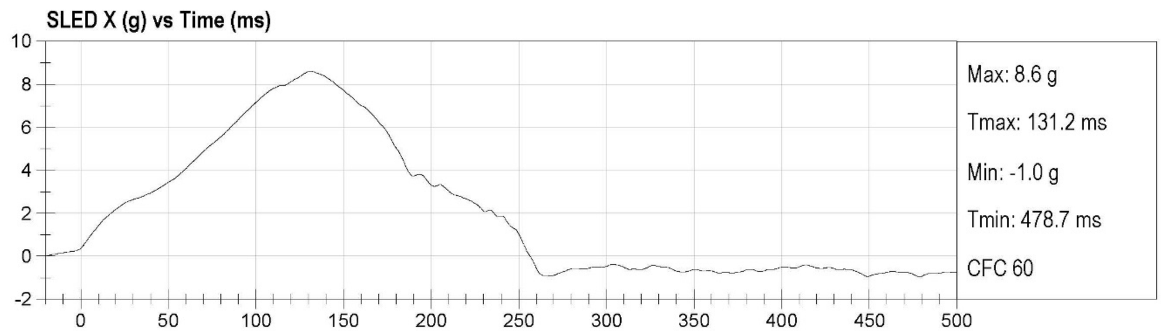

RRP LEFT FEMUR FZ (N) vs Time (ms)
Max: 815.0 N
Tmax: 173.6 ms
Min: -3066.1 N
Tmin: 189.0 ms
CFC 600

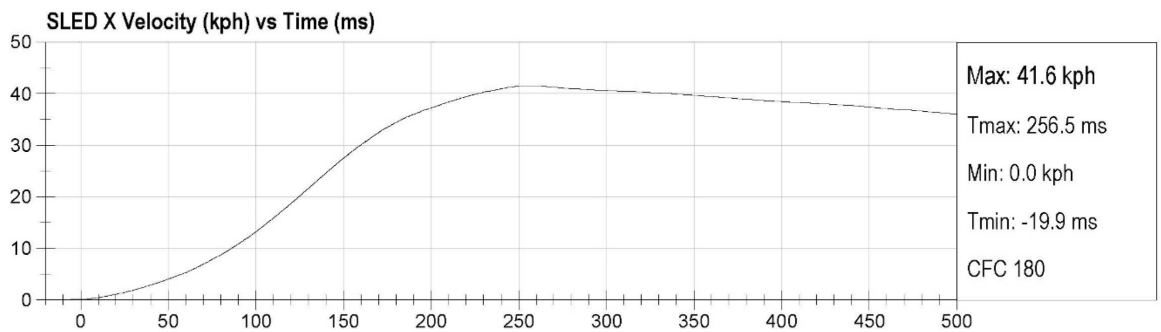

RRP RIGHT FEMUR FZ (N) vs Time (ms)
Max: 1037.5 N
Tmax: 237.8 ms
Min: -3092.0 N
Tmin: 184.7 ms
CFC 600

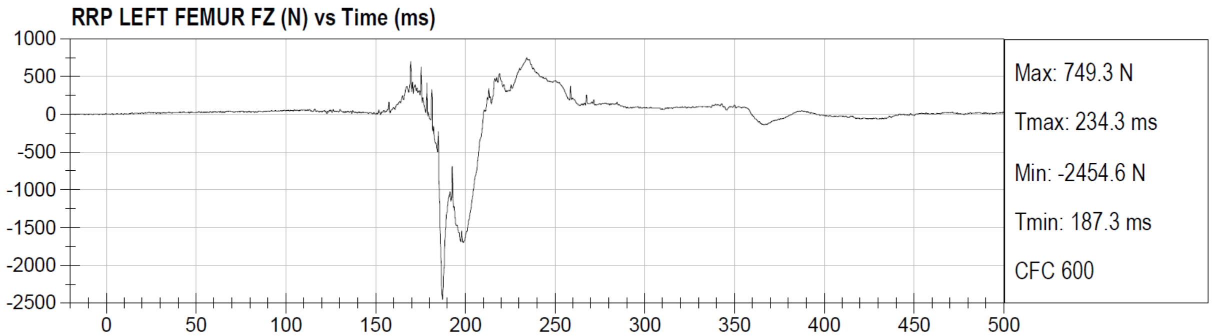
## A.2: Test 1A* Data

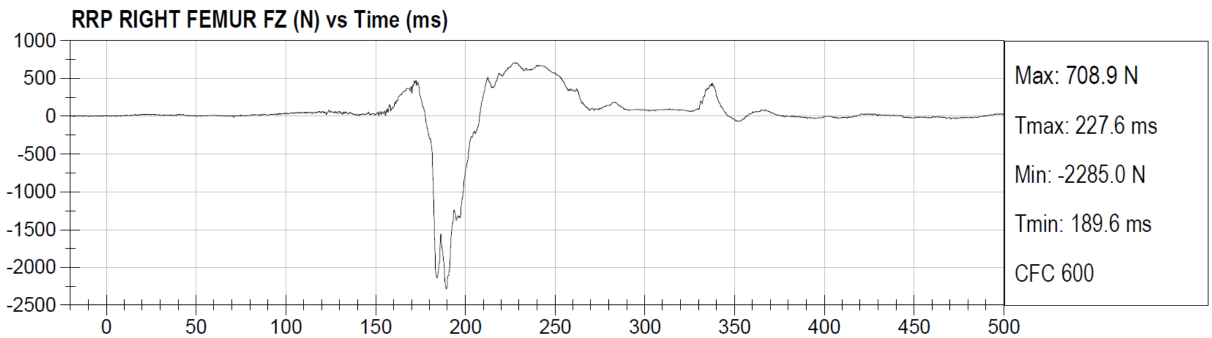
Test Date: 05/06/2021

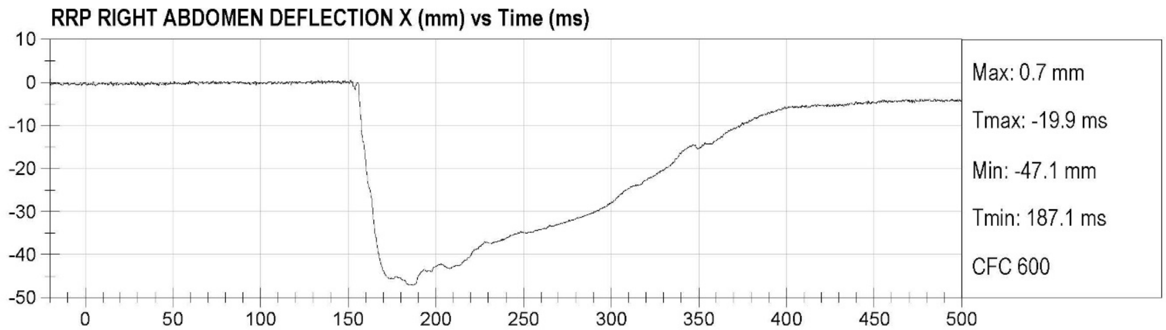
MGA Test ID: S21139

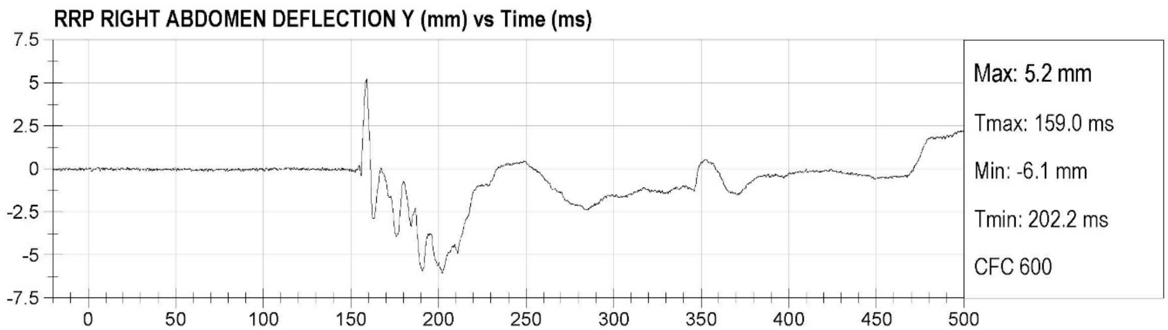


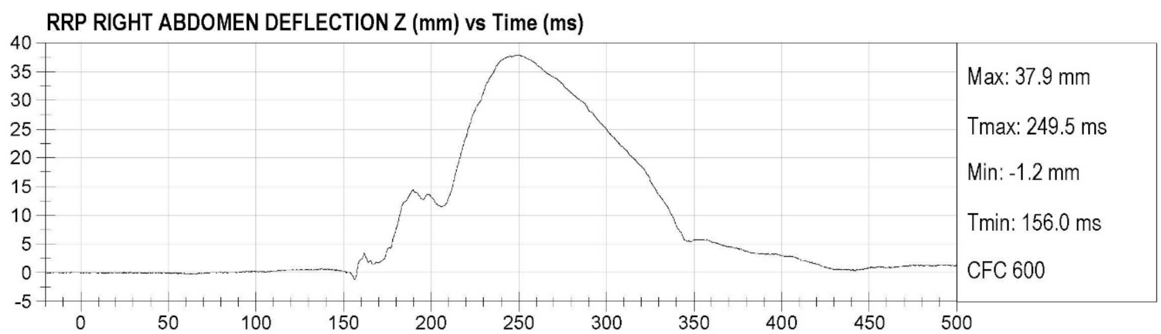



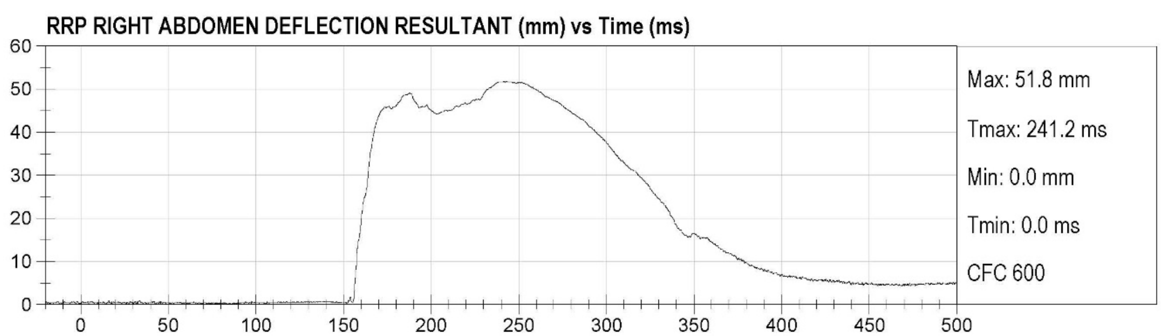

RRP LEFT FEMUR FZ (N) vs Time (ms)
1000
500
0
-500
-1000
-1500
-2000
-2500
0
50
100
150
200
250
300
350
400
450
500
Max: 749.3 N
Tmax: 234.3 ms
Min: -2454.6 N
Tmin: 187.3 ms
CFC 600

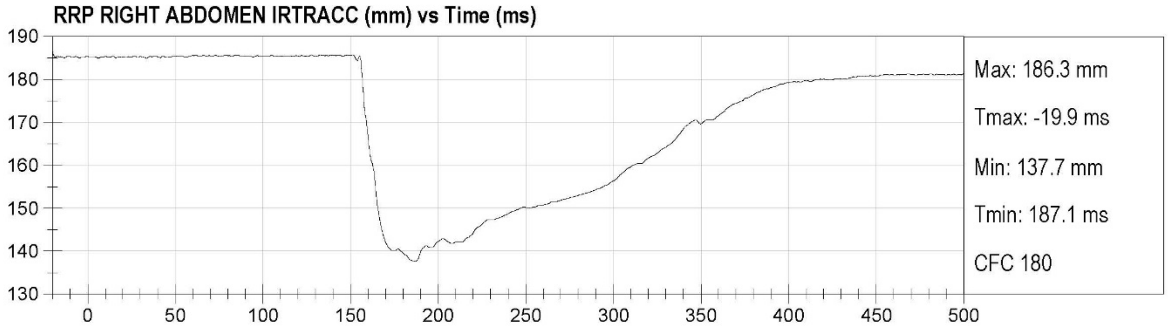

RRP RIGHT FEMUR FZ (N) vs Time (ms)
1000
500
0
-500
-1000
-1500
-2000
-2500
0
50
100
150
200
250
300
350
400
450
500
Max: 708.9 N
Tmax: 227.6 ms
Min: -2285.0 N
Tmin: 189.6 ms
CFC 600

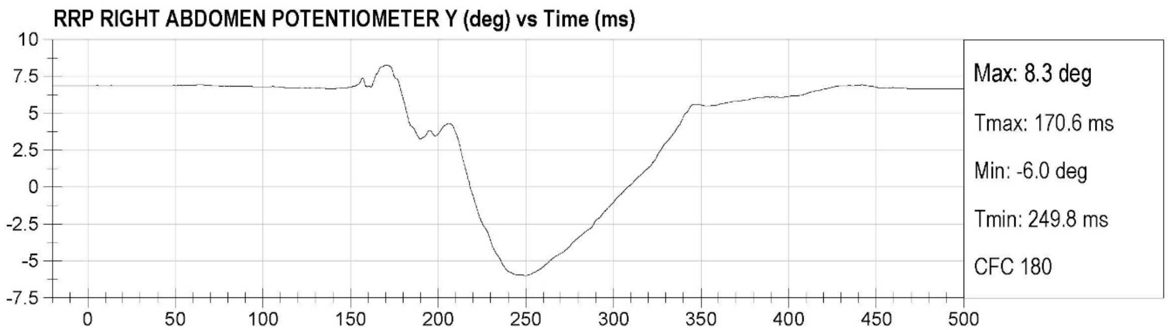

RRP RIGHT ABDOMEN DEFLECTION X (mm) vs Time (ms)
Max: 0.7 mm
Tmax: -19.9 ms
Min: -47.1 mm
Tmin: 187.1 ms
CFC 600

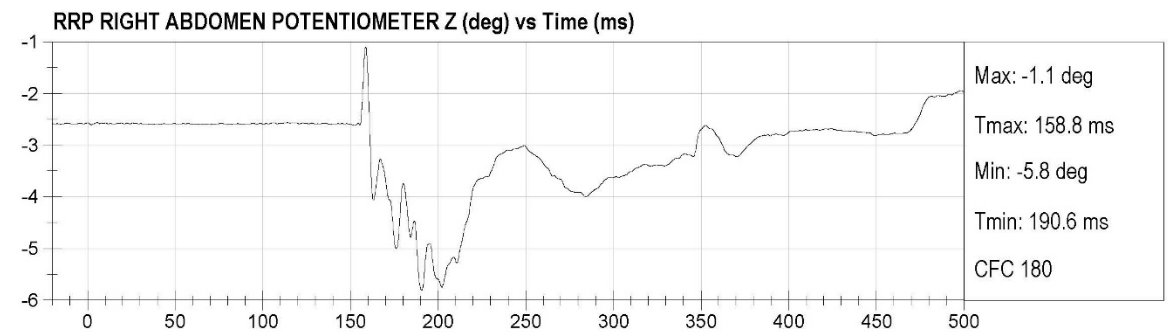

RRP RIGHT ABDOMEN DEFLECTION Y (mm) vs Time (ms)
Max: 5.2 mm
Tmax: 159.0 ms
Min: -6.1 mm
Tmin: 202.2 ms
CFC 600

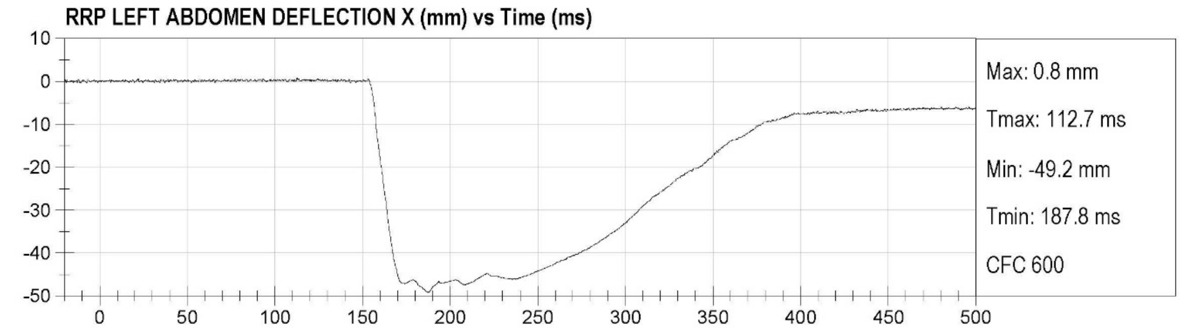

RRP RIGHT ABDOMEN DEFLECTION Z (mm) vs Time (ms)
Max: 37.9 mm
Tmax: 249.5 ms
Min: -1.2 mm
Tmin: 156.0 ms
CFC 600

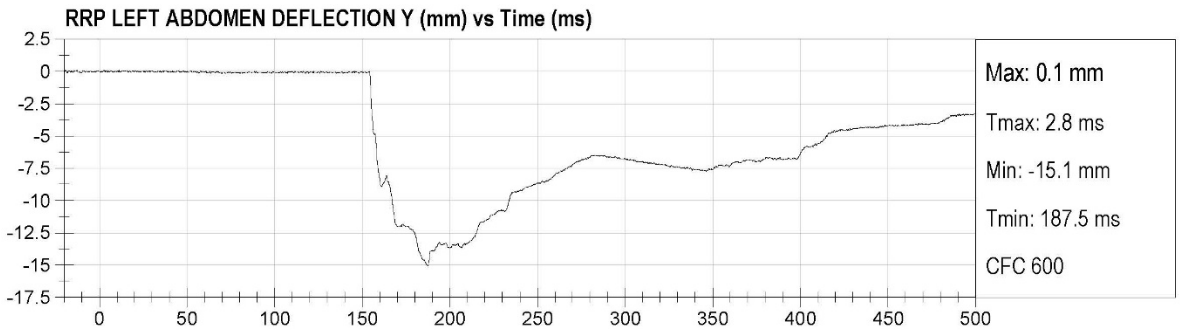

RRP RIGHT ABDOMEN DEFLECTION RESULTANT (mm) vs Time (ms)
Max: 51.8 mm
Tmax: 241.2 ms
Min: 0.0 mm
Tmin: 0.0 ms
CFC 600

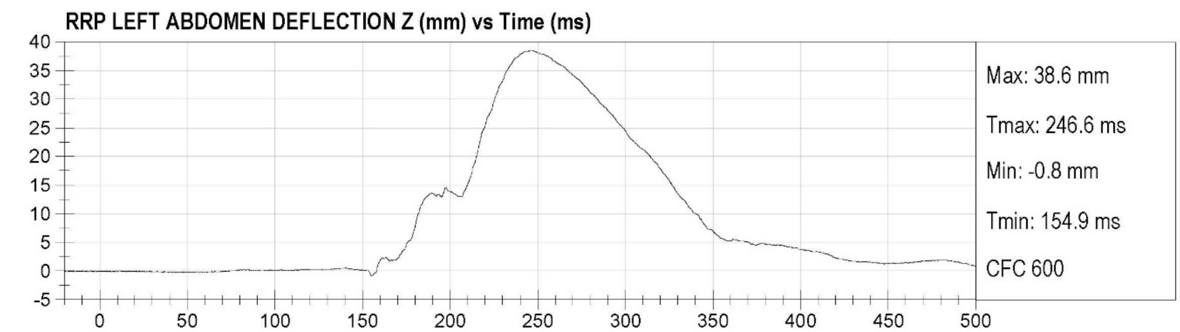

RRP RIGHT ABDOMEN IRTRACC (mm) vs Time (ms)
Max: 186.3 mm
Tmax: -19.9 ms
Min: 137.7 mm
Tmin: 187.1 ms
CFC 180

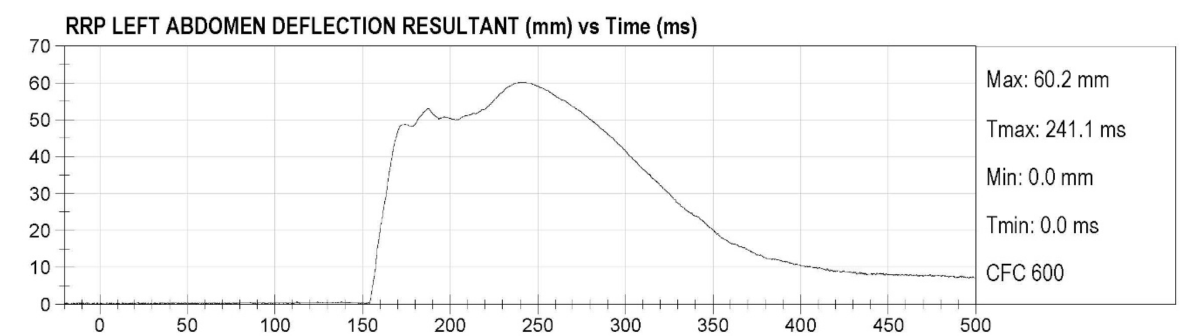

RRP RIGHT ABDOMEN POTENTIOMETER Y (deg) vs Time (ms)
Max: 8.3 deg
Tmax: 170.6 ms
Min: -6.0 deg
Tmin: 249.8 ms
CFC 180

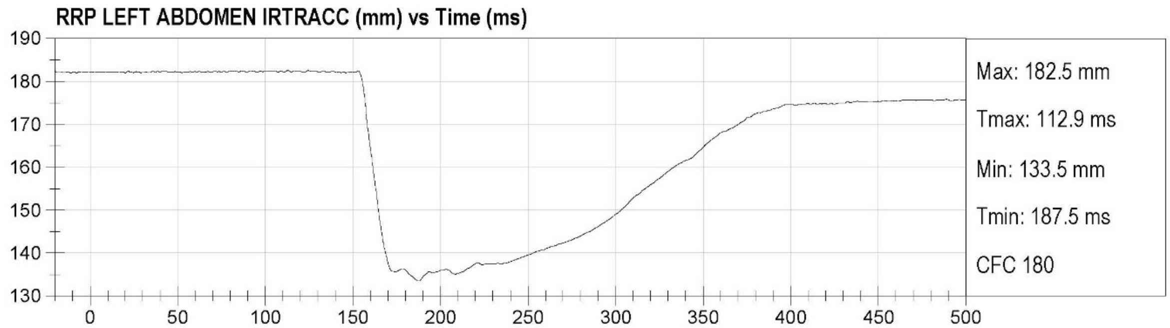

RRP RIGHT ABDOMEN POTENTIOMETER Z (deg) vs Time (ms)
Max: -1.1 deg
Tmax: 158.8 ms
Min: -5.8 deg
Tmin: 190.6 ms
CFC 180

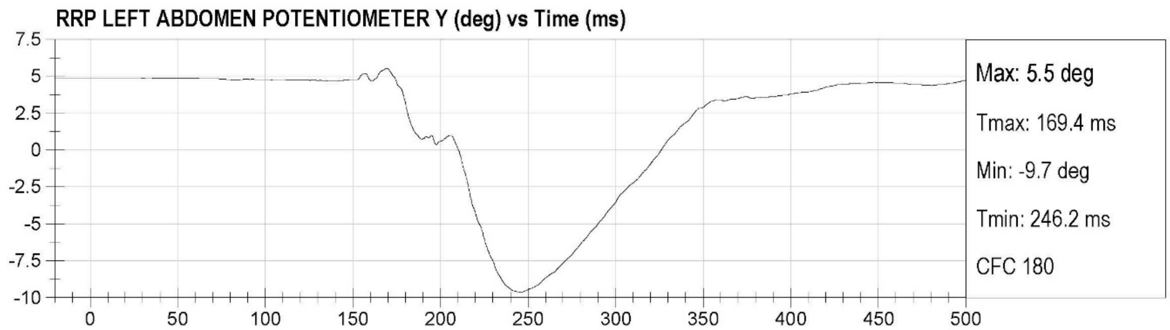

RRP LEFT ABDOMEN DEFLECTION X (mm) vs Time (ms)
Max: 0.8 mm
Tmax: 112.7 ms
Min: -49.2 mm
Tmin: 187.8 ms
CFC 600

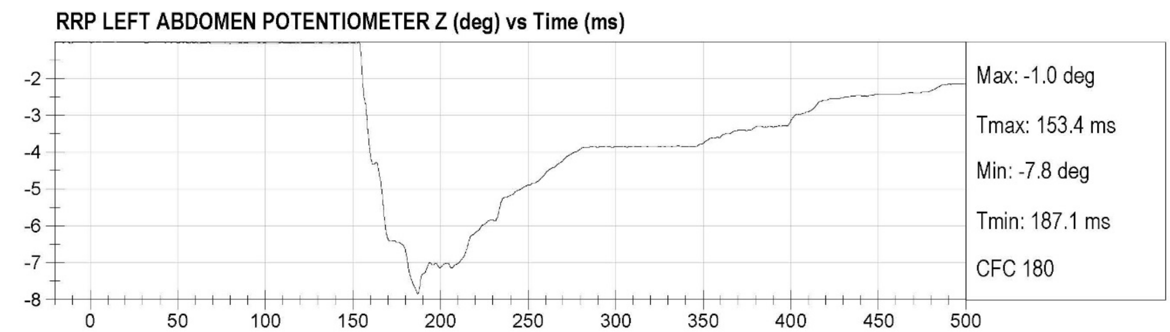

RRP LEFT ABDOMEN DEFLECTION Y (mm) vs Time (ms)
Max: 0.1 mm
Tmax: 2.8 ms
Min: -15.1 mm
Tmin: 187.5 ms
CFC 600


RRP LEFT ABDOMEN DEFLECTION Z (mm) vs Time (ms)
Max: 38.6 mm
Tmax: 246.6 ms
Min: -0.8 mm
Tmin: 154.9 ms
CFC 600

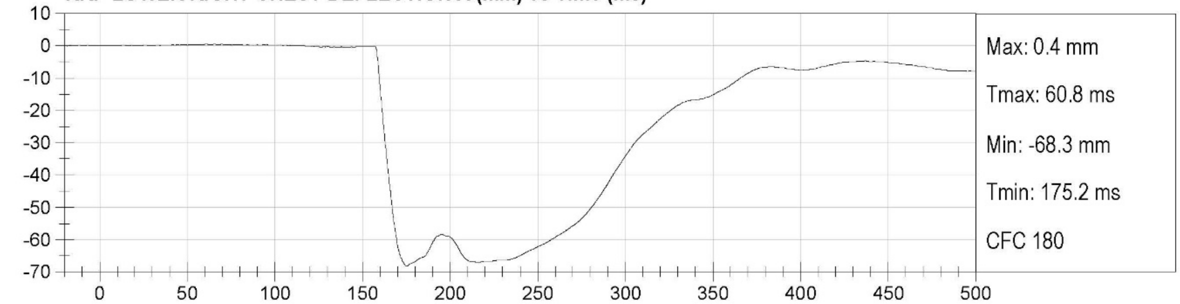

RRP LEFT ABDOMEN DEFLECTION RESULTANT (mm) vs Time (ms)
Max: 60.2 mm
Tmax: 241.1 ms
Min: 0.0 mm
Tmin: 0.0 ms
CFC 600


RRP LEFT ABDOMEN IRTRACC (mm) vs Time (ms)
Max: 182.5 mm
Tmax: 112.9 ms
Min: 133.5 mm
Tmin: 187.5 ms
CFC 180

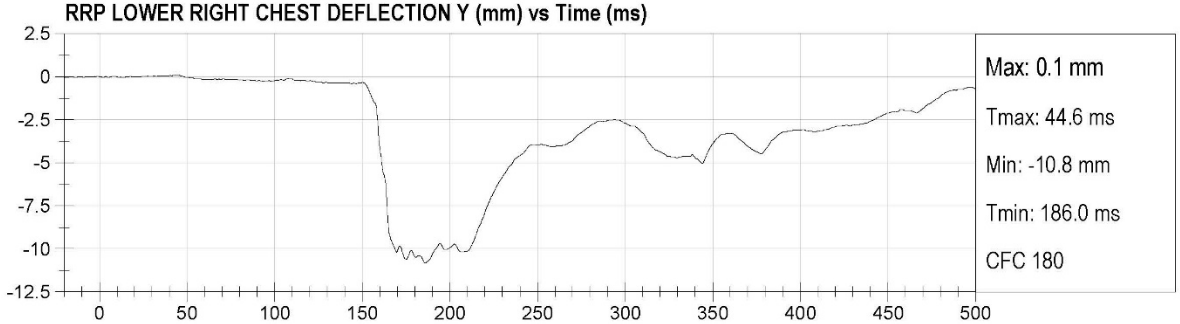

RRP LEFT ABDOMEN POTENTIOMETER Y (deg) vs Time (ms)
Max: 5.5 deg
Tmax: 169.4 ms
Min: -9.7 deg
Tmin: 246.2 ms
CFC 180


RRP LEFT ABDOMEN POTENTIOMETER Z (deg) vs Time (ms)
Max: -1.0 deg
Tmax: 153.4 ms
Min: -7.8 deg
Tmin: 187.1 ms
CFC 180

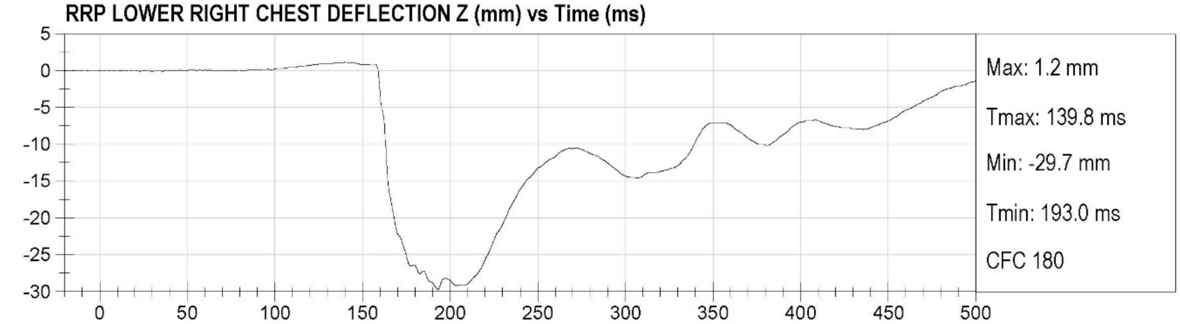
RRP LOWER RIGHT CHEST DEFLECTION X (mm) vs Time (ms)



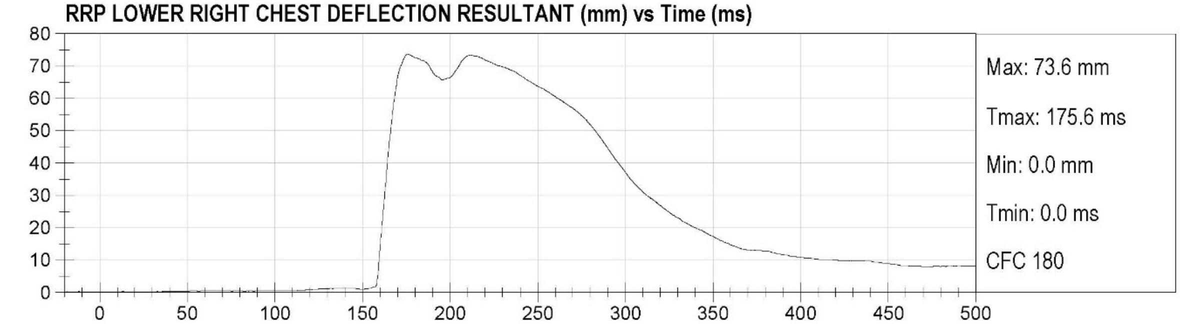

RRP LOWER RIGHT CHEST DEFLECTION Y (mm) vs Time (ms)



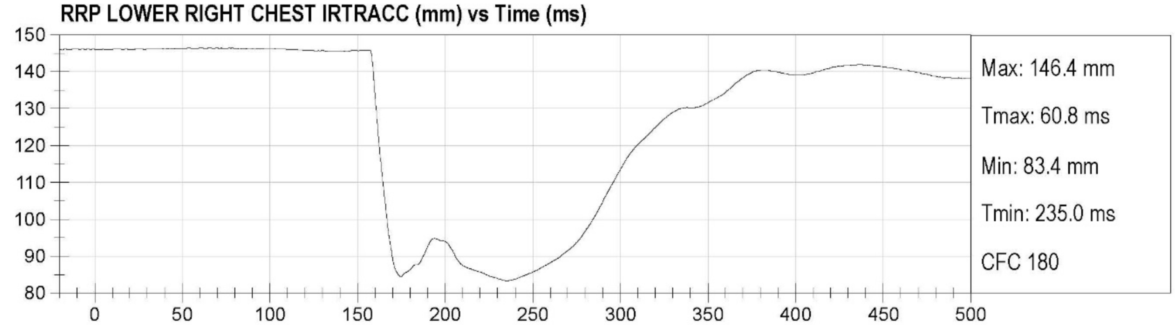

RRP LOWER RIGHT CHEST DEFLECTION Z (mm) vs Time (ms)



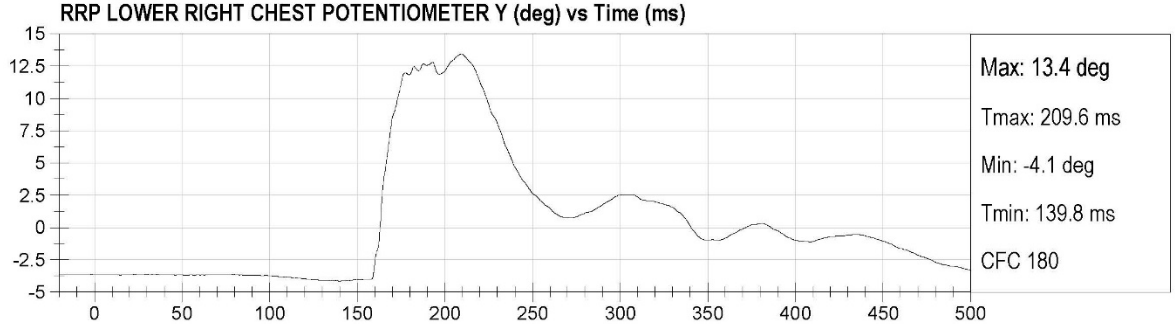

RRP LOWER RIGHT CHEST DEFLECTION RESULTANT (mm) vs Time (ms)



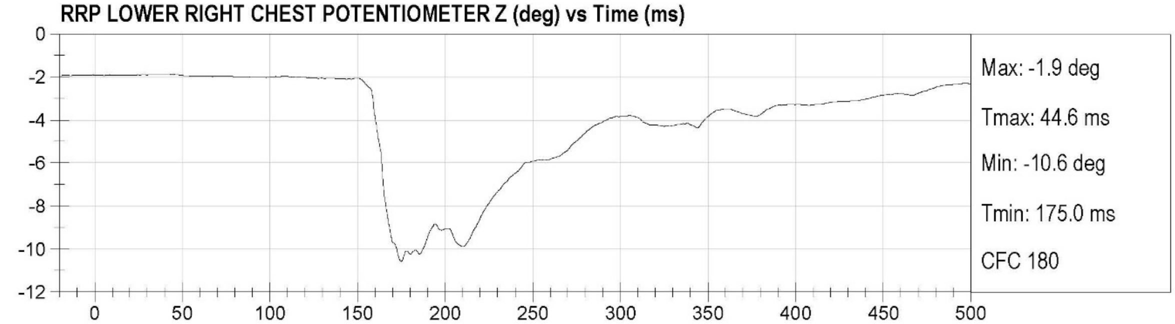
RRP LOWER RIGHT CHEST IRTRACC (mm) vs Time (ms)



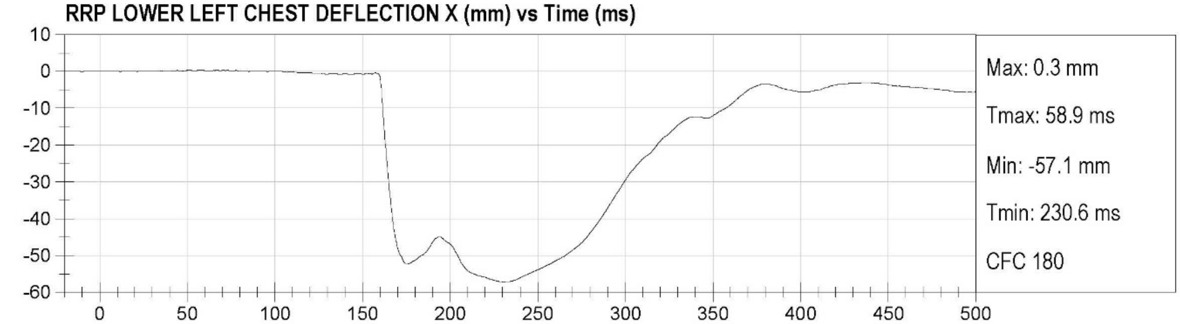

RRP LOWER RIGHT CHEST POTENTIOMETER Y (deg) vs Time (ms)



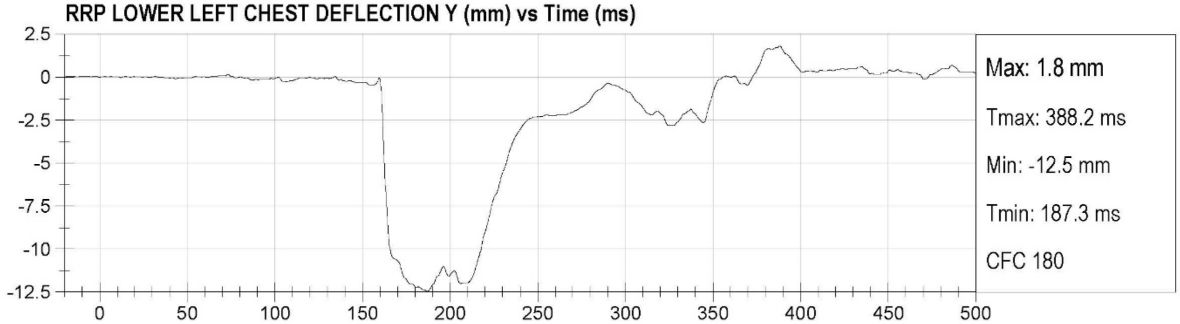

RRP LOWER RIGHT CHEST POTENTIOMETER Z (deg) vs Time (ms)



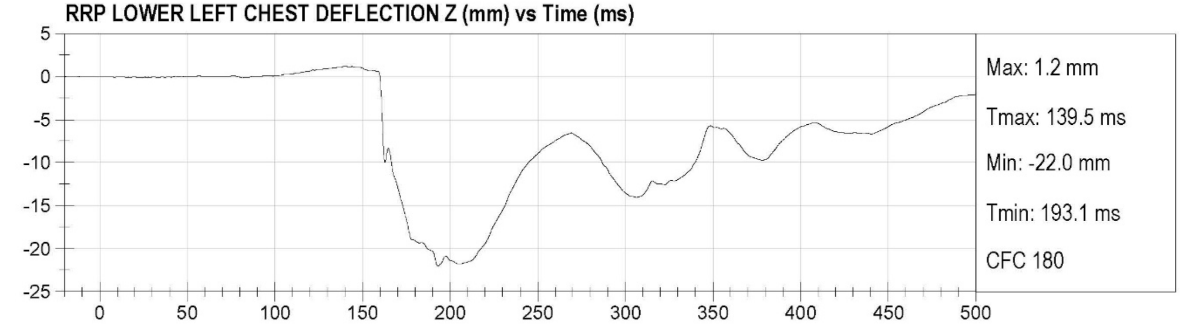
RRP LOWER LEFT CHEST DEFLECTION X (mm) vs Time (ms)



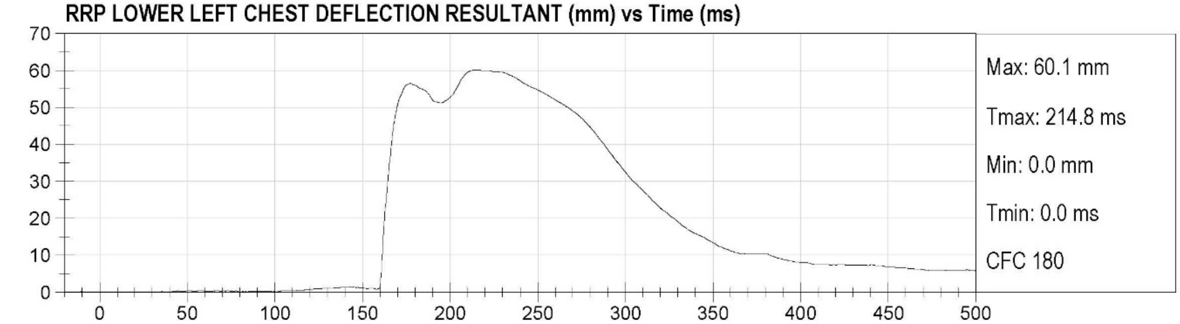

RRP LOWER LEFT CHEST DEFLECTION Y (mm) vs Time (ms)

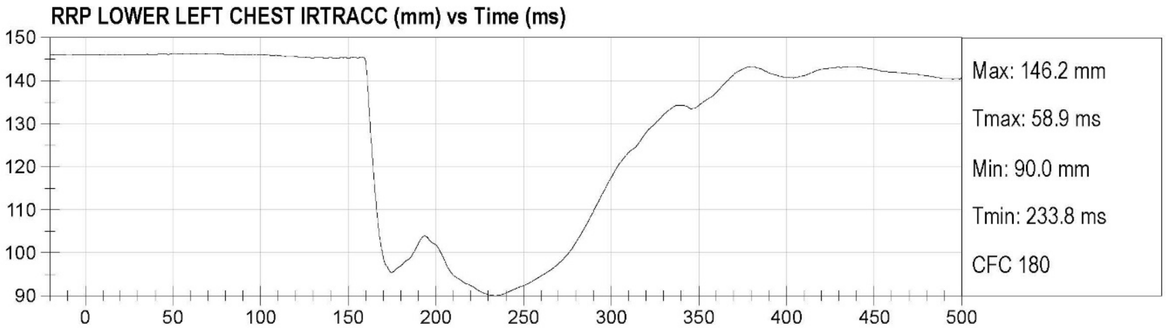


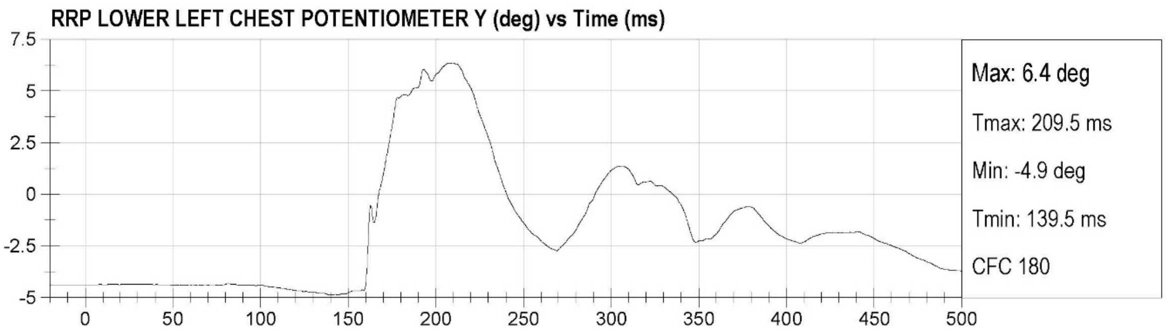

RRP LOWER LEFT CHEST DEFLECTION Z (mm) vs Time (ms)

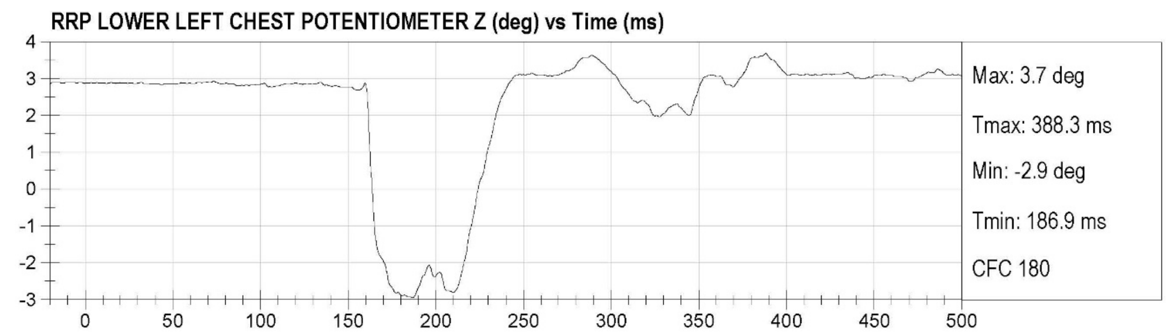



RRP LOWER LEFT CHEST DEFLECTION RESULTANT (mm) vs Time (ms)

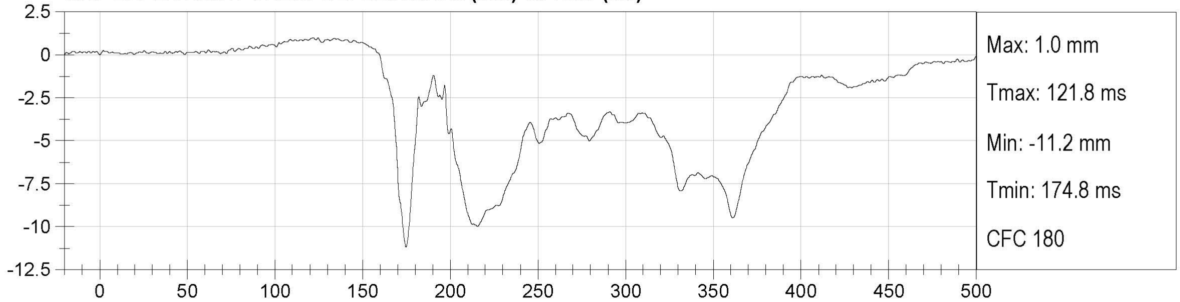



RRP LOWER LEFT CHEST IRTRACC (mm) vs Time (ms)
Max: 146.2 mm
Tmax: 58.9 ms
Min: 90.0 mm
Tmin: 233.8 ms
CFC 180

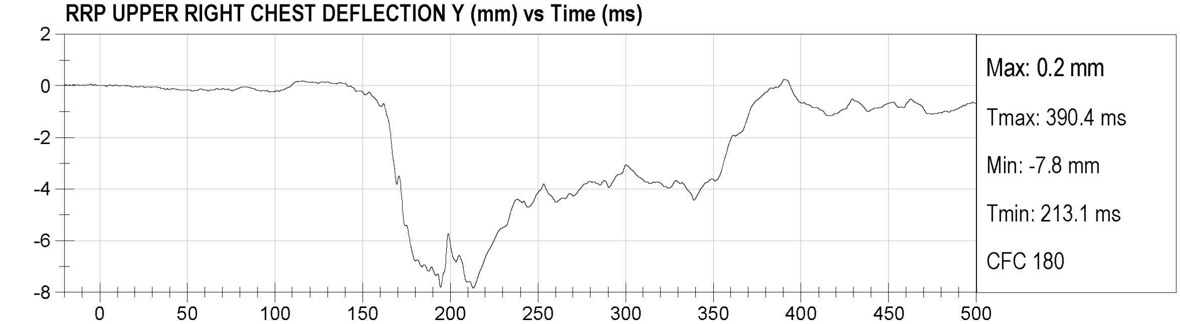

RRP LOWER LEFT CHEST POTENTIOMETER Y (deg) vs Time (ms)
Max: 6.4 deg
Tmax: 209.5 ms
Min: -4.9 deg
Tmin: 139.5 ms
CFC 180


RRP LOWER LEFT CHEST POTENTIOMETER Z (deg) vs Time (ms)
Max: 3.7 deg
Tmax: 388.3 ms
Min: -2.9 deg
Tmin: 186.9 ms
CFC 180

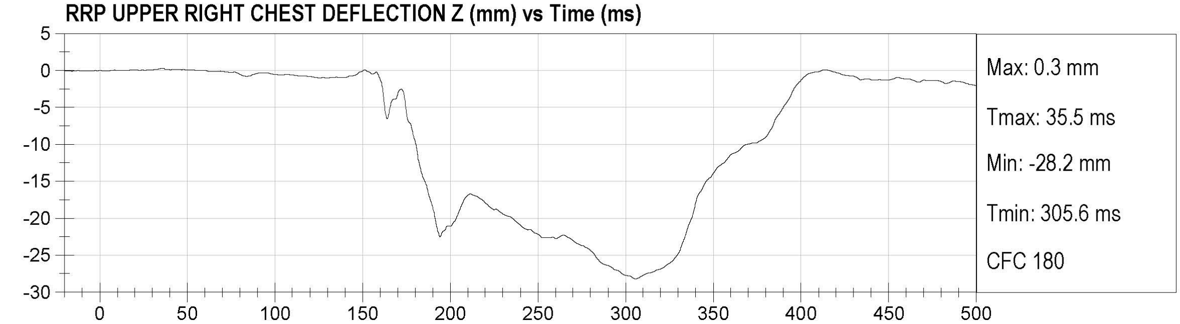
RRP UPPER RIGHT CHEST DEFLECTION X (mm) vs Time (ms)



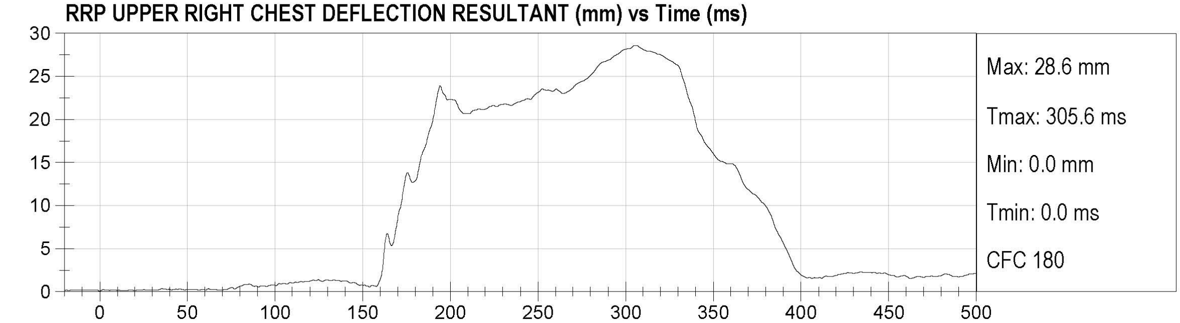

RRP UPPER RIGHT CHEST DEFLECTION Y (mm) vs Time (ms)

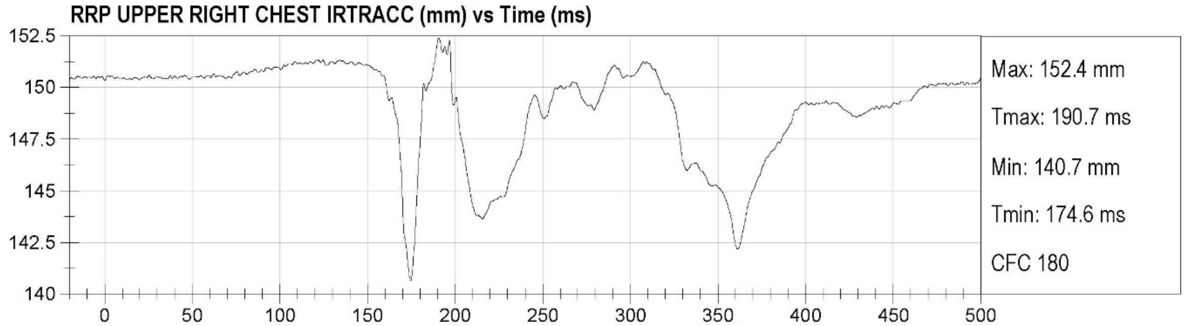


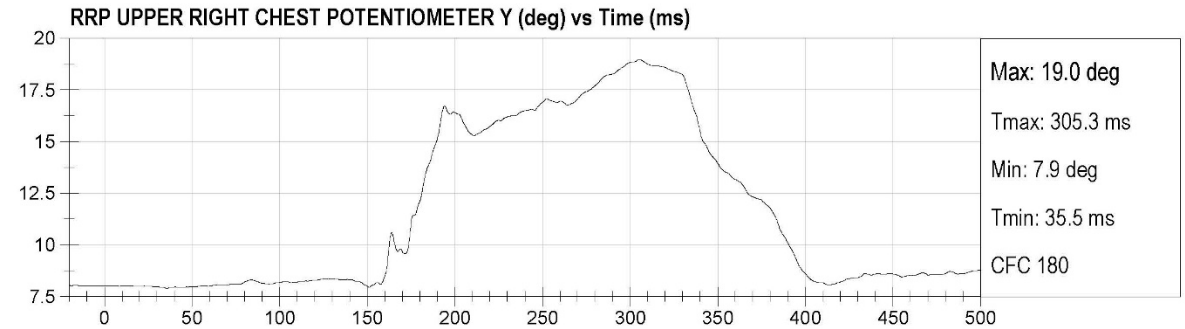

RRP UPPER RIGHT CHEST DEFLECTION Z (mm) vs Time (ms)

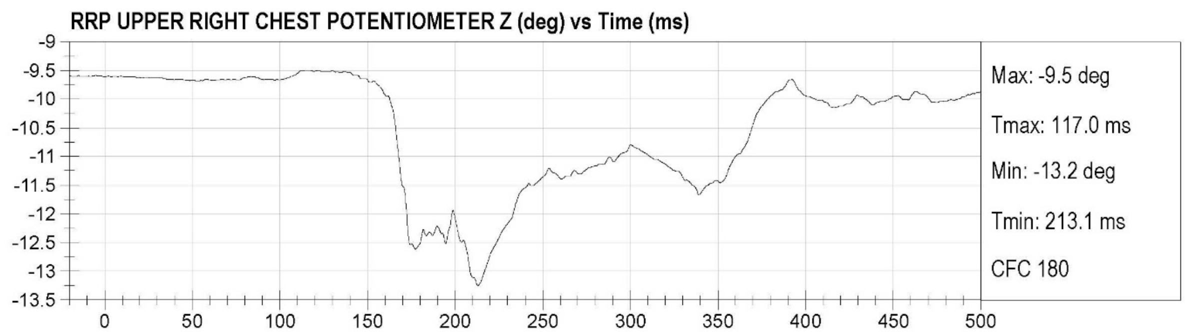


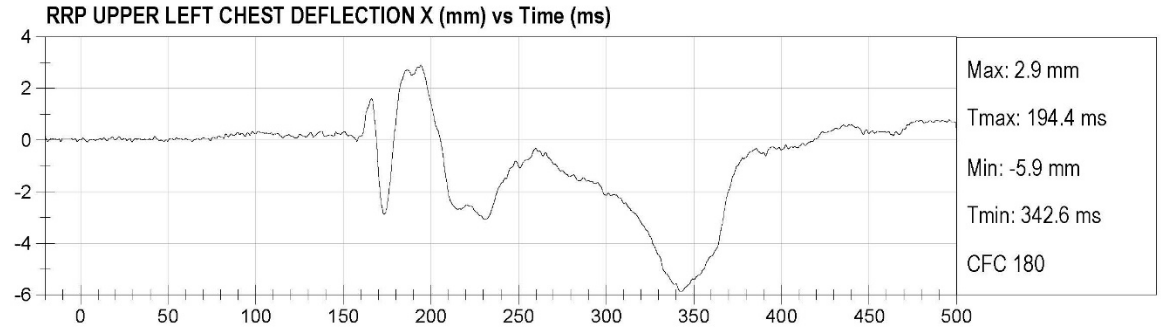

RRP UPPER RIGHT CHEST DEFLECTION RESULTANT (mm) vs Time (ms)

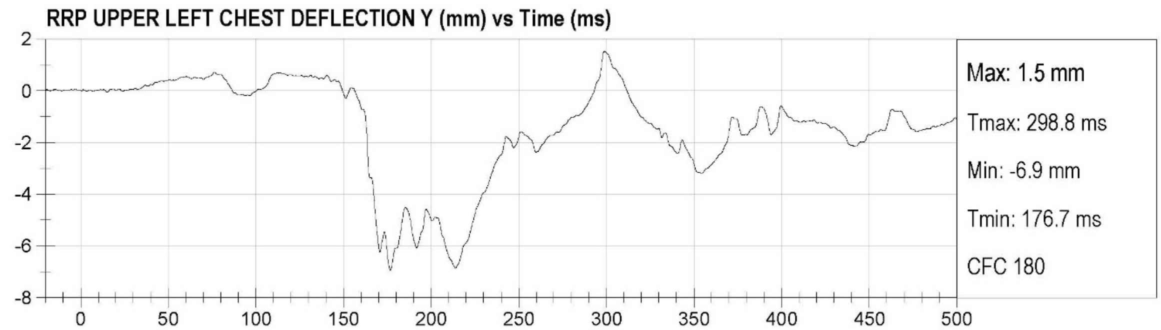


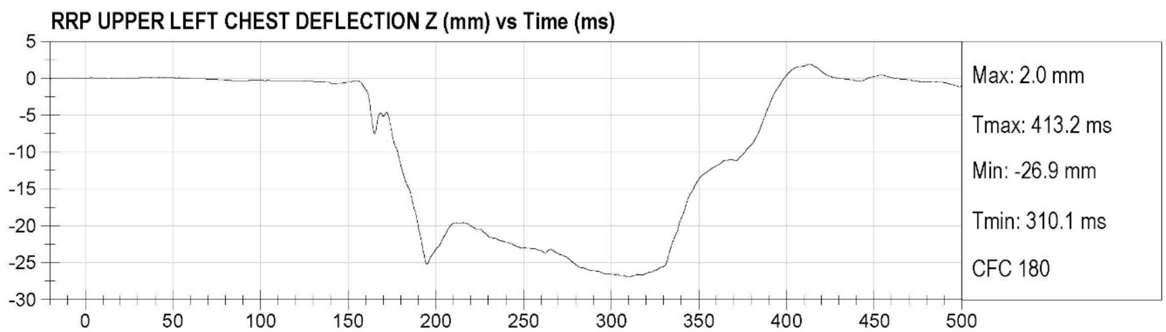

RRP UPPER RIGHT CHEST IRTRACC (mm) vs Time (ms)
Max: 152.4 mm
Tmax: 190.7 ms
Min: 140.7 mm
Tmin: 174.6 ms
CFC 180

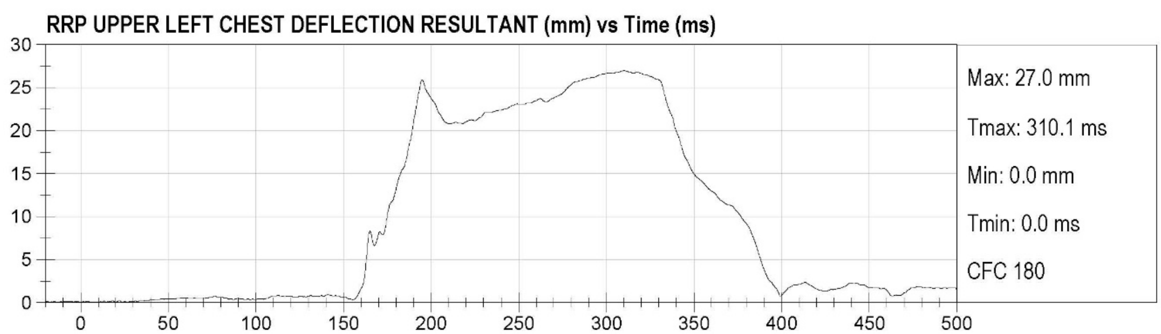

RRP UPPER RIGHT CHEST POTENTIOMETER Y (deg) vs Time (ms)
Max: 19.0 deg
Tmax: 305.3 ms
Min: 7.9 deg
Tmin: 35.5 ms
CFC 180


RRP UPPER RIGHT CHEST POTENTIOMETER Z (deg) vs Time (ms)
Max: -9.5 deg
Tmax: 117.0 ms
Min: -13.2 deg
Tmin: 213.1 ms
CFC 180

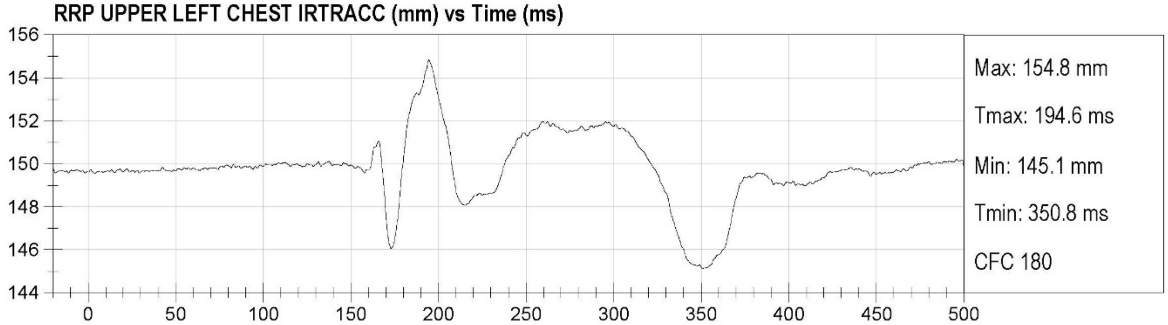

RRP UPPER LEFT CHEST DEFLECTION X (mm) vs Time (ms)
Max: 2.9 mm
Tmax: 194.4 ms
Min: -5.9 mm
Tmin: 342.6 ms
CFC 180


RRP UPPER LEFT CHEST DEFLECTION Y (mm) vs Time (ms)
Max: 1.5 mm
Tmax: 298.8 ms
Min: -6.9 mm
Tmin: 176.7 ms
CFC 180

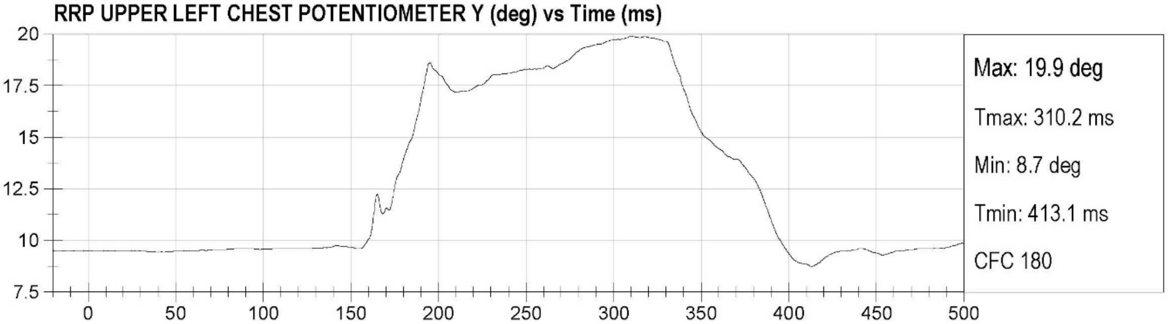

RRP UPPER LEFT CHEST DEFLECTION Z (mm) vs Time (ms)
Max: 2.0 mm
Tmax: 413.2 ms
Min: -26.9 mm
Tmin: 310.1 ms
CFC 180


RRP UPPER LEFT CHEST DEFLECTION RESULTANT (mm) vs Time (ms)
Max: 27.0 mm
Tmax: 310.1 ms
Min: 0.0 mm
Tmin: 0.0 ms
CFC 180

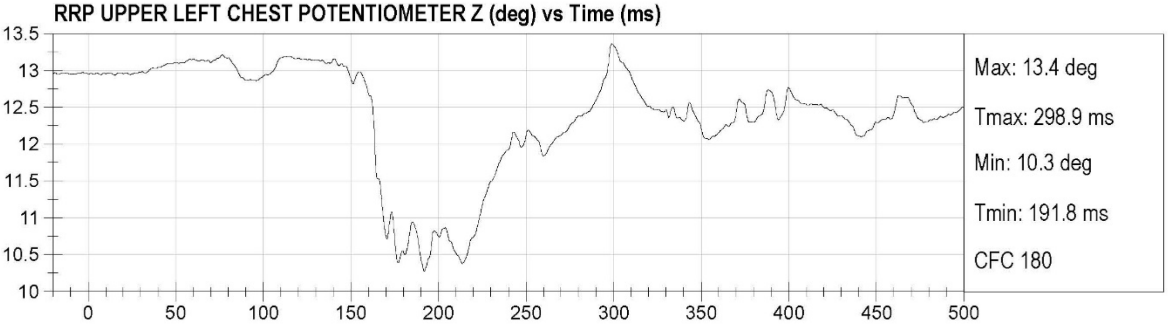
RRP UPPER LEFT CHEST IRTRACC (mm) vs Time (ms)

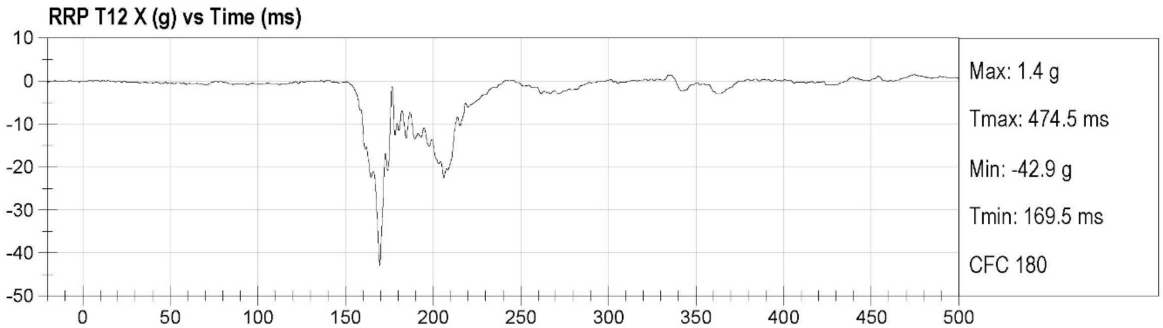


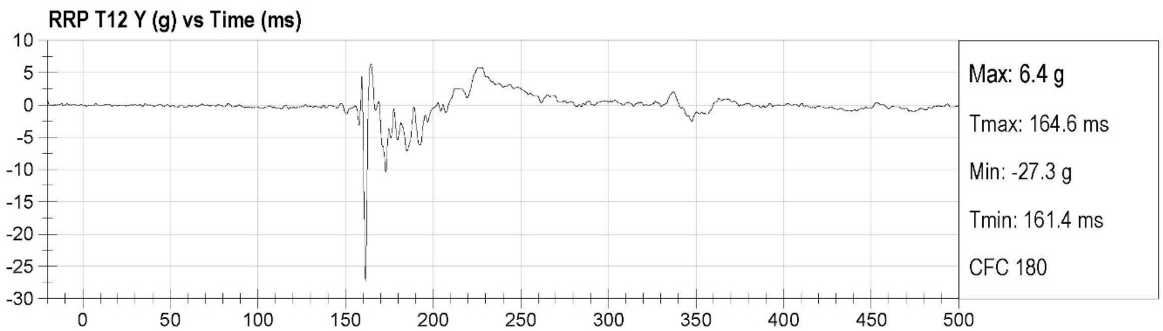

RRP UPPER LEFT CHEST POTENTIOMETER Y (deg) vs Time (ms)

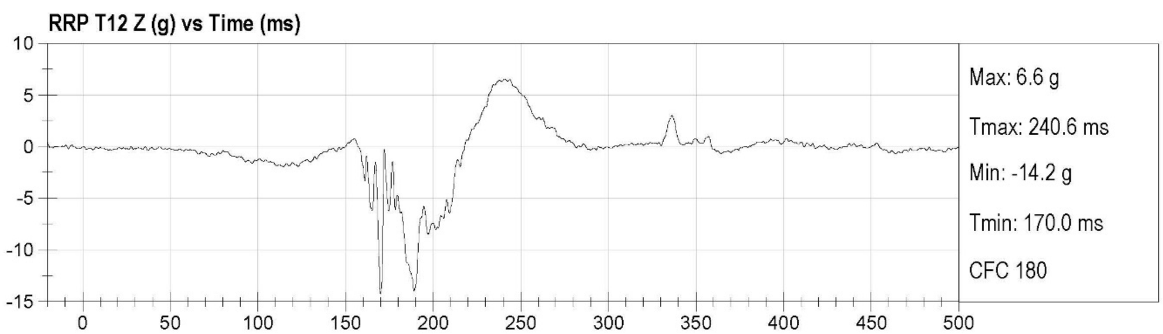



RRP UPPER LEFT CHEST POTENTIOMETER Z (deg) vs Time (ms)

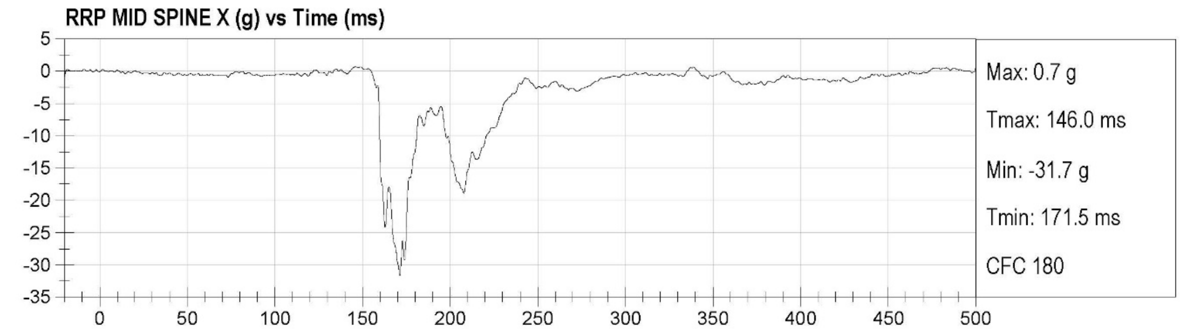


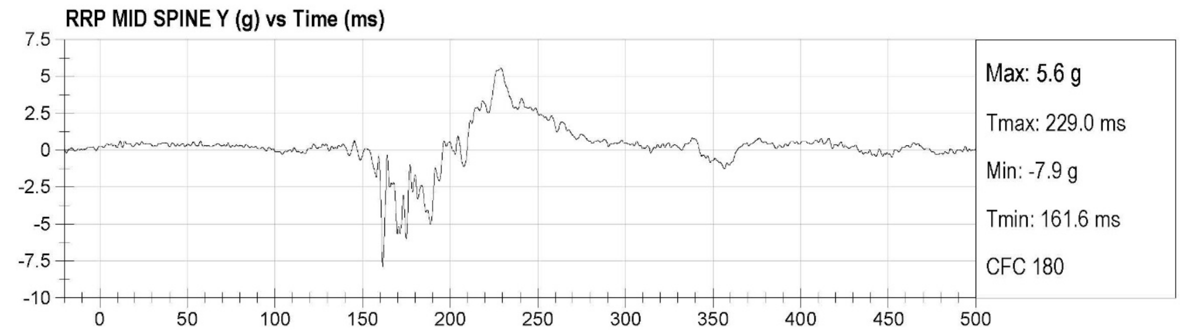

RRP T12 X (g) vs Time (ms)
Max: 1.4 g
Tmax: 474.5 ms
Min: -42.9 g
Tmin: 169.5 ms
CFC 180
10 0 -10 -20 -30 -40 -50
0 50 100 150 200 250 300 350 400 450 500

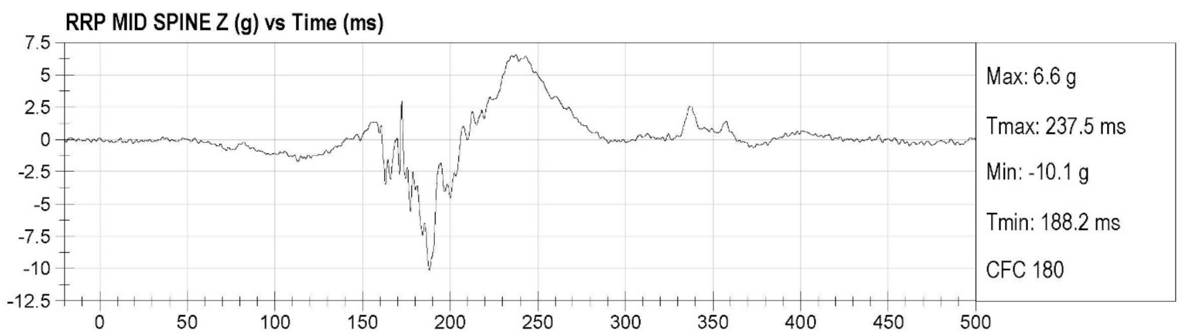

RRP T12 Y (g) vs Time (ms)
Max: 6.4 g
Tmax: 164.6 ms
Min: -27.3 g
Tmin: 161.4 ms
CFC 180
10 5 0 -5 -10 -15 -20 -25 -30
0 50 100 150 200 250 300 350 400 450 500


RRP T12 Z (g) vs Time (ms)
Max: 6.6 g
Tmax: 240.6 ms
Min: -14.2 g
Tmin: 170.0 ms
CFC 180
10 5 0 -5 -10 -15
0 50 100 150 200 250 300 350 400 450 500

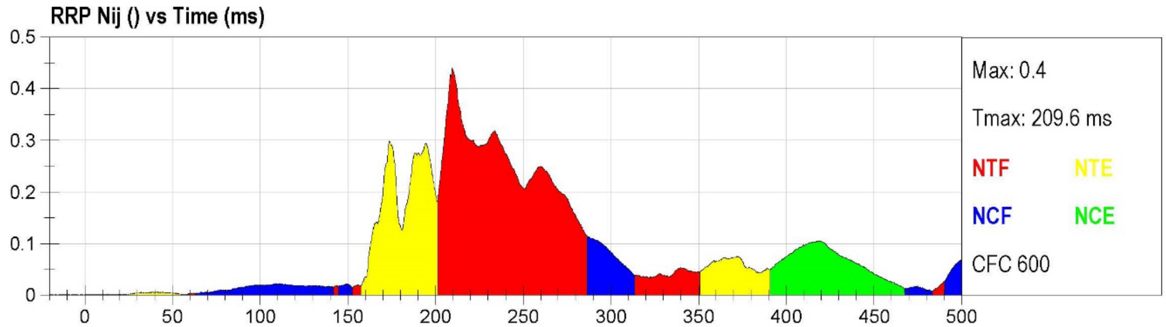

RRP T12 Resultant (g) vs Time (ms)
Max: 44.9 g
Tmax: 169.6 ms
Min: 0.0 g
Tmin: -16.3 ms
CFC 180
50 40 30 20 10 0
0 50 100 150 200 250 300 350 400 450 500


RRP MID SPINE X (g) vs Time (ms)
Max: 0.7 g
Tmax: 146.0 ms
Min: -31.7 g
Tmin: 171.5 ms
CFC 180

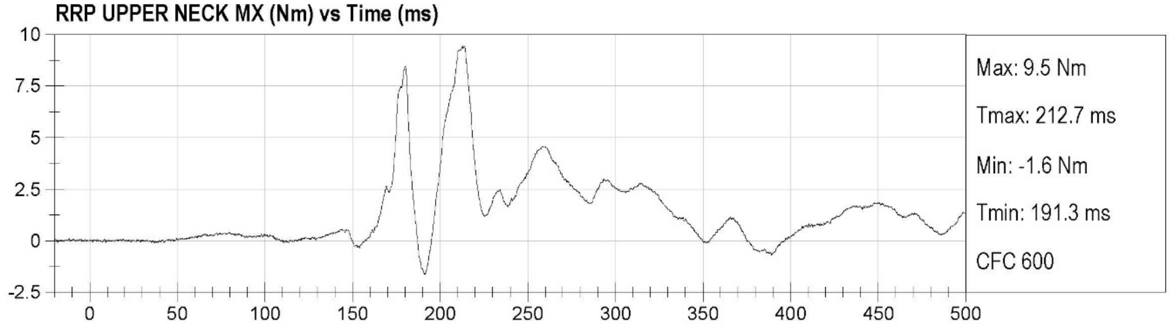

RRP MID SPINE Y (g) vs Time (ms)
Max: 5.6 g
Tmax: 229.0 ms
Min: -7.9 g
Tmin: 161.6 ms
CFC 180


RRP MID SPINE Z (g) vs Time (ms)
Max: 6.6 g
Tmax: 237.5 ms
Min: -10.1 g
Tmin: 188.2 ms
CFC 180

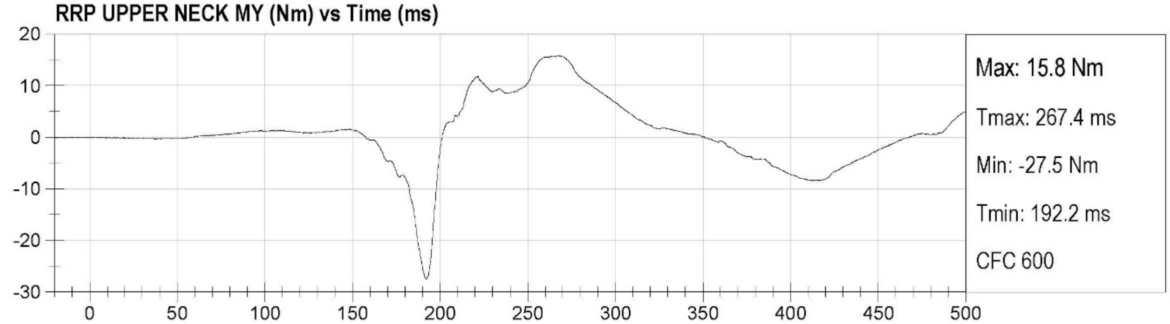

RRP MID SPINE Resultant (g) vs Time (ms)
Max: 32.2 g
Tmax: 171.4 ms
Min: 0.0 g
Tmin: 495.9 ms
CFC 180


RRP Nij () vs Time (ms)
0.5
0.4
0.3
0.2
0.1
0
0
50
100
150
200
250
300
350
400
450
500
Max: 0.4
Tmax: 209.6 ms
NTF
NTE
NCF
NCE
CFC 600

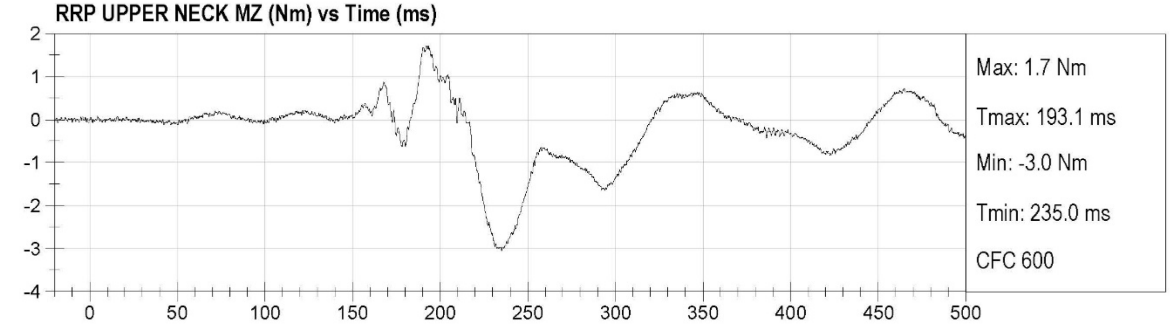
RRP UPPER NECK MX (Nm) vs Time (ms)



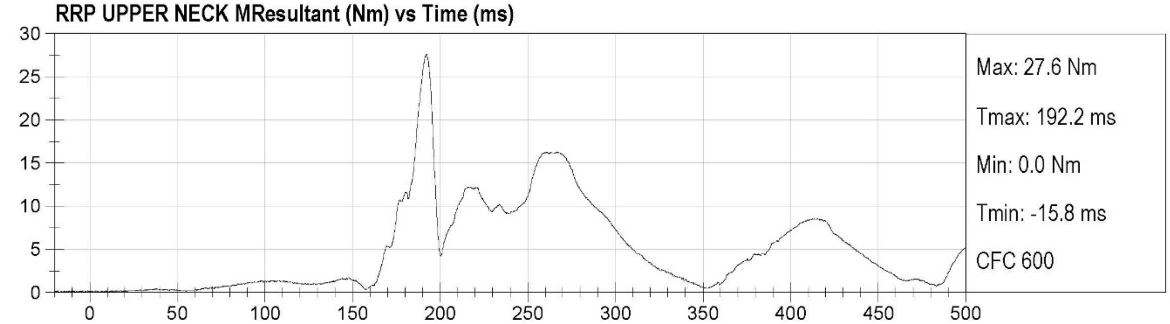

RRP UPPER NECK MY (Nm) vs Time (ms)

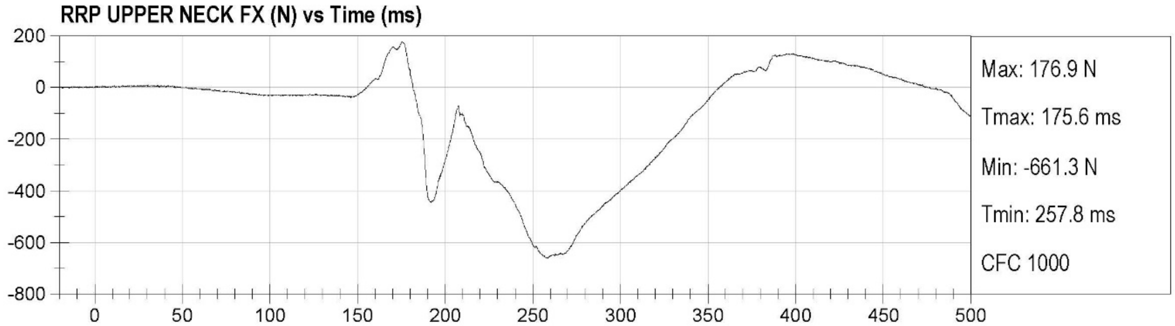


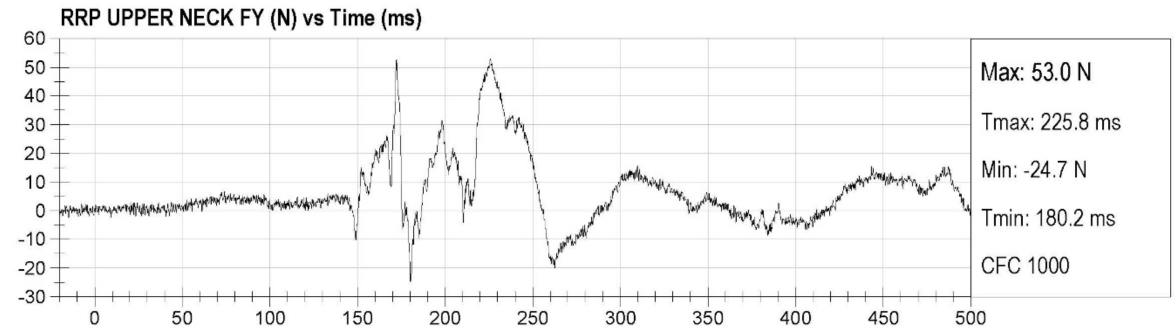

RRP UPPER NECK MZ (Nm) vs Time (ms)

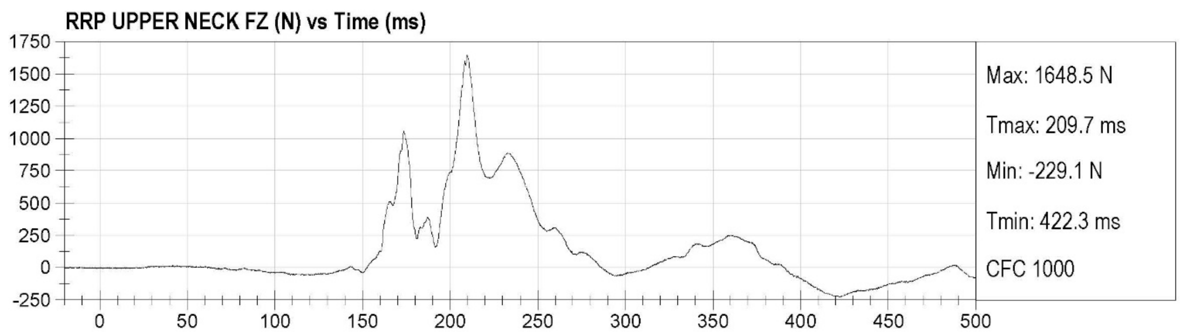


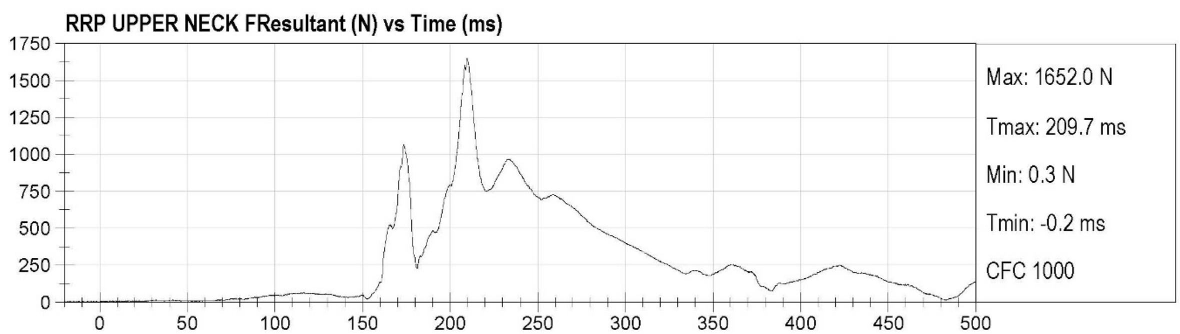

RRP UPPER NECK MResultant (Nm) vs Time (ms)

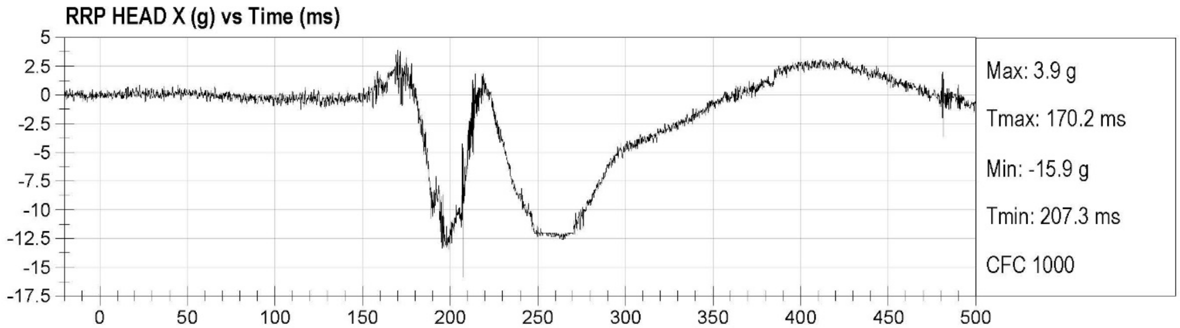


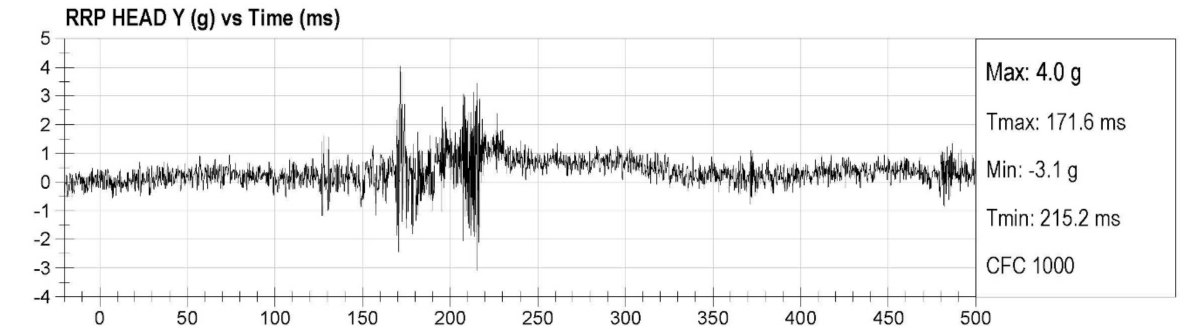

RRP UPPER NECK FX (N) vs Time (ms)
Max: 176.9 N
Tmax: 175.6 ms
Min: -661.3 N
Tmin: 257.8 ms
CFC 1000

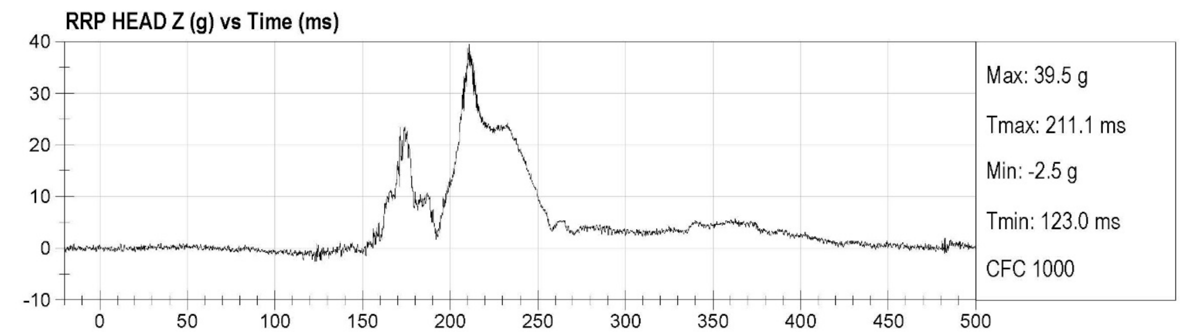

RRP UPPER NECK FY (N) vs Time (ms)
Max: 53.0 N
Tmax: 225.8 ms
Min: -24.7 N
Tmin: 180.2 ms
CFC 1000

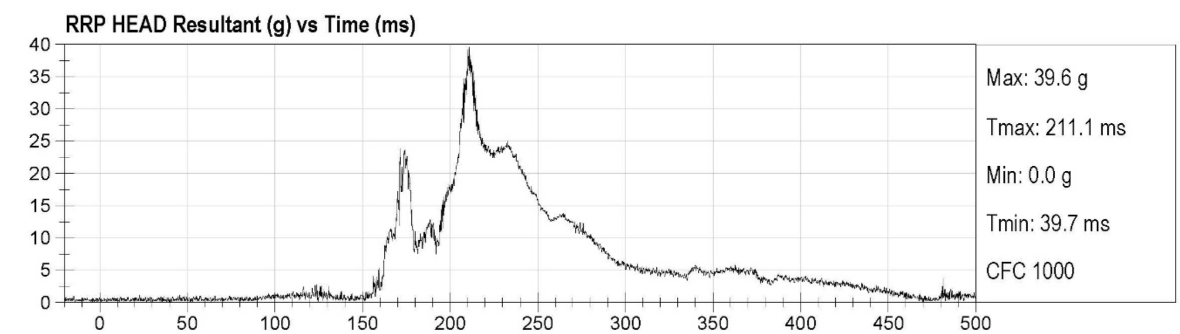

RRP UPPER NECK FZ (N) vs Time (ms)
Max: 1648.5 N
Tmax: 209.7 ms
Min: -229.1 N
Tmin: 422.3 ms
CFC 1000

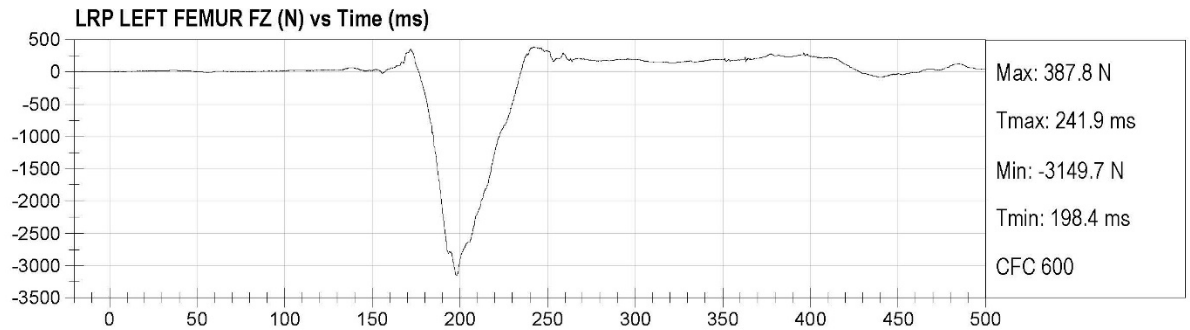

RRP UPPER NECK FResultant (N) vs Time (ms)
Max: 1652.0 N
Tmax: 209.7 ms
Min: 0.3 N
Tmin: -0.2 ms
CFC 1000

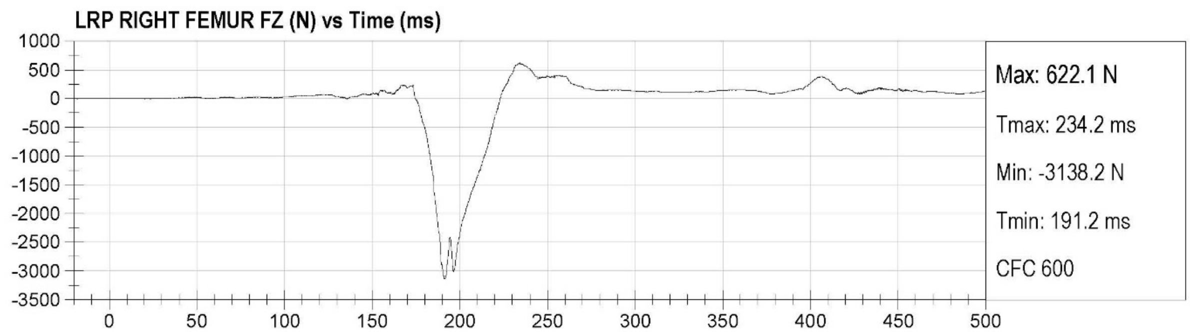

RRP HEAD X (g) vs Time (ms)
Max: 3.9 g
Tmax: 170.2 ms
Min: -15.9 g
Tmin: 207.3 ms
CFC 1000
5
2.5
0
-2.5
-5
-7.5
-10
-12.5
-15
-17.5
0
50
100
150
200
250
300
350
400
450
500

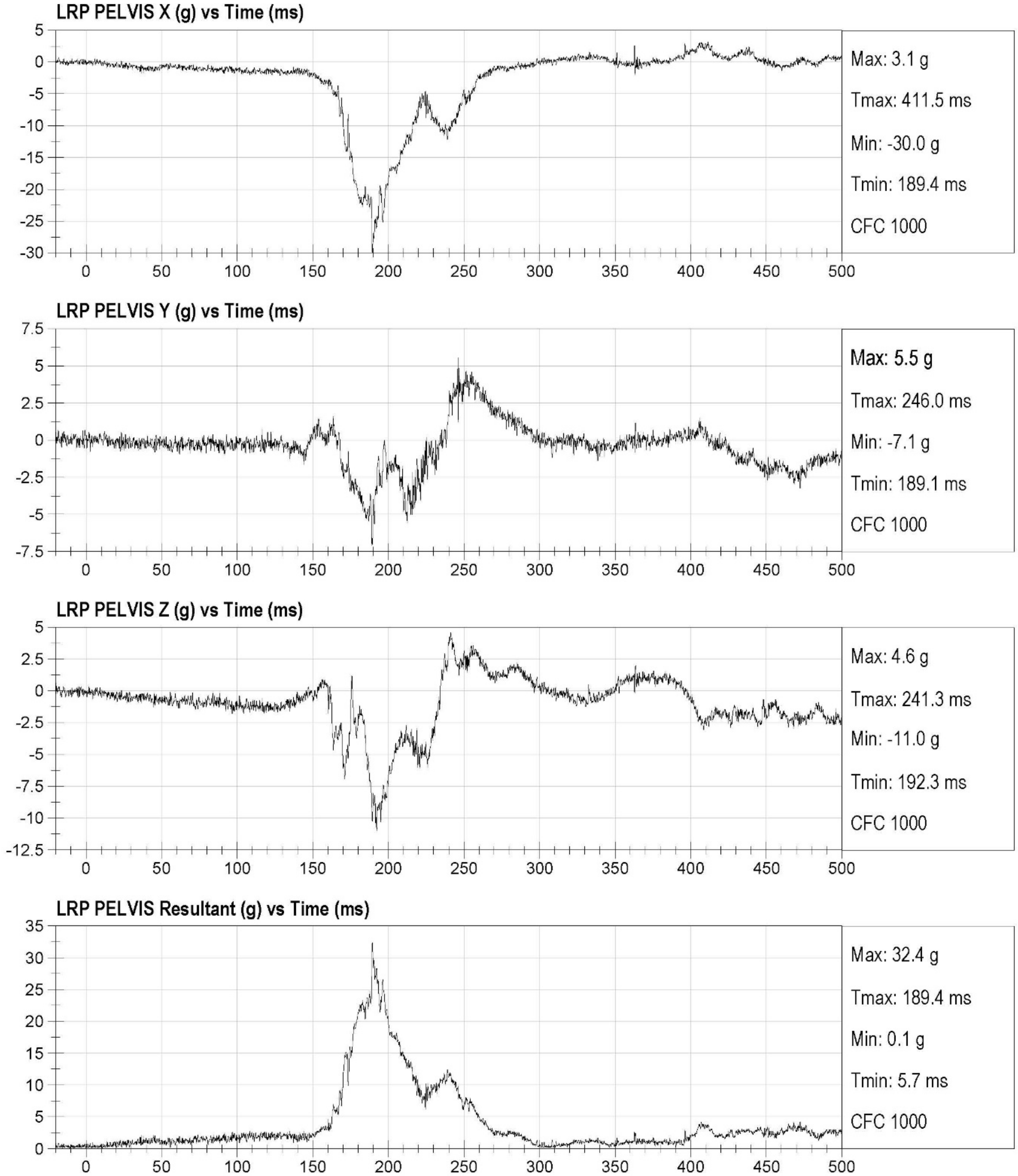

RRP HEAD Y (g) vs Time (ms)
Max: 4.0 g
Tmax: 171.6 ms
Min: -3.1 g
Tmin: 215.2 ms
CFC 1000
5
4
3
2
1
0
-1
-2
-3
-4
0
50
100
150
200
250
300
350
400
450
500

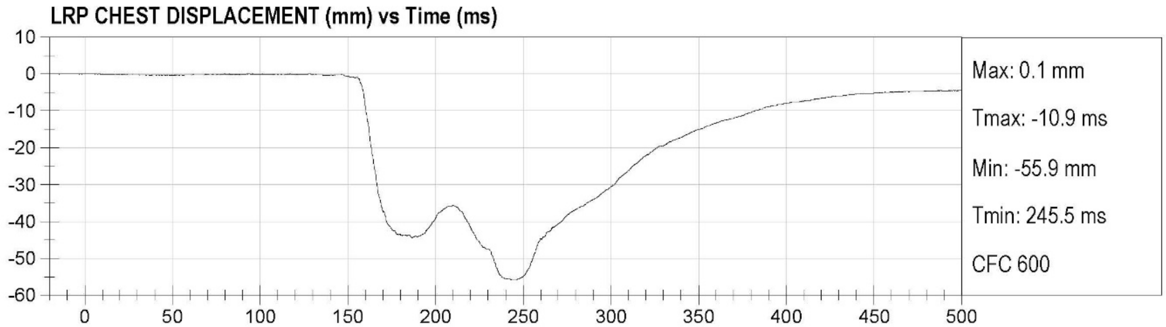

RRP HEAD Z (g) vs Time (ms)
Max: 39.5 g
Tmax: 211.1 ms
Min: -2.5 g
Tmin: 123.0 ms
CFC 1000
40
30
20
10
0
-10
0
50
100
150
200
250
300
350
400
450
500

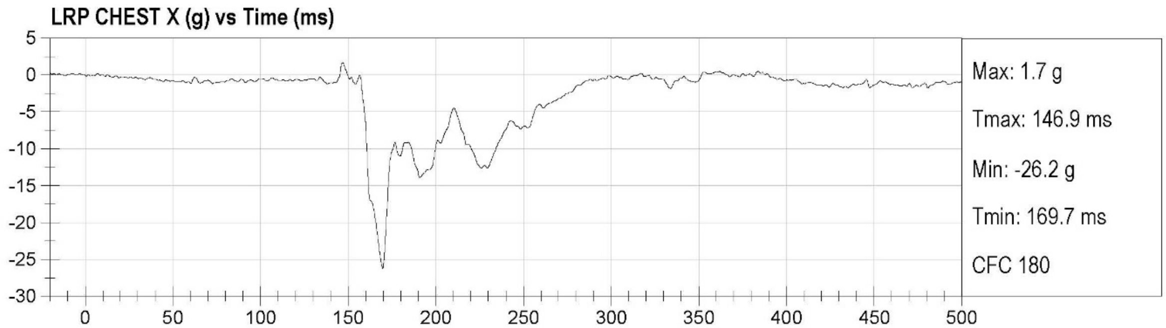

RRP HEAD Resultant (g) vs Time (ms)
Max: 39.6 g
Tmax: 211.1 ms
Min: 0.0 g
Tmin: 39.7 ms
CFC 1000
40
35
30
25
20
15
10
5
0
0
50
100
150
200
250
300
350
400
450
500

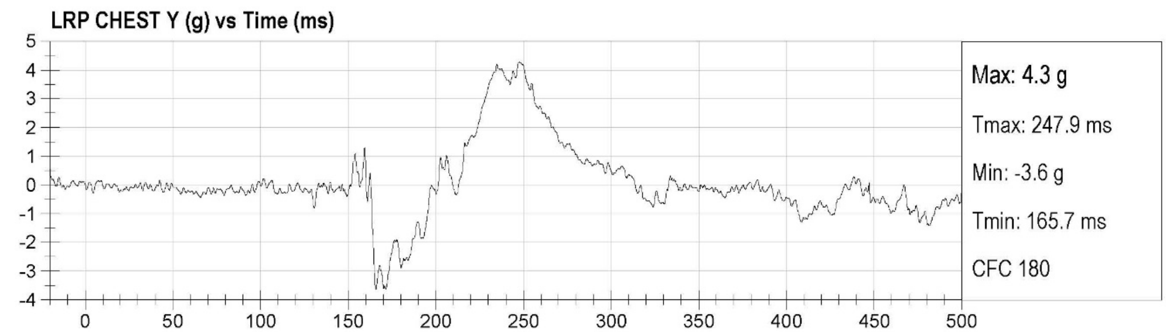

LRP LEFT FEMUR FZ (N) vs Time (ms)
Max: 387.8 N
Tmax: 241.9 ms
Min: -3149.7 N
Tmin: 198.4 ms
CFC 600

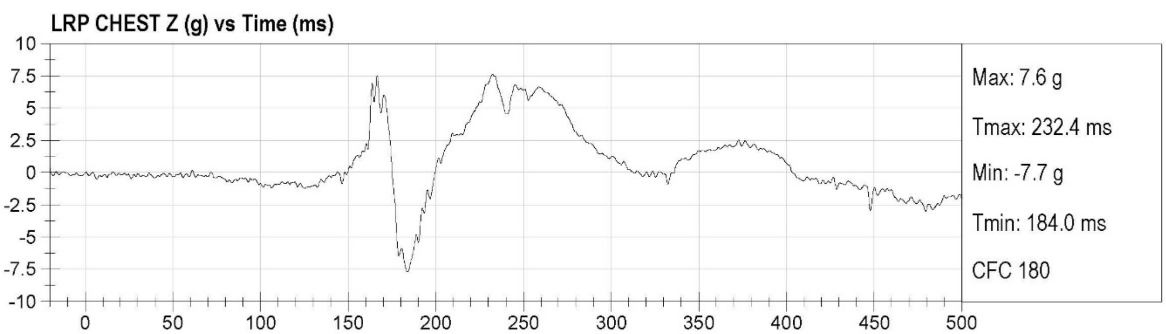

LRP RIGHT FEMUR FZ (N) vs Time (ms)
Max: 622.1 N
Tmax: 234.2 ms
Min: -3138.2 N
Tmin: 191.2 ms
CFC 600


LRP PELVIS X (g) vs Time (ms)
Max: 3.1 g
Tmax: 411.5 ms
Min: -30.0 g
Tmin: 189.4 ms
CFC 1000
LRP PELVIS Y (g) vs Time (ms)
Max: 5.5 g
Tmax: 246.0 ms
Min: -7.1 g
Tmin: 189.1 ms
CFC 1000
LRP PELVIS Z (g) vs Time (ms)
Max: 4.6 g
Tmax: 241.3 ms
Min: -11.0 g
Tmin: 192.3 ms
CFC 1000
LRP PELVIS Resultant (g) vs Time (ms)
Max: 32.4 g
Tmax: 189.4 ms
Min: 0.1 g
Tmin: 5.7 ms
CFC 1000

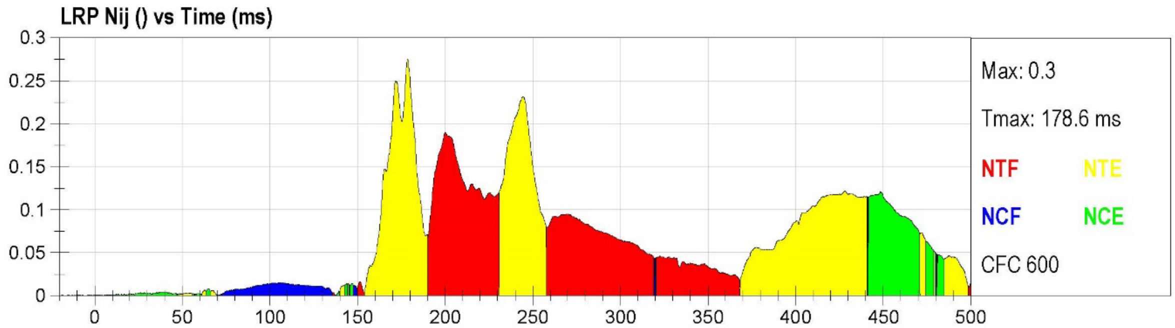

LRP CHEST DISPLACEMENT (mm) vs Time (ms)
Max: 0.1 mm
Tmax: -10.9 ms
Min: -55.9 mm
Tmin: 245.5 ms
CFC 600
10
0
-10
-20
-30
-40
-50
-60
0
50
100
150
200
250
300
350
400
450
500

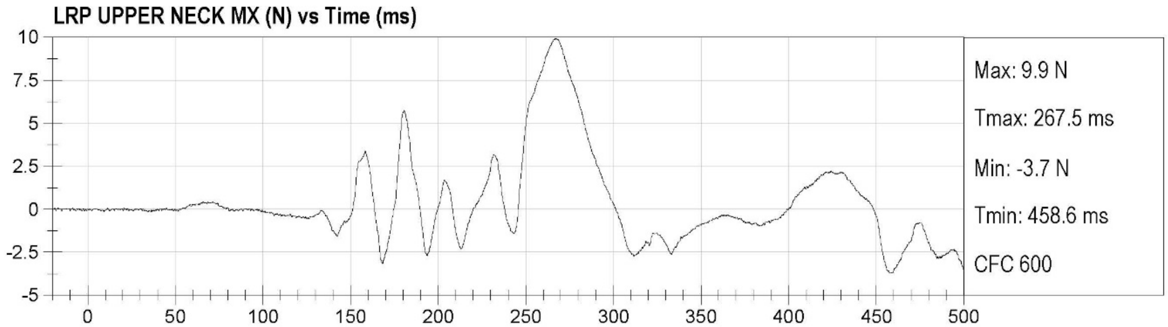

LRP CHEST X (g) vs Time (ms)
Max: 1.7 g
Tmax: 146.9 ms
Min: -26.2 g
Tmin: 169.7 ms
CFC 180

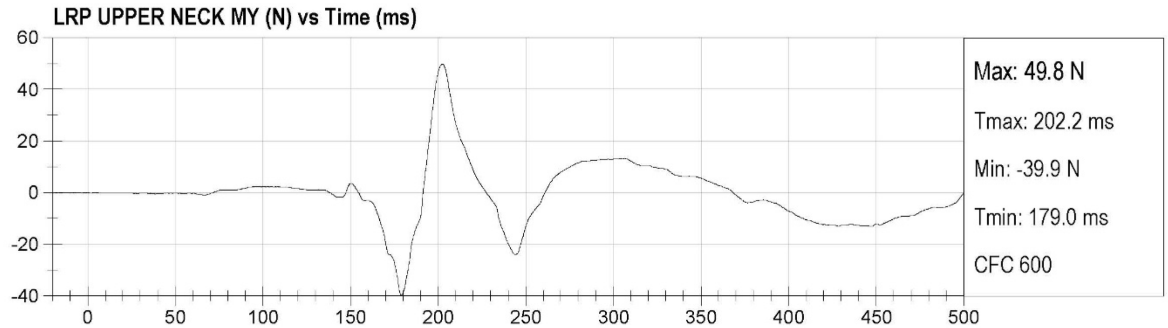

LRP CHEST Y (g) vs Time (ms)
Max: 4.3 g
Tmax: 247.9 ms
Min: -3.6 g
Tmin: 165.7 ms
CFC 180

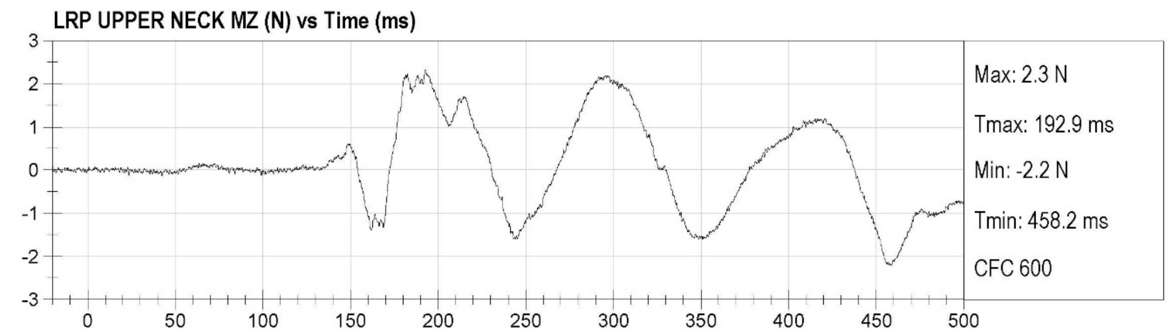

LRP CHEST Z (g) vs Time (ms)
Max: 7.6 g
Tmax: 232.4 ms
Min: -7.7 g
Tmin: 184.0 ms
CFC 180

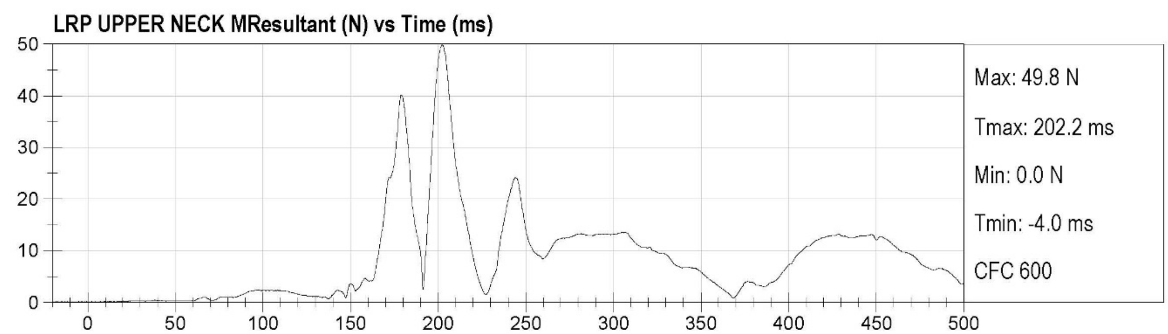

LRP CHEST Resultant (g) vs Time (ms)
Max: 27.0 g
Tmax: 169.8 ms
Min: 0.0 g
Tmin: -16.2 ms
CFC 180

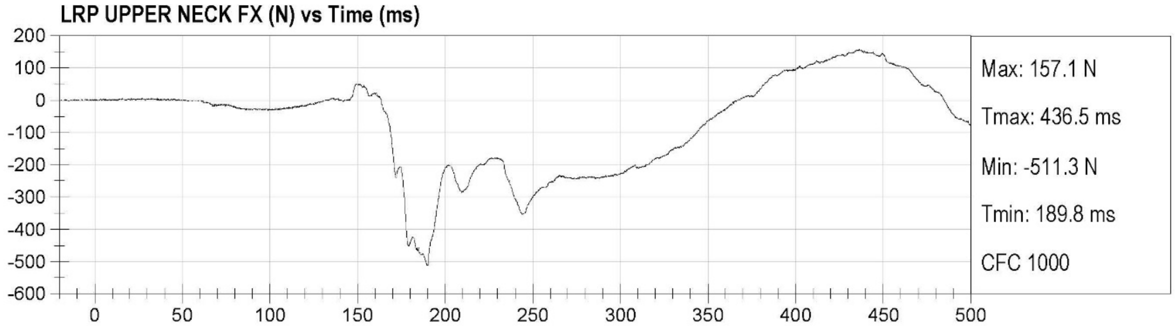

LRP Nij () vs Time (ms)
0.3
0.25
0.2
0.15
0.1
0.05
0
0
50
100
150
200
250
300
350
400
450
500
Max: 0.3
Tmax: 178.6 ms
NTF
NTE
NCF
NCE
CFC 600

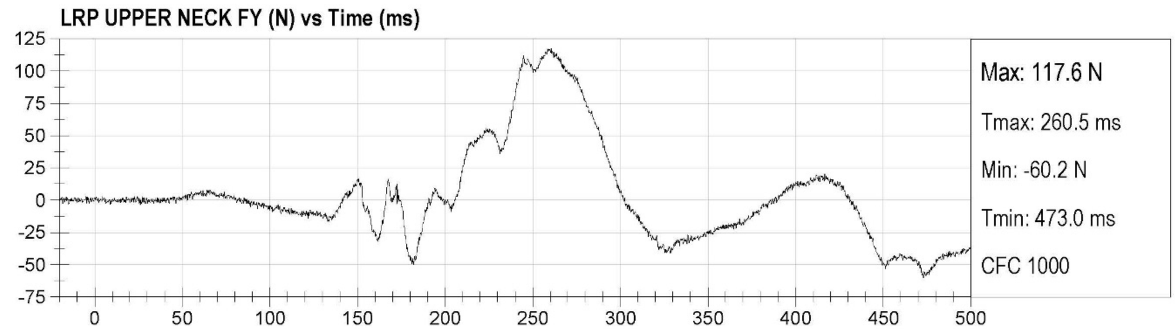

LRP UPPER NECK MX (N) vs Time (ms)
Max: 9.9 N
Tmax: 267.5 ms
Min: -3.7 N
Tmin: 458.6 ms
CFC 600

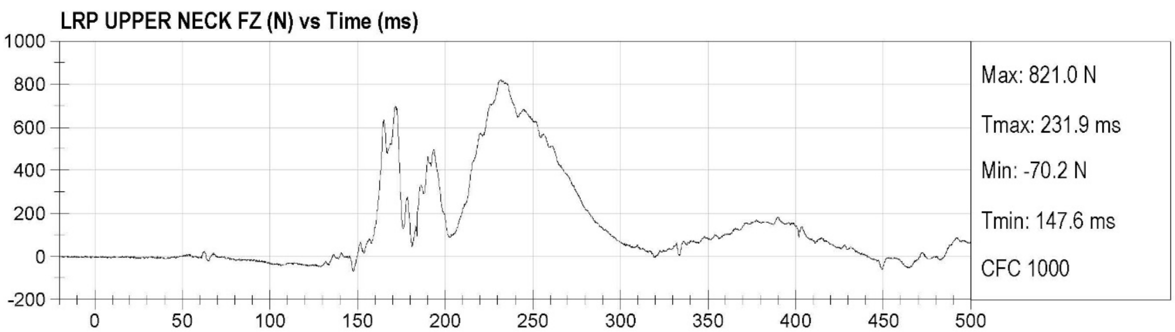

LRP UPPER NECK MY (N) vs Time (ms)
Max: 49.8 N
Tmax: 202.2 ms
Min: -39.9 N
Tmin: 179.0 ms
CFC 600

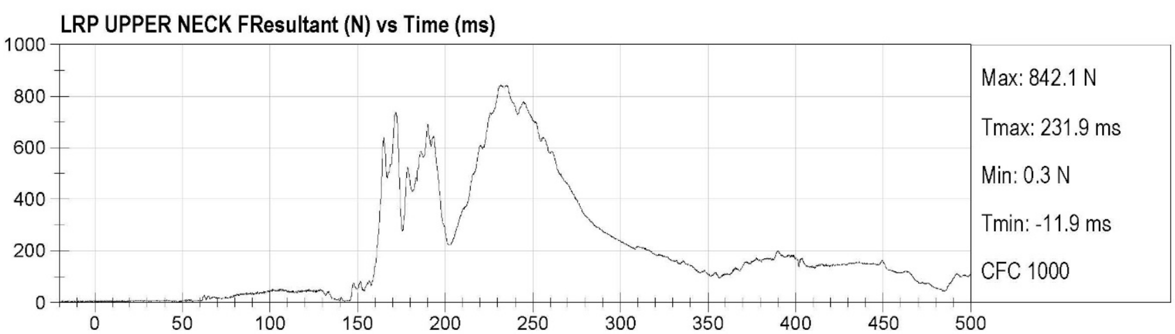

LRP UPPER NECK MZ (N) vs Time (ms)
Max: 2.3 N
Tmax: 192.9 ms
Min: -2.2 N
Tmin: 458.2 ms
CFC 600


LRP UPPER NECK MResultant (N) vs Time (ms)
Max: 49.8 N
Tmax: 202.2 ms
Min: 0.0 N
Tmin: -4.0 ms
CFC 600

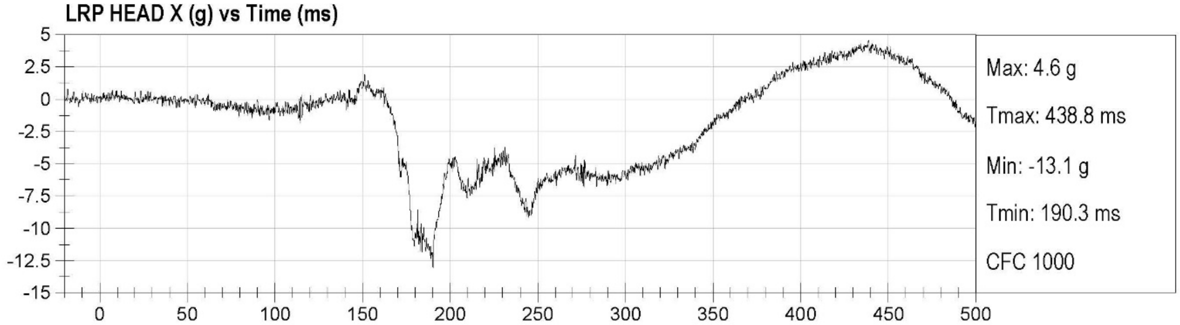

LRP UPPER NECK FX (N) vs Time (ms)
Max: 157.1 N
Tmax: 436.5 ms
Min: -511.3 N
Tmin: 189.8 ms
CFC 1000


LRP UPPER NECK FY (N) vs Time (ms)
Max: 117.6 N
Tmax: 260.5 ms
Min: -60.2 N
Tmin: 473.0 ms
CFC 1000

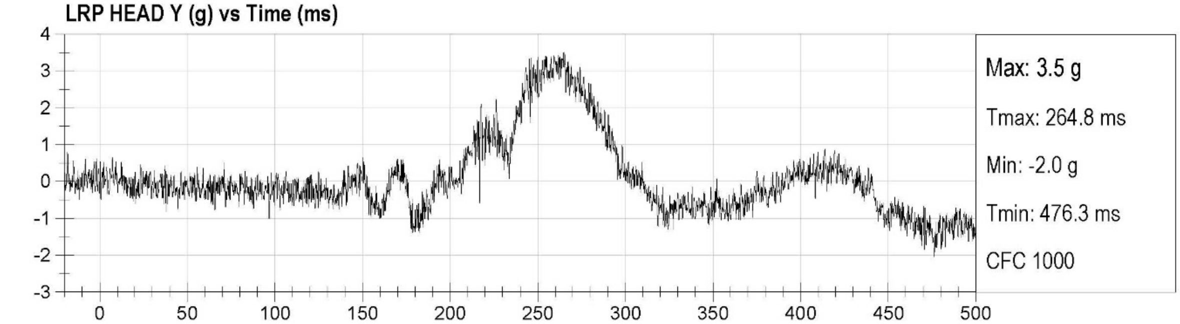

LRP UPPER NECK FZ (N) vs Time (ms)
Max: 821.0 N
Tmax: 231.9 ms
Min: -70.2 N
Tmin: 147.6 ms
CFC 1000


LRP UPPER NECK FResultant (N) vs Time (ms)
Max: 842.1 N
Tmax: 231.9 ms
Min: 0.3 N
Tmin: -11.9 ms
CFC 1000

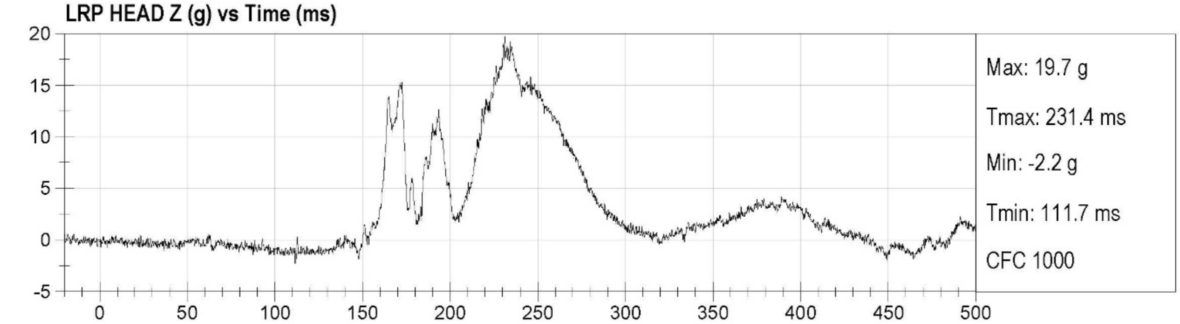
LRP HEAD X (g) vs Time (ms)



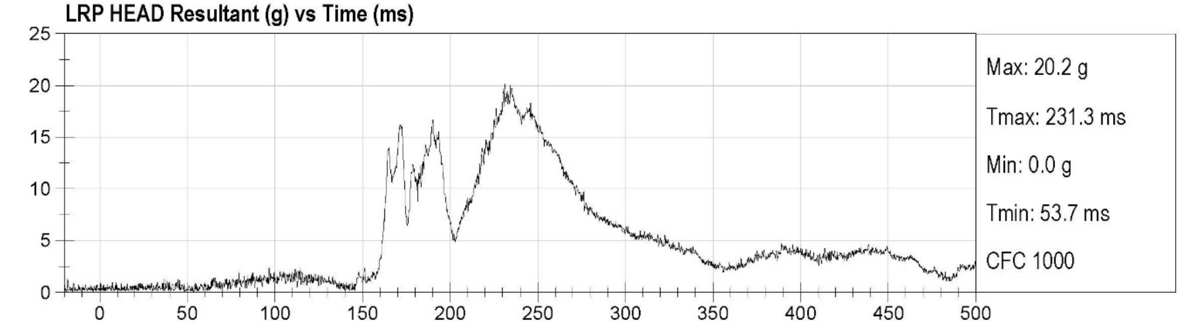

LRP HEAD Y (g) vs Time (ms)




LRP HEAD Z (g) vs Time (ms)



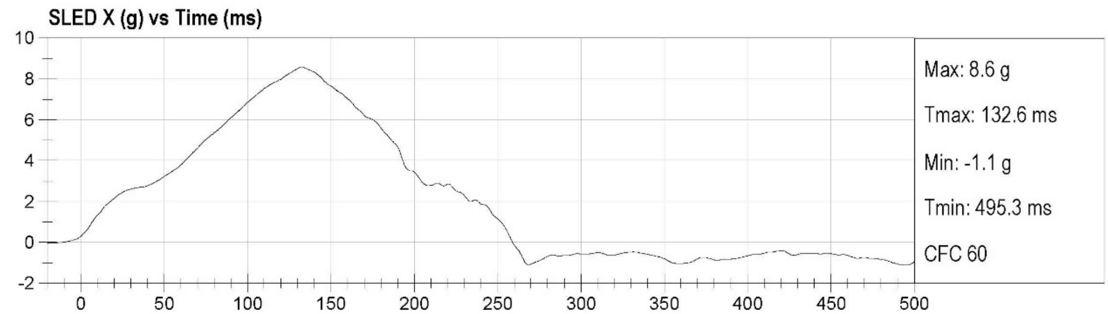

LRP HEAD Resultant (g) vs Time (ms)

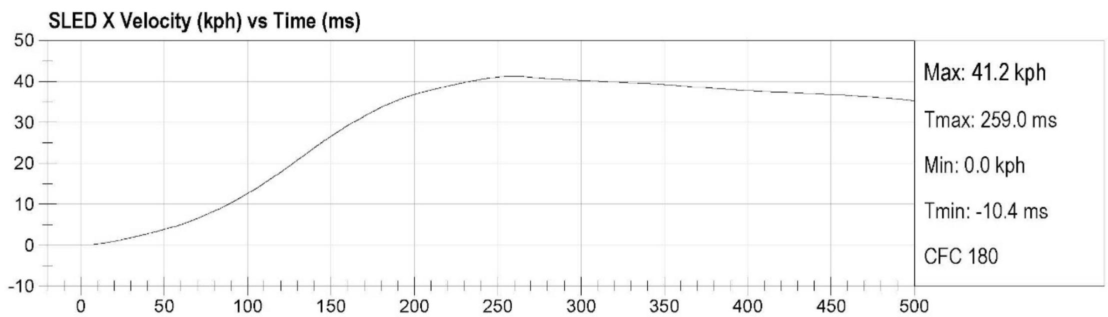


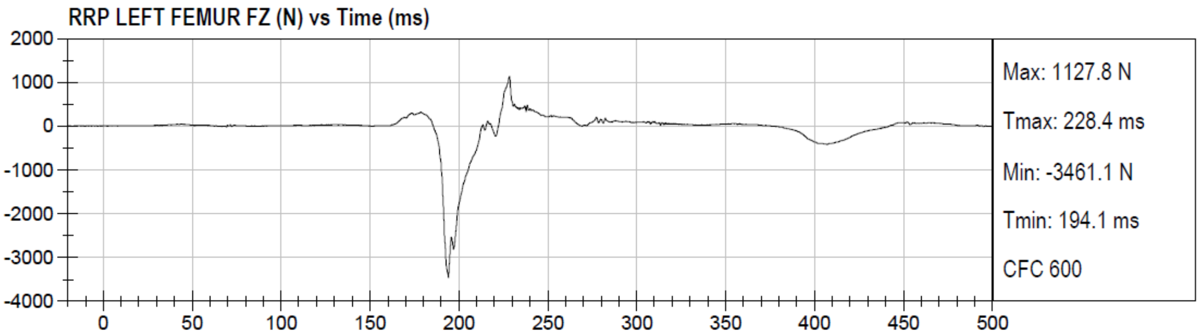
## A.3: Test 1BD Data

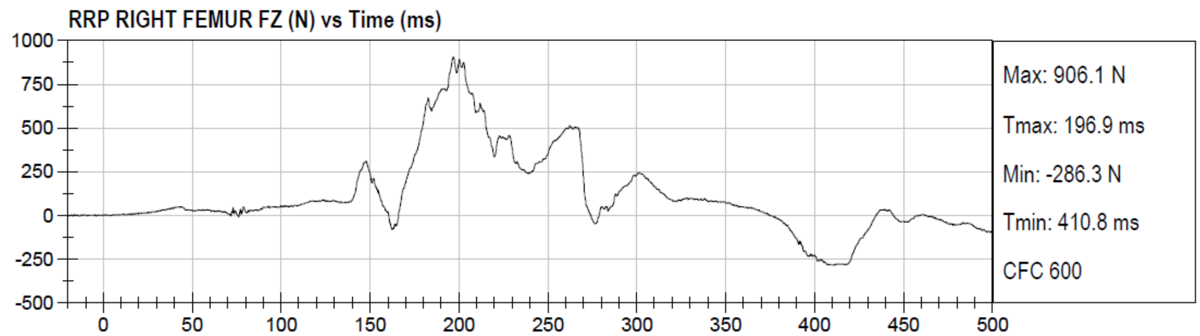
Test Date: 06/08/2021

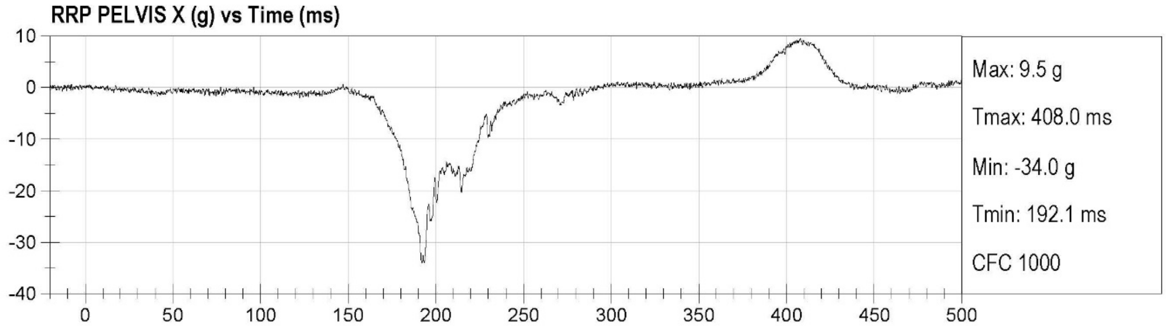
MGA Test ID: S21157

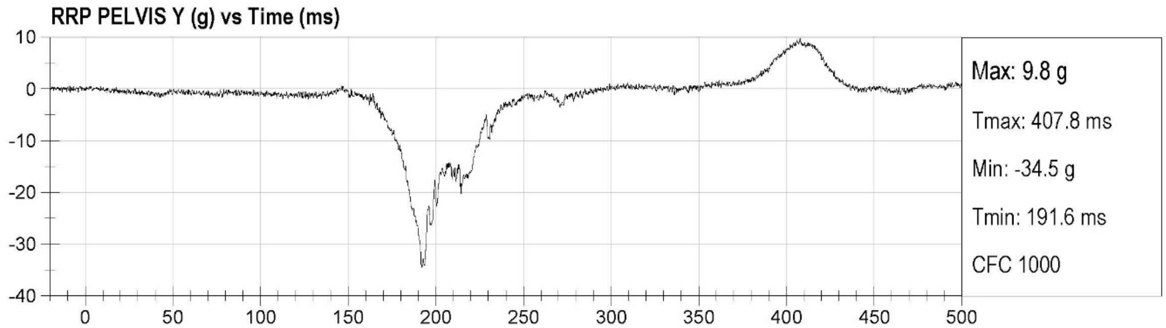


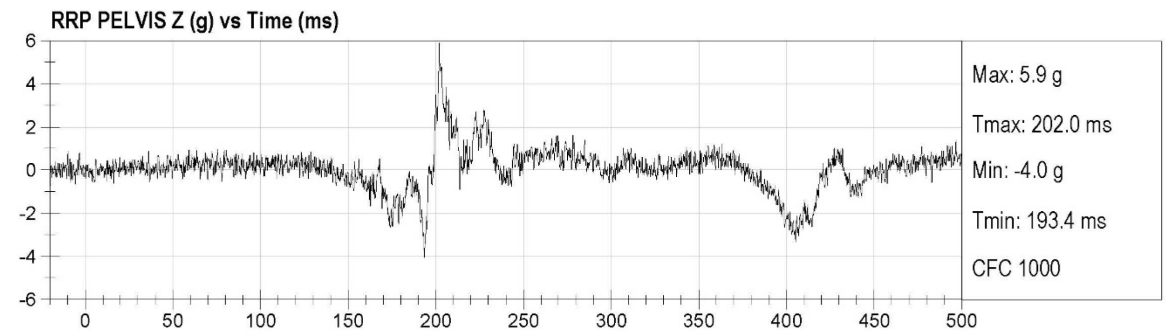



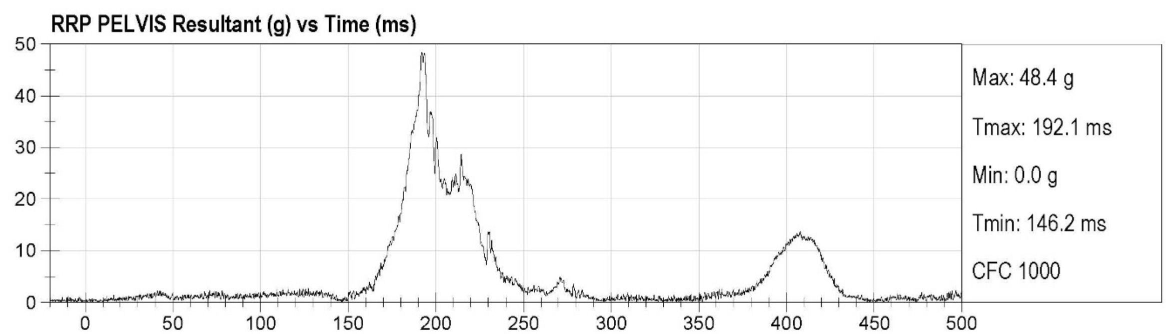

RRP LEFT FEMUR FZ (N) vs Time (ms)
Max: 1127.8 N
Tmax: 228.4 ms
Min: -3461.1 N
Tmin: 194.1 ms
CFC 600
2000
1000
0
-1000
-2000
-3000
-4000
0
50
100
150
200
250
300
350
400
450
500

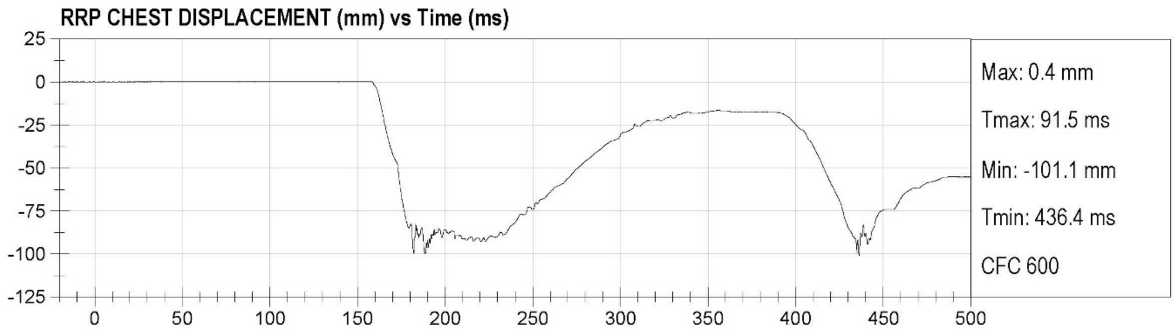

RRP RIGHT FEMUR FZ (N) vs Time (ms)
Max: 906.1 N
Tmax: 196.9 ms
Min: -286.3 N
Tmin: 410.8 ms
CFC 600
1000
750
500
250
0
-250
-500
0
50
100
150
200
250
300
350
400
450
500

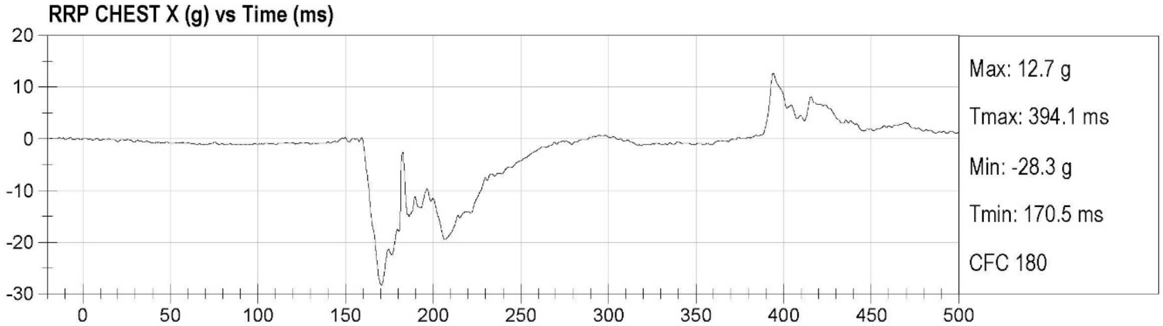

RRP PELVIS X (g) vs Time (ms)
Max: 9.5 g
Tmax: 408.0 ms
Min: -34.0 g
Tmin: 192.1 ms
CFC 1000

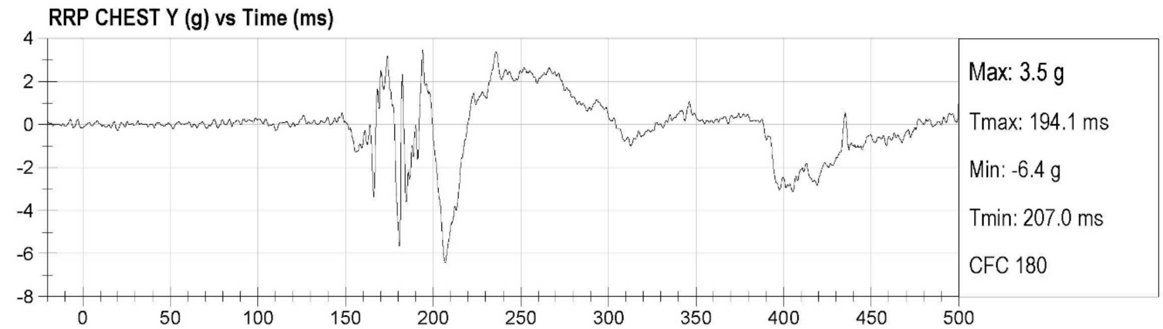

RRP PELVIS Y (g) vs Time (ms)
Max: 9.8 g
Tmax: 407.8 ms
Min: -34.5 g
Tmin: 191.6 ms
CFC 1000

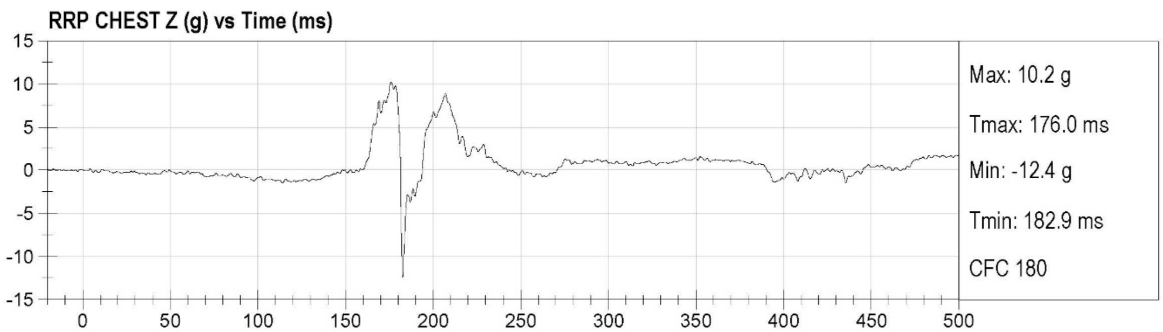

RRP PELVIS Z (g) vs Time (ms)
Max: 5.9 g
Tmax: 202.0 ms
Min: -4.0 g
Tmin: 193.4 ms
CFC 1000

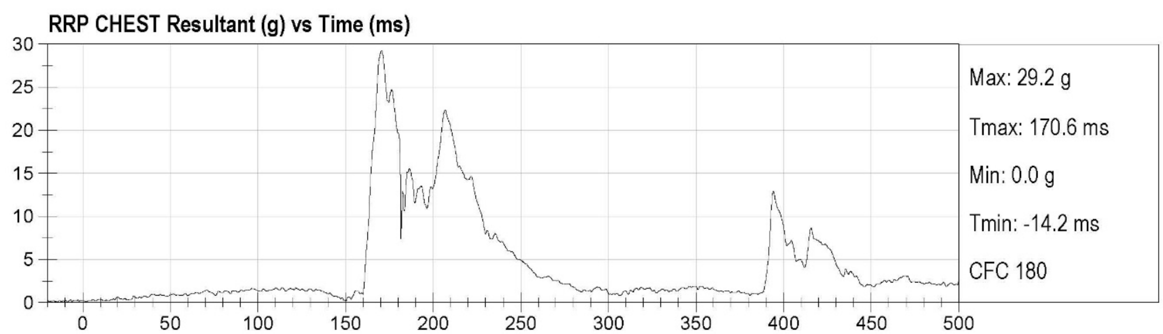

RRP PELVIS Resultant (g) vs Time (ms)
Max: 48.4 g
Tmax: 192.1 ms
Min: 0.0 g
Tmin: 146.2 ms
CFC 1000

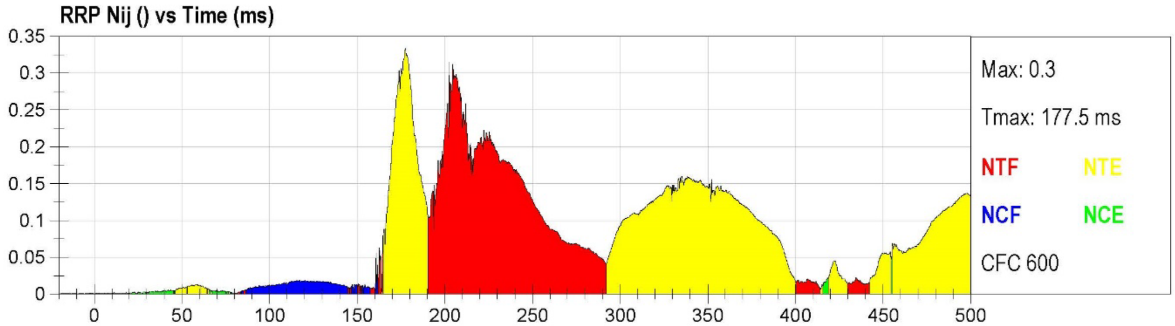

RRP CHEST DISPLACEMENT (mm) vs Time (ms)
Max: 0.4 mm
Tmax: 91.5 ms
Min: -101.1 mm
Tmin: 436.4 ms
CFC 600
25
0
-25
-50
-75
-100
-125
0
50
100
150
200
250
300
350
400
450
500


RRP CHEST X (g) vs Time (ms)
Max: 12.7 g
Tmax: 394.1 ms
Min: -28.3 g
Tmin: 170.5 ms
CFC 180

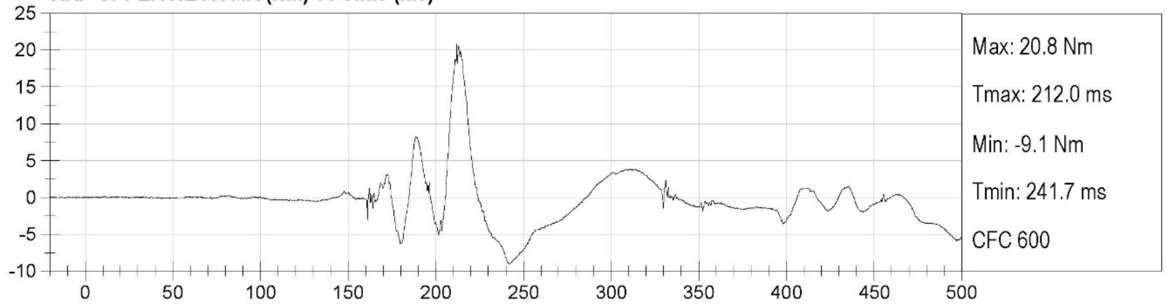

RRP CHEST Y (g) vs Time (ms)
Max: 3.5 g
Tmax: 194.1 ms
Min: -6.4 g
Tmin: 207.0 ms
CFC 180


RRP CHEST Z (g) vs Time (ms)
Max: 10.2 g
Tmax: 176.0 ms
Min: -12.4 g
Tmin: 182.9 ms
CFC 180

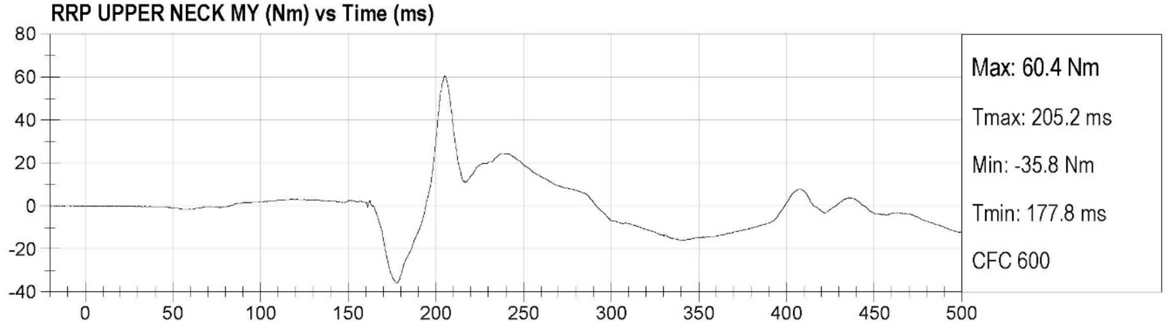

RRP CHEST Resultant (g) vs Time (ms)
Max: 29.2 g
Tmax: 170.6 ms
Min: 0.0 g
Tmin: -14.2 ms
CFC 180


RRP Nij () vs Time (ms)
Max: 0.3
Tmax: 177.5 ms
NTF
NTE
NCF
NCE
CFC 600

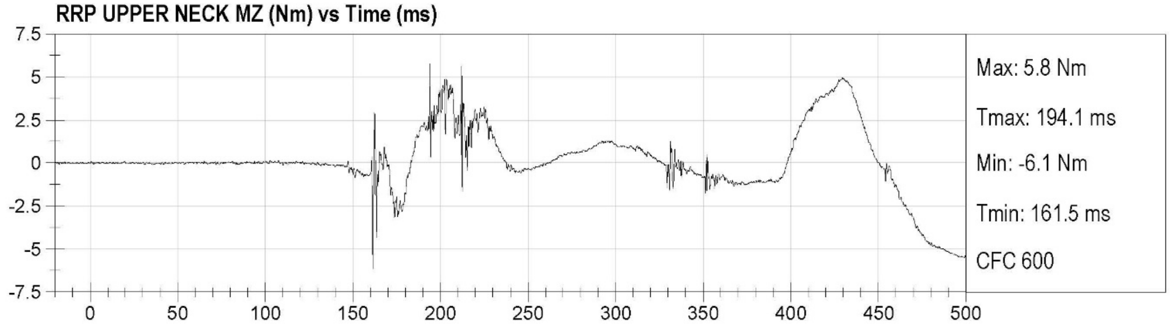
RRP UPPER NECK MX (Nm) vs Time (ms)



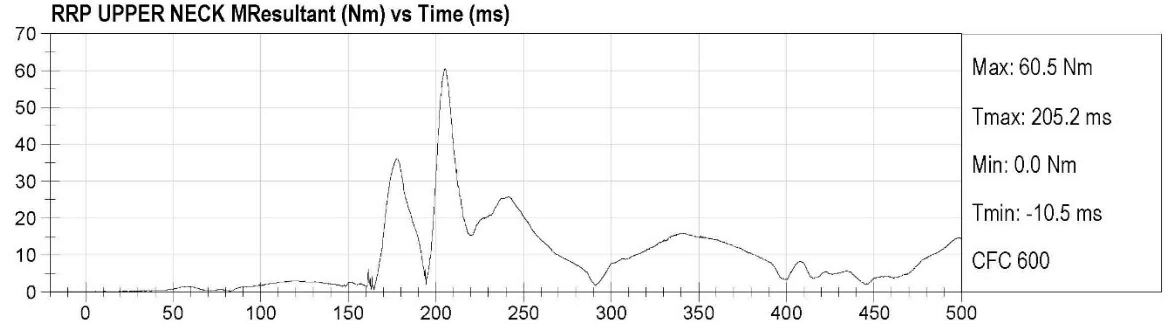

RRP UPPER NECK MY (Nm) vs Time (ms)

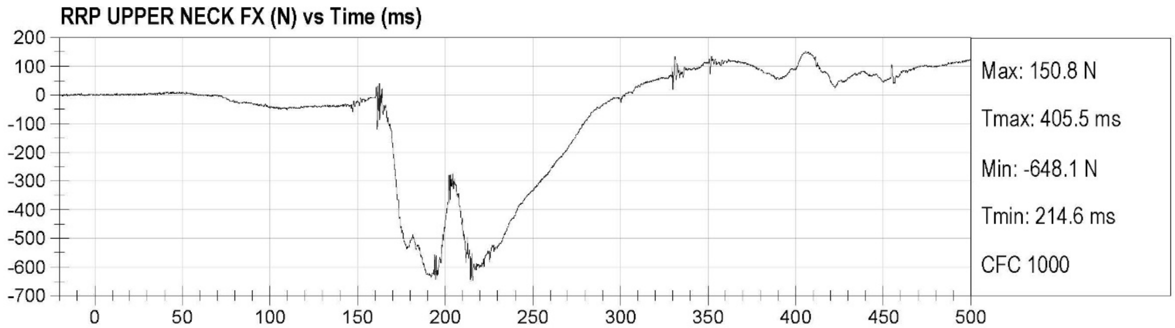


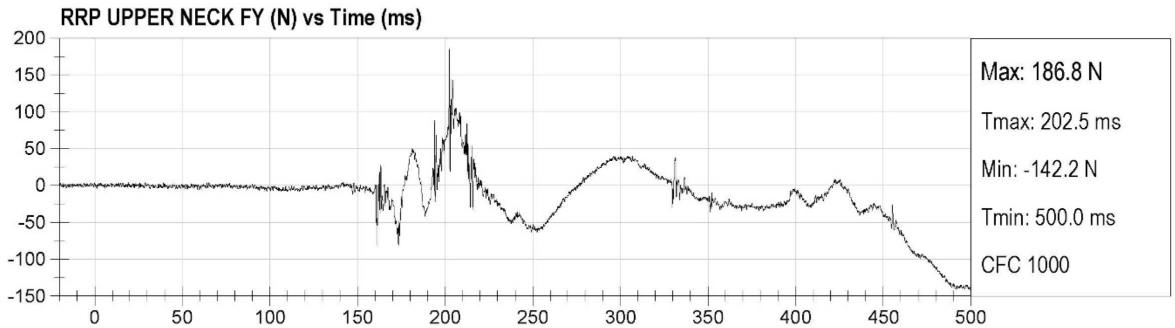

RRP UPPER NECK MZ (Nm) vs Time (ms)

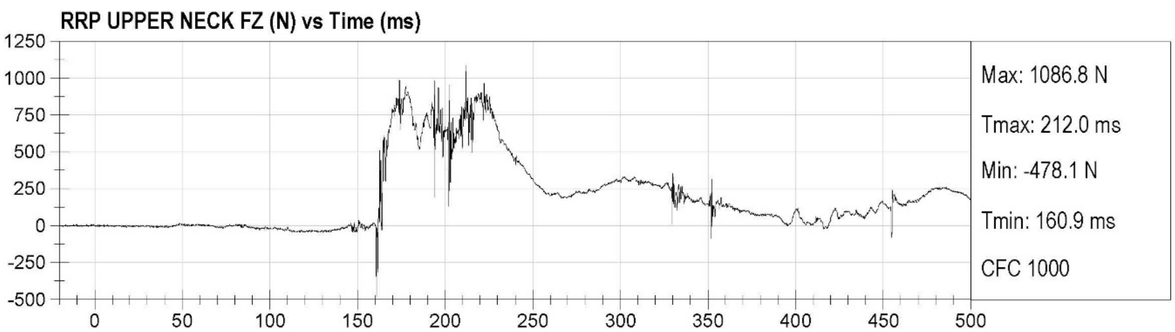


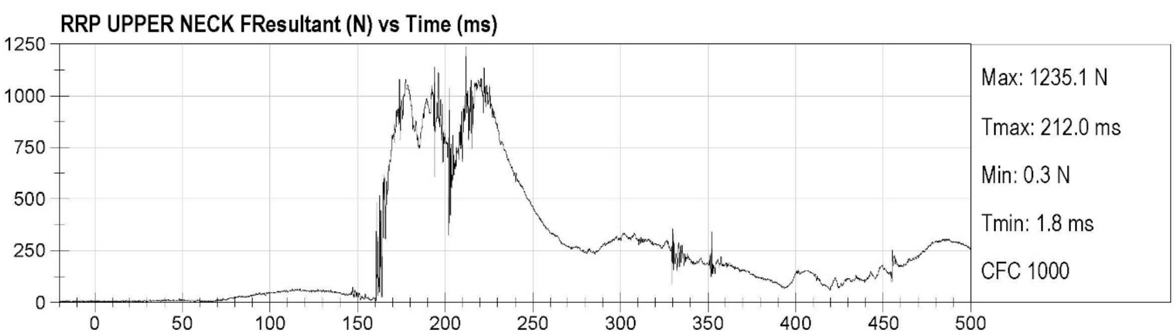

RRP UPPER NECK MResultant (Nm) vs Time (ms)

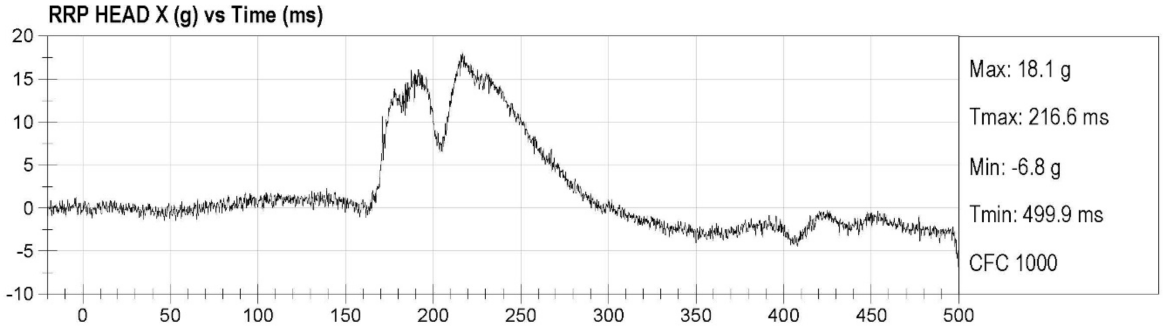


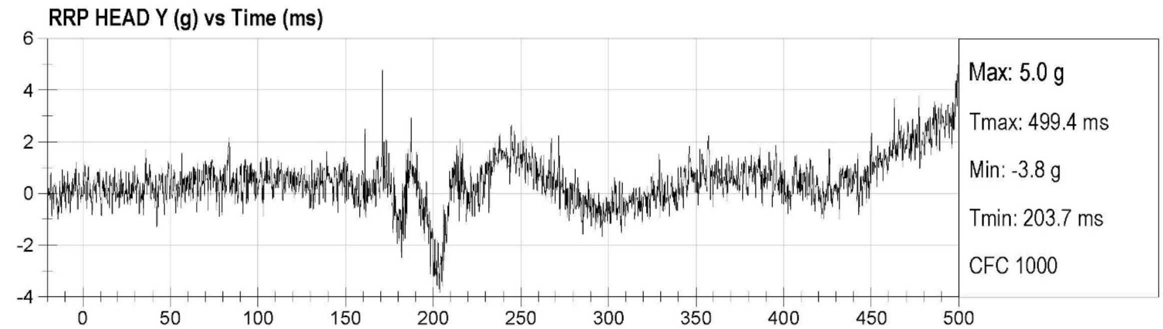

RRP UPPER NECK FX (N) vs Time (ms)
Max: 150.8 N
Tmax: 405.5 ms
Min: -648.1 N
Tmin: 214.6 ms
CFC 1000

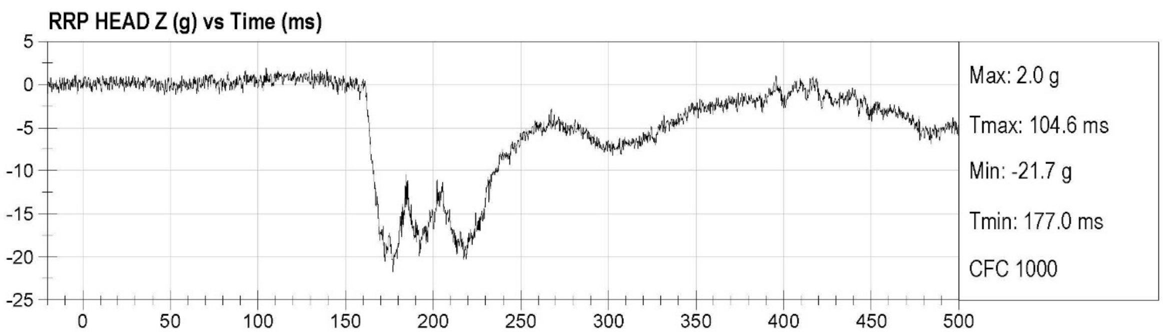

RRP UPPER NECK FY (N) vs Time (ms)
Max: 186.8 N
Tmax: 202.5 ms
Min: -142.2 N
Tmin: 500.0 ms
CFC 1000

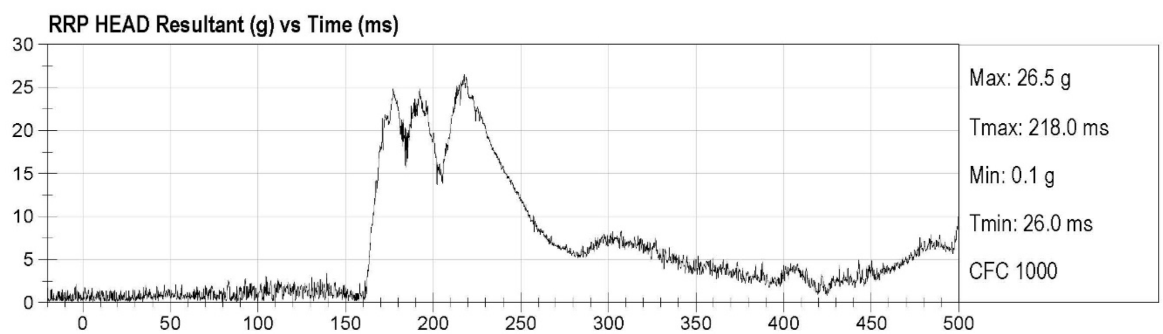

RRP UPPER NECK FZ (N) vs Time (ms)
Max: 1086.8 N
Tmax: 212.0 ms
Min: -478.1 N
Tmin: 160.9 ms
CFC 1000

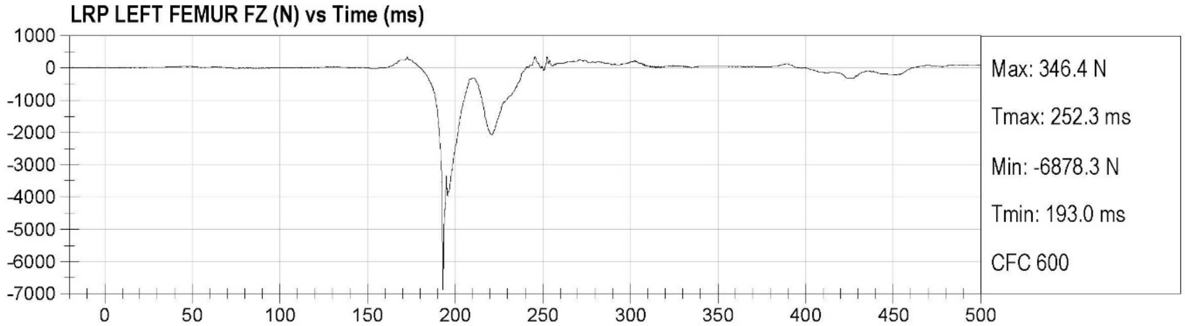

RRP UPPER NECK FResultant (N) vs Time (ms)
Max: 1235.1 N
Tmax: 212.0 ms
Min: 0.3 N
Tmin: 1.8 ms
CFC 1000

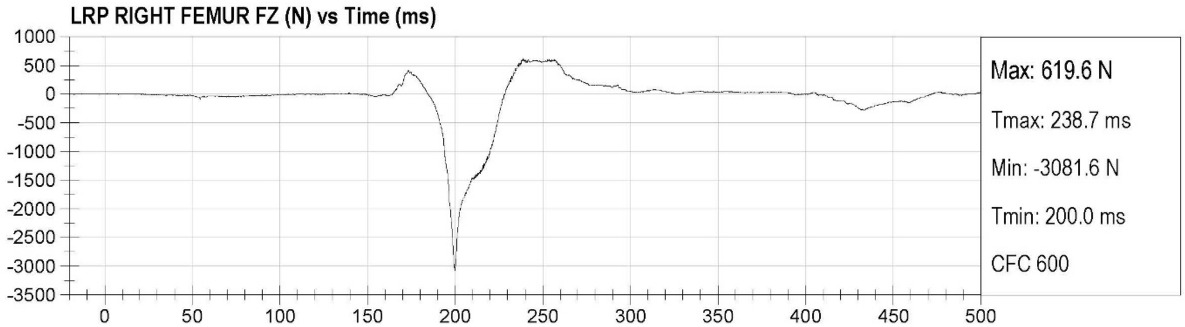

RRP HEAD X (g) vs Time (ms)
Max: 18.1 g
Tmax: 216.6 ms
Min: -6.8 g
Tmin: 499.9 ms
CFC 1000

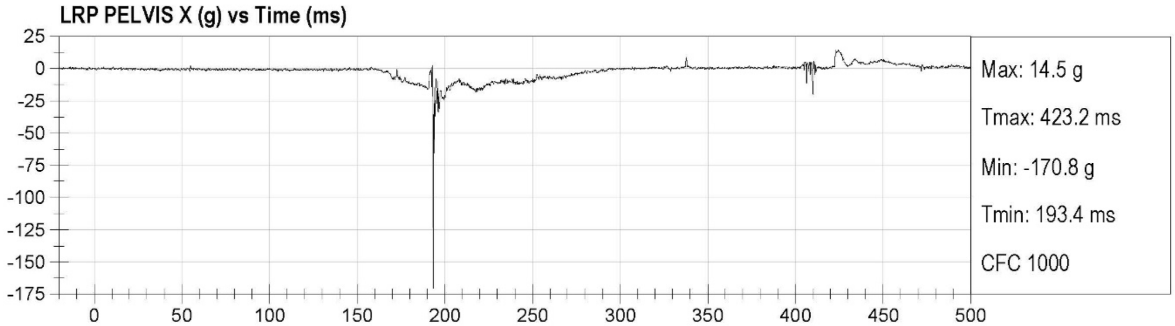

RRP HEAD Y (g) vs Time (ms)
Max: 5.0 g
Tmax: 499.4 ms
Min: -3.8 g
Tmin: 203.7 ms
CFC 1000

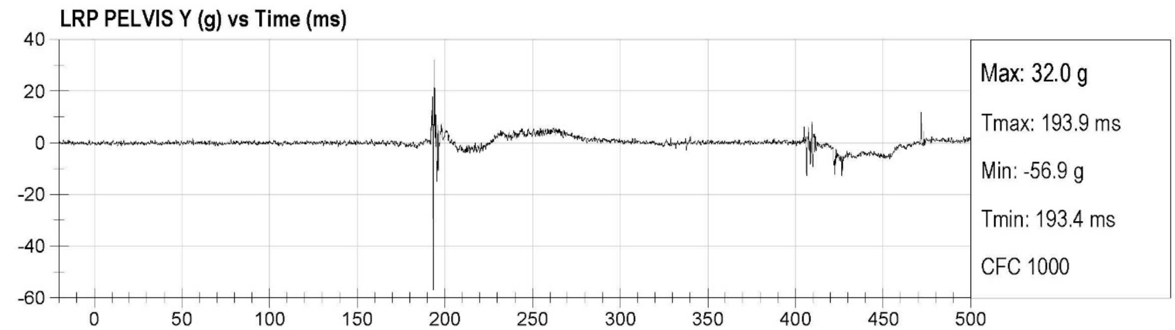

RRP HEAD Z (g) vs Time (ms)
Max: 2.0 g
Tmax: 104.6 ms
Min: -21.7 g
Tmin: 177.0 ms
CFC 1000

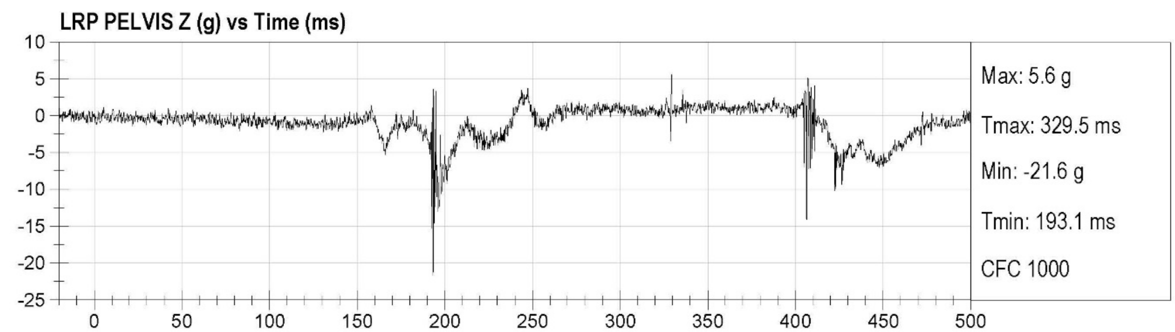

RRP HEAD Resultant (g) vs Time (ms)
Max: 26.5 g
Tmax: 218.0 ms
Min: 0.1 g
Tmin: 26.0 ms
CFC 1000

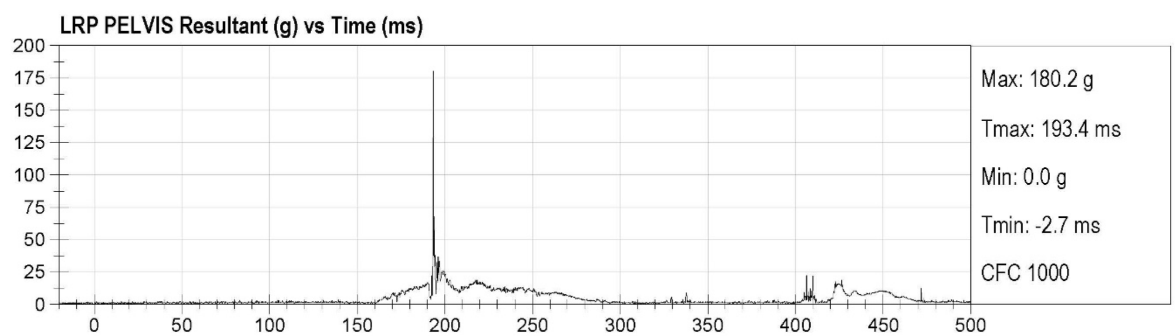

LRP LEFT FEMUR FZ (N) vs Time (ms)
Max: 346.4 N
Tmax: 252.3 ms
Min: -6878.3 N
Tmin: 193.0 ms
CFC 600

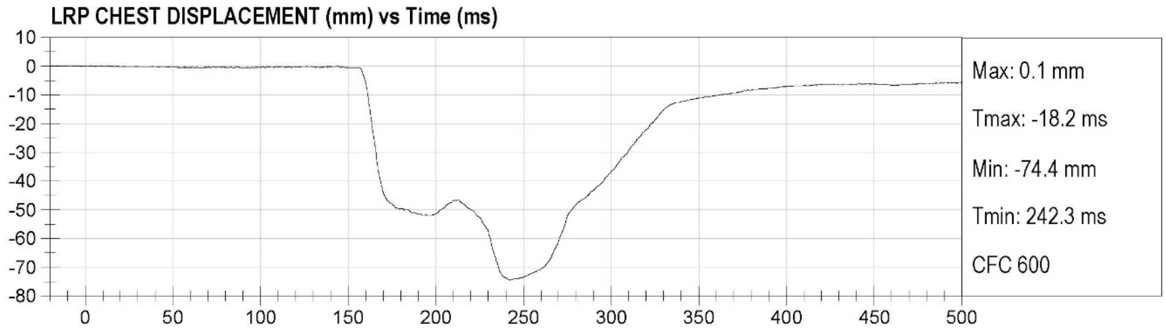

LRP RIGHT FEMUR FZ (N) vs Time (ms)
Max: 619.6 N
Tmax: 238.7 ms
Min: -3081.6 N
Tmin: 200.0 ms
CFC 600

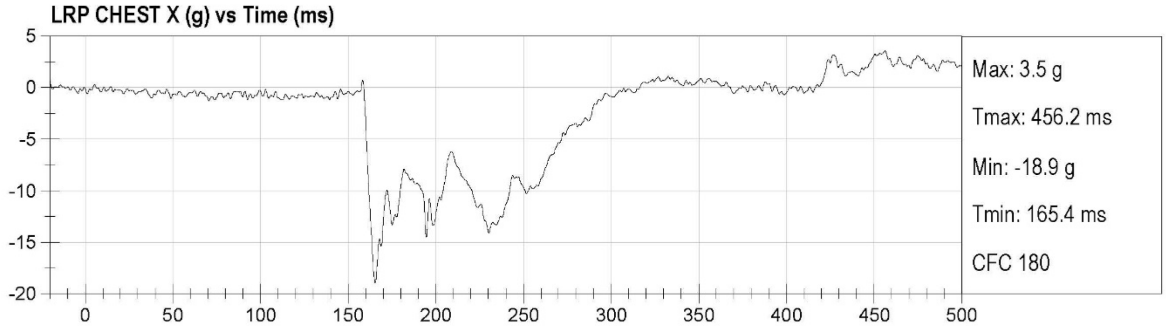

LRP PELVIS X (g) vs Time (ms)
Max: 14.5 g
Tmax: 423.2 ms
Min: -170.8 g
Tmin: 193.4 ms
CFC 1000

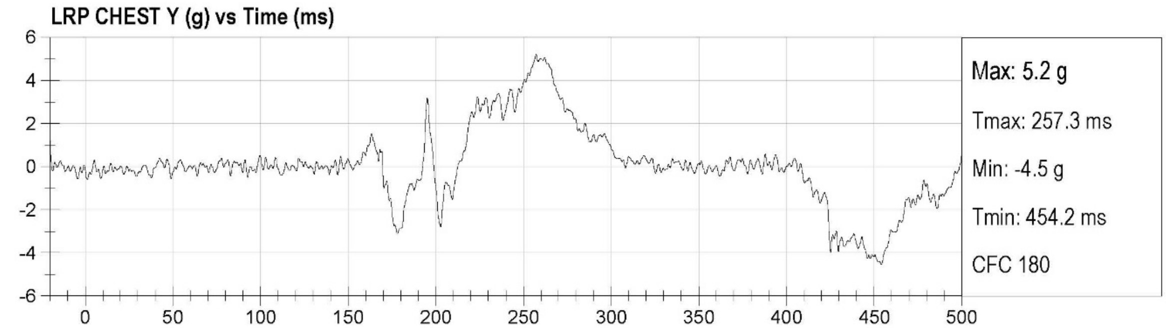

LRP PELVIS Y (g) vs Time (ms)
Max: 32.0 g
Tmax: 193.9 ms
Min: -56.9 g
Tmin: 193.4 ms
CFC 1000

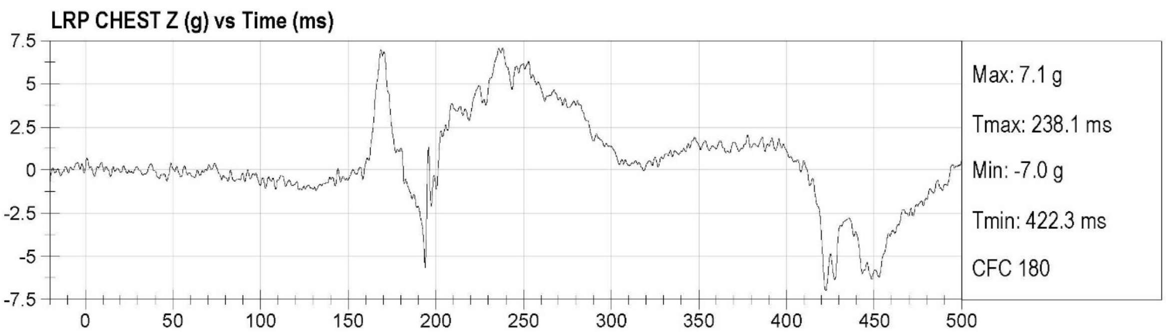

LRP PELVIS Z (g) vs Time (ms)
Max: 5.6 g
Tmax: 329.5 ms
Min: -21.6 g
Tmin: 193.1 ms
CFC 1000

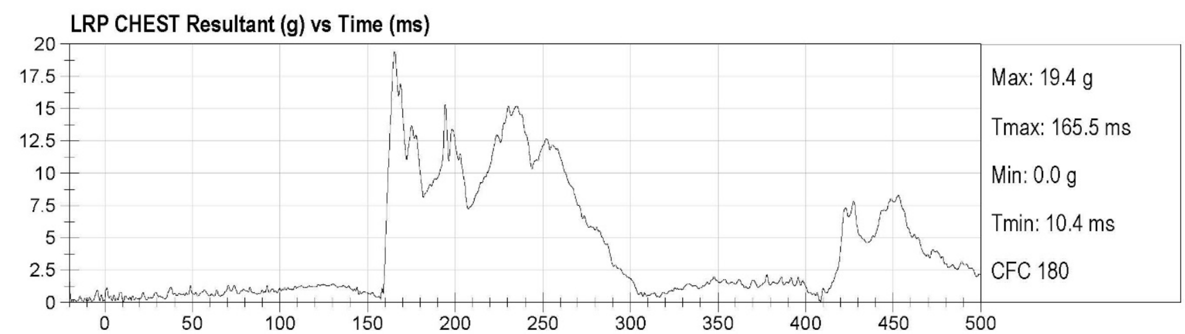

LRP PELVIS Resultant (g) vs Time (ms)
Max: 180.2 g
Tmax: 193.4 ms
Min: 0.0 g
Tmin: -2.7 ms
CFC 1000

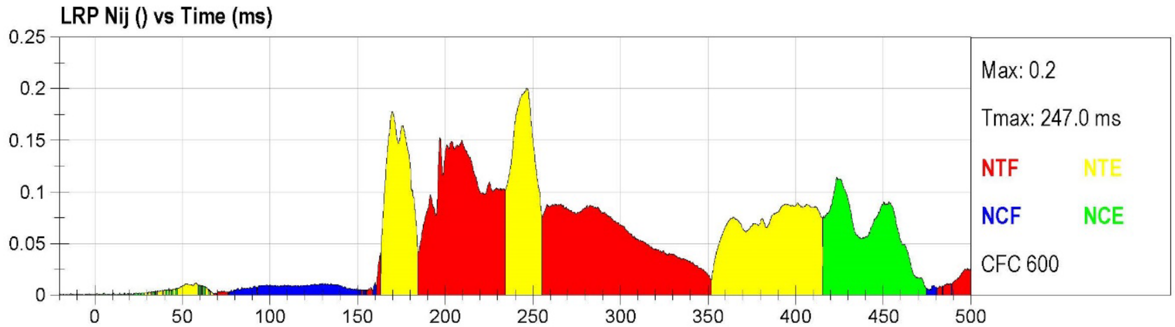

LRP CHEST DISPLACEMENT (mm) vs Time (ms)
Max: 0.1 mm
Tmax: -18.2 ms
Min: -74.4 mm
Tmin: 242.3 ms
CFC 600
10
0
-10
-20
-30
-40
-50
-60
-70
-80
0
50
100
150
200
250
300
350
400
450
500


LRP CHEST X (g) vs Time (ms)
Max: 3.5 g
Tmax: 456.2 ms
Min: -18.9 g
Tmin: 165.4 ms
CFC 180

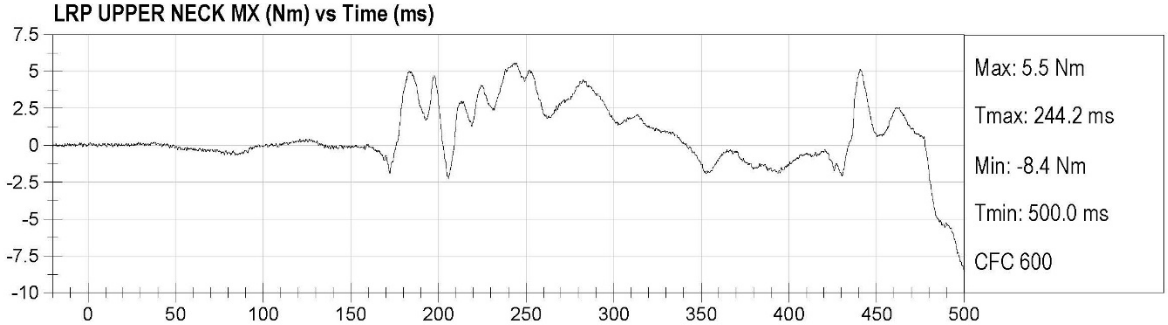

LRP CHEST Y (g) vs Time (ms)
Max: 5.2 g
Tmax: 257.3 ms
Min: -4.5 g
Tmin: 454.2 ms
CFC 180


LRP CHEST Z (g) vs Time (ms)
Max: 7.1 g
Tmax: 238.1 ms
Min: -7.0 g
Tmin: 422.3 ms
CFC 180

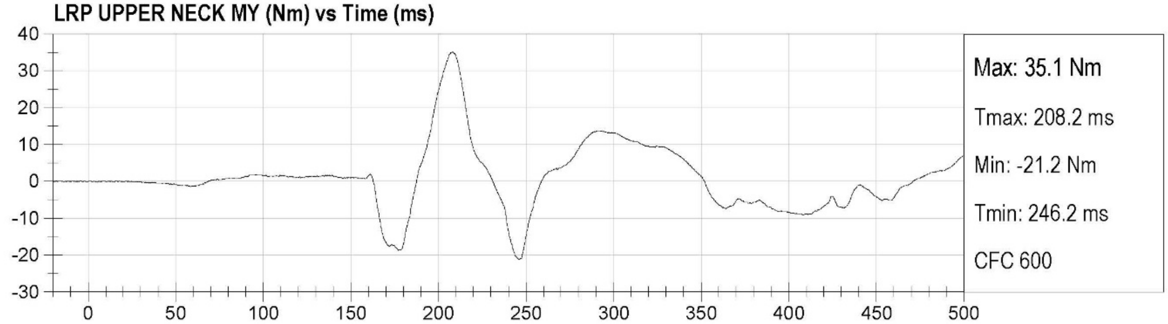

LRP CHEST Resultant (g) vs Time (ms)
Max: 19.4 g
Tmax: 165.5 ms
Min: 0.0 g
Tmin: 10.4 ms
CFC 180


LRP Nij () vs Time (ms)
Max: 0.2
Tmax: 247.0 ms
NTF
NTE
NCF
NCE
CFC 600
0.25
0.2
0.15
0.1
0.05
0
0
50
100
150
200
250
300
350
400
450
500

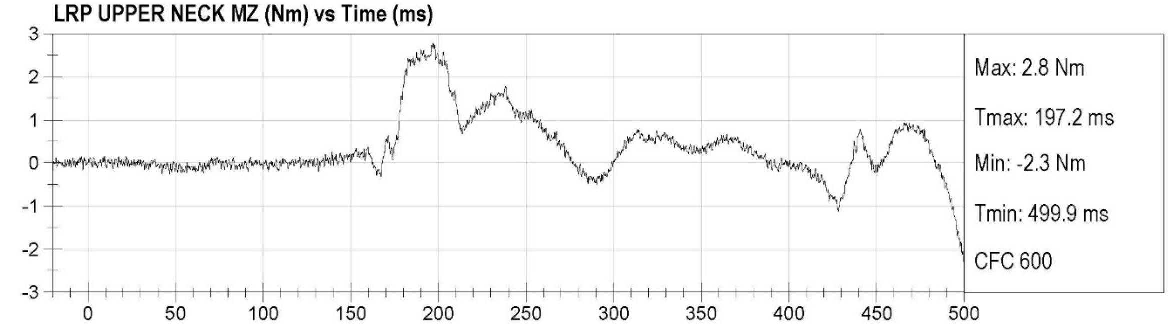
LRP UPPER NECK MX (Nm) vs Time (ms)



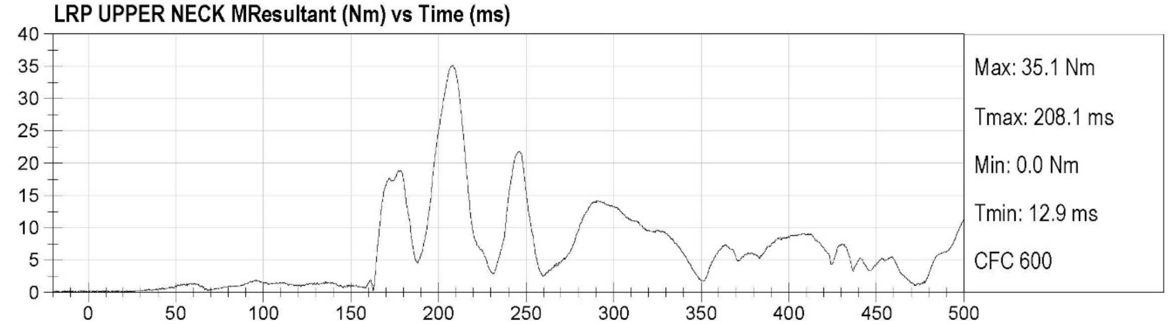

LRP UPPER NECK MY (Nm) vs Time (ms)



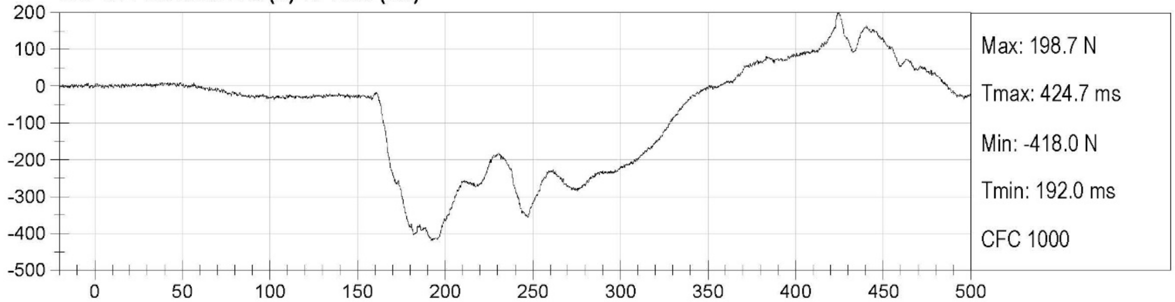

LRP UPPER NECK MZ (Nm) vs Time (ms)



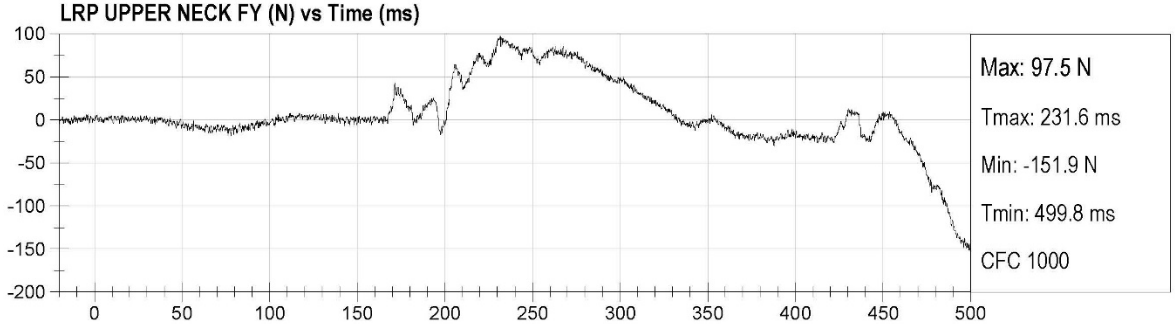

LRP UPPER NECK MResultant (Nm) vs Time (ms)



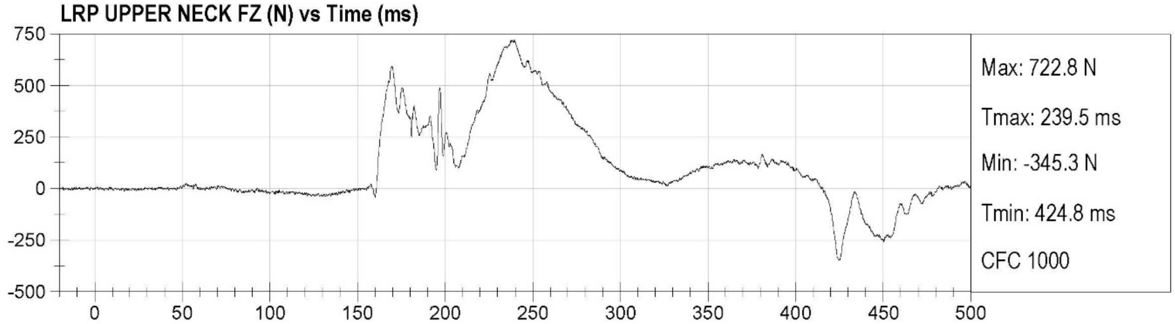
LRP UPPER NECK FX (N) vs Time (ms)



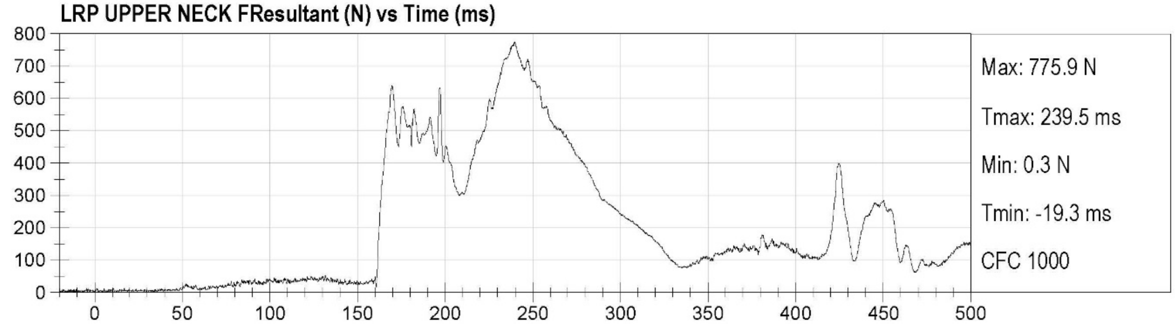

LRP UPPER NECK FY (N) vs Time (ms)

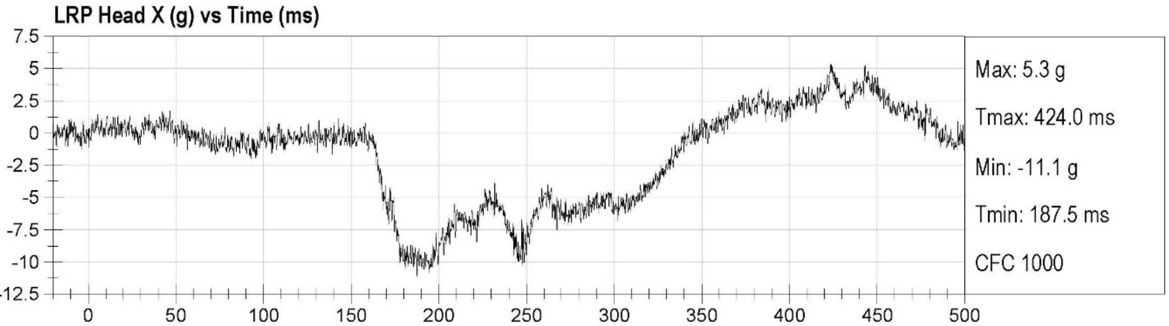


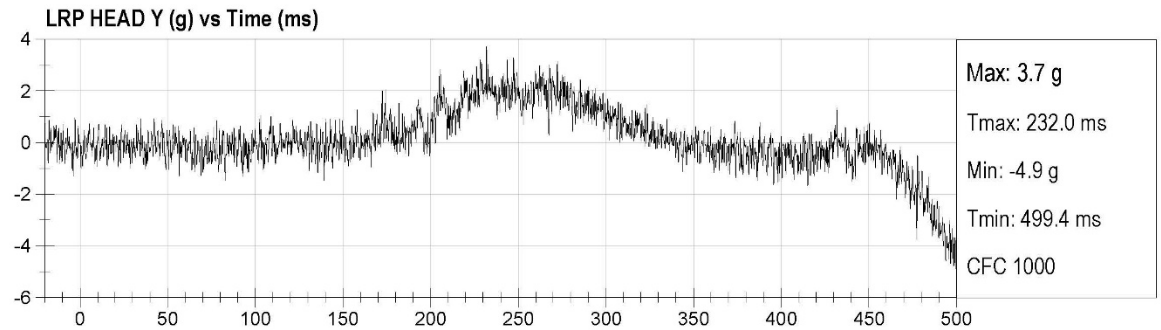

LRP UPPER NECK FZ (N) vs Time (ms)

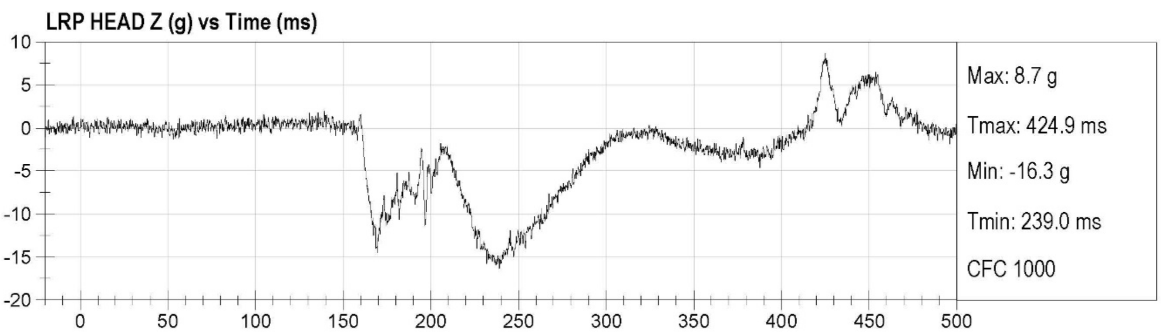


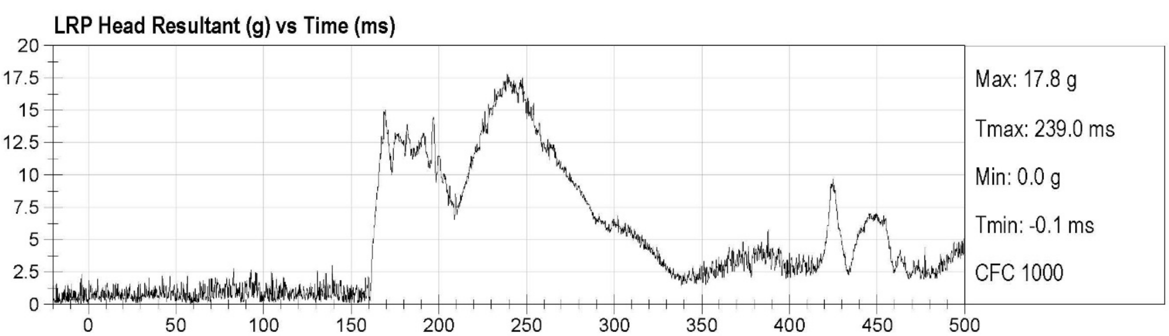

LRP UPPER NECK FResultant (N) vs Time (ms)




LRP Head X (g) vs Time (ms)
Max: 5.3 g
Tmax: 424.0 ms
Min: -11.1 g
Tmin: 187.5 ms
CFC 1000


LRP HEAD Y (g) vs Time (ms)
Max: 3.7 g
Tmax: 232.0 ms
Min: -4.9 g
Tmin: 499.4 ms
CFC 1000


LRP HEAD Z (g) vs Time (ms)
Max: 8.7 g
Tmax: 424.9 ms
Min: -16.3 g
Tmin: 239.0 ms
CFC 1000


LRP Head Resultant (g) vs Time (ms)
Max: 17.8 g
Tmax: 239.0 ms
Min: 0.0 g
Tmin: -0.1 ms
CFC 1000

## A.4: Test 1BQ Data

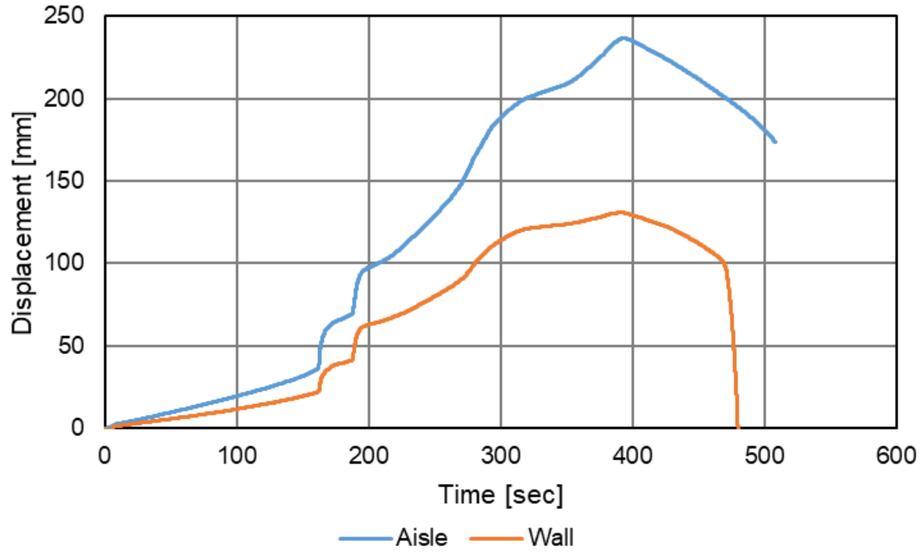



**Figure A1. Test 1BQ Displacement versus Time**

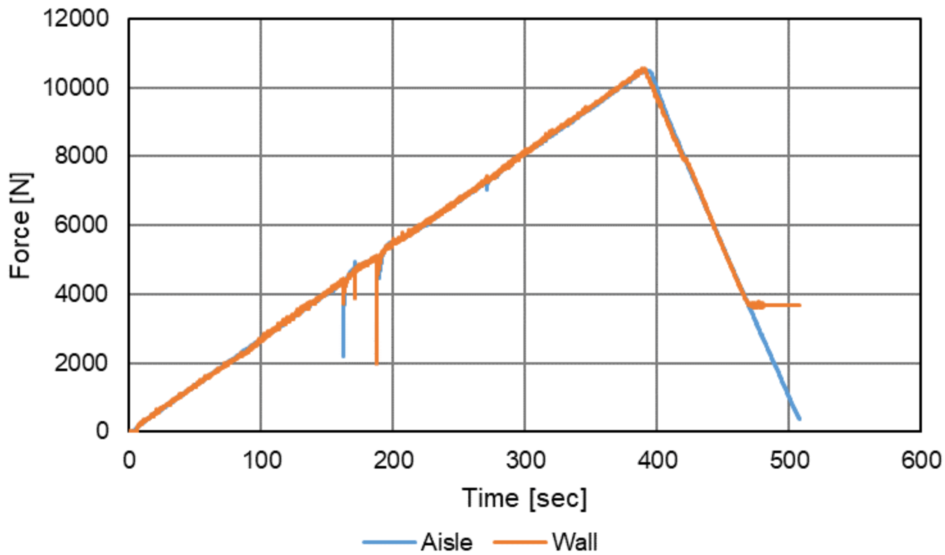



**Figure A2. Test 1BQ Force versus Time**

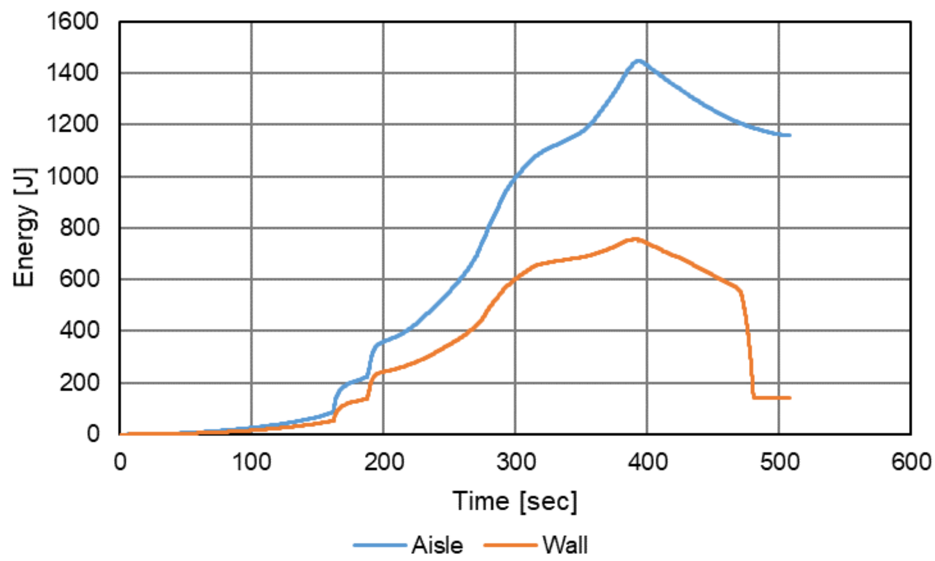



**Figure A3. Test 1BQ Energy-absorption versus Time**

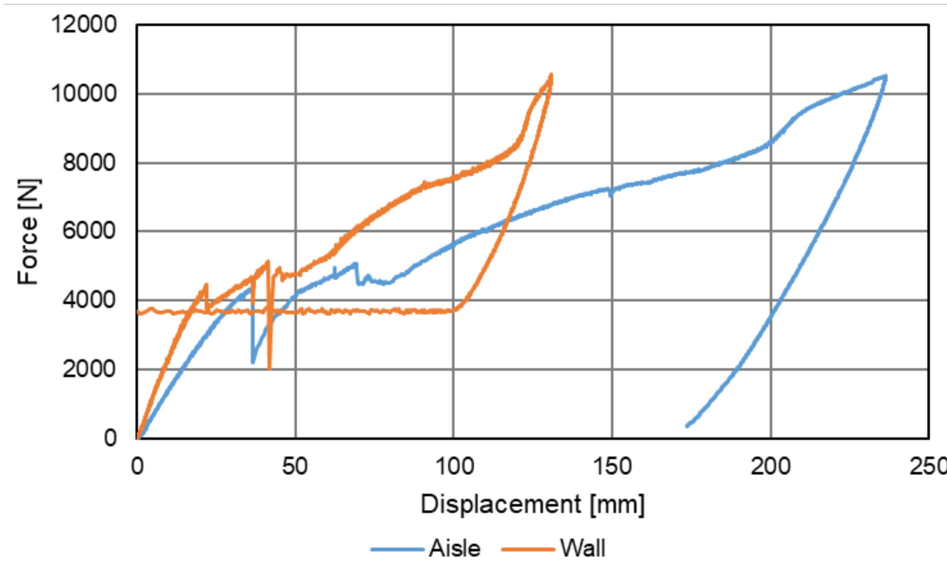
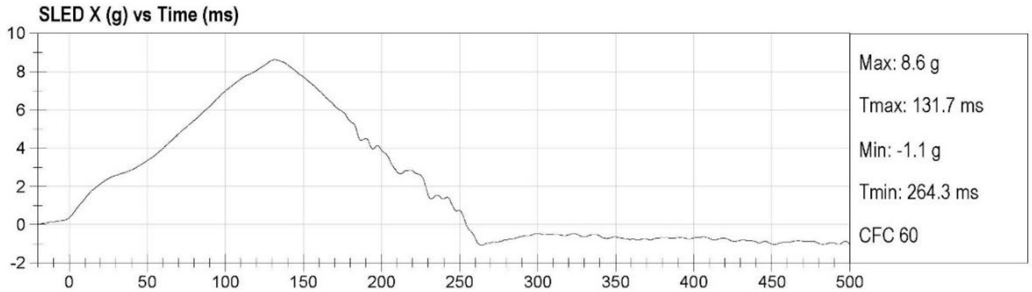


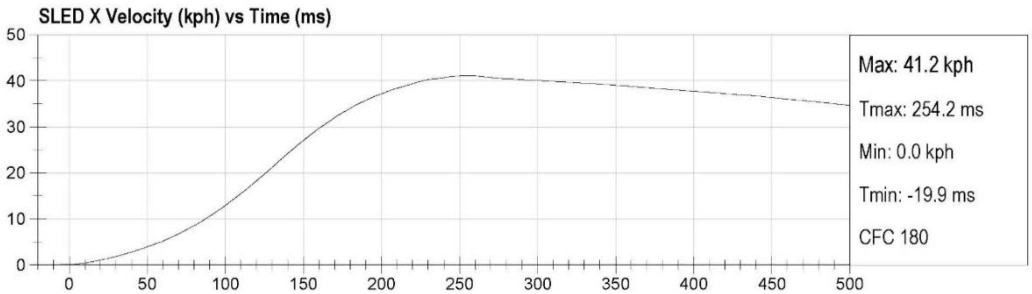

**Figure A4. Test 1BQ Force versus Displacement**

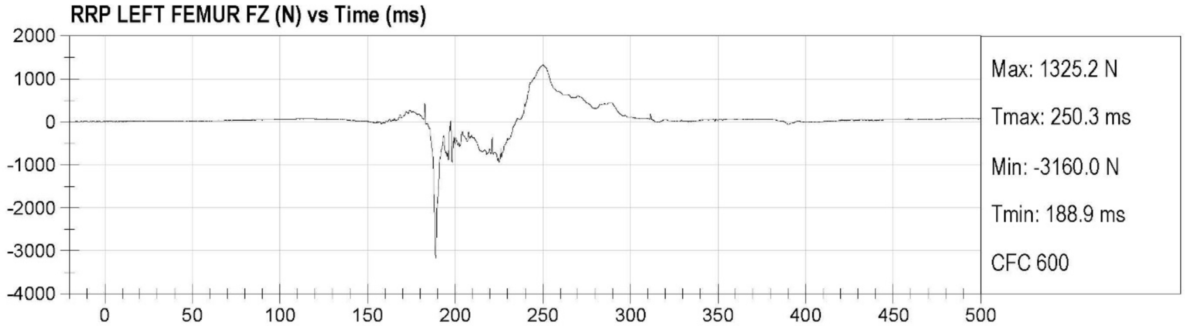
## A.5: Test 2A Data

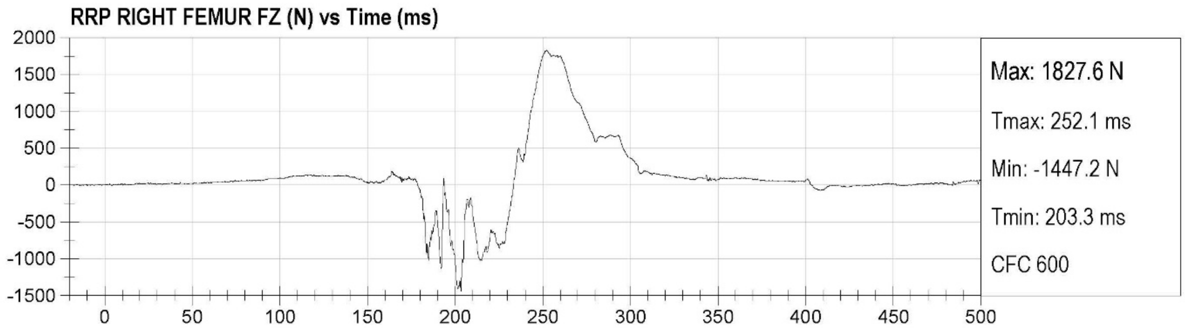
Test Date: 05/05/2021

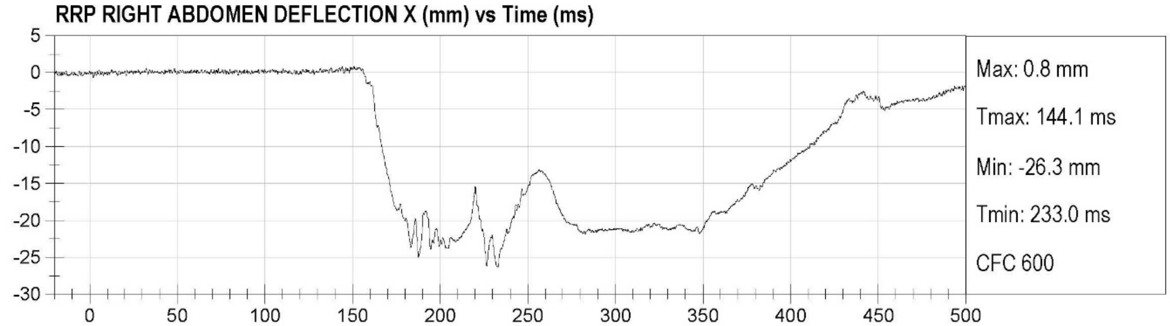
MGA Test ID: S21138

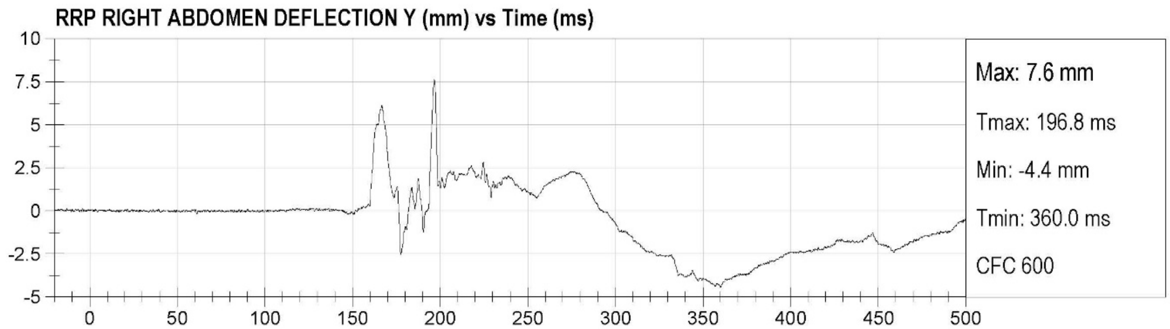


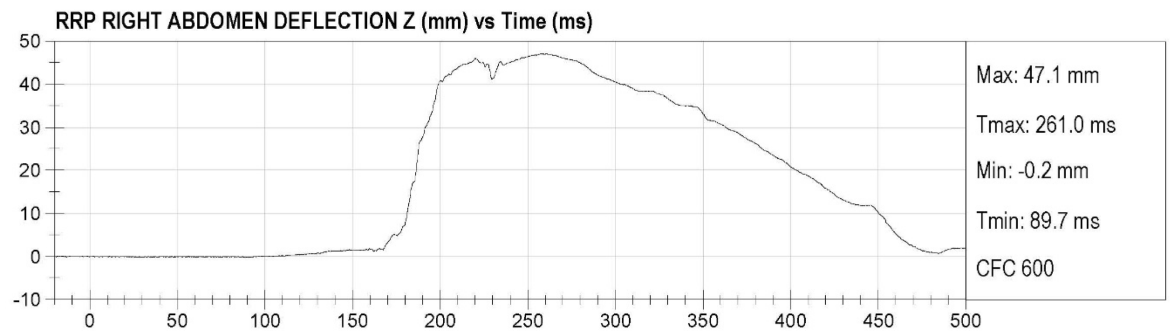



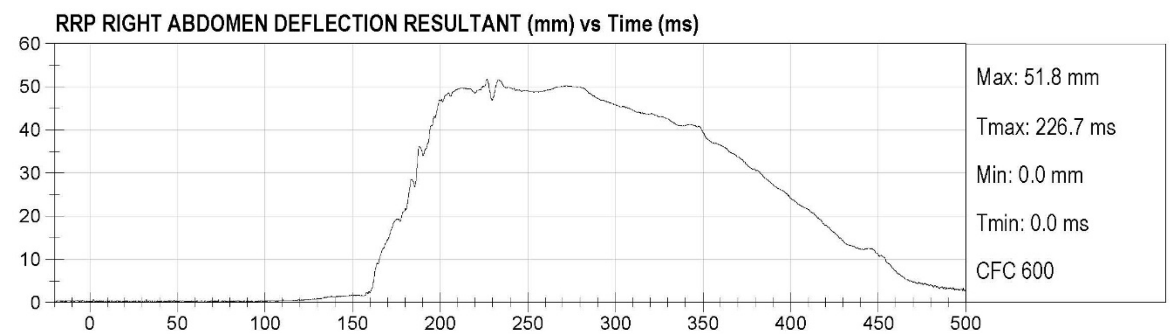

RRP LEFT FEMUR FZ (N) vs Time (ms)
Max: 1325.2 N
Tmax: 250.3 ms
Min: -3160.0 N
Tmin: 188.9 ms
CFC 600

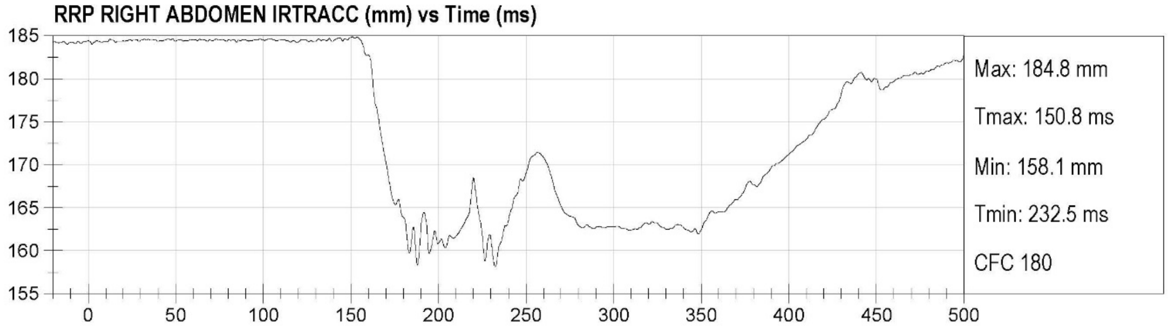

RRP RIGHT FEMUR FZ (N) vs Time (ms)
Max: 1827.6 N
Tmax: 252.1 ms
Min: -1447.2 N
Tmin: 203.3 ms
CFC 600

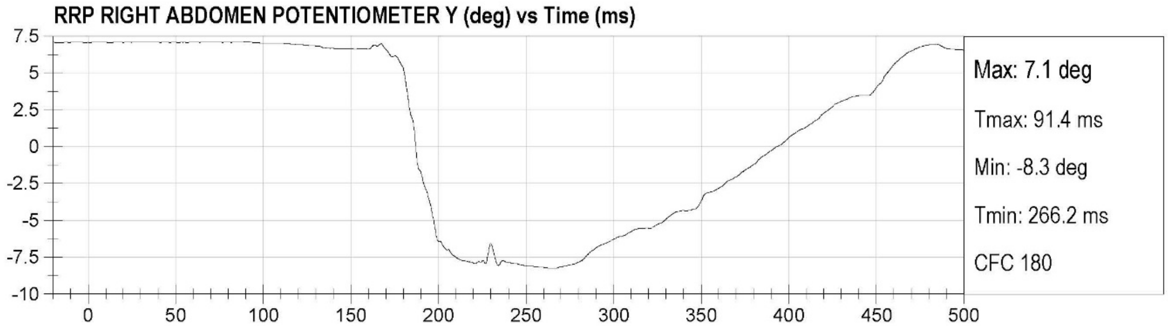

RRP RIGHT ABDOMEN DEFLECTION X (mm) vs Time (ms)
Max: 0.8 mm
Tmax: 144.1 ms
Min: -26.3 mm
Tmin: 233.0 ms
CFC 600

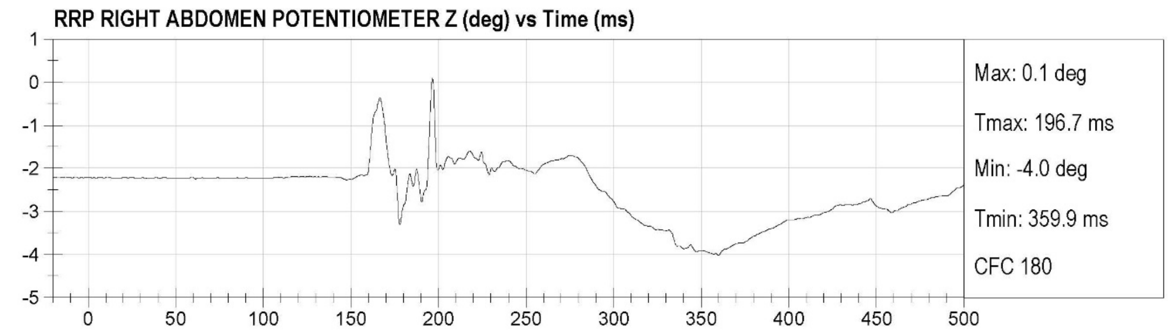

RRP RIGHT ABDOMEN DEFLECTION Y (mm) vs Time (ms)
Max: 7.6 mm
Tmax: 196.8 ms
Min: -4.4 mm
Tmin: 360.0 ms
CFC 600

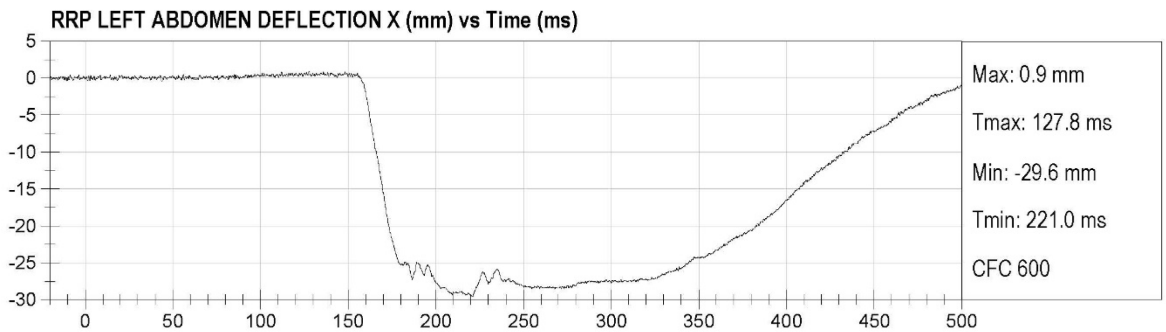

RRP RIGHT ABDOMEN DEFLECTION Z (mm) vs Time (ms)
Max: 47.1 mm
Tmax: 261.0 ms
Min: -0.2 mm
Tmin: 89.7 ms
CFC 600

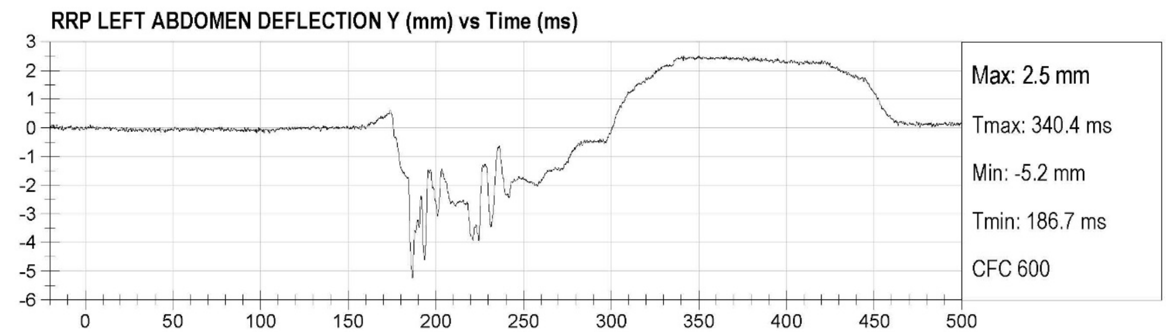

RRP RIGHT ABDOMEN DEFLECTION RESULTANT (mm) vs Time (ms)
Max: 51.8 mm
Tmax: 226.7 ms
Min: 0.0 mm
Tmin: 0.0 ms
CFC 600

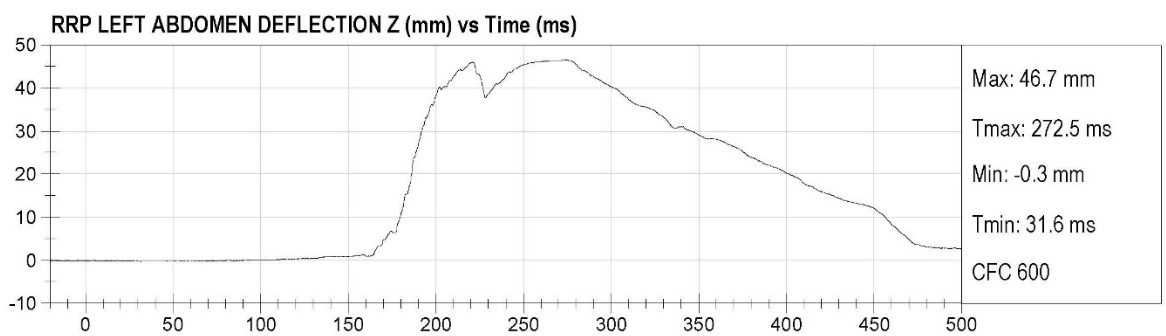

RRP RIGHT ABDOMEN IRTRACC (mm) vs Time (ms)
185
180
175
170
165
160
155
0
50
100
150
200
250
300
350
400
450
500
Max: 184.8 mm
Tmax: 150.8 ms
Min: 158.1 mm
Tmin: 232.5 ms
CFC 180

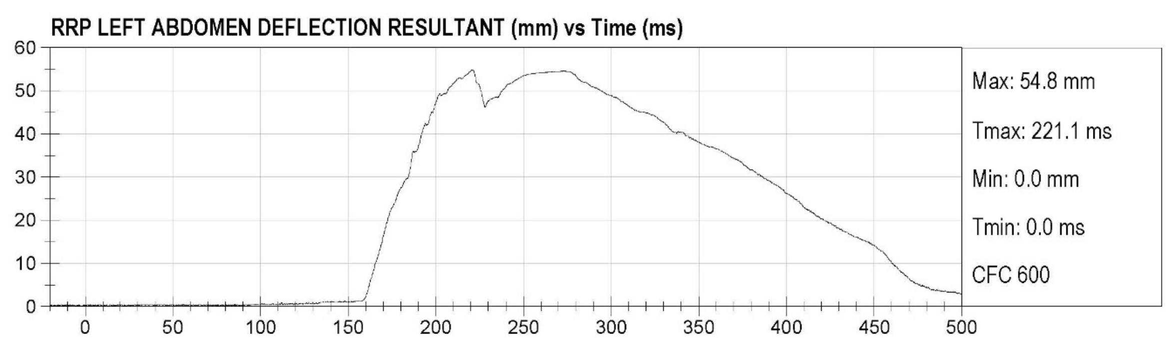

RRP RIGHT ABDOMEN POTENTIOMETER Y (deg) vs Time (ms)
7.5
5
2.5
0
-2.5
-5
-7.5
-10
0
50
100
150
200
250
300
350
400
450
500
Max: 7.1 deg
Tmax: 91.4 ms
Min: -8.3 deg
Tmin: 266.2 ms
CFC 180

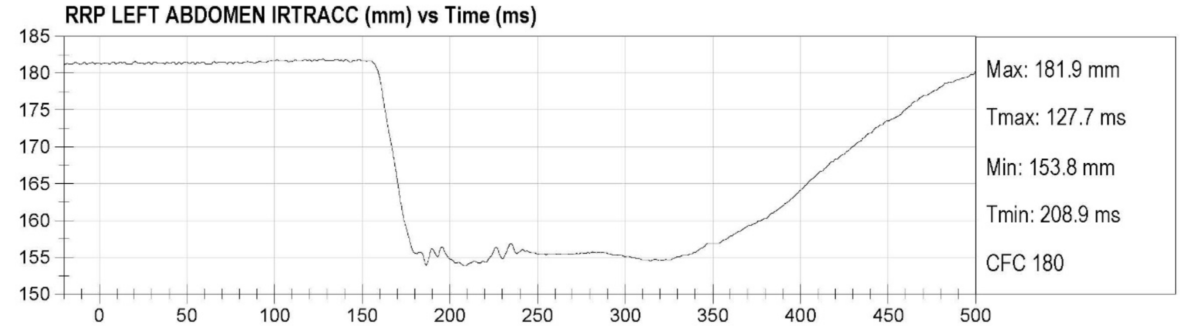

RRP RIGHT ABDOMEN POTENTIOMETER Z (deg) vs Time (ms)
1
0
-1
-2
-3
-4
-5
0
50
100
150
200
250
300
350
400
450
500
Max: 0.1 deg
Tmax: 196.7 ms
Min: -4.0 deg
Tmin: 359.9 ms
CFC 180

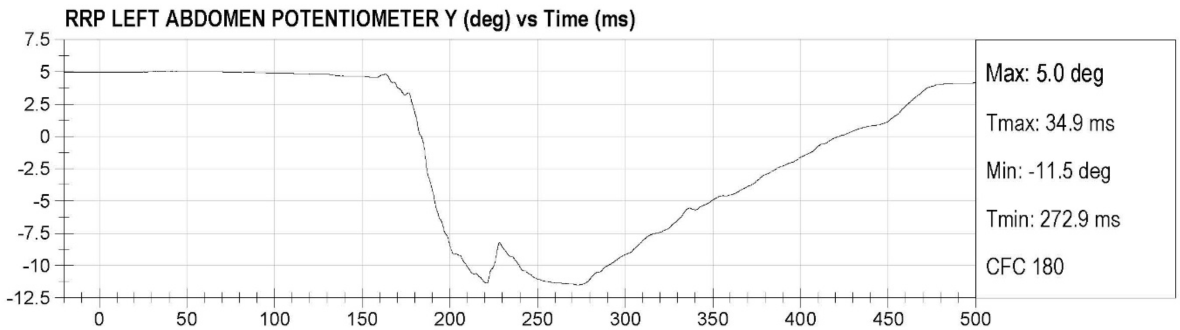

RRP LEFT ABDOMEN DEFLECTION X (mm) vs Time (ms)
Max: 0.9 mm
Tmax: 127.8 ms
Min: -29.6 mm
Tmin: 221.0 ms
CFC 600

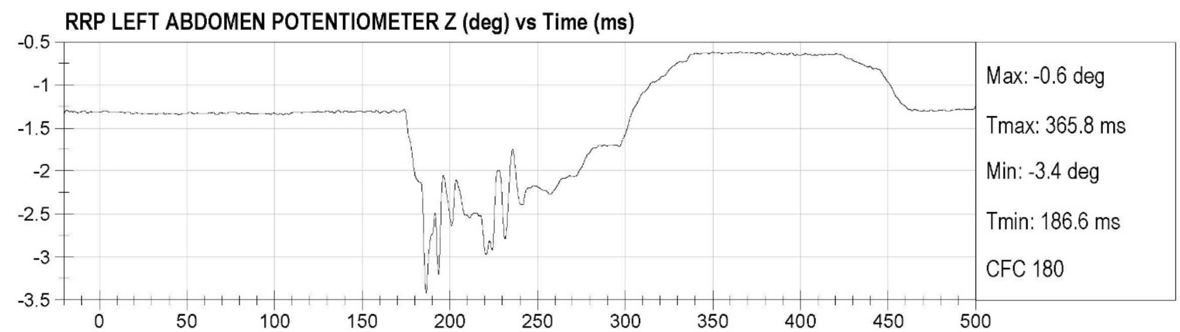

RRP LEFT ABDOMEN DEFLECTION Y (mm) vs Time (ms)
Max: 2.5 mm
Tmax: 340.4 ms
Min: -5.2 mm
Tmin: 186.7 ms
CFC 600


RRP LEFT ABDOMEN DEFLECTION Z (mm) vs Time (ms)
Max: 46.7 mm
Tmax: 272.5 ms
Min: -0.3 mm
Tmin: 31.6 ms
CFC 600

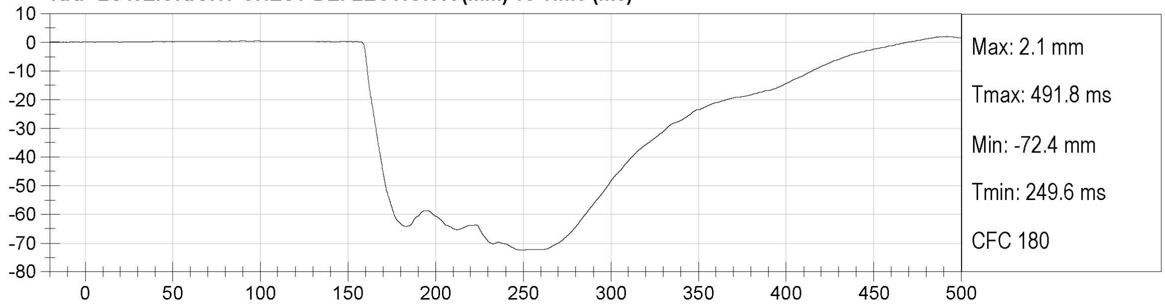

RRP LEFT ABDOMEN DEFLECTION RESULTANT (mm) vs Time (ms)
Max: 54.8 mm
Tmax: 221.1 ms
Min: 0.0 mm
Tmin: 0.0 ms
CFC 600


RRP LEFT ABDOMEN IRTRACC (mm) vs Time (ms)
185
180
175
170
165
160
155
150
0
50
100
150
200
250
300
350
400
450
500
Max: 181.9 mm
Tmax: 127.7 ms
Min: 153.8 mm
Tmin: 208.9 ms
CFC 180

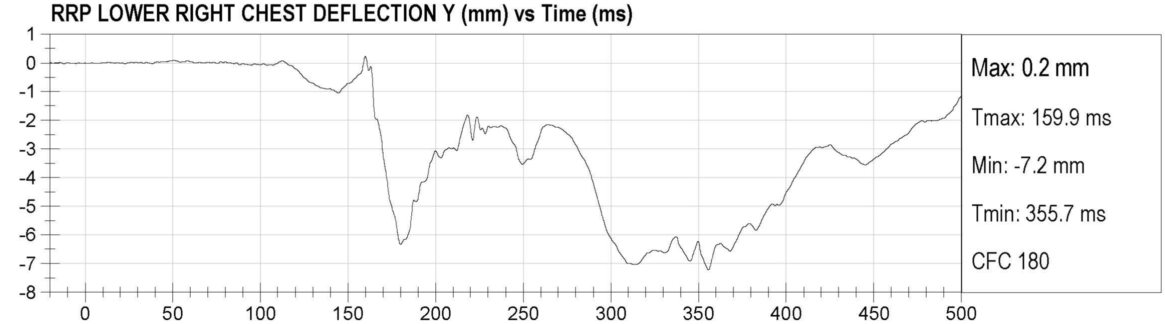

RRP LEFT ABDOMEN POTENTIOMETER Y (deg) vs Time (ms)
7.5
5
2.5
0
-2.5
-5
-7.5
-10
-12.5
0
50
100
150
200
250
300
350
400
450
500
Max: 5.0 deg
Tmax: 34.9 ms
Min: -11.5 deg
Tmin: 272.9 ms
CFC 180


RRP LEFT ABDOMEN POTENTIOMETER Z (deg) vs Time (ms)
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
0
50
100
150
200
250
300
350
400
450
500
Max: -0.6 deg
Tmax: 365.8 ms
Min: -3.4 deg
Tmin: 186.6 ms
CFC 180

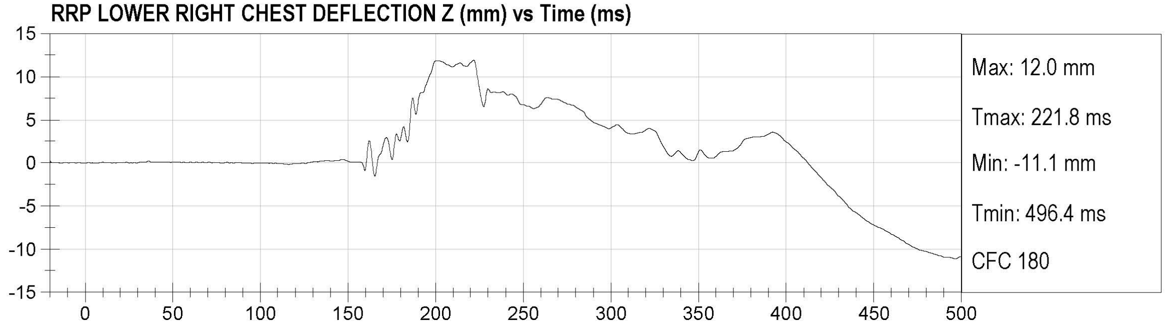
RRP LOWER RIGHT CHEST DEFLECTION X (mm) vs Time (ms)



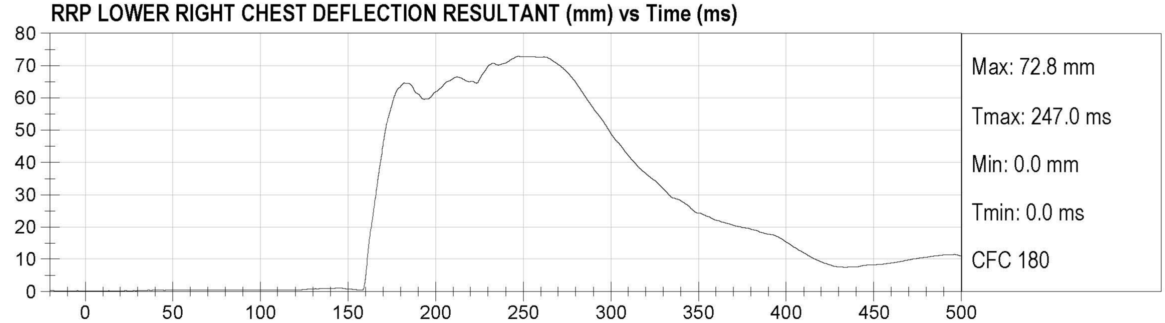

RRP LOWER RIGHT CHEST DEFLECTION Y (mm) vs Time (ms)



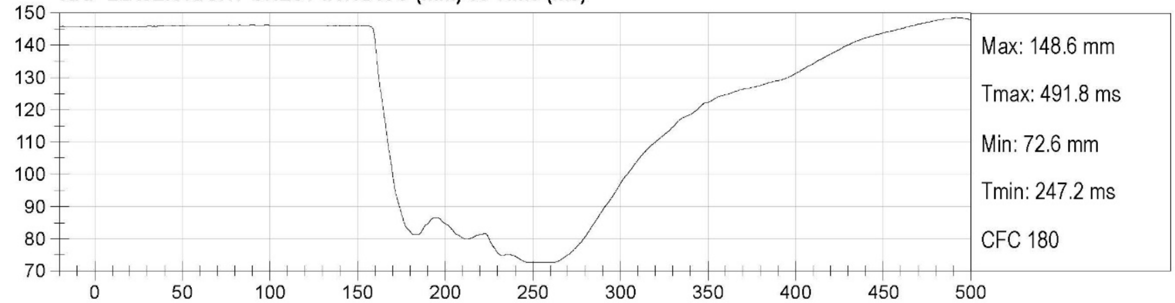

RRP LOWER RIGHT CHEST DEFLECTION Z (mm) vs Time (ms)



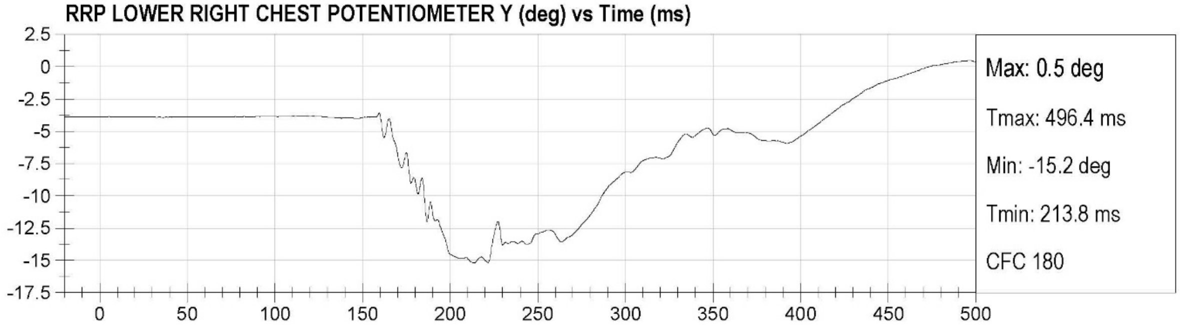

RRP LOWER RIGHT CHEST DEFLECTION RESULTANT (mm) vs Time (ms)



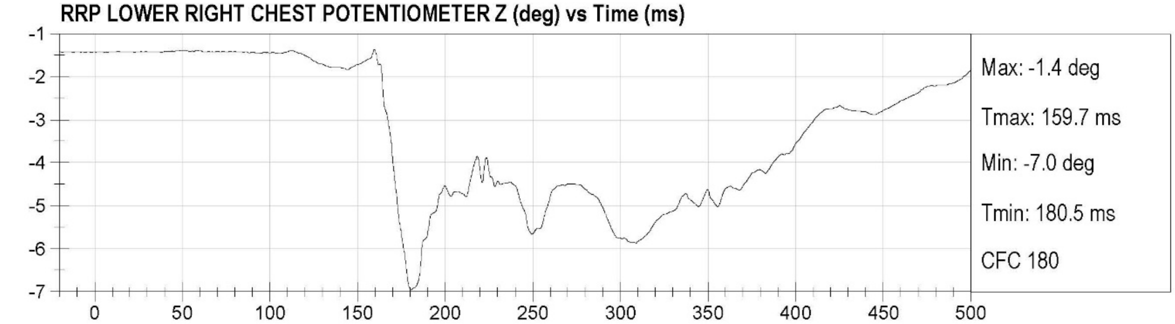
RRP LOWER RIGHT CHEST IRTRACC (mm) vs Time (ms)



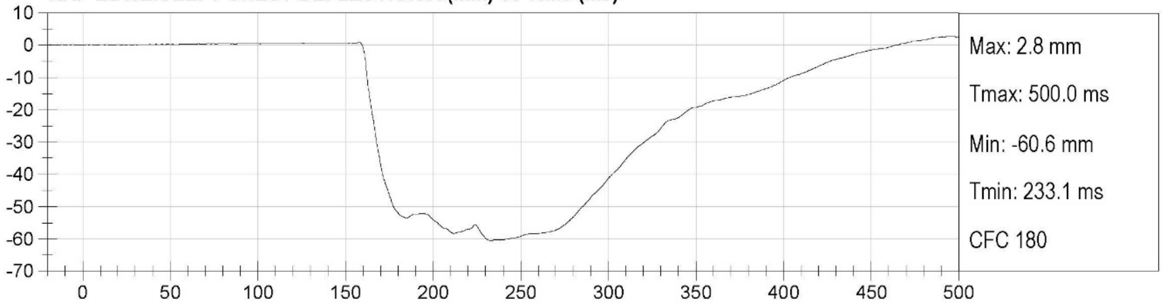

RRP LOWER RIGHT CHEST POTENTIOMETER Y (deg) vs Time (ms)



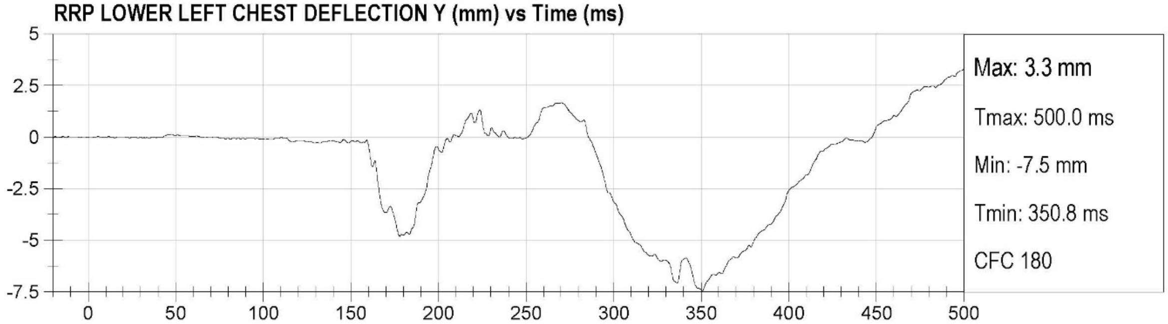

RRP LOWER RIGHT CHEST POTENTIOMETER Z (deg) vs Time (ms)



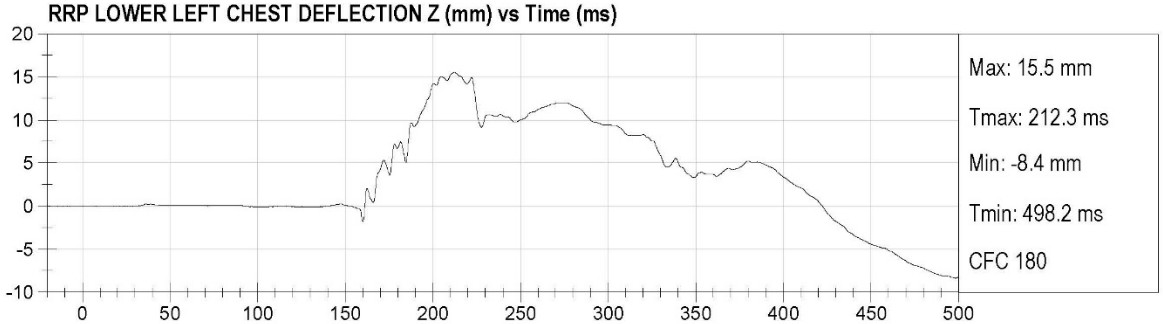
RRP LOWER LEFT CHEST DEFLECTION X (mm) vs Time (ms)



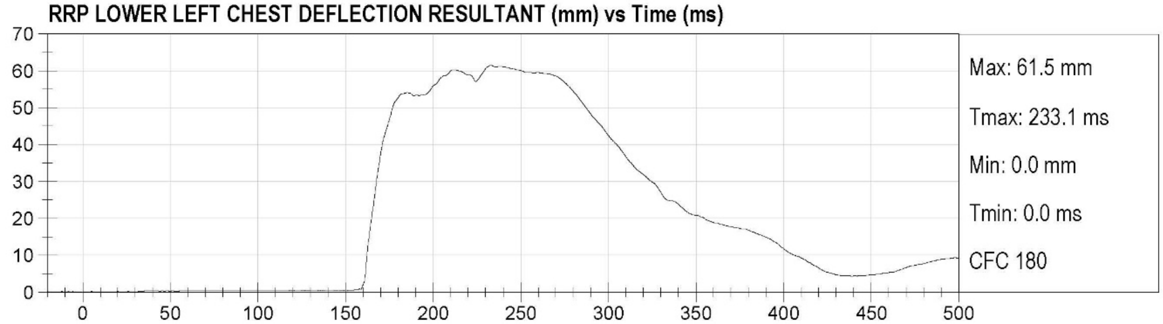

RRP LOWER LEFT CHEST DEFLECTION Y (mm) vs Time (ms)

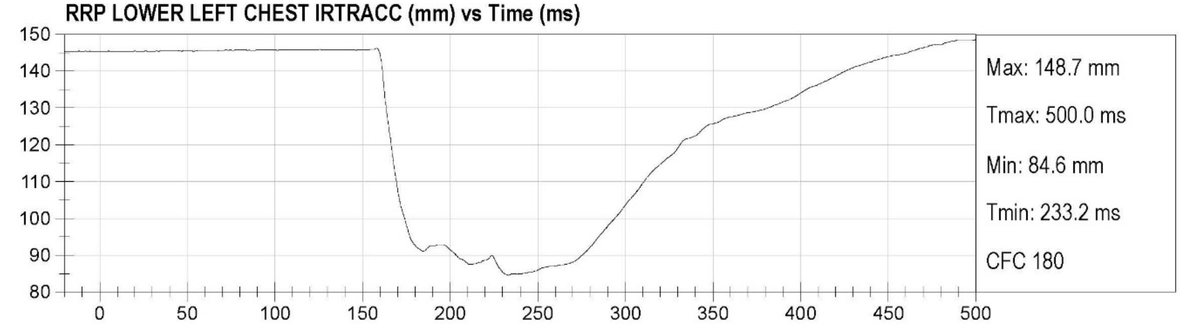


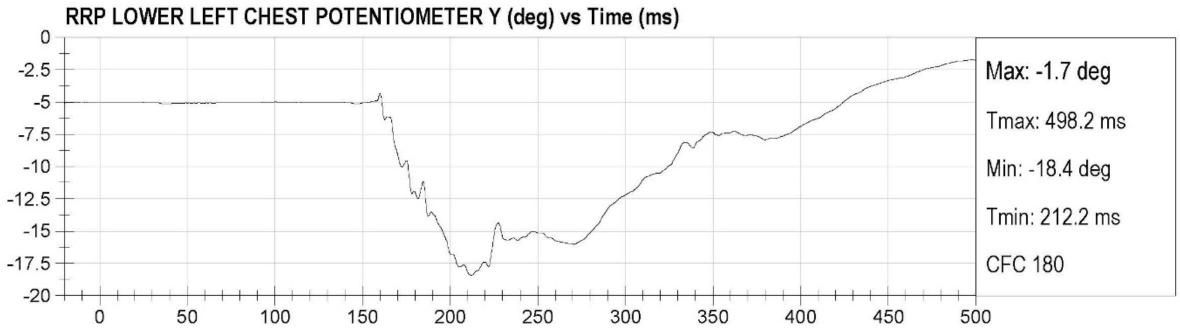

RRP LOWER LEFT CHEST DEFLECTION Z (mm) vs Time (ms)

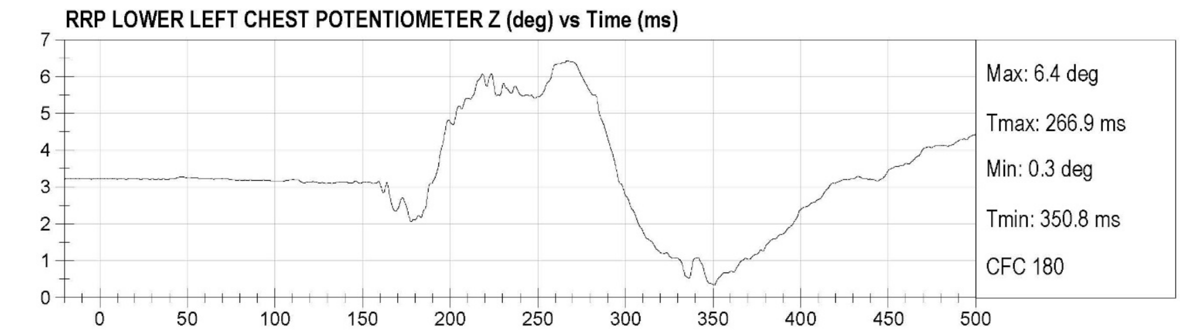


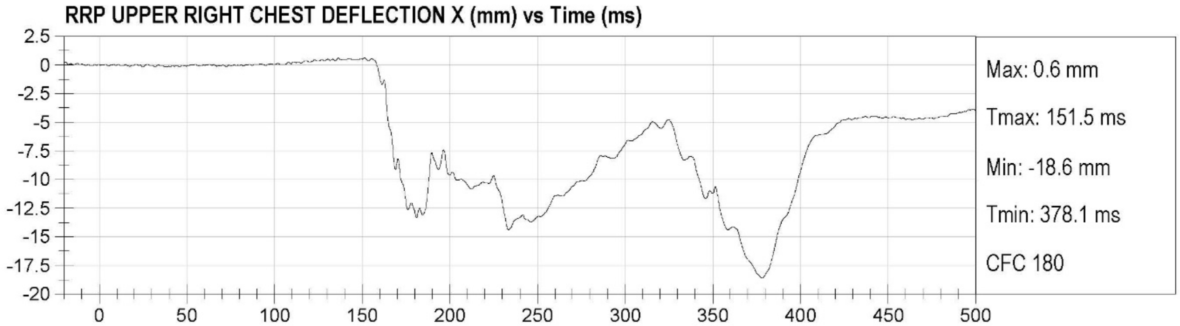

RRP LOWER LEFT CHEST DEFLECTION RESULTANT (mm) vs Time (ms)

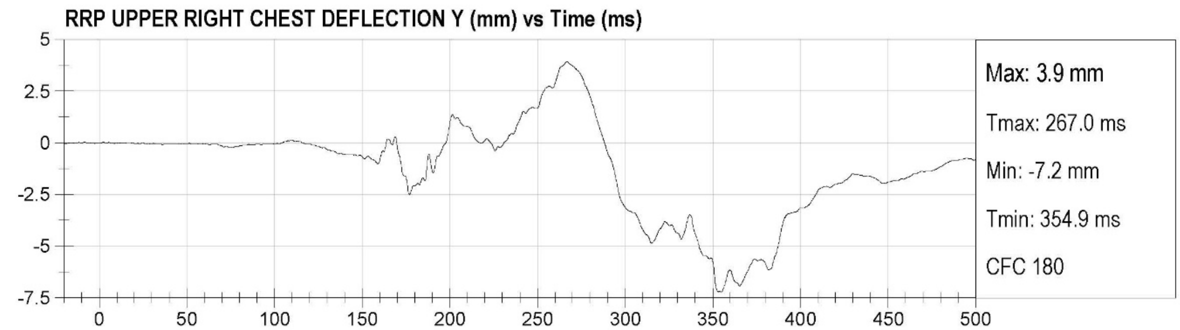



RRP LOWER LEFT CHEST IRTRACC (mm) vs Time (ms)
Max: 148.7 mm
Tmax: 500.0 ms
Min: 84.6 mm
Tmin: 233.2 ms
CFC 180

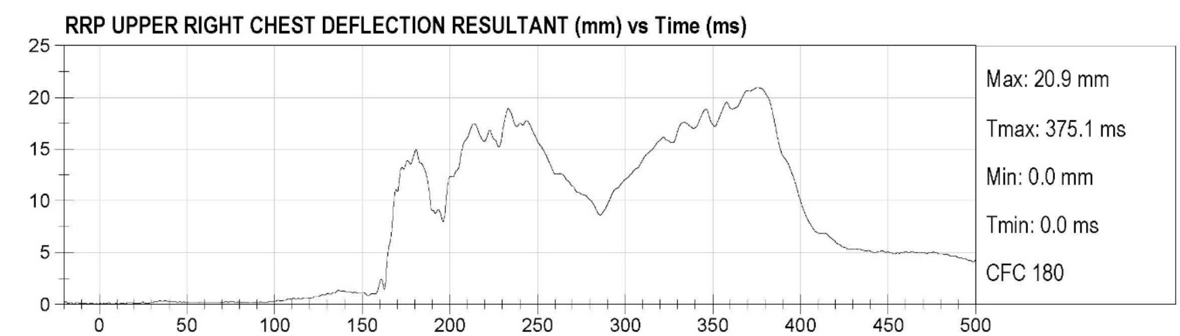

RRP LOWER LEFT CHEST POTENTIOMETER Y (deg) vs Time (ms)
Max: -1.7 deg
Tmax: 498.2 ms
Min: -18.4 deg
Tmin: 212.2 ms
CFC 180

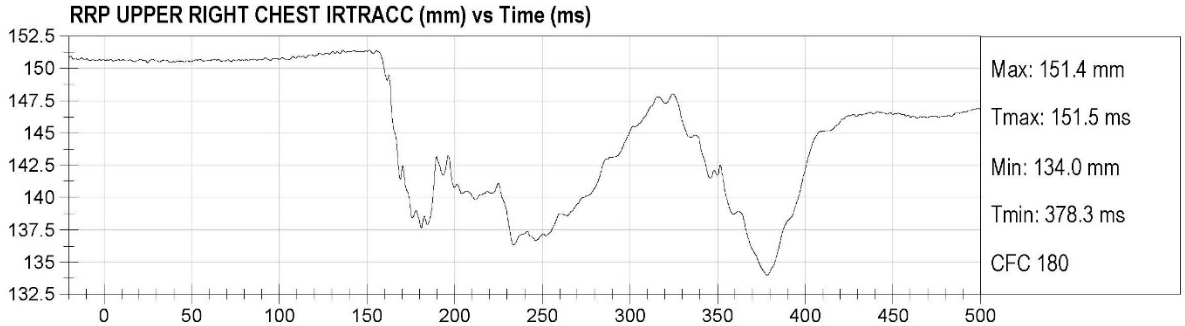

RRP LOWER LEFT CHEST POTENTIOMETER Z (deg) vs Time (ms)
Max: 6.4 deg
Tmax: 266.9 ms
Min: 0.3 deg
Tmin: 350.8 ms
CFC 180

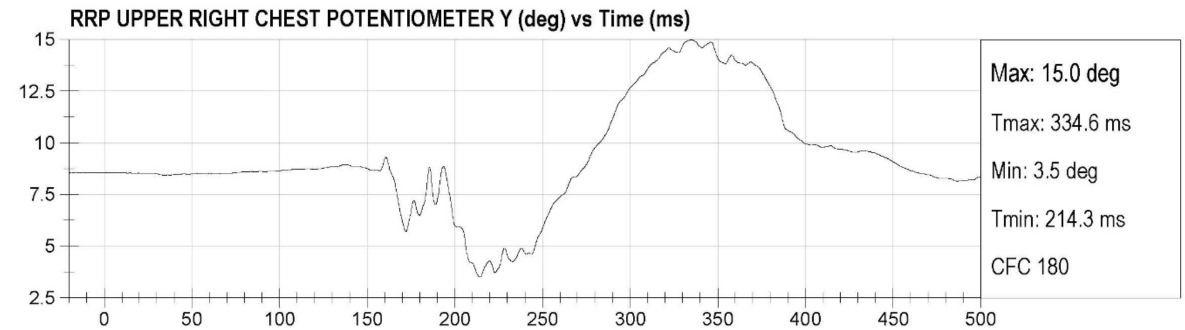

RRP UPPER RIGHT CHEST DEFLECTION X (mm) vs Time (ms)
Max: 0.6 mm
Tmax: 151.5 ms
Min: -18.6 mm
Tmin: 378.1 ms
CFC 180

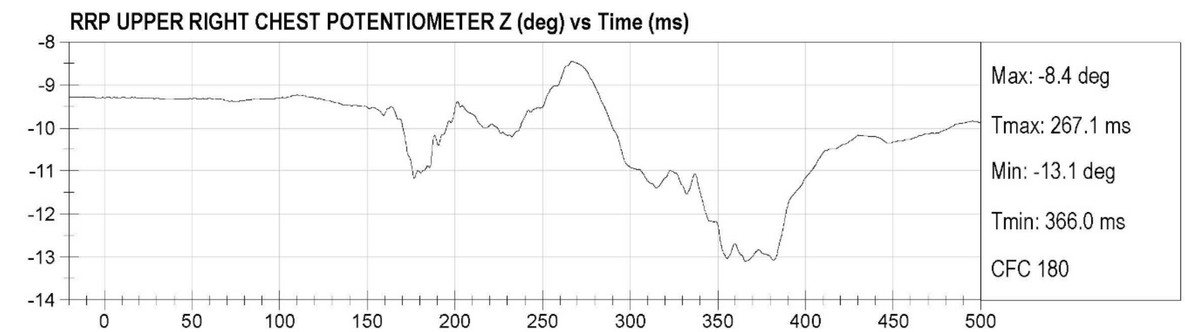

RRP UPPER RIGHT CHEST DEFLECTION Y (mm) vs Time (ms)
Max: 3.9 mm
Tmax: 267.0 ms
Min: -7.2 mm
Tmin: 354.9 ms
CFC 180

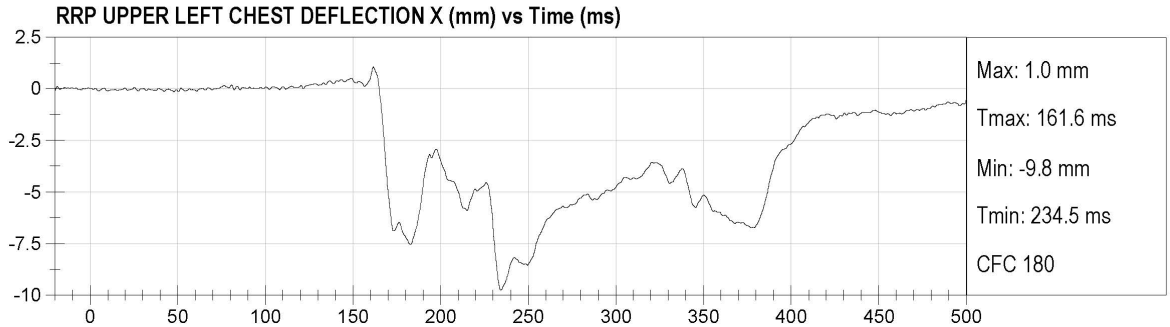

RRP UPPER RIGHT CHEST DEFLECTION Z (mm) vs Time (ms)
Max: 13.8 mm
Tmax: 214.3 ms
Min: -14.9 mm
Tmin: 334.8 ms
CFC 180

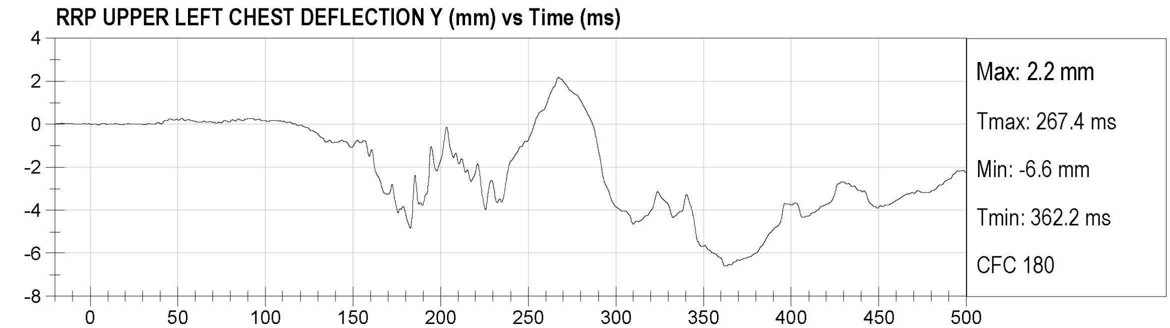

RRP UPPER RIGHT CHEST DEFLECTION RESULTANT (mm) vs Time (ms)
Max: 20.9 mm
Tmax: 375.1 ms
Min: 0.0 mm
Tmin: 0.0 ms
CFC 180

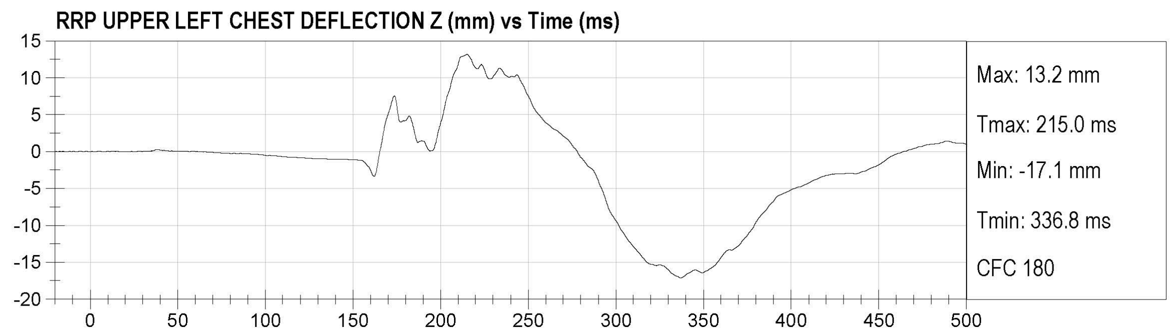

RRP UPPER RIGHT CHEST IRTRACC (mm) vs Time (ms)
Max: 151.4 mm
Tmax: 151.5 ms
Min: 134.0 mm
Tmin: 378.3 ms
CFC 180

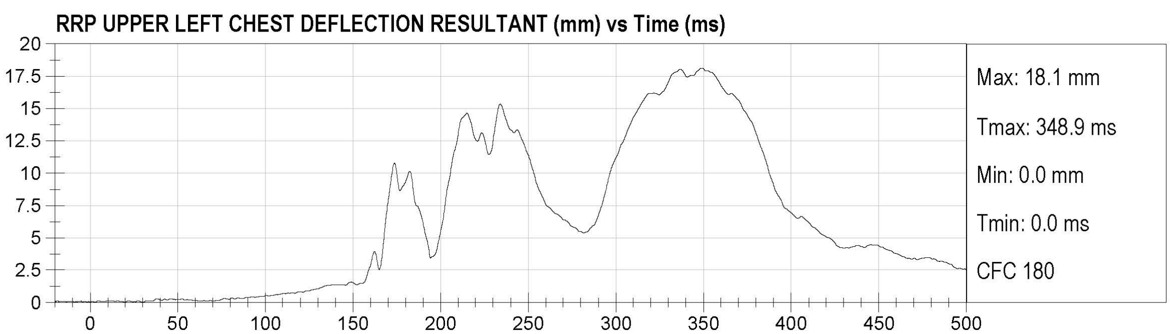

RRP UPPER RIGHT CHEST POTENTIOMETER Y (deg) vs Time (ms)
Max: 15.0 deg
Tmax: 334.6 ms
Min: 3.5 deg
Tmin: 214.3 ms
CFC 180

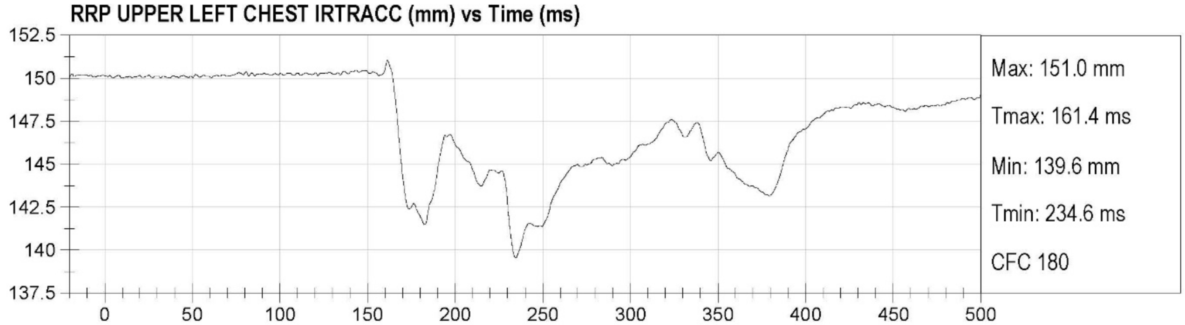

RRP UPPER RIGHT CHEST POTENTIOMETER Z (deg) vs Time (ms)
Max: -8.4 deg
Tmax: 267.1 ms
Min: -13.1 deg
Tmin: 366.0 ms
CFC 180

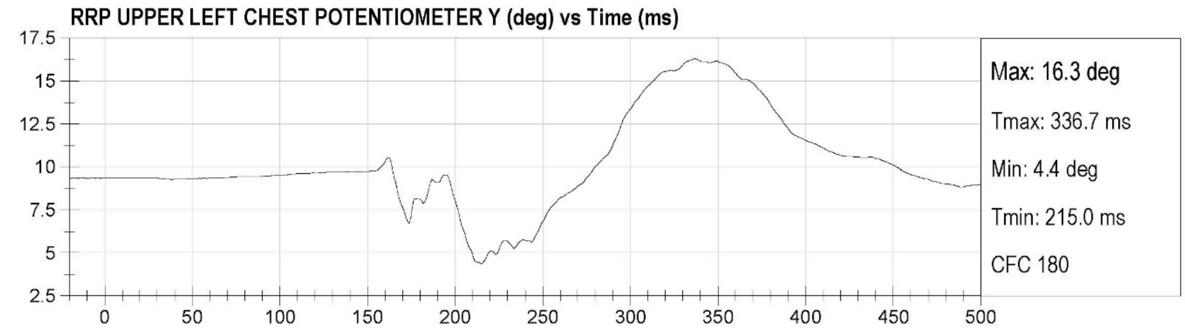

RRP UPPER LEFT CHEST DEFLECTION X (mm) vs Time (ms)
Max: 1.0 mm
Tmax: 161.6 ms
Min: -9.8 mm
Tmin: 234.5 ms
CFC 180

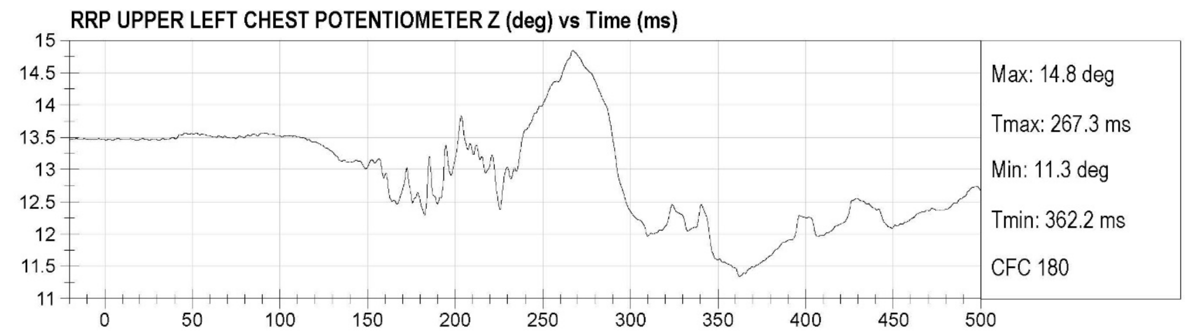

RRP UPPER LEFT CHEST DEFLECTION Y (mm) vs Time (ms)
Max: 2.2 mm
Tmax: 267.4 ms
Min: -6.6 mm
Tmin: 362.2 ms
CFC 180

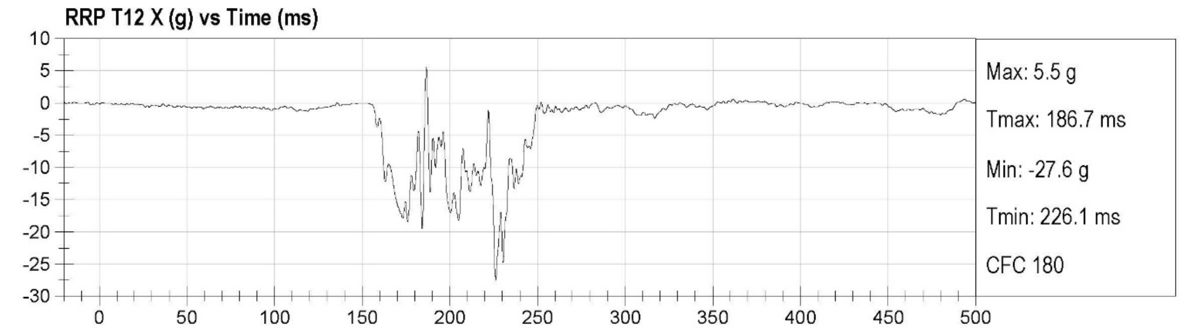

RRP UPPER LEFT CHEST DEFLECTION Z (mm) vs Time (ms)
Max: 13.2 mm
Tmax: 215.0 ms
Min: -17.1 mm
Tmin: 336.8 ms
CFC 180

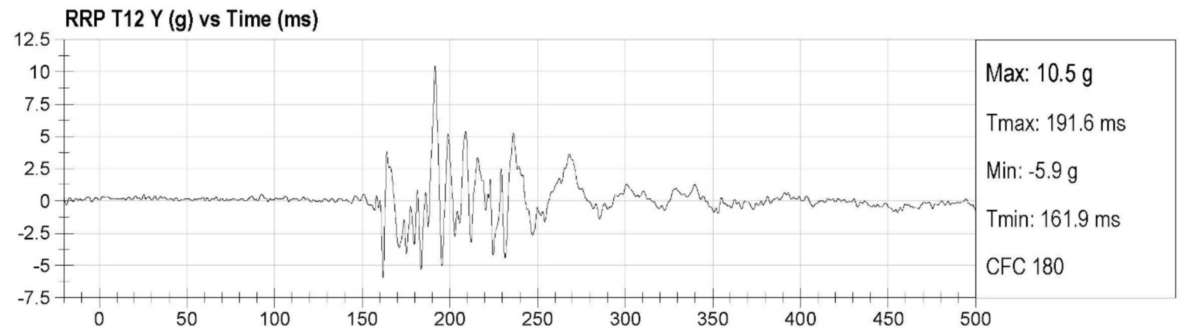

RRP UPPER LEFT CHEST DEFLECTION RESULTANT (mm) vs Time (ms)
Max: 18.1 mm
Tmax: 348.9 ms
Min: 0.0 mm
Tmin: 0.0 ms
CFC 180

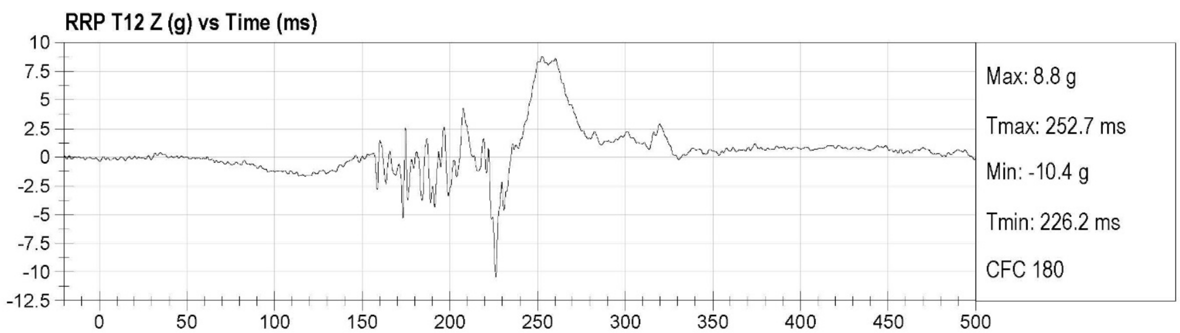

RRP UPPER LEFT CHEST IRTRACC (mm) vs Time (ms)
Max: 151.0 mm
Tmax: 161.4 ms
Min: 139.6 mm
Tmin: 234.6 ms
CFC 180

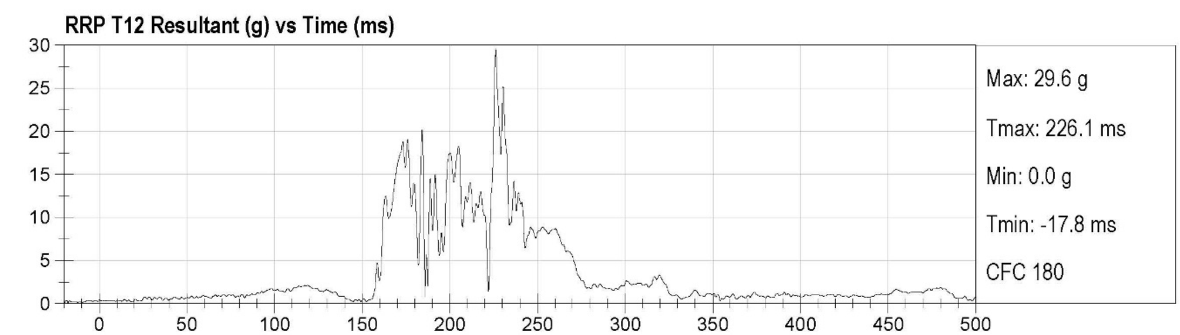

RRP UPPER LEFT CHEST POTENTIOMETER Y (deg) vs Time (ms)
Max: 16.3 deg
Tmax: 336.7 ms
Min: 4.4 deg
Tmin: 215.0 ms
CFC 180

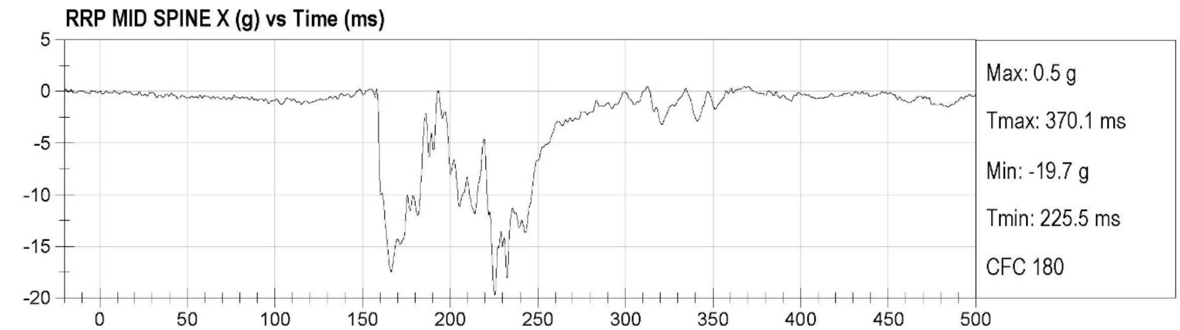

RRP UPPER LEFT CHEST POTENTIOMETER Z (deg) vs Time (ms)
Max: 14.8 deg
Tmax: 267.3 ms
Min: 11.3 deg
Tmin: 362.2 ms
CFC 180

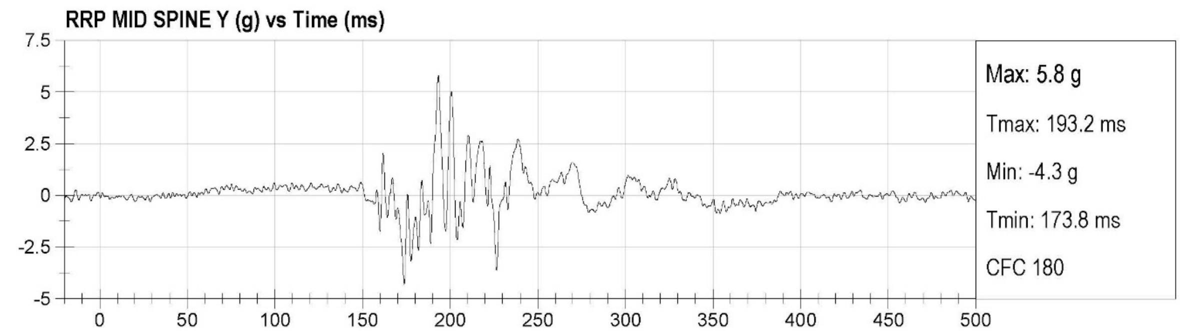

RRP T12 X (g) vs Time (ms)
Max: 5.5 g
Tmax: 186.7 ms
Min: -27.6 g
Tmin: 226.1 ms
CFC 180

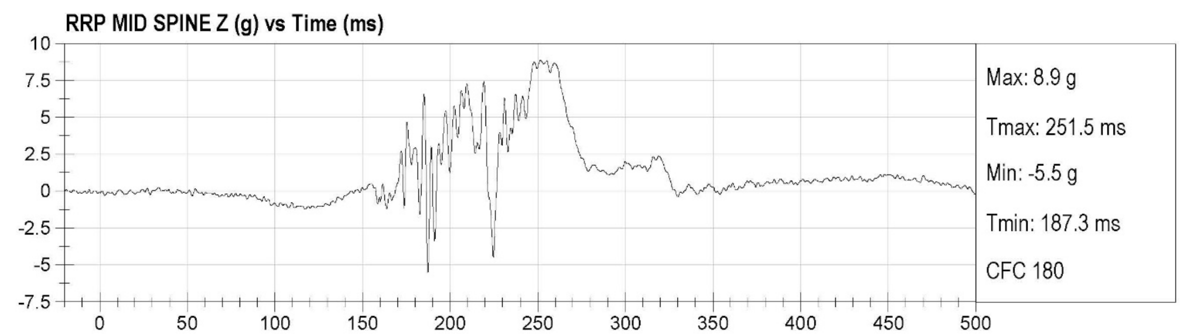

RRP T12 Y (g) vs Time (ms)
Max: 10.5 g
Tmax: 191.6 ms
Min: -5.9 g
Tmin: 161.9 ms
CFC 180

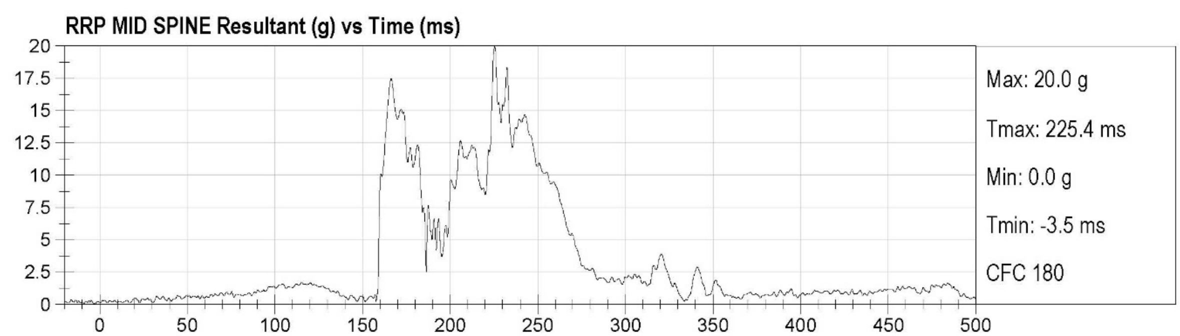

RRP T12 Z (g) vs Time (ms)
Max: 8.8 g
Tmax: 252.7 ms
Min: -10.4 g
Tmin: 226.2 ms
CFC 180

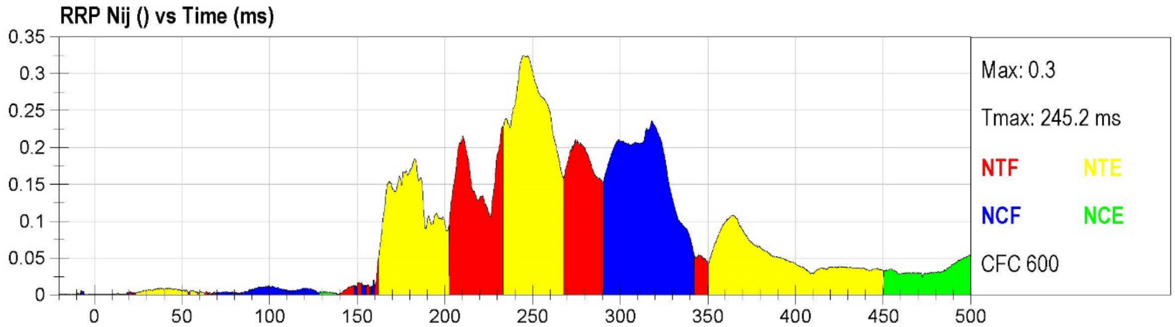

RRP T12 Resultant (g) vs Time (ms)
Max: 29.6 g
Tmax: 226.1 ms
Min: 0.0 g
Tmin: -17.8 ms
CFC 180


RRP MID SPINE X (g) vs Time (ms)
Max: 0.5 g
Tmax: 370.1 ms
Min: -19.7 g
Tmin: 225.5 ms
CFC 180


RRP MID SPINE Y (g) vs Time (ms)
Max: 5.8 g
Tmax: 193.2 ms
Min: -4.3 g
Tmin: 173.8 ms
CFC 180

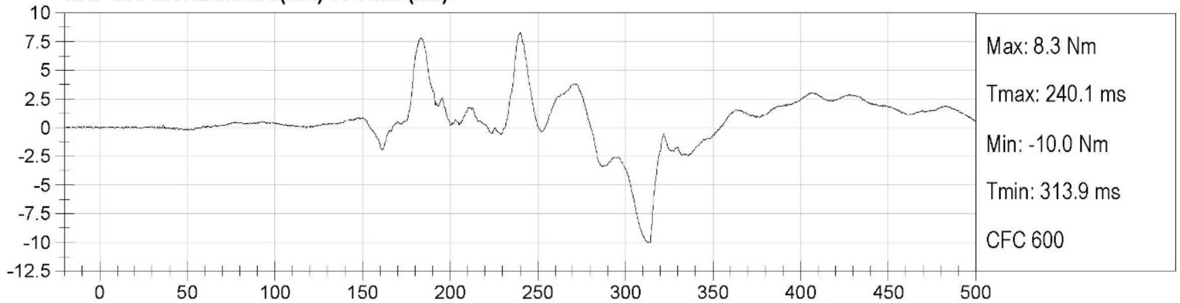

RRP MID SPINE Z (g) vs Time (ms)
Max: 8.9 g
Tmax: 251.5 ms
Min: -5.5 g
Tmin: 187.3 ms
CFC 180


RRP MID SPINE Resultant (g) vs Time (ms)
Max: 20.0 g
Tmax: 225.4 ms
Min: 0.0 g
Tmin: -3.5 ms
CFC 180

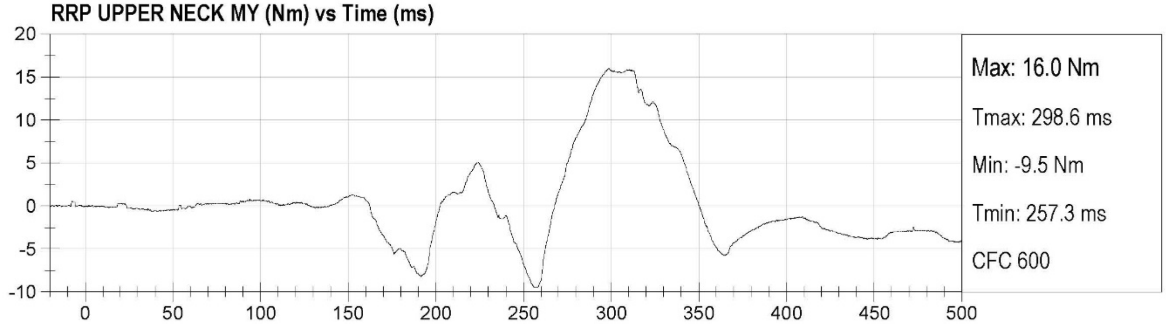


RRP Nij () vs Time (ms)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
50
100
150
200
250
300
350
400
450
500
Max: 0.3
Tmax: 245.2 ms
NTF
NTE
NCF
NCE
CFC 600

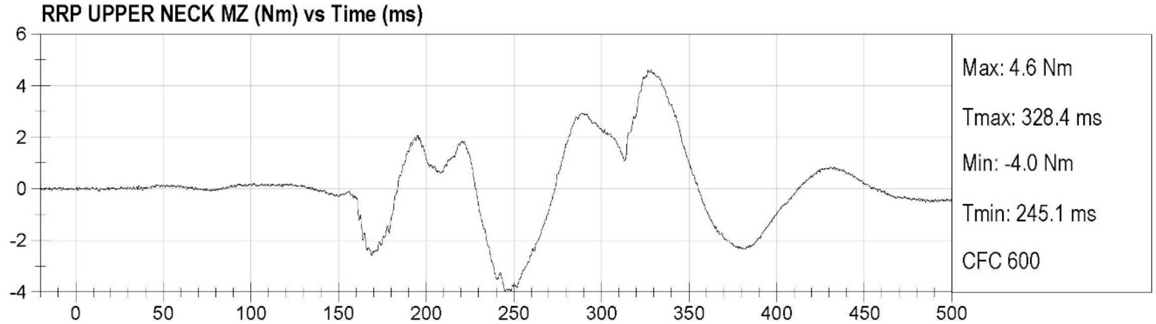
RRP UPPER NECK MX (Nm) vs Time (ms)



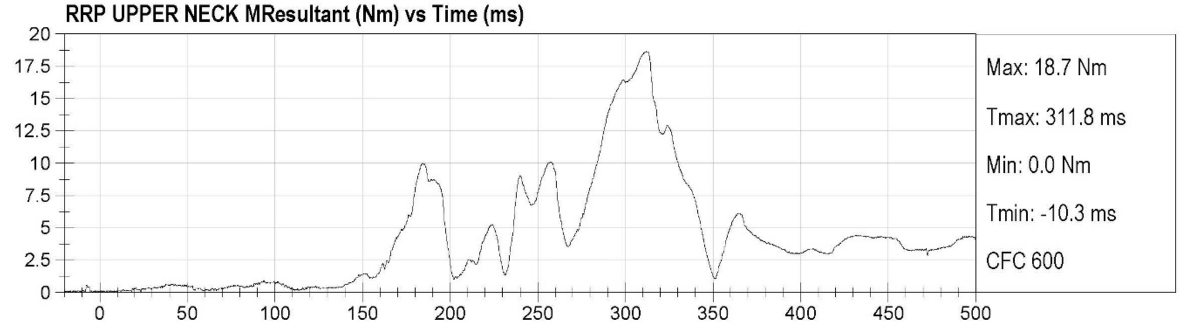

RRP UPPER NECK MY (Nm) vs Time (ms)

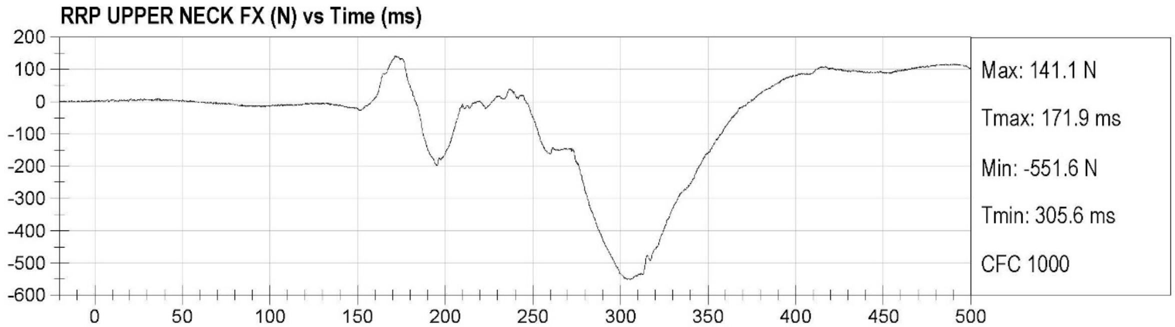


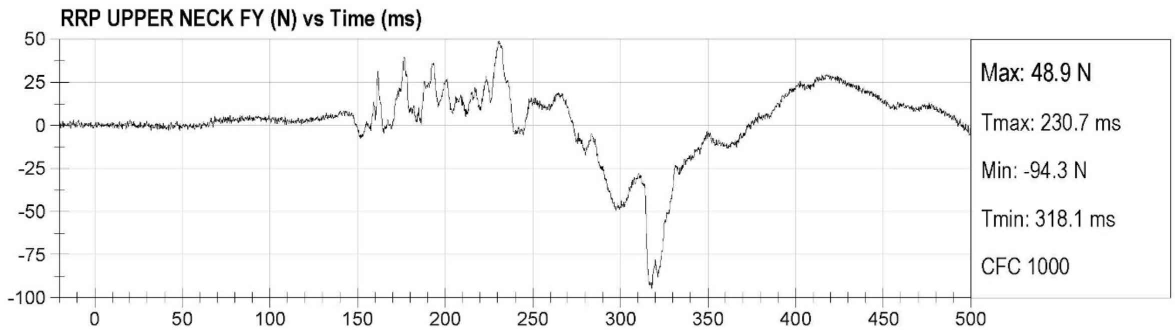

RRP UPPER NECK MZ (Nm) vs Time (ms)

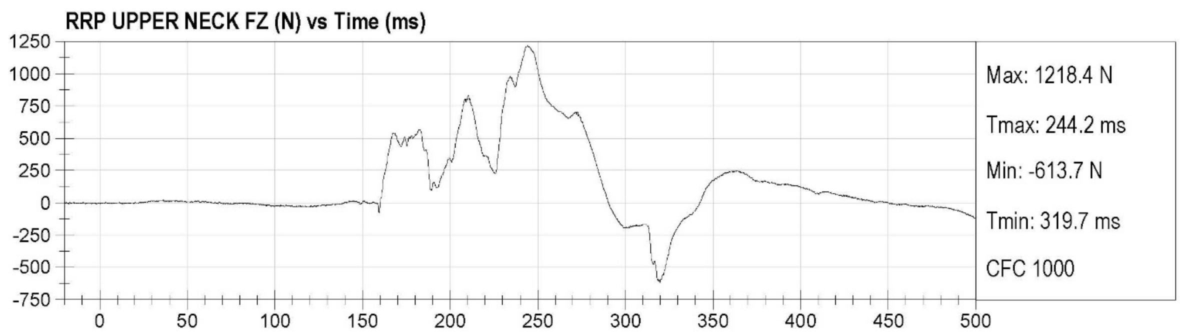


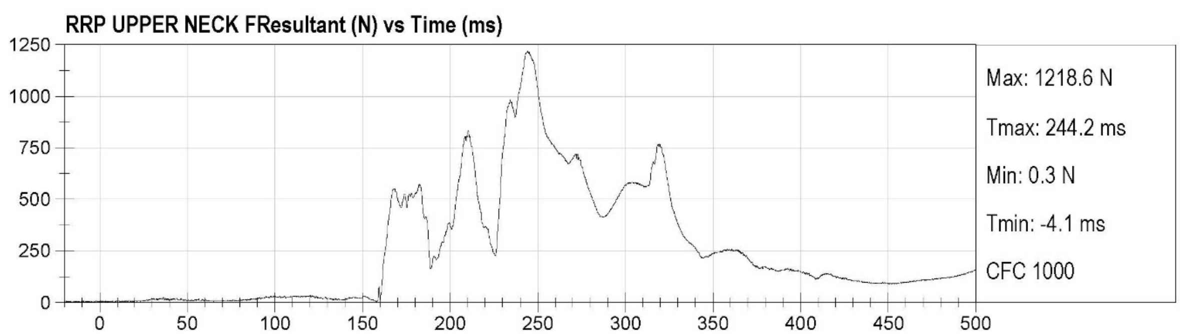

RRP UPPER NECK MResultant (Nm) vs Time (ms)

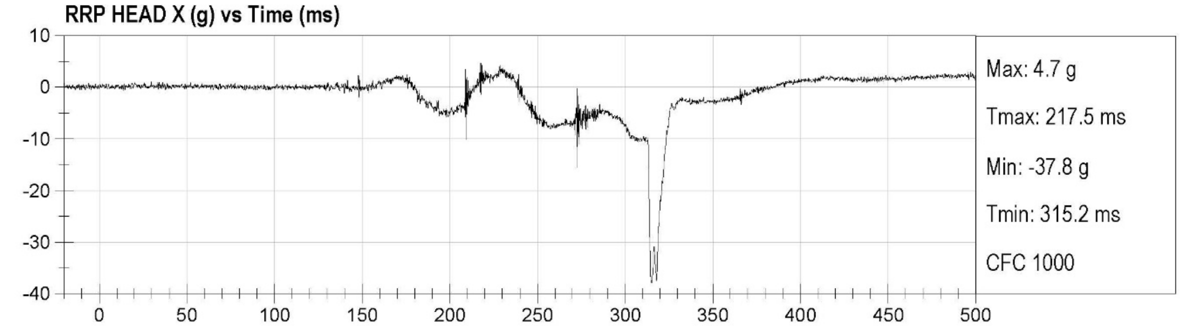


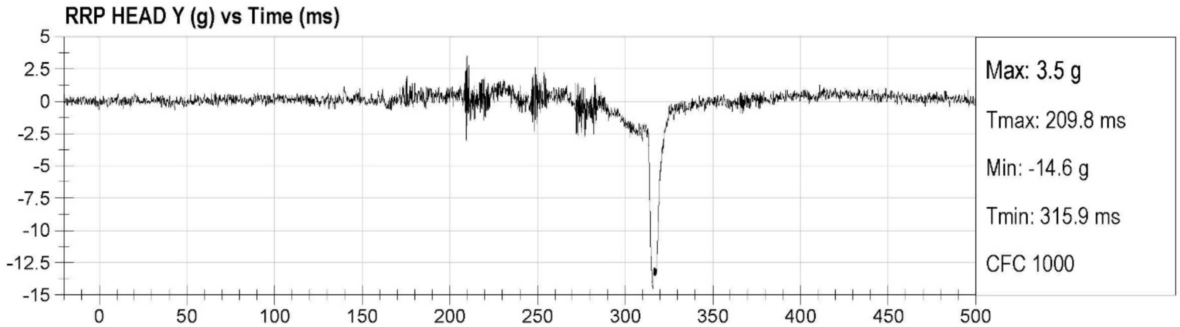

RRP UPPER NECK FX (N) vs Time (ms)
Max: 141.1 N
Tmax: 171.9 ms
Min: -551.6 N
Tmin: 305.6 ms
CFC 1000

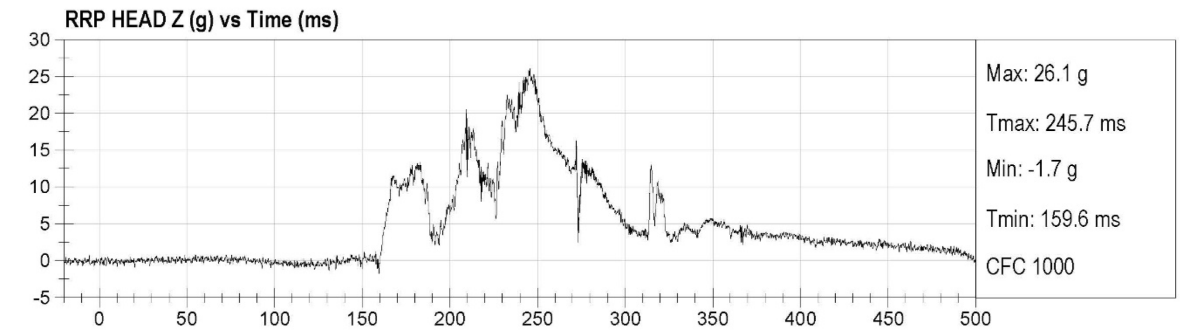

RRP UPPER NECK FY (N) vs Time (ms)
Max: 48.9 N
Tmax: 230.7 ms
Min: -94.3 N
Tmin: 318.1 ms
CFC 1000

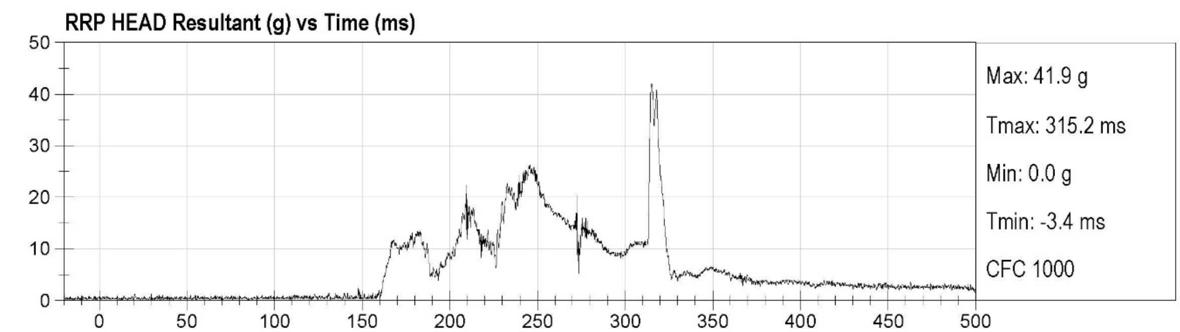

RRP UPPER NECK FZ (N) vs Time (ms)
Max: 1218.4 N
Tmax: 244.2 ms
Min: -613.7 N
Tmin: 319.7 ms
CFC 1000

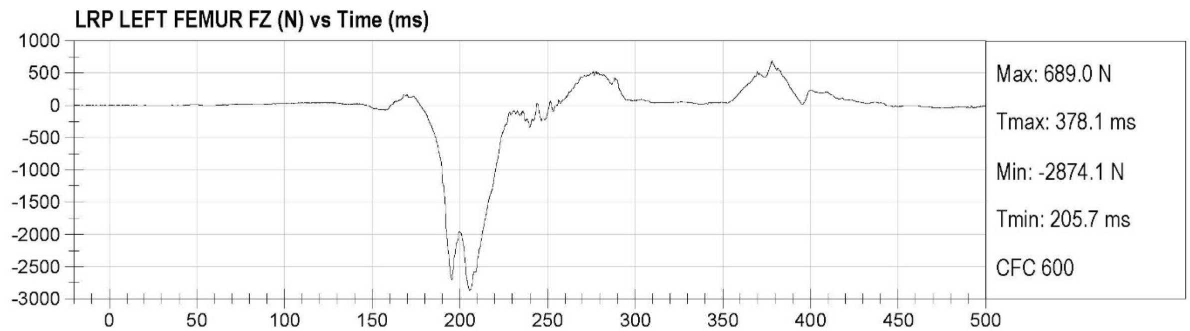

RRP UPPER NECK FResultant (N) vs Time (ms)
Max: 1218.6 N
Tmax: 244.2 ms
Min: 0.3 N
Tmin: -4.1 ms
CFC 1000

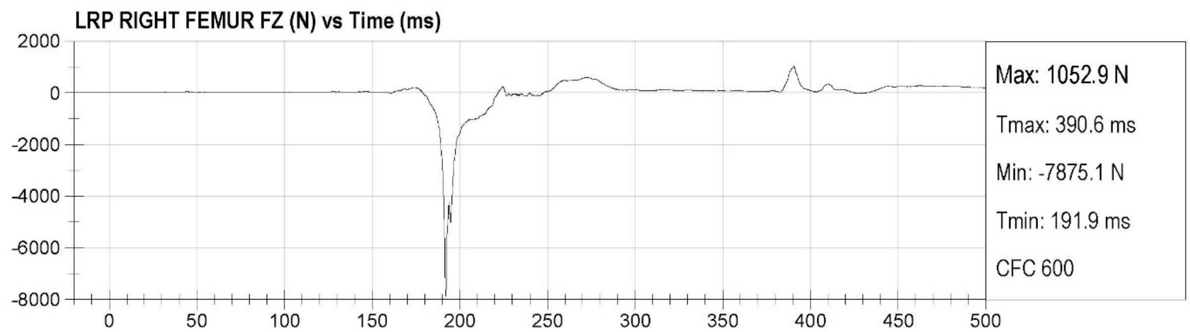

RRP HEAD X (g) vs Time (ms)
Max: 4.7 g
Tmax: 217.5 ms
Min: -37.8 g
Tmin: 315.2 ms
CFC 1000

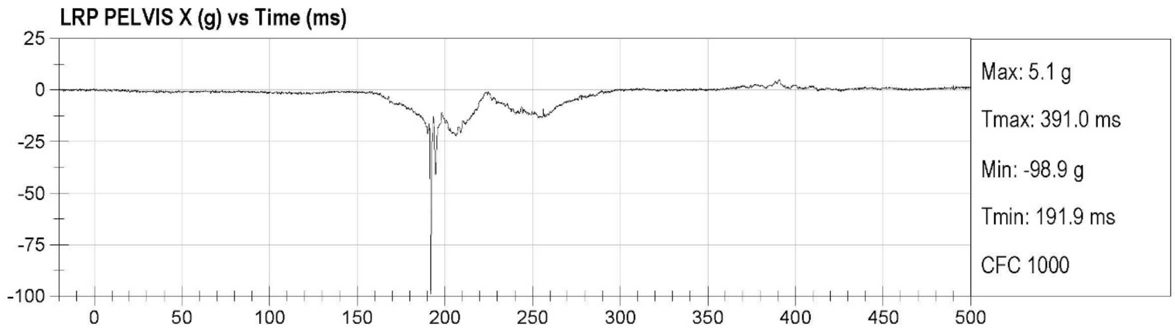

RRP HEAD Y (g) vs Time (ms)
Max: 3.5 g
Tmax: 209.8 ms
Min: -14.6 g
Tmin: 315.9 ms
CFC 1000

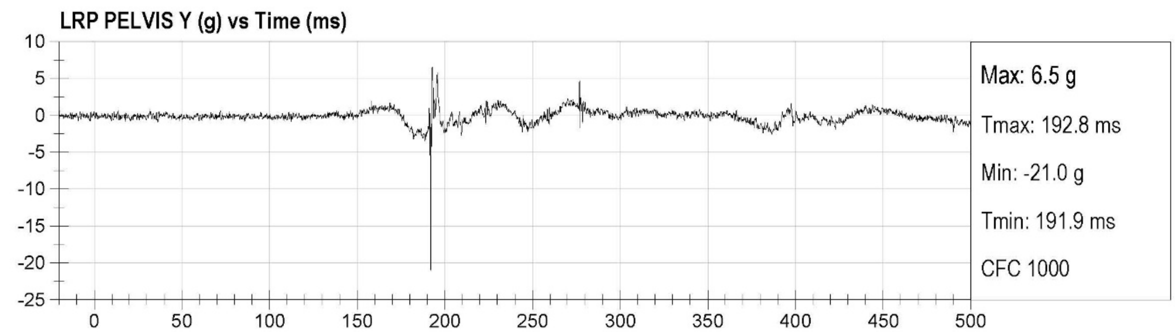

RRP HEAD Z (g) vs Time (ms)
Max: 26.1 g
Tmax: 245.7 ms
Min: -1.7 g
Tmin: 159.6 ms
CFC 1000

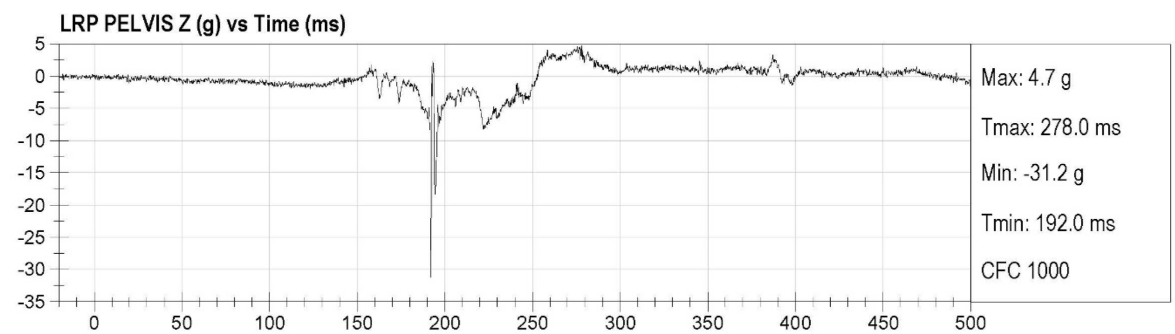

RRP HEAD Resultant (g) vs Time (ms)
Max: 41.9 g
Tmax: 315.2 ms
Min: 0.0 g
Tmin: -3.4 ms
CFC 1000

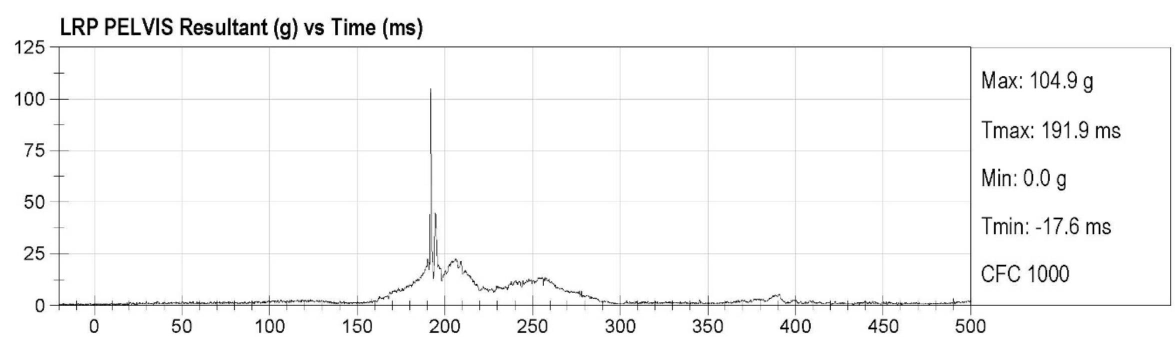

LRP LEFT FEMUR FZ (N) vs Time (ms)
Max: 689.0 N
Tmax: 378.1 ms
Min: -2874.1 N
Tmin: 205.7 ms
CFC 600

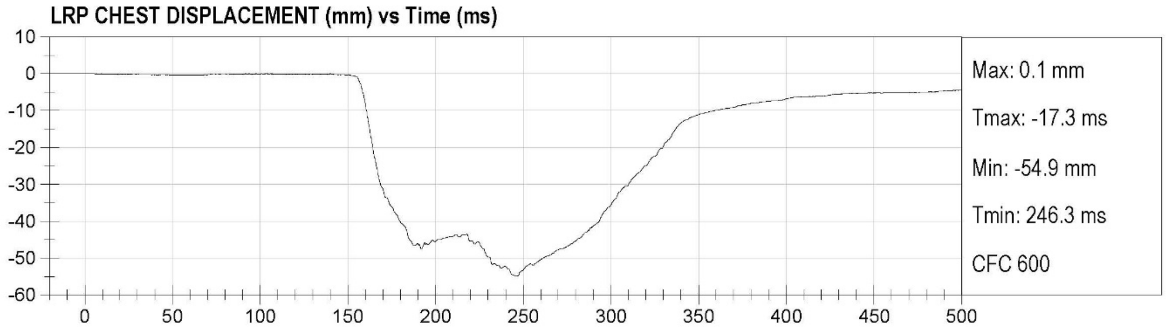

LRP RIGHT FEMUR FZ (N) vs Time (ms)
Max: 1052.9 N
Tmax: 390.6 ms
Min: -7875.1 N
Tmin: 191.9 ms
CFC 600


LRP PELVIS X (g) vs Time (ms)
Max: 5.1 g
Tmax: 391.0 ms
Min: -98.9 g
Tmin: 191.9 ms
CFC 1000

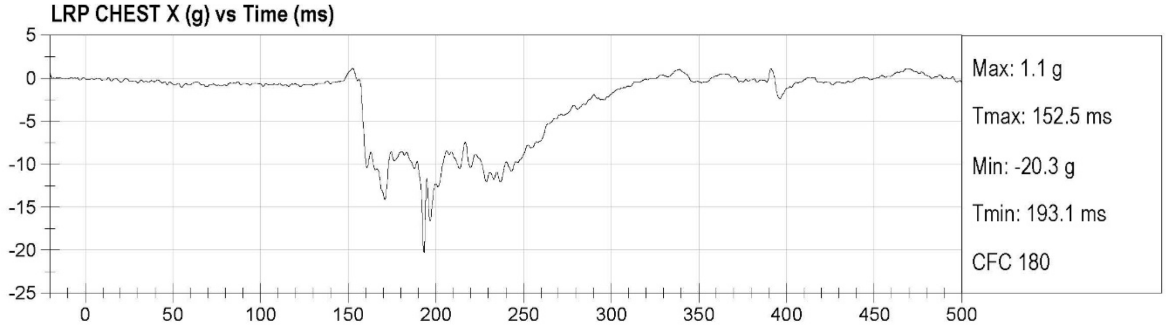

LRP PELVIS Y (g) vs Time (ms)
Max: 6.5 g
Tmax: 192.8 ms
Min: -21.0 g
Tmin: 191.9 ms
CFC 1000

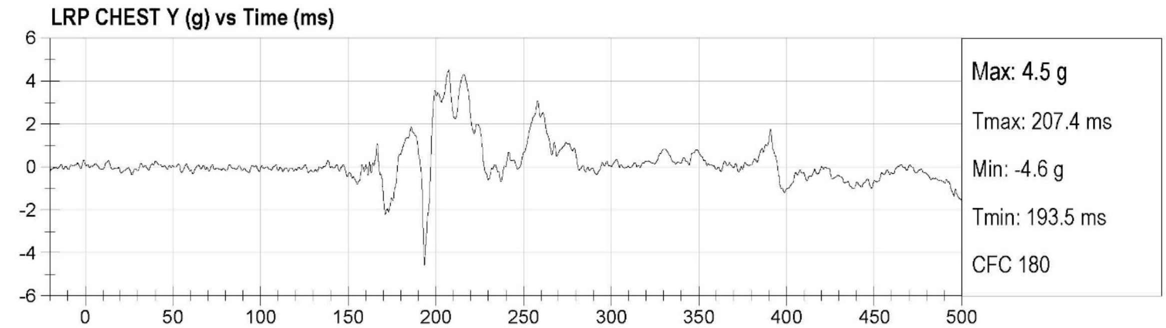

LRP PELVIS Z (g) vs Time (ms)
Max: 4.7 g
Tmax: 278.0 ms
Min: -31.2 g
Tmin: 192.0 ms
CFC 1000

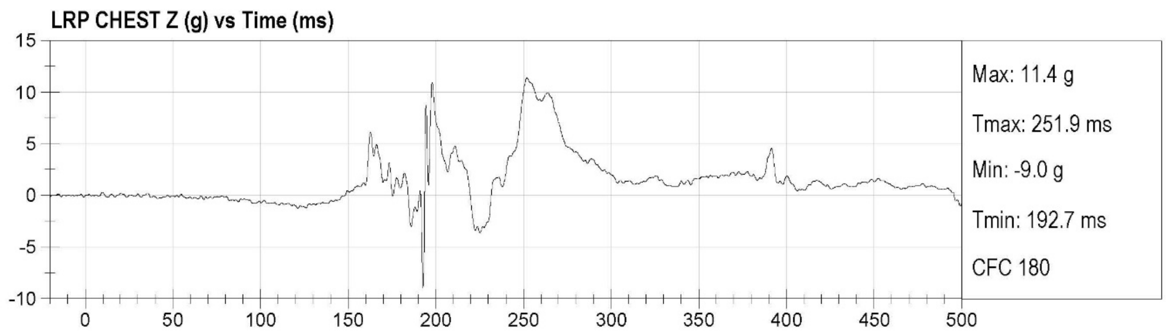

LRP PELVIS Resultant (g) vs Time (ms)
Max: 104.9 g
Tmax: 191.9 ms
Min: 0.0 g
Tmin: -17.6 ms
CFC 1000

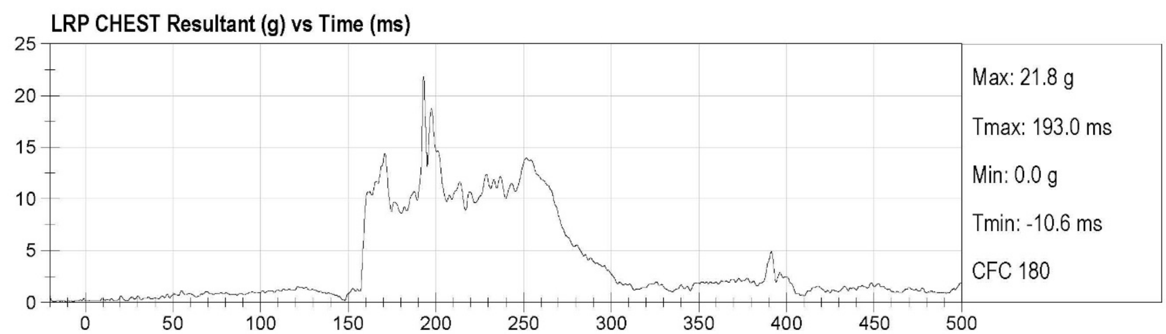


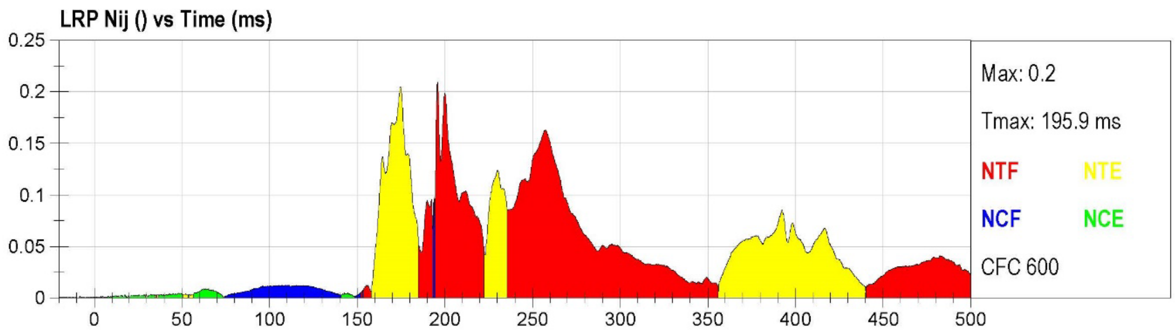
LRP CHEST DISPLACEMENT (mm) vs Time (ms)
10
0
-10
-20
-30
-40
-50
-60
0
50
100
150
200
250
300
350
400
450
500
Max: 0.1 mm
Tmax: -17.3 ms
Min: -54.9 mm
Tmin: 246.3 ms
CFC 600

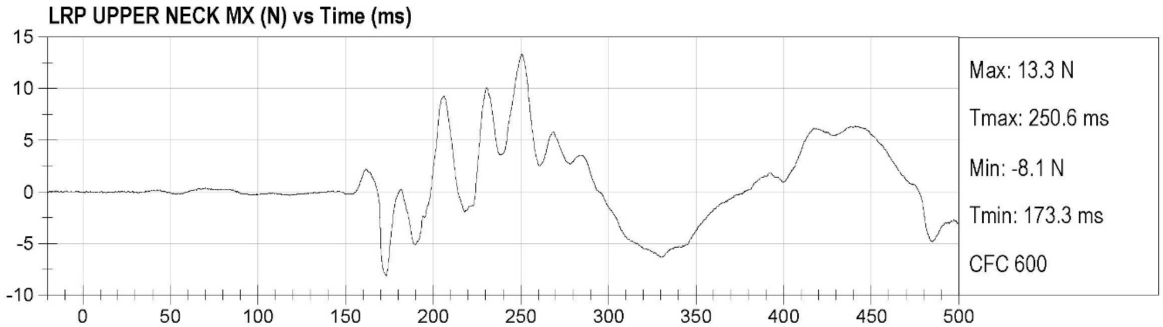

LRP CHEST X (g) vs Time (ms)
Max: 1.1 g
Tmax: 152.5 ms
Min: -20.3 g
Tmin: 193.1 ms
CFC 180

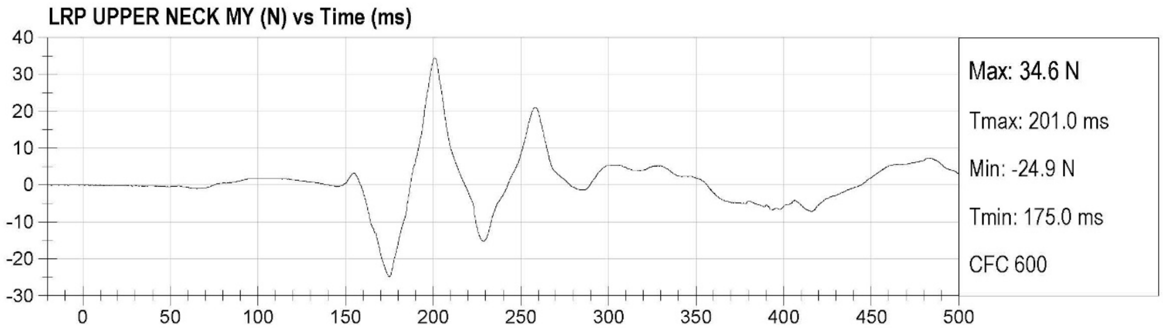

LRP CHEST Y (g) vs Time (ms)
Max: 4.5 g
Tmax: 207.4 ms
Min: -4.6 g
Tmin: 193.5 ms
CFC 180

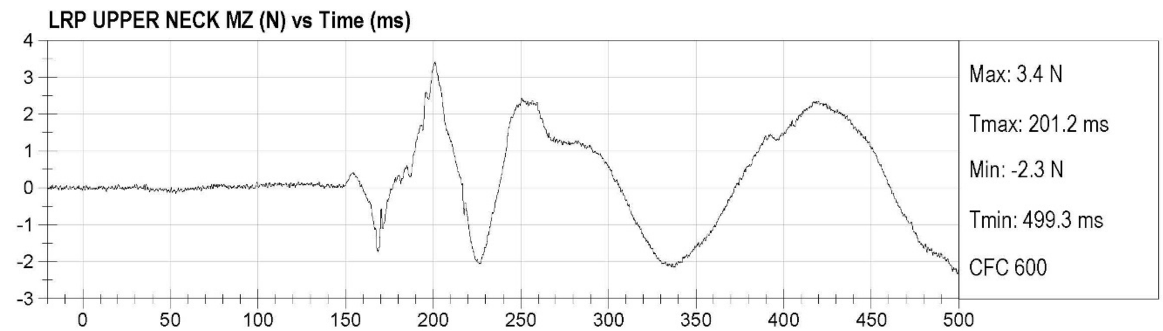

LRP CHEST Z (g) vs Time (ms)
Max: 11.4 g
Tmax: 251.9 ms
Min: -9.0 g
Tmin: 192.7 ms
CFC 180

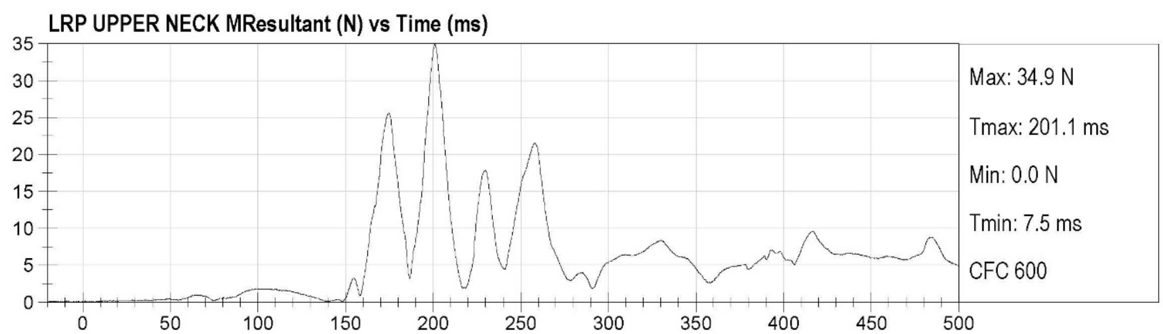

LRP CHEST Resultant (g) vs Time (ms)
Max: 21.8 g
Tmax: 193.0 ms
Min: 0.0 g
Tmin: -10.6 ms
CFC 180


LRP Nij () vs Time (ms)
0.25
0.2
0.15
0.1
0.05
0
0
50
100
150
200
250
300
350
400
450
500
Max: 0.2
Tmax: 195.9 ms
NTF
NTE
NCF
NCE
CFC 600

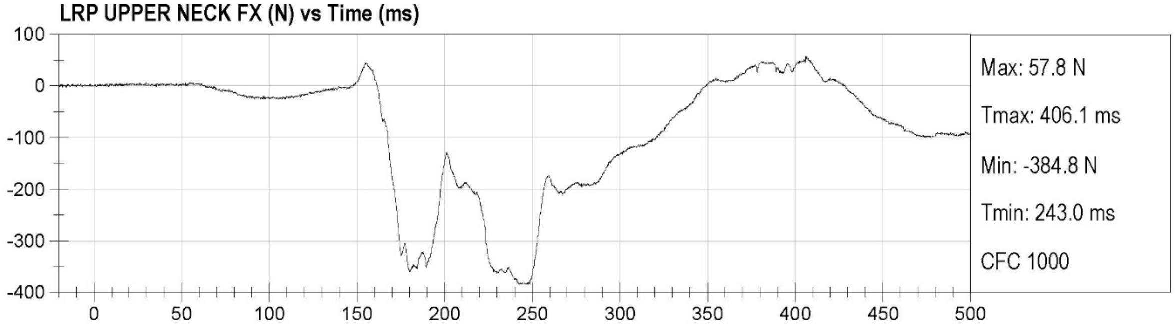

LRP UPPER NECK MX (N) vs Time (ms)
Max: 13.3 N
Tmax: 250.6 ms
Min: -8.1 N
Tmin: 173.3 ms
CFC 600


LRP UPPER NECK MY (N) vs Time (ms)
Max: 34.6 N
Tmax: 201.0 ms
Min: -24.9 N
Tmin: 175.0 ms
CFC 600

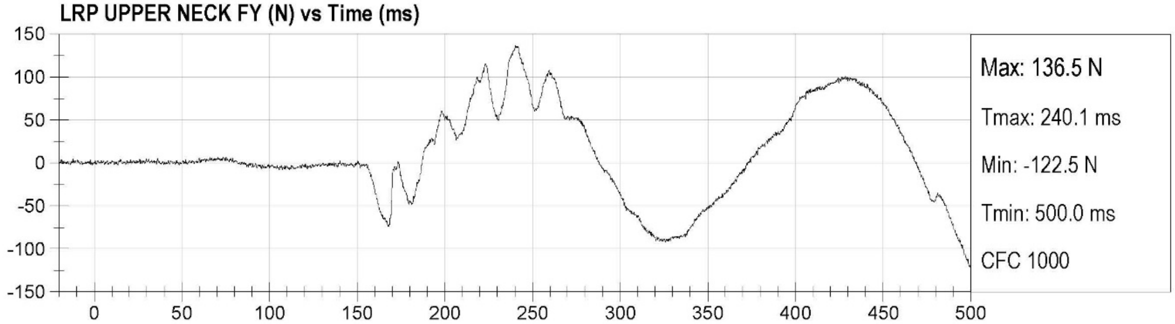

LRP UPPER NECK MZ (N) vs Time (ms)
Max: 3.4 N
Tmax: 201.2 ms
Min: -2.3 N
Tmin: 499.3 ms
CFC 600


LRP UPPER NECK MResultant (N) vs Time (ms)
Max: 34.9 N
Tmax: 201.1 ms
Min: 0.0 N
Tmin: 7.5 ms
CFC 600

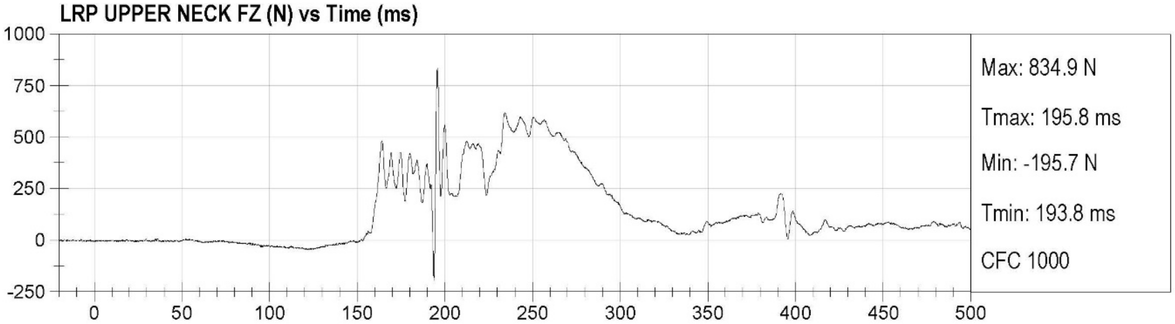
LRP UPPER NECK FX (N) vs Time (ms)



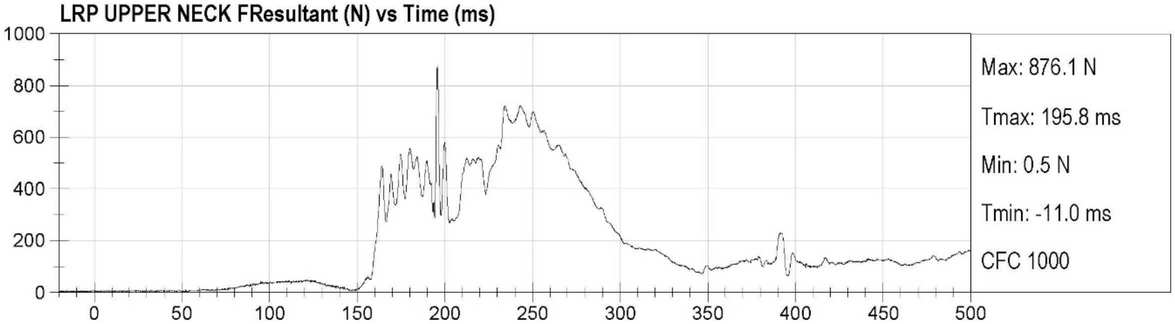

LRP UPPER NECK FY (N) vs Time (ms)



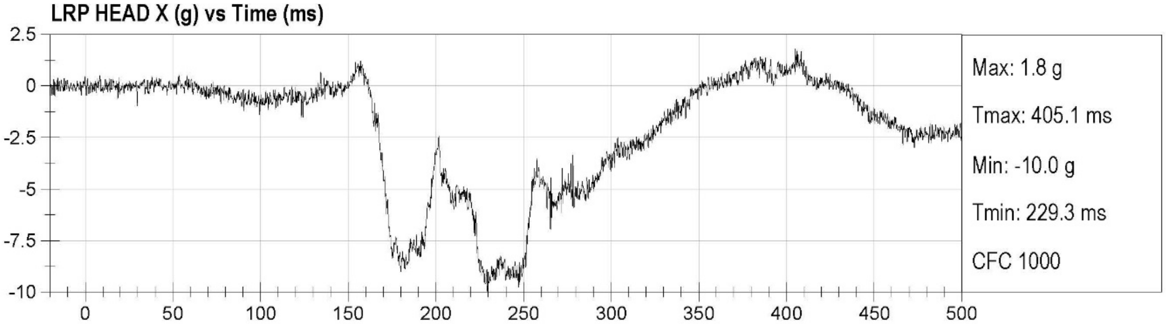

LRP UPPER NECK FZ (N) vs Time (ms)



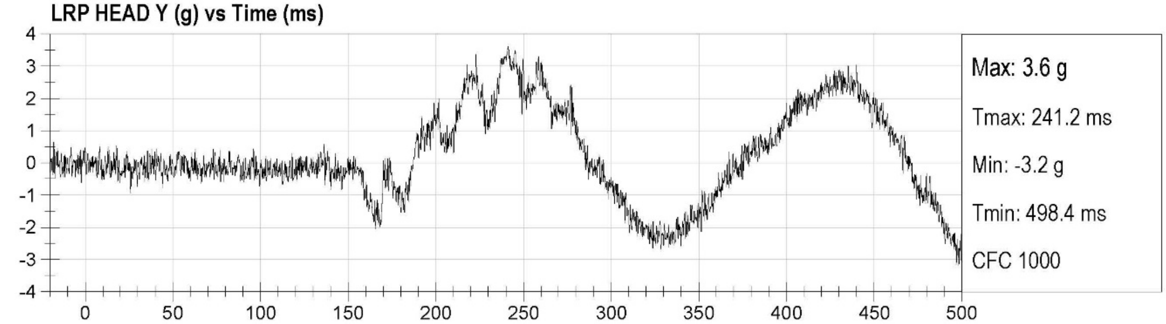

LRP UPPER NECK FResultant (N) vs Time (ms)



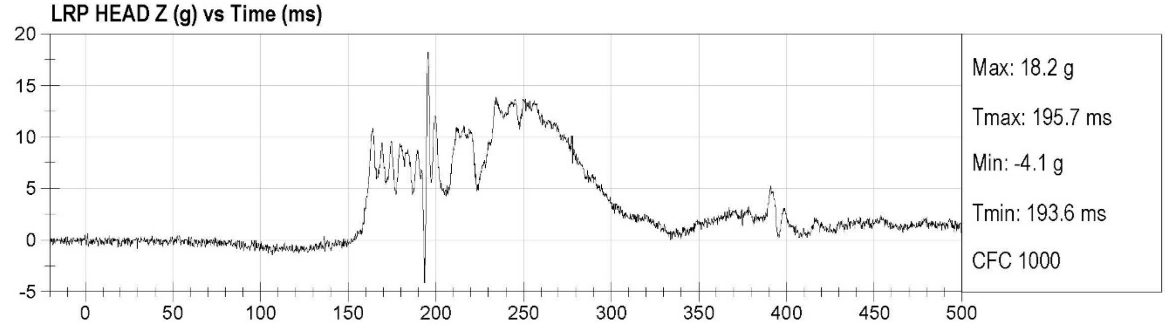
LRP HEAD X (g) vs Time (ms)



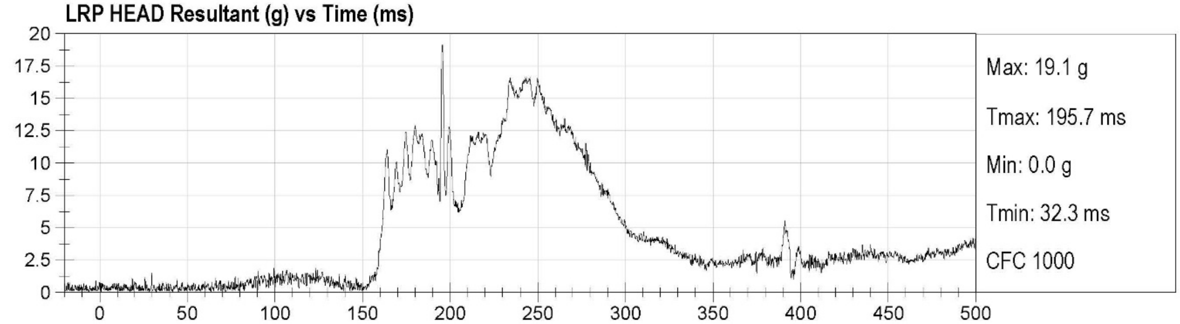

LRP HEAD Y (g) vs Time (ms)




LRP HEAD Z (g) vs Time (ms)



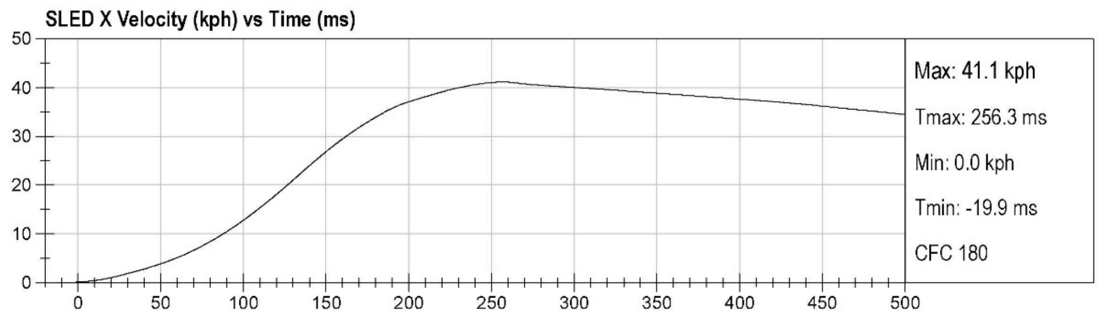

LRP HEAD Resultant (g) vs Time (ms)

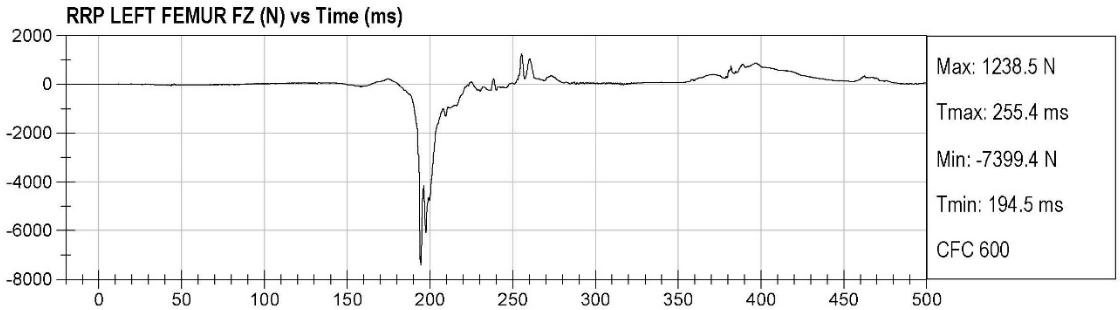


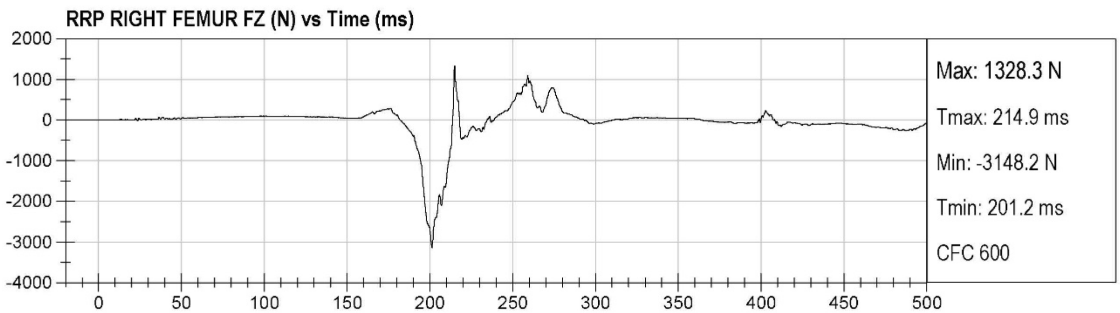
## A.6: Test 2BD Data

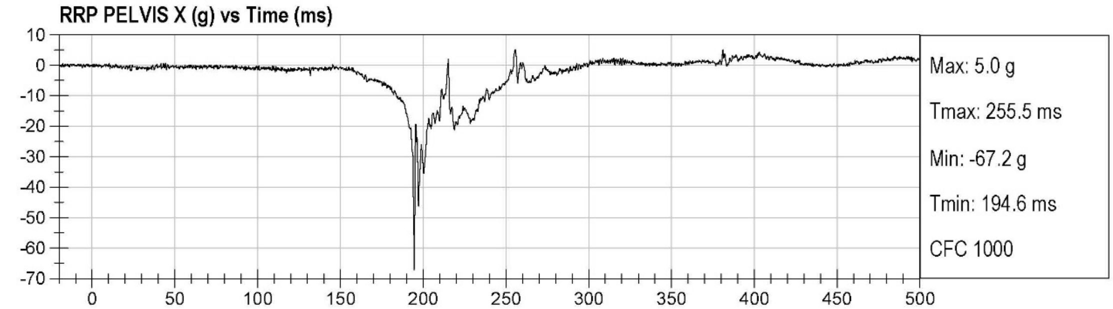
Test Date: 05/07/2021

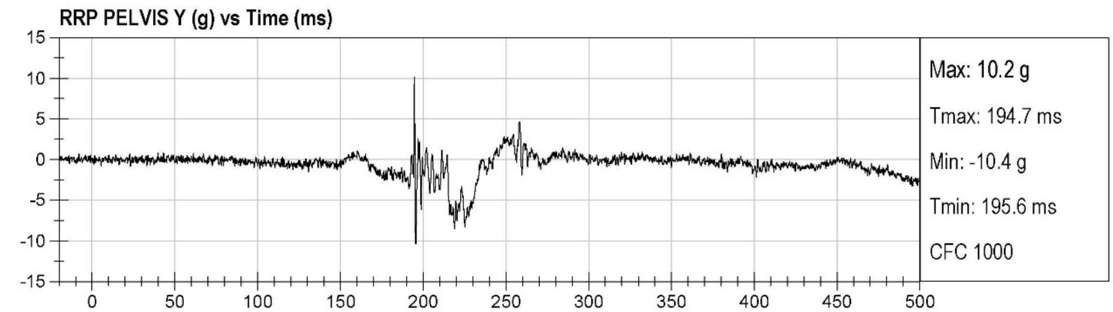
MGA Test ID: S21140

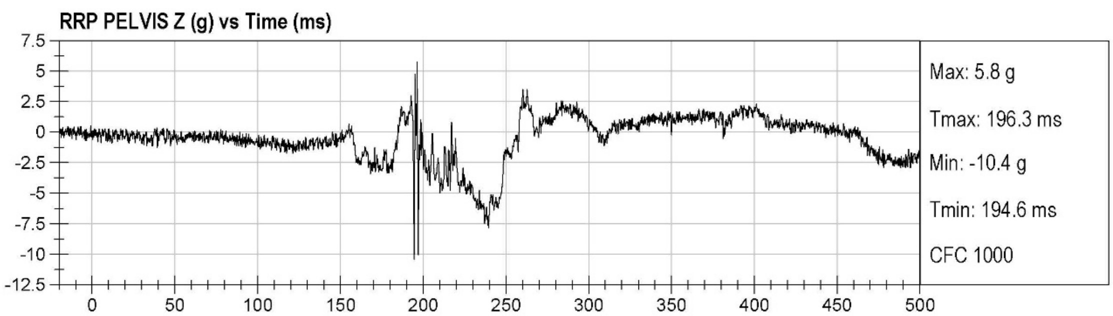



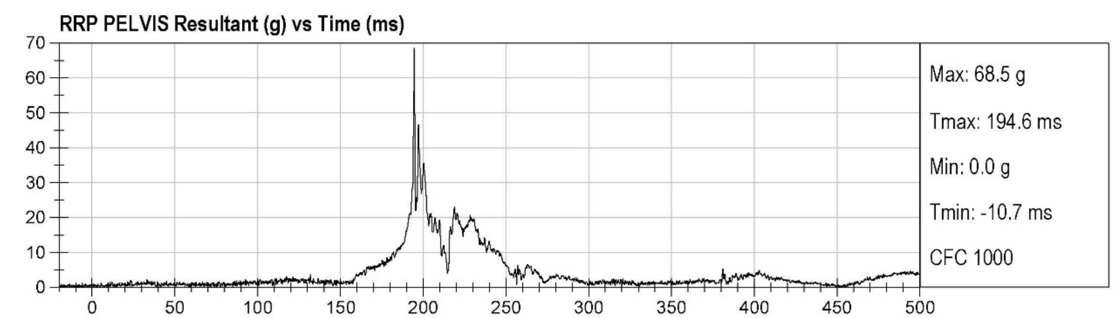

RRP LEFT FEMUR FZ (N) vs Time (ms)
Max: 1238.5 N
Tmax: 255.4 ms
Min: -7399.4 N
Tmin: 194.5 ms
CFC 600
2000
0
-2000
-4000
-6000
-8000
0
50
100
150
200
250
300
350
400
450
500

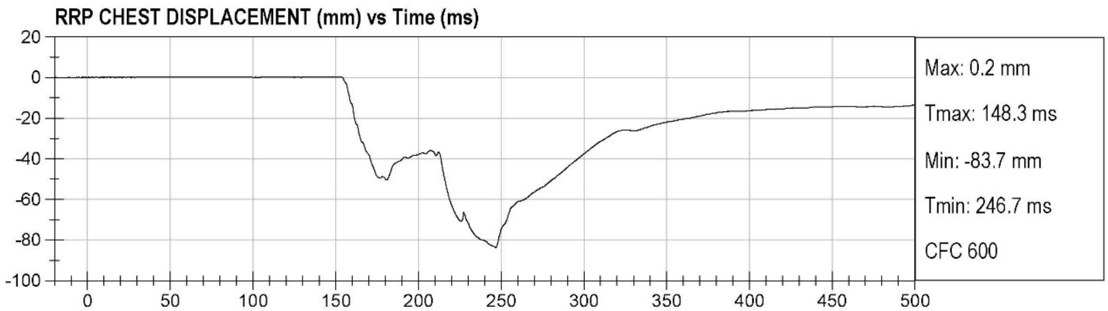

RRP RIGHT FEMUR FZ (N) vs Time (ms)
Max: 1328.3 N
Tmax: 214.9 ms
Min: -3148.2 N
Tmin: 201.2 ms
CFC 600
2000
1000
0
-1000
-2000
-3000
-4000
0
50
100
150
200
250
300
350
400
450
500

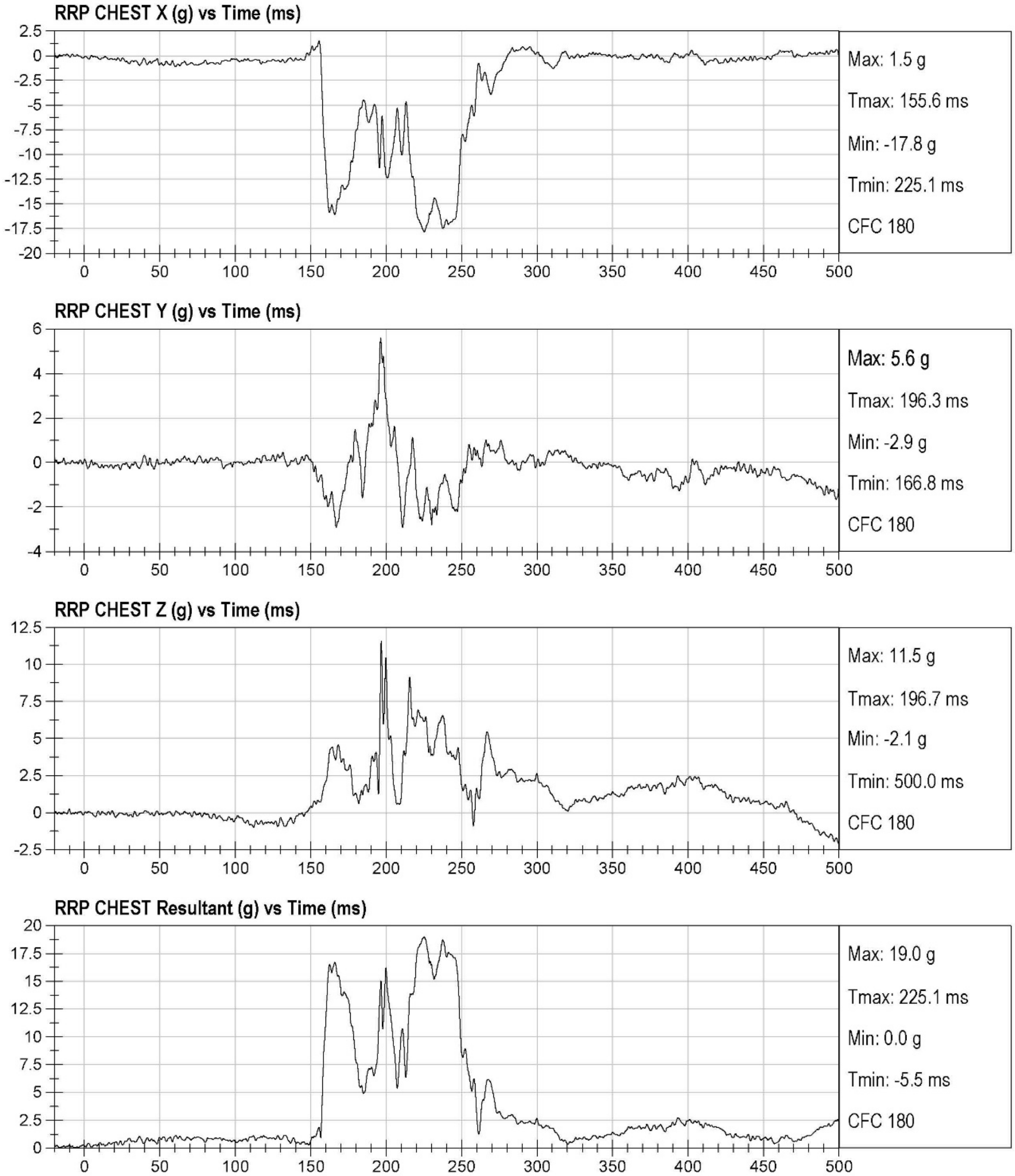

RRP PELVIS X (g) vs Time (ms)
Max: 5.0 g
Tmax: 255.5 ms
Min: -67.2 g
Tmin: 194.6 ms
CFC 1000

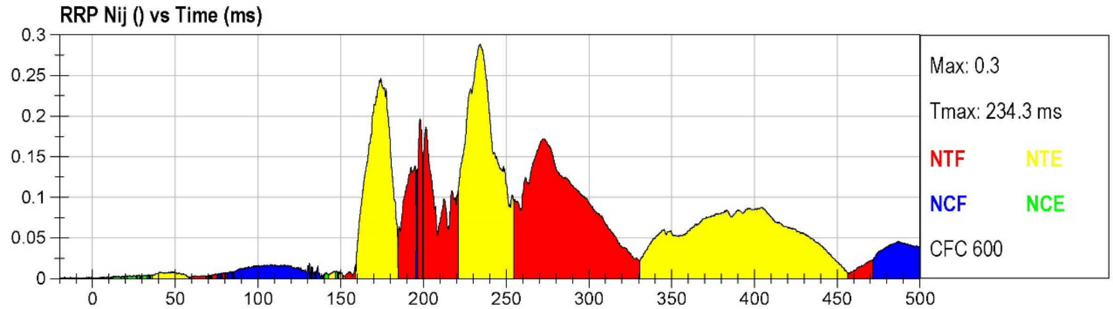

RRP PELVIS Y (g) vs Time (ms)
Max: 10.2 g
Tmax: 194.7 ms
Min: -10.4 g
Tmin: 195.6 ms
CFC 1000


RRP PELVIS Z (g) vs Time (ms)
Max: 5.8 g
Tmax: 196.3 ms
Min: -10.4 g
Tmin: 194.6 ms
CFC 1000

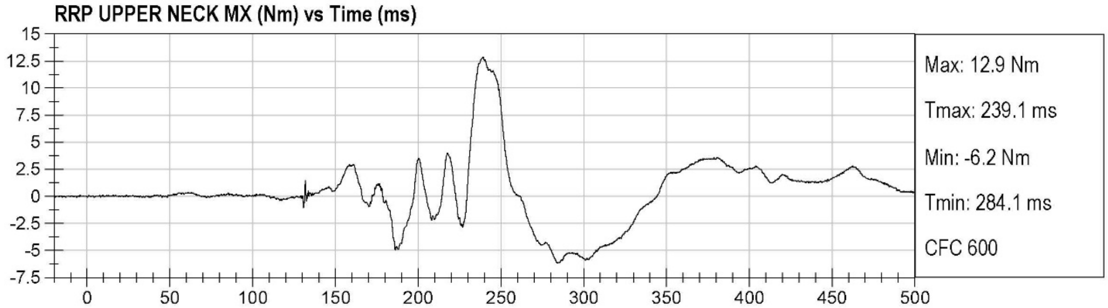

RRP PELVIS Resultant (g) vs Time (ms)
Max: 68.5 g
Tmax: 194.6 ms
Min: 0.0 g
Tmin: -10.7 ms
CFC 1000

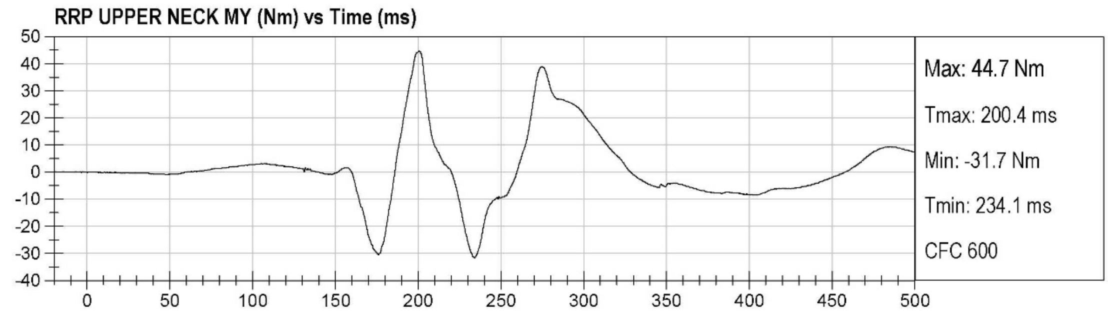

RRP CHEST DISPLACEMENT (mm) vs Time (ms)
20
0
-20
-40
-60
-80
-100
0
50
100
150
200
250
300
350
400
450
500
Max: 0.2 mm
Tmax: 148.3 ms
Min: -83.7 mm
Tmin: 246.7 ms
CFC 600

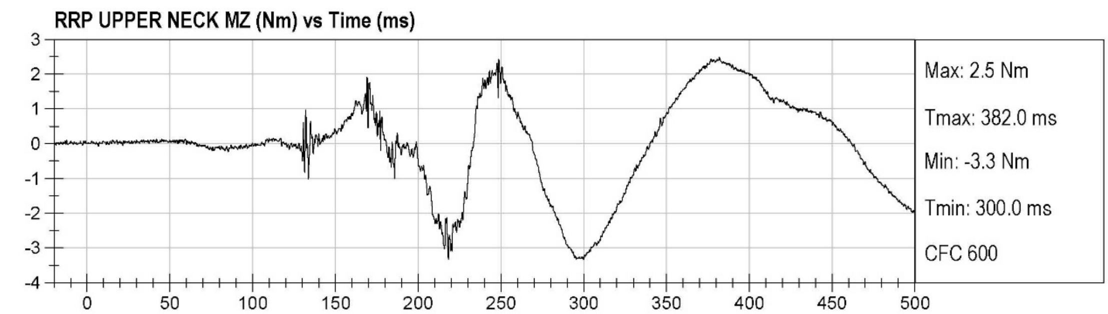

RRP CHEST X (g) vs Time (ms)
Max: 1.5 g
Tmax: 155.6 ms
Min: -17.8 g
Tmin: 225.1 ms
CFC 180
RRP CHEST Y (g) vs Time (ms)
Max: 5.6 g
Tmax: 196.3 ms
Min: -2.9 g
Tmin: 166.8 ms
CFC 180
RRP CHEST Z (g) vs Time (ms)
Max: 11.5 g
Tmax: 196.7 ms
Min: -2.1 g
Tmin: 500.0 ms
CFC 180
RRP CHEST Resultant (g) vs Time (ms)
Max: 19.0 g
Tmax: 225.1 ms
Min: 0.0 g
Tmin: -5.5 ms
CFC 180

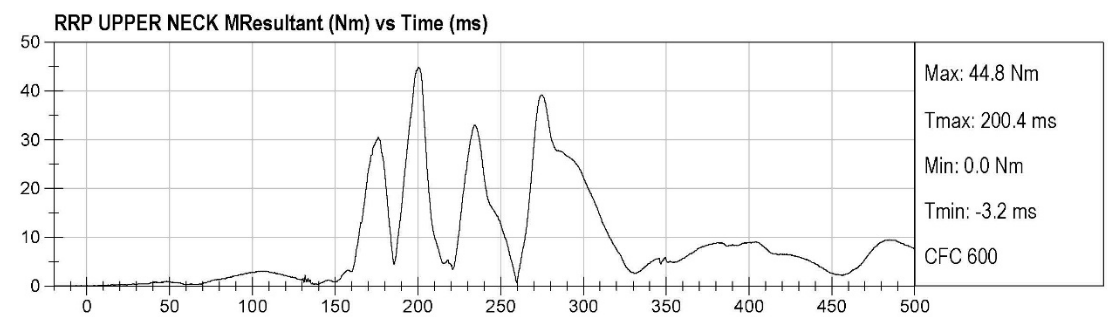


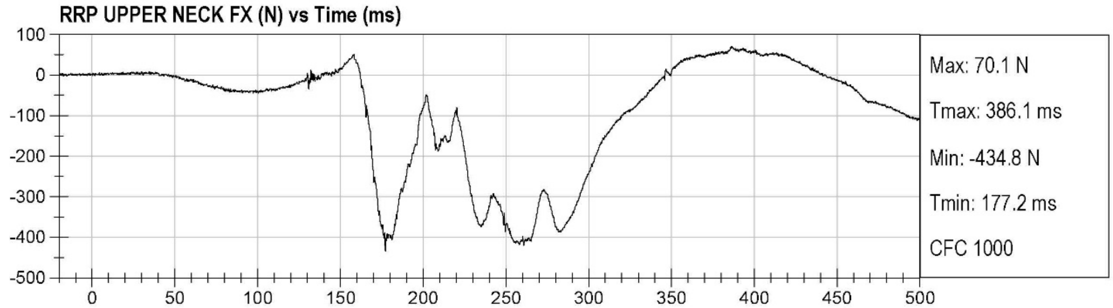
RRP Nij () vs Time (ms)
Max: 0.3
Tmax: 234.3 ms
NTF
NTE
NCF
NCE
CFC 600

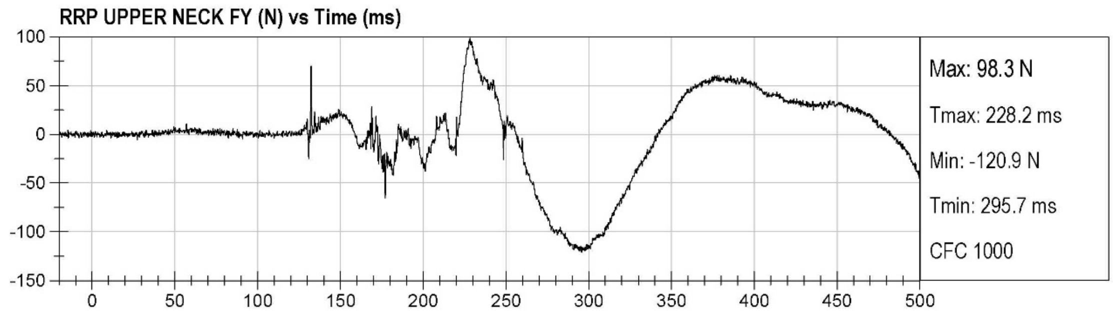

RRP UPPER NECK MX (Nm) vs Time (ms)
Max: 12.9 Nm
Tmax: 239.1 ms
Min: -6.2 Nm
Tmin: 284.1 ms
CFC 600
15
12.5
10
7.5
5
2.5
0
-2.5
-5
-7.5
0 50 100 150 200 250 300 350 400 450 500

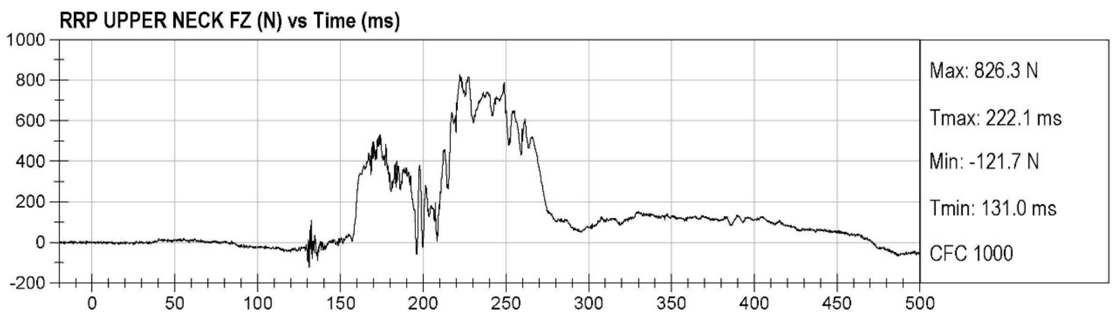

RRP UPPER NECK MY (Nm) vs Time (ms)
Max: 44.7 Nm
Tmax: 200.4 ms
Min: -31.7 Nm
Tmin: 234.1 ms
CFC 600
50
40
30
20
10
0
-10
-20
-30
-40
0 50 100 150 200 250 300 350 400 450 500

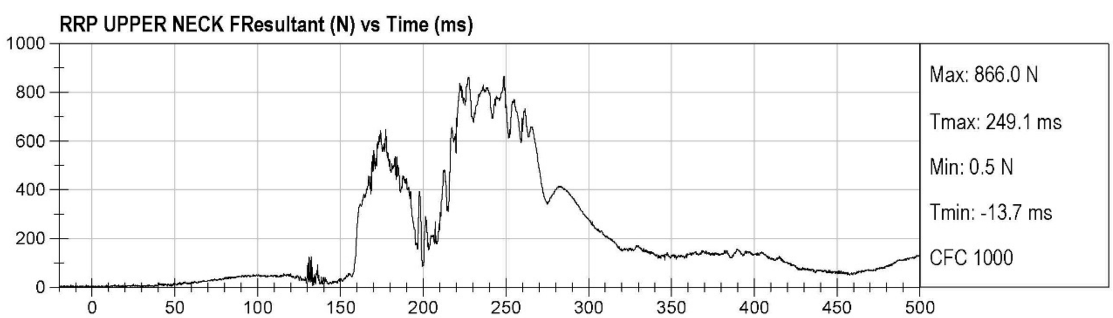

RRP UPPER NECK MZ (Nm) vs Time (ms)
Max: 2.5 Nm
Tmax: 382.0 ms
Min: -3.3 Nm
Tmin: 300.0 ms
CFC 600
3
2
1
0
-1
-2
-3
-4
0 50 100 150 200 250 300 350 400 450 500

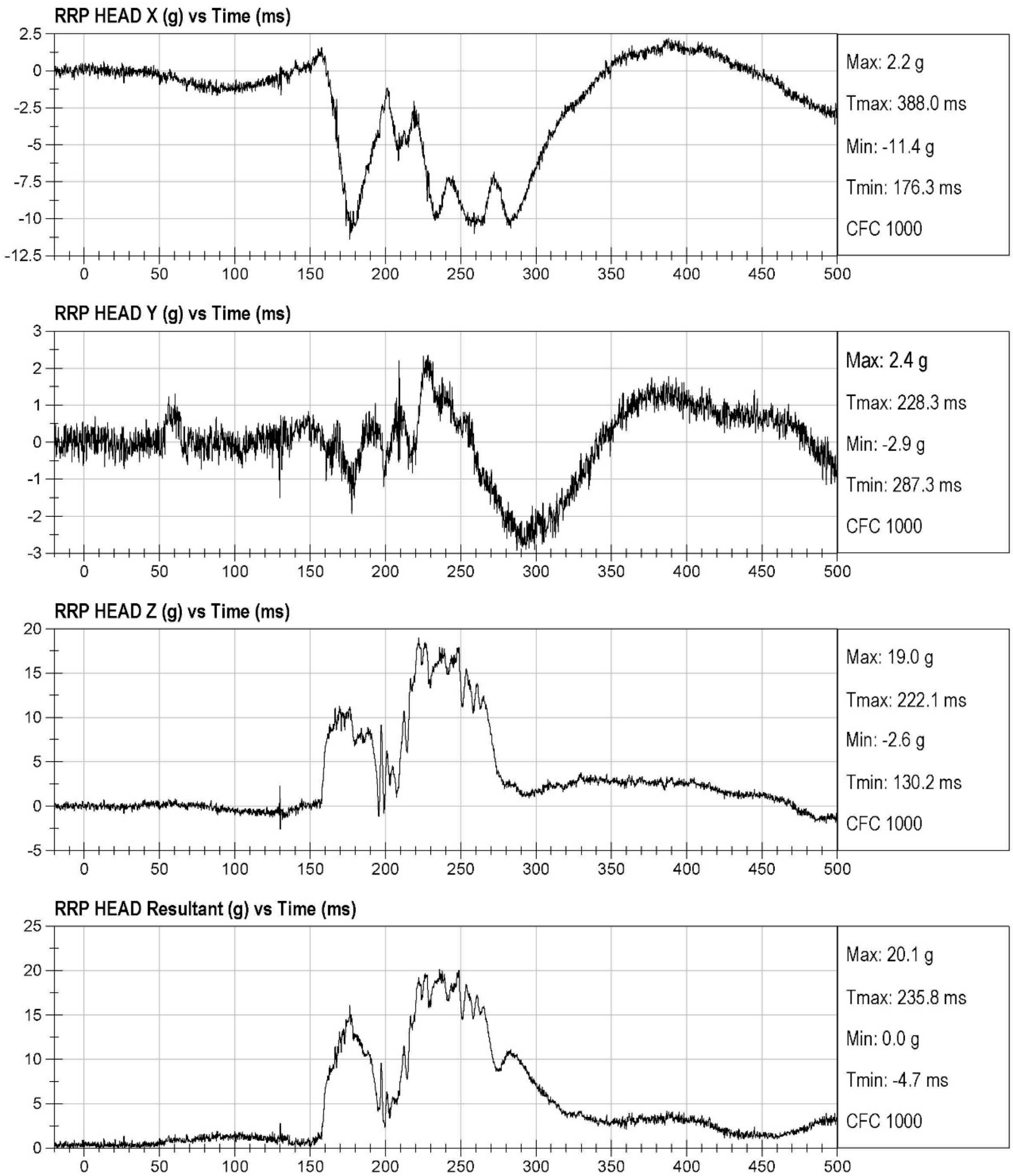

RRP UPPER NECK MResultant (Nm) vs Time (ms)
Max: 44.8 Nm
Tmax: 200.4 ms
Min: 0.0 Nm
Tmin: -3.2 ms
CFC 600
50
40
30
20
10
0
0 50 100 150 200 250 300 350 400 450 500

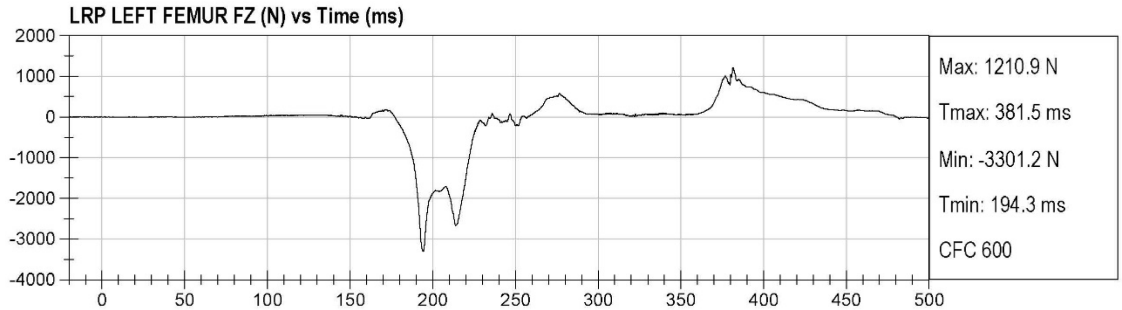

RRP UPPER NECK FX (N) vs Time (ms)
Max: 70.1 N
Tmax: 386.1 ms
Min: -434.8 N
Tmin: 177.2 ms
CFC 1000

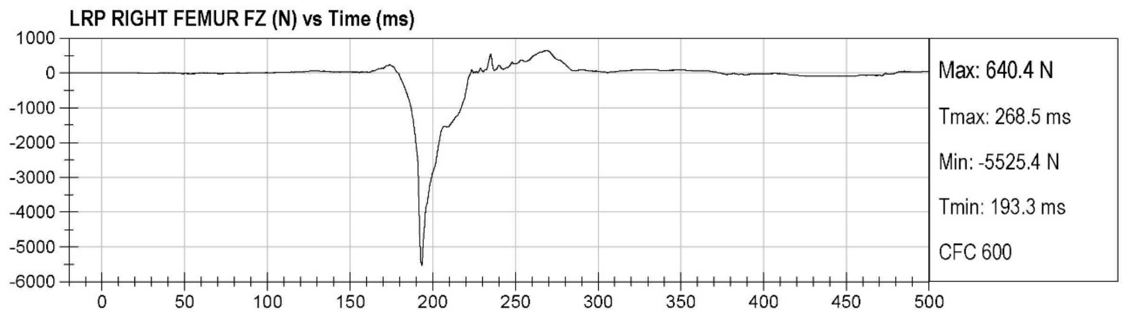

RRP UPPER NECK FY (N) vs Time (ms)
Max: 98.3 N
Tmax: 228.2 ms
Min: -120.9 N
Tmin: 295.7 ms
CFC 1000

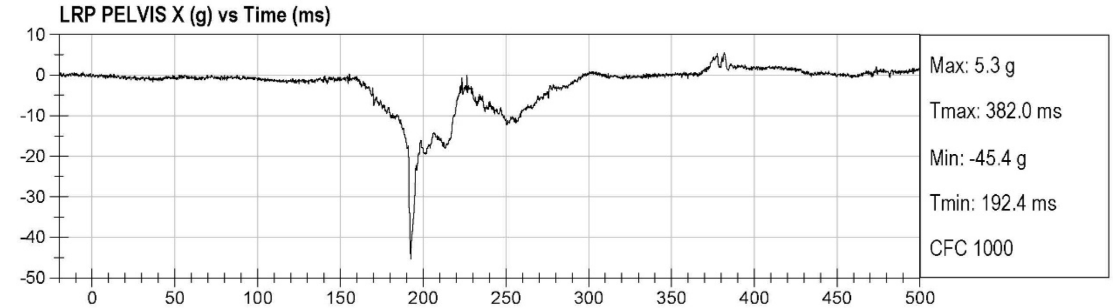

RRP UPPER NECK FZ (N) vs Time (ms)
Max: 826.3 N
Tmax: 222.1 ms
Min: -121.7 N
Tmin: 131.0 ms
CFC 1000

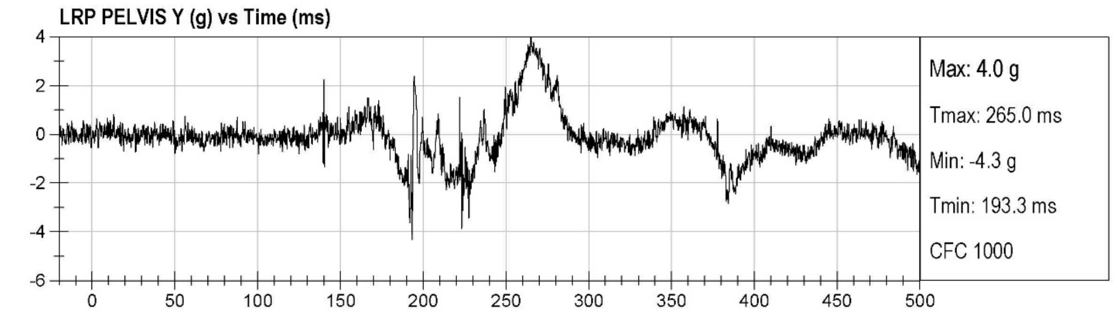

RRP UPPER NECK FResultant (N) vs Time (ms)
Max: 866.0 N
Tmax: 249.1 ms
Min: 0.5 N
Tmin: -13.7 ms
CFC 1000

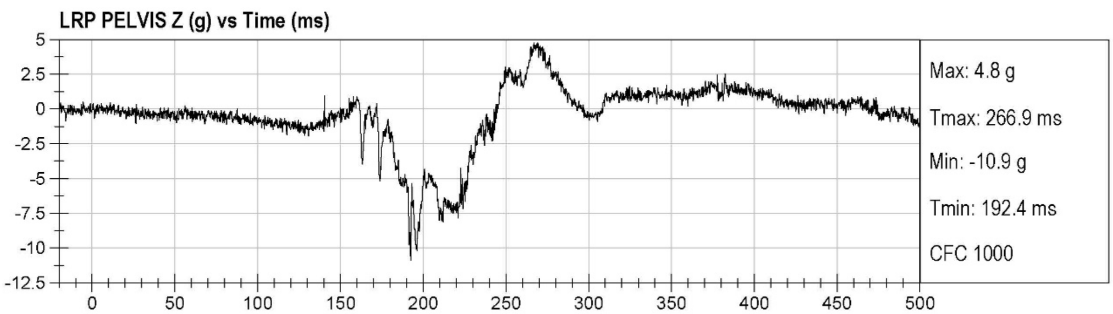

RRP HEAD X (g) vs Time (ms)
Max: 2.2 g
Tmax: 388.0 ms
Min: -11.4 g
Tmin: 176.3 ms
CFC 1000
RRP HEAD Y (g) vs Time (ms)
Max: 2.4 g
Tmax: 228.3 ms
Min: -2.9 g
Tmin: 287.3 ms
CFC 1000
RRP HEAD Z (g) vs Time (ms)
Max: 19.0 g
Tmax: 222.1 ms
Min: -2.6 g
Tmin: 130.2 ms
CFC 1000
RRP HEAD Resultant (g) vs Time (ms)
Max: 20.1 g
Tmax: 235.8 ms
Min: 0.0 g
Tmin: -4.7 ms
CFC 1000

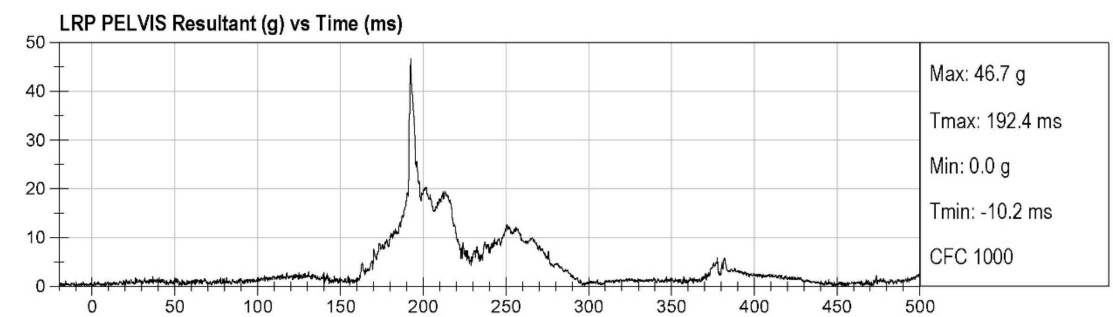

LRP LEFT FEMUR FZ (N) vs Time (ms)
Max: 1210.9 N
Tmax: 381.5 ms
Min: -3301.2 N
Tmin: 194.3 ms
CFC 600

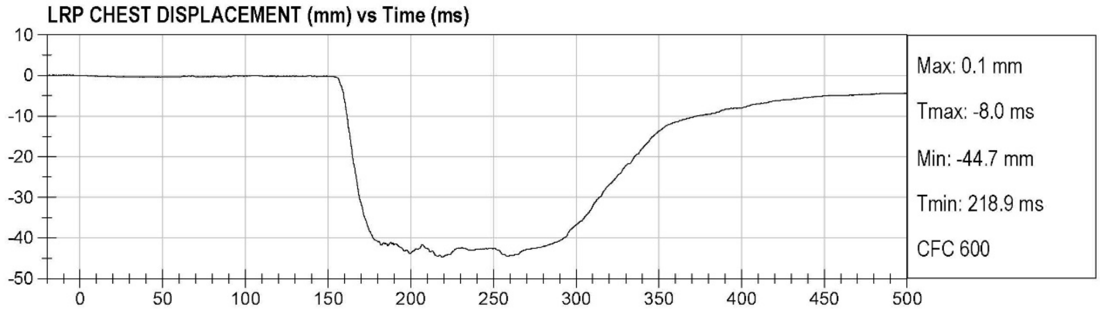

LRP RIGHT FEMUR FZ (N) vs Time (ms)
Max: 640.4 N
Tmax: 268.5 ms
Min: -5525.4 N
Tmin: 193.3 ms
CFC 600

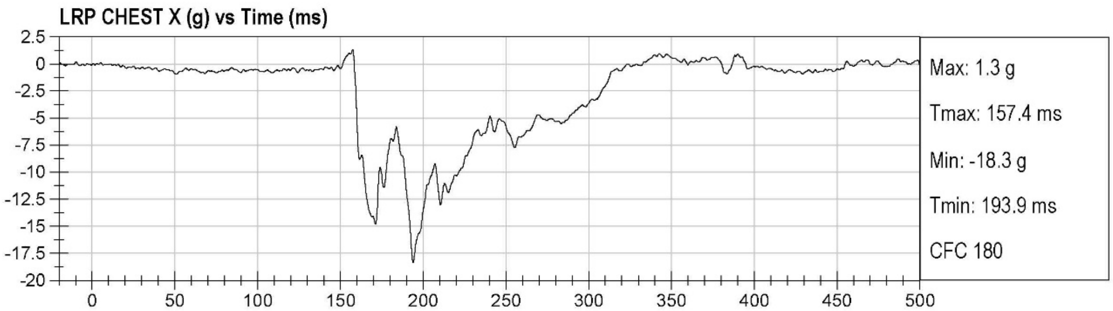

LRP PELVIS X (g) vs Time (ms)
Max: 5.3 g
Tmax: 382.0 ms
Min: -45.4 g
Tmin: 192.4 ms
CFC 1000

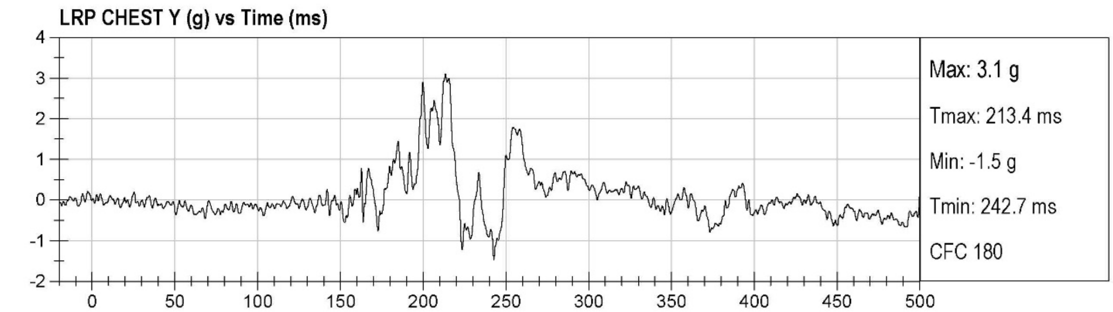

LRP PELVIS Y (g) vs Time (ms)
Max: 4.0 g
Tmax: 265.0 ms
Min: -4.3 g
Tmin: 193.3 ms
CFC 1000

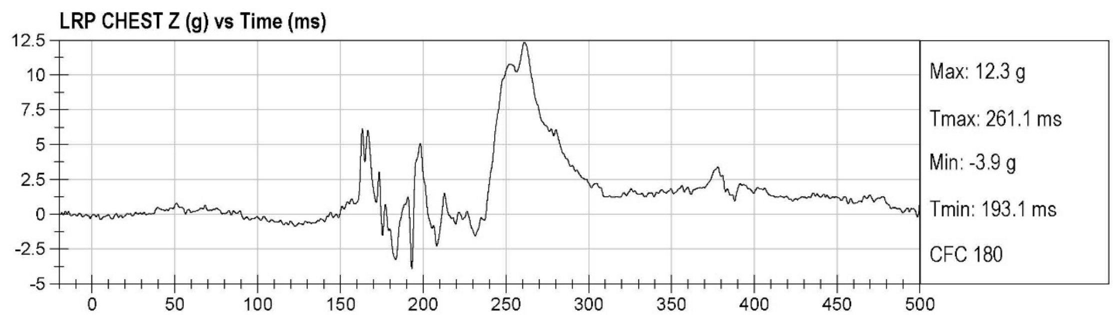

LRP PELVIS Z (g) vs Time (ms)
Max: 4.8 g
Tmax: 266.9 ms
Min: -10.9 g
Tmin: 192.4 ms
CFC 1000


LRP PELVIS Resultant (g) vs Time (ms)
Max: 46.7 g
Tmax: 192.4 ms
Min: 0.0 g
Tmin: -10.2 ms
CFC 1000

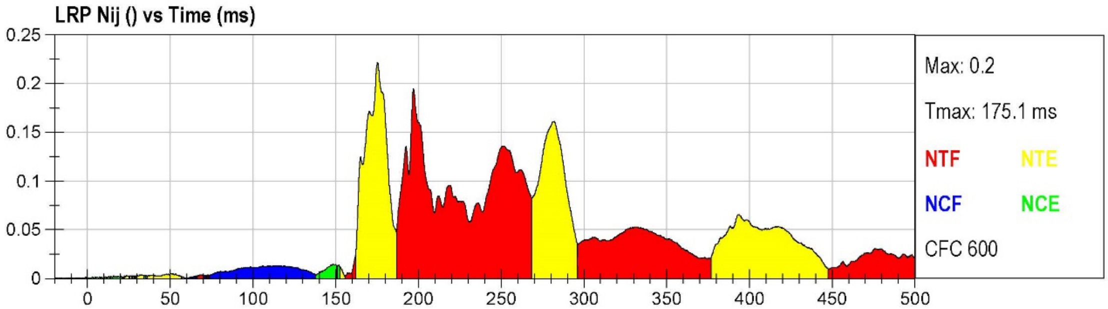

LRP CHEST DISPLACEMENT (mm) vs Time (ms)
Max: 0.1 mm
Tmax: -8.0 ms
Min: -44.7 mm
Tmin: 218.9 ms
CFC 600

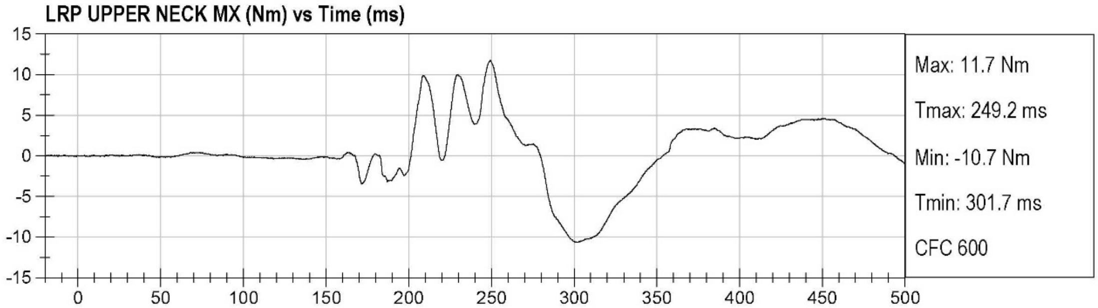

LRP CHEST X (g) vs Time (ms)
Max: 1.3 g
Tmax: 157.4 ms
Min: -18.3 g
Tmin: 193.9 ms
CFC 180
2.5 0 -2.5 -5 -7.5 -10 -12.5 -15 -17.5 -20
0 50 100 150 200 250 300 350 400 450 500

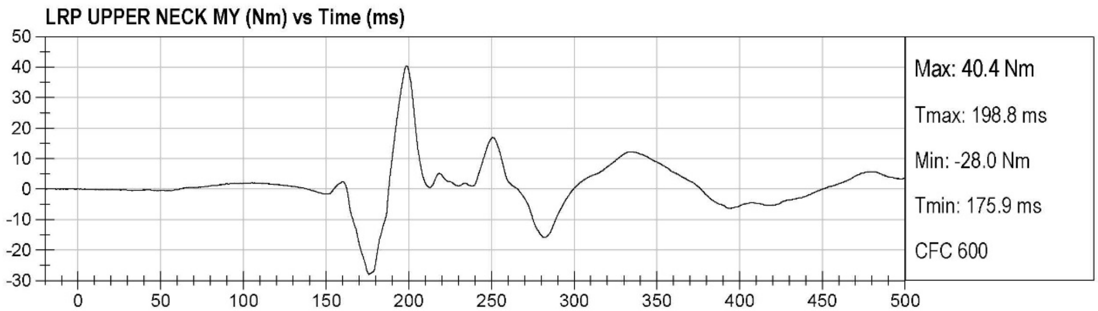

LRP CHEST Y (g) vs Time (ms)
Max: 3.1 g
Tmax: 213.4 ms
Min: -1.5 g
Tmin: 242.7 ms
CFC 180
4 3 2 1 0 -1 -2
0 50 100 150 200 250 300 350 400 450 500

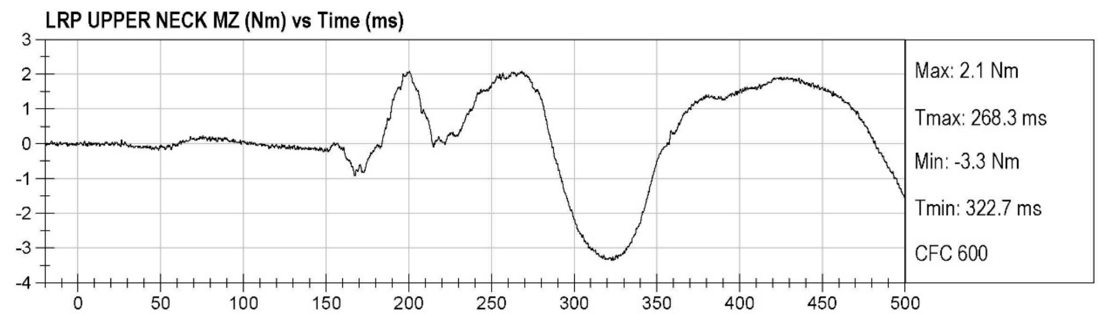

LRP CHEST Z (g) vs Time (ms)
Max: 12.3 g
Tmax: 261.1 ms
Min: -3.9 g
Tmin: 193.1 ms
CFC 180
12.5 10 7.5 5 2.5 0 -2.5 -5
0 50 100 150 200 250 300 350 400 450 500

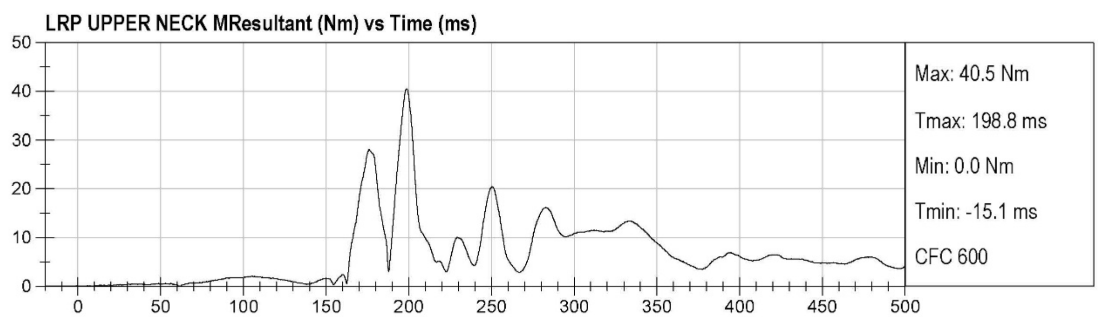

LRP CHEST Resultant (g) vs Time (ms)
Max: 18.5 g
Tmax: 193.6 ms
Min: 0.0 g
Tmin: 0.9 ms
CFC 180
20 17.5 15 12.5 10 7.5 5 2.5 0
0 50 100 150 200 250 300 350 400 450 500


LRP Nij () vs Time (ms)
0.25
0.2
0.15
0.1
0.05
0
0
50
100
150
200
250
300
350
400
450
500
Max: 0.2
Tmax: 175.1 ms
NTF
NTE
NCF
NCE
CFC 600

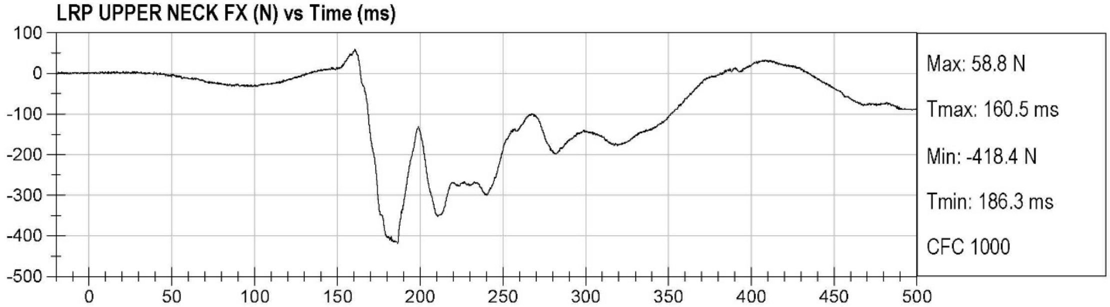

LRP UPPER NECK MX (Nm) vs Time (ms)
Max: 11.7 Nm
Tmax: 249.2 ms
Min: -10.7 Nm
Tmin: 301.7 ms
CFC 600


LRP UPPER NECK MY (Nm) vs Time (ms)
Max: 40.4 Nm
Tmax: 198.8 ms
Min: -28.0 Nm
Tmin: 175.9 ms
CFC 600

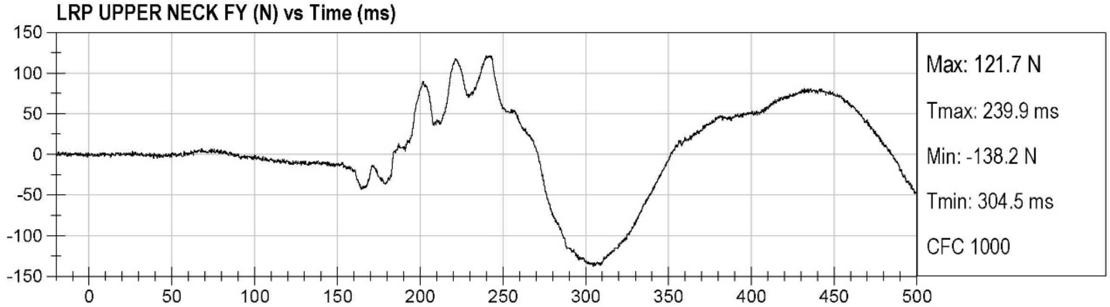

LRP UPPER NECK MZ (Nm) vs Time (ms)
Max: 2.1 Nm
Tmax: 268.3 ms
Min: -3.3 Nm
Tmin: 322.7 ms
CFC 600


LRP UPPER NECK MResultant (Nm) vs Time (ms)
Max: 40.5 Nm
Tmax: 198.8 ms
Min: 0.0 Nm
Tmin: -15.1 ms
CFC 600

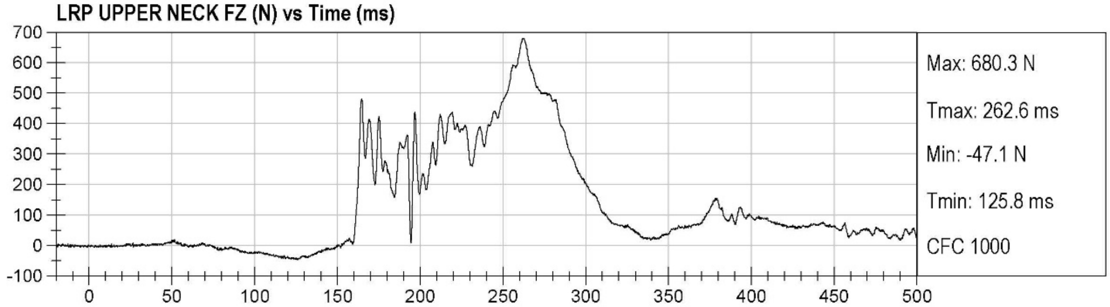
LRP UPPER NECK FX (N) vs Time (ms)



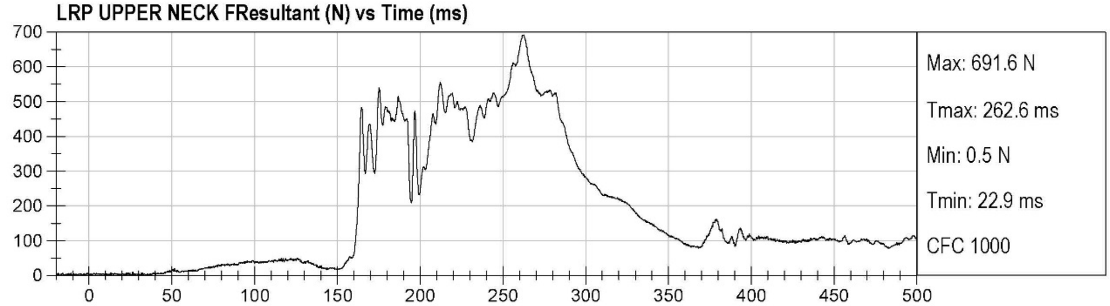

LRP UPPER NECK FY (N) vs Time (ms)

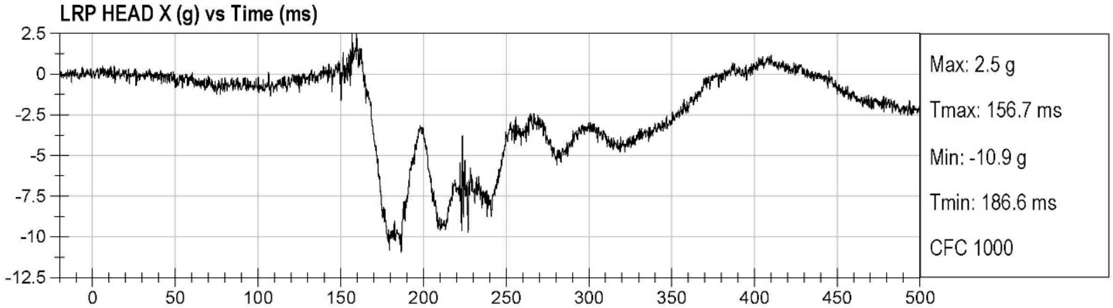


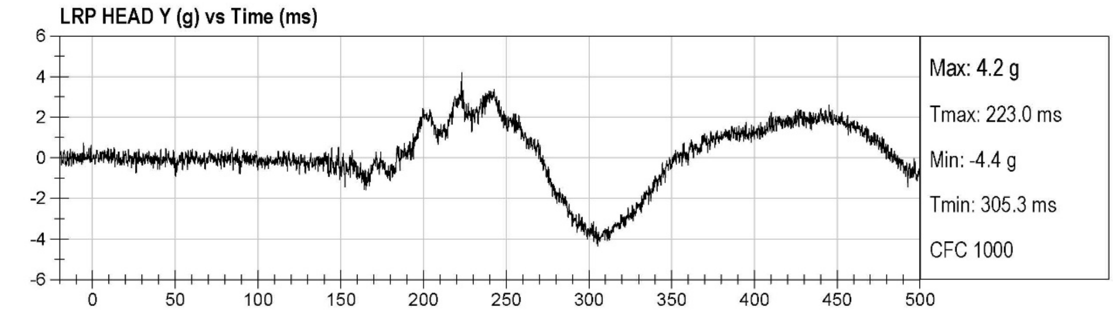

LRP UPPER NECK FZ (N) vs Time (ms)

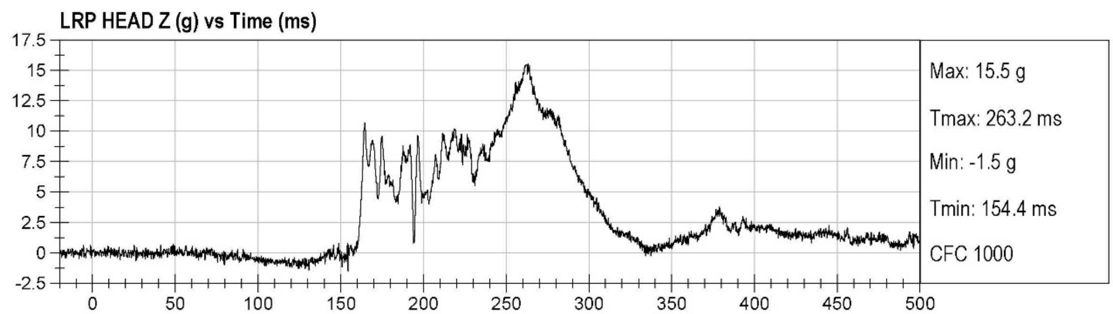


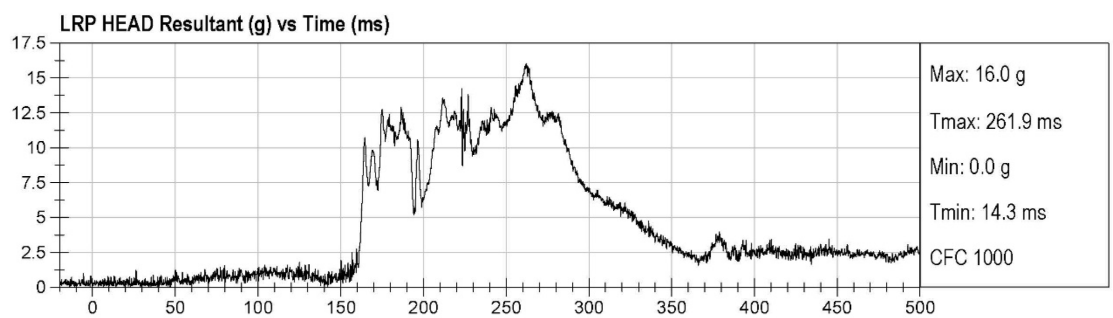

LRP UPPER NECK FResultant (N) vs Time (ms)




LRP HEAD X (g) vs Time (ms)
Max: 2.5 g
Tmax: 156.7 ms
Min: -10.9 g
Tmin: 186.6 ms
CFC 1000


LRP HEAD Y (g) vs Time (ms)
Max: 4.2 g
Tmax: 223.0 ms
Min: -4.4 g
Tmin: 305.3 ms
CFC 1000


LRP HEAD Z (g) vs Time (ms)
Max: 15.5 g
Tmax: 263.2 ms
Min: -1.5 g
Tmin: 154.4 ms
CFC 1000


LRP HEAD Resultant (g) vs Time (ms)
Max: 16.0 g
Tmax: 261.9 ms
Min: 0.0 g
Tmin: 14.3 ms
CFC 1000

## A.7: Test 2BQ Data

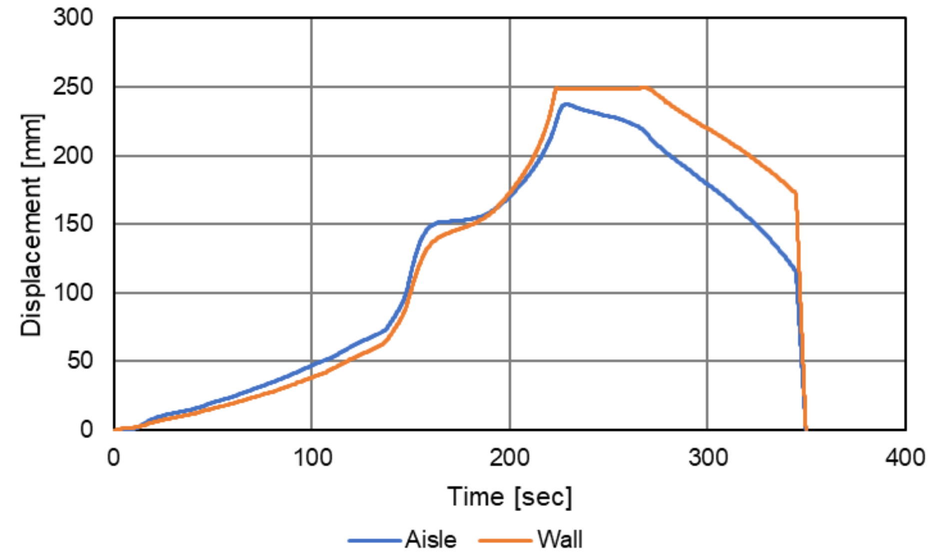



**Figure A5. Test 2BQ Displacement versus Time**

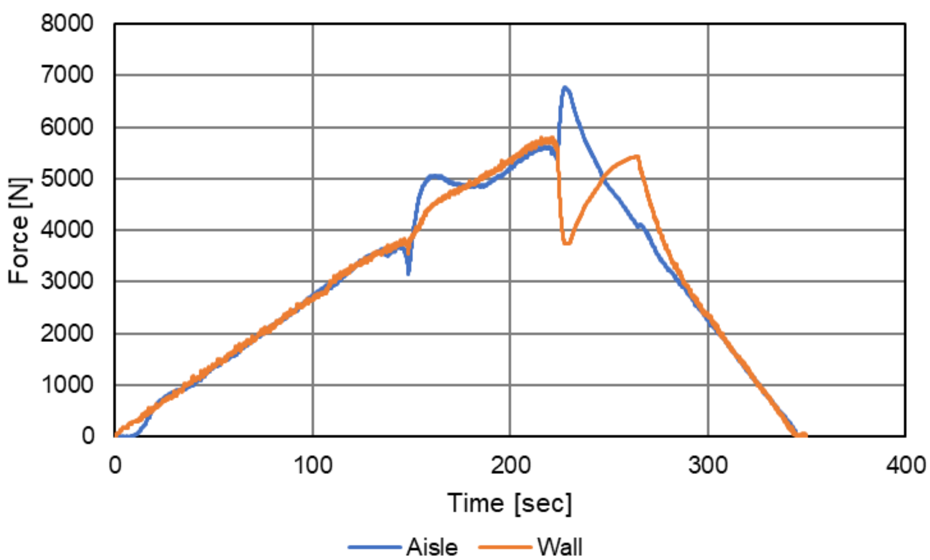



**Figure A6. Test 2BQ Force versus Time**

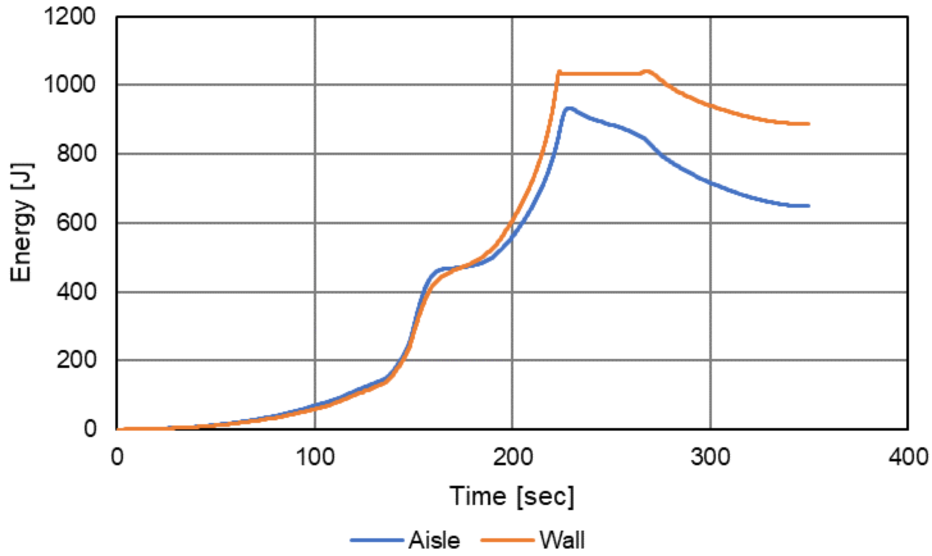



**Figure A7. Test 2BQ Energy-absorption versus Time**

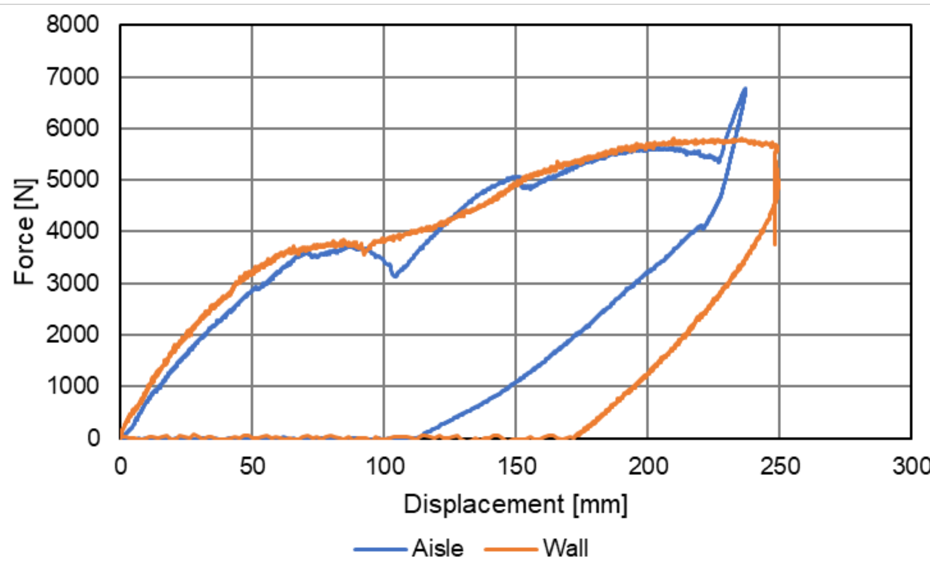
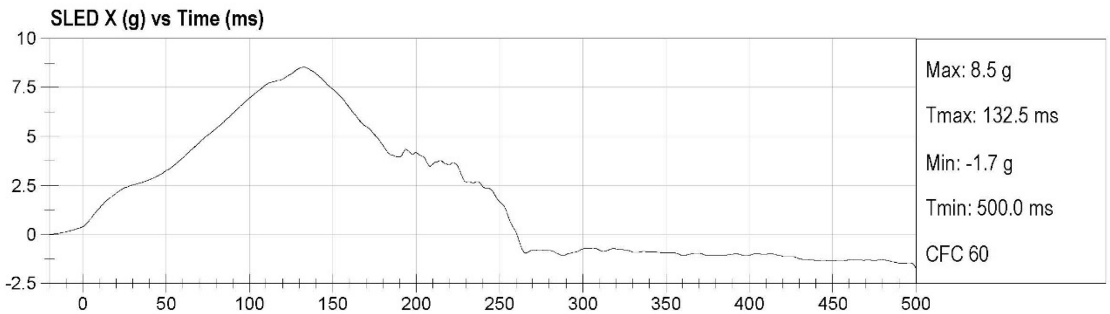


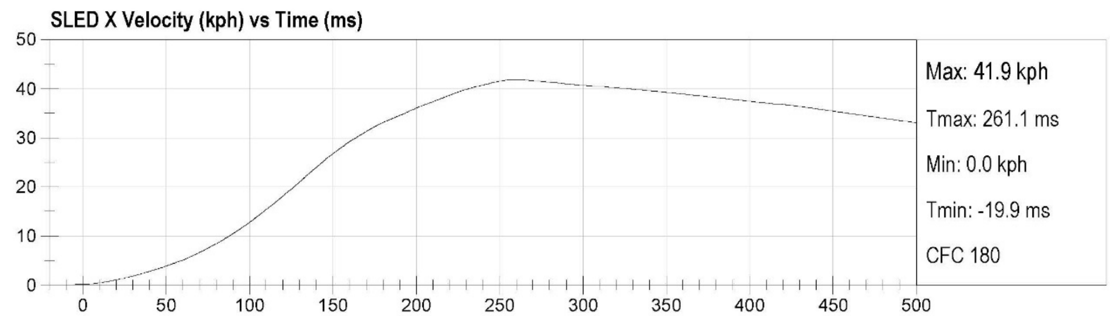

**Figure A8. Test 2BQ Force versus Displacement**

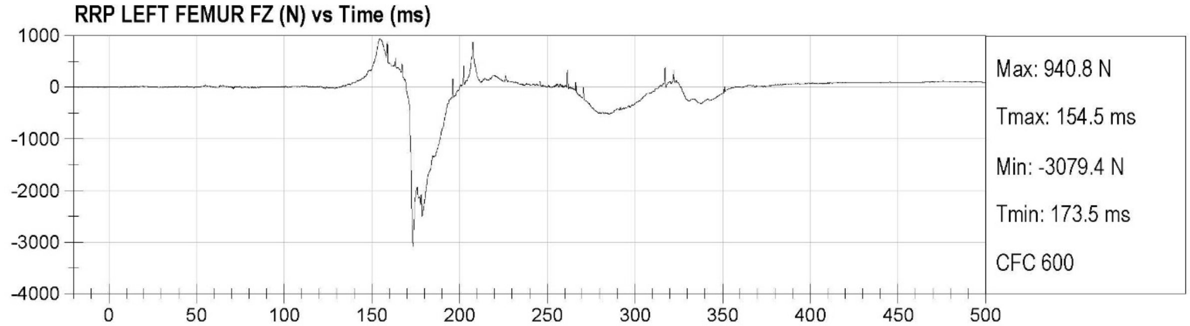
## A.8: Test 3A Data

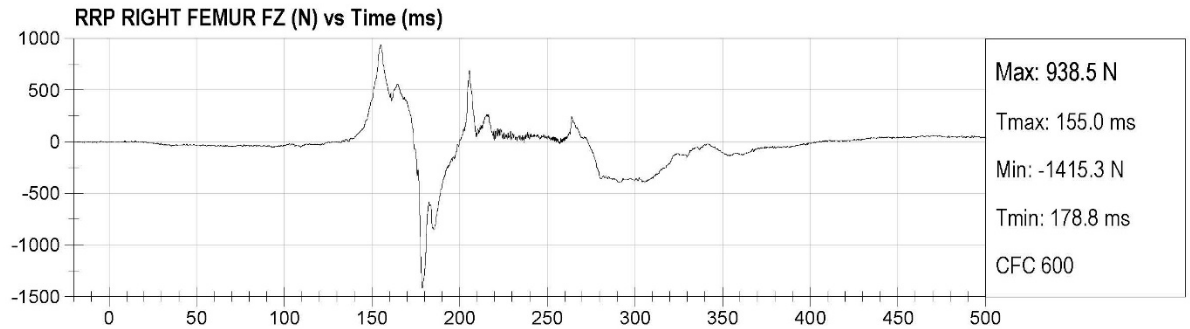
Test Date: 05/11/2021

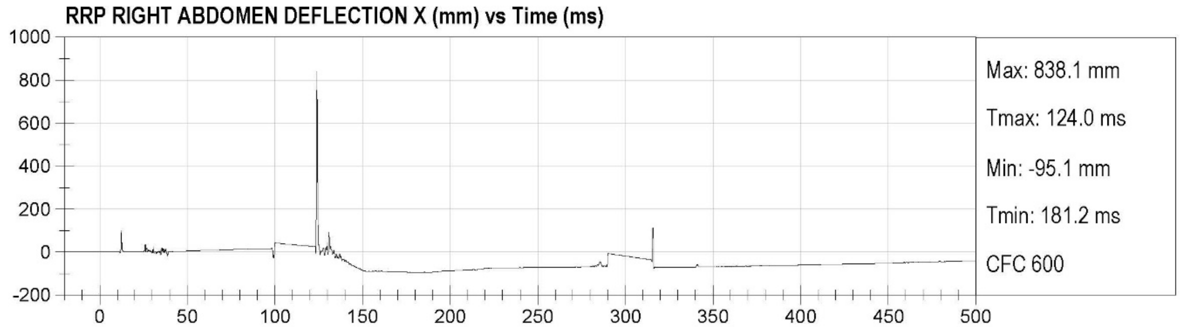
MGA Test ID: S21142

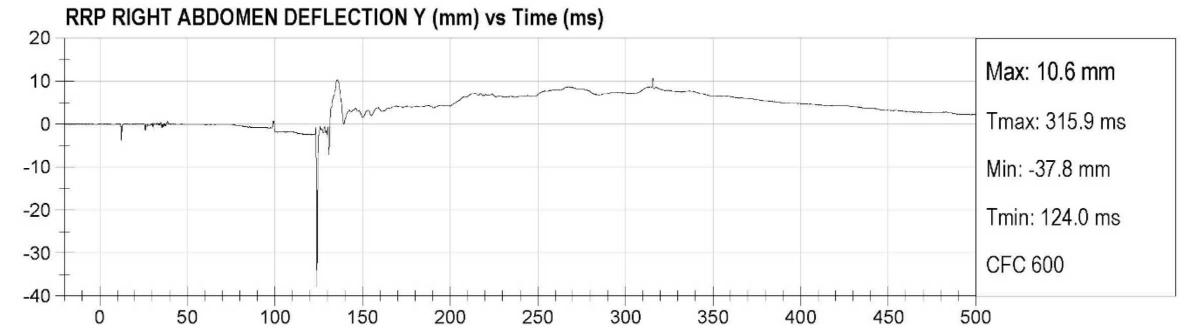


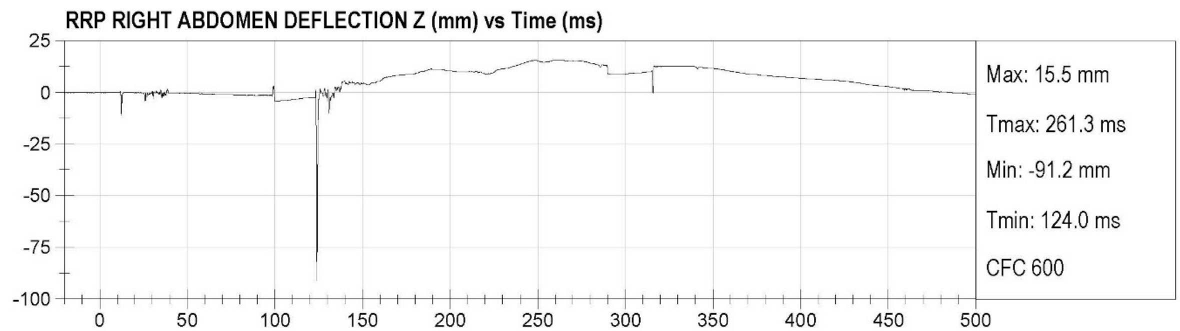



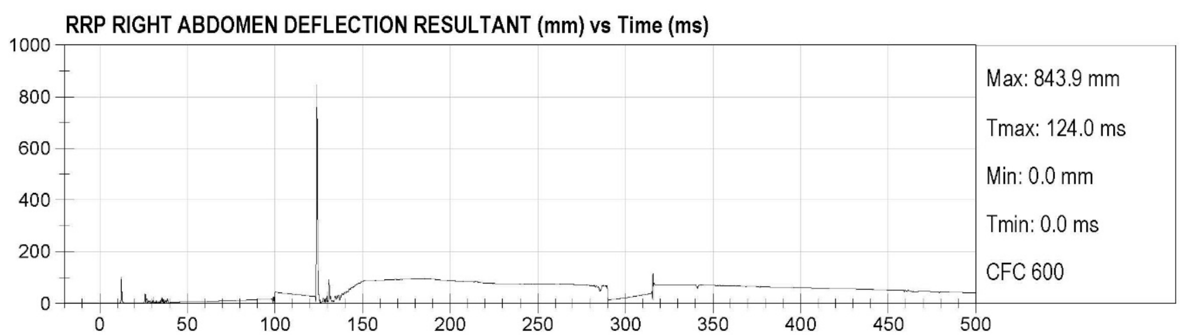

RRP LEFT FEMUR FZ (N) vs Time (ms)
1000
0
-1000
-2000
-3000
-4000
0
50
100
150
200
250
300
350
400
450
500
Max: 940.8 N
Tmax: 154.5 ms
Min: -3079.4 N
Tmin: 173.5 ms
CFC 600


RRP RIGHT FEMUR FZ (N) vs Time (ms)
1000
500
0
-500
-1000
-1500
0
50
100
150
200
250
300
350
400
450
500
Max: 938.5 N
Tmax: 155.0 ms
Min: -1415.3 N
Tmin: 178.8 ms
CFC 600

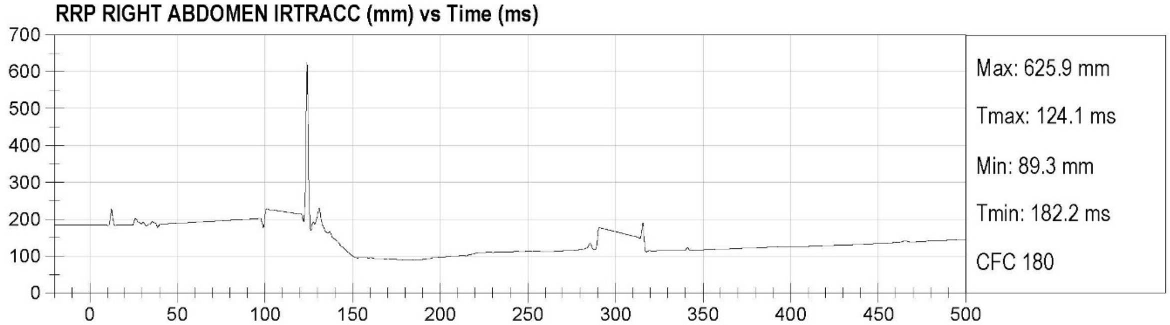

RRP RIGHT ABDOMEN DEFLECTION X (mm) vs Time (ms)
Max: 838.1 mm
Tmax: 124.0 ms
Min: -95.1 mm
Tmin: 181.2 ms
CFC 600


RRP RIGHT ABDOMEN DEFLECTION Y (mm) vs Time (ms)
Max: 10.6 mm
Tmax: 315.9 ms
Min: -37.8 mm
Tmin: 124.0 ms
CFC 600

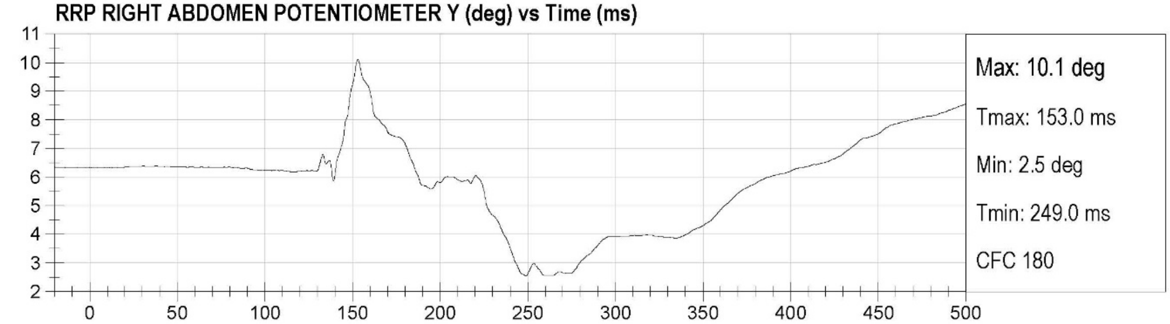

RRP RIGHT ABDOMEN DEFLECTION Z (mm) vs Time (ms)
Max: 15.5 mm
Tmax: 261.3 ms
Min: -91.2 mm
Tmin: 124.0 ms
CFC 600


RRP RIGHT ABDOMEN DEFLECTION RESULTANT (mm) vs Time (ms)
Max: 843.9 mm
Tmax: 124.0 ms
Min: 0.0 mm
Tmin: 0.0 ms
CFC 600

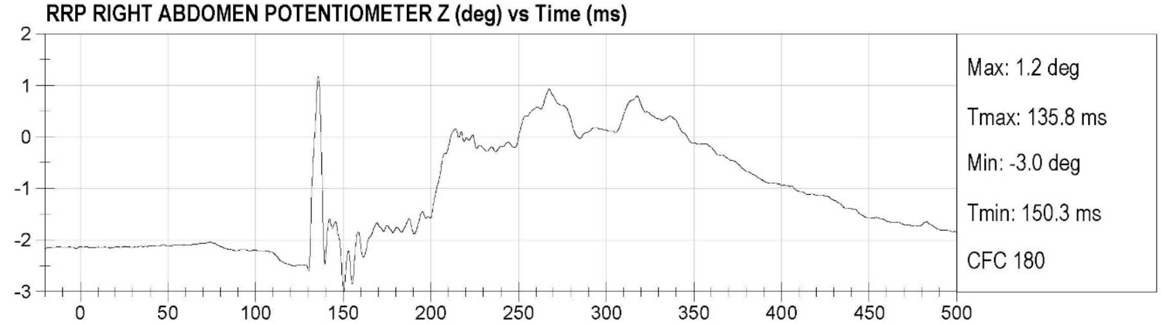
RRP RIGHT ABDOMEN IRTRACC (mm) vs Time (ms)

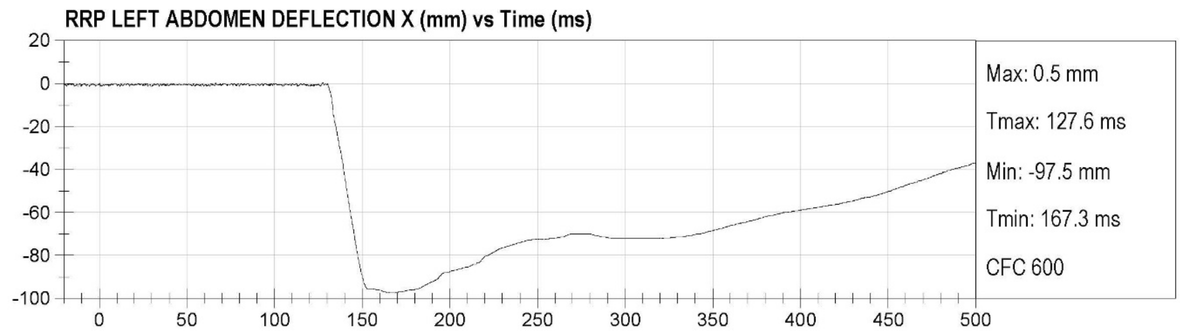


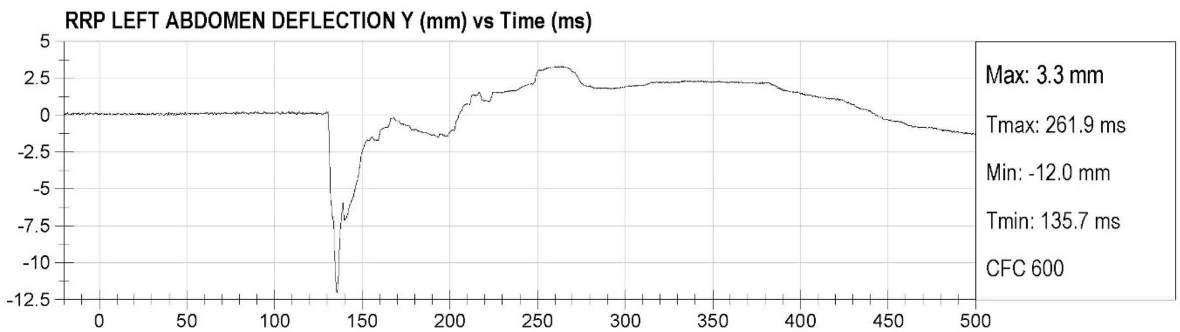

RRP RIGHT ABDOMEN POTENTIOMETER Y (deg) vs Time (ms)

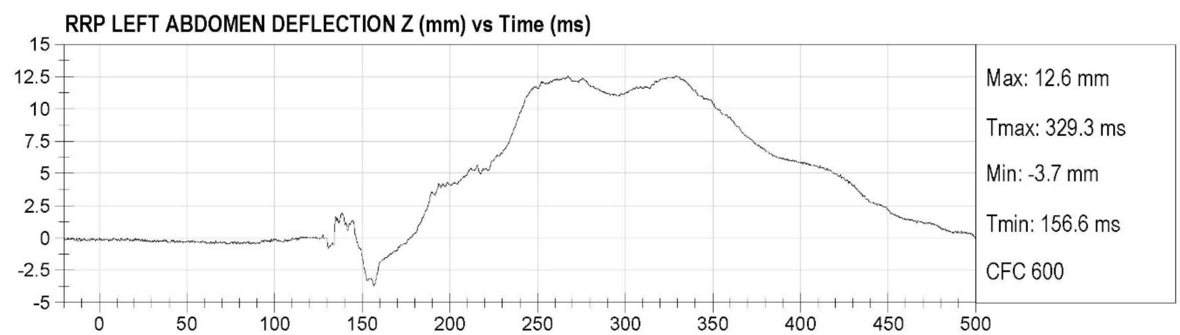


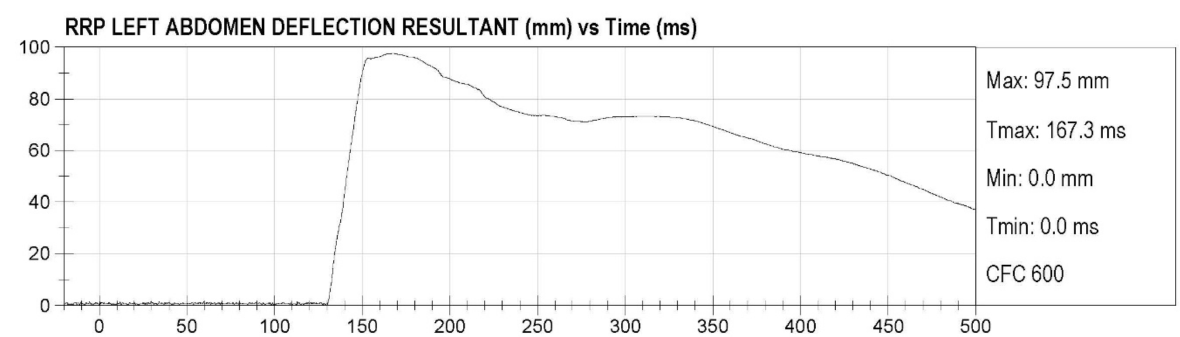

RRP RIGHT ABDOMEN POTENTIOMETER Z (deg) vs Time (ms)

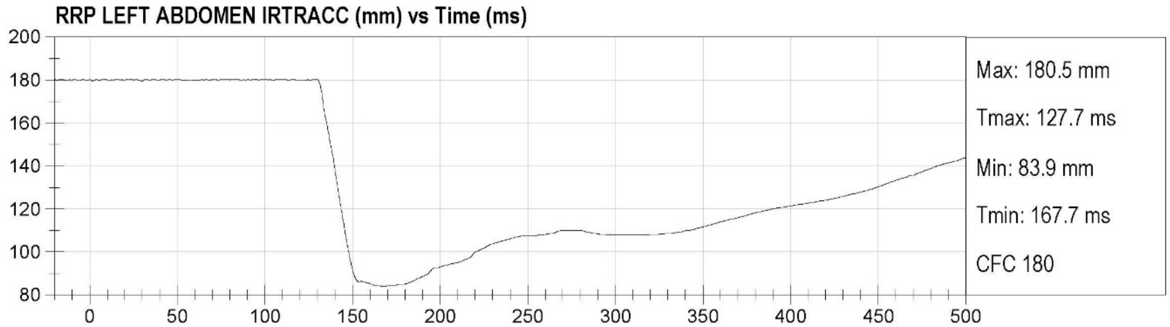


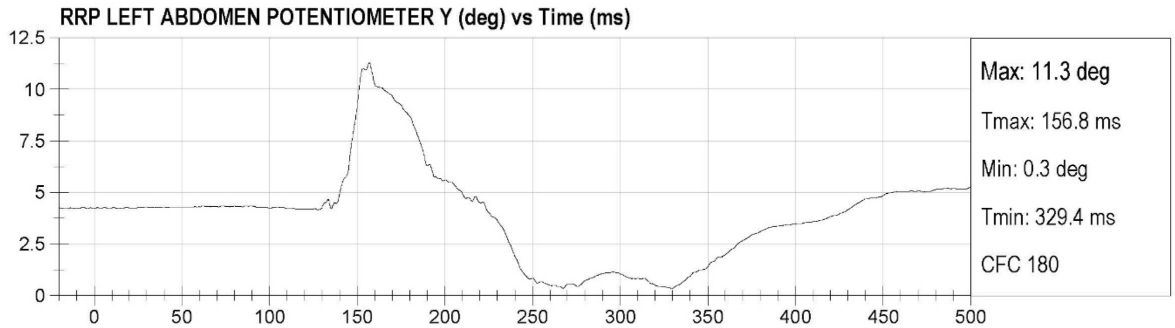

RRP LEFT ABDOMEN DEFLECTION X (mm) vs Time (ms)
Max: 0.5 mm
Tmax: 127.6 ms
Min: -97.5 mm
Tmin: 167.3 ms
CFC 600

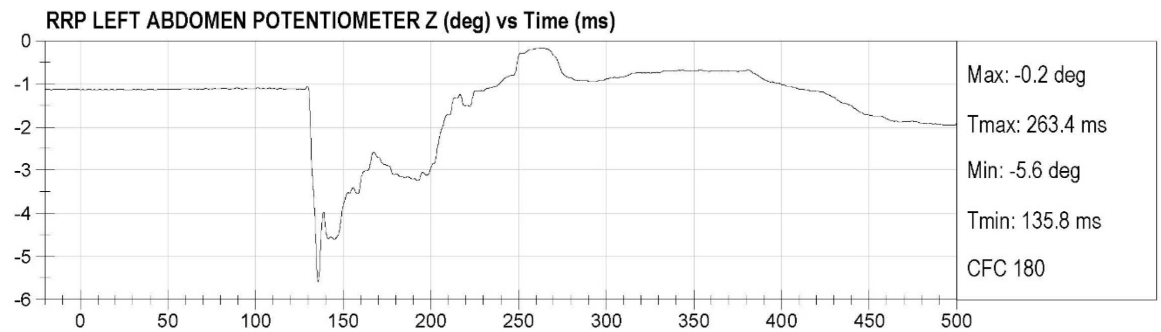

RRP LEFT ABDOMEN DEFLECTION Y (mm) vs Time (ms)
Max: 3.3 mm
Tmax: 261.9 ms
Min: -12.0 mm
Tmin: 135.7 ms
CFC 600

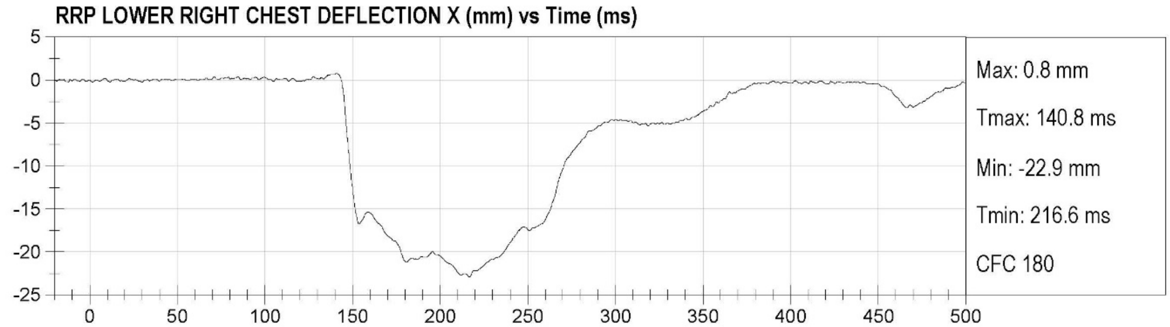

RRP LEFT ABDOMEN DEFLECTION Z (mm) vs Time (ms)
Max: 12.6 mm
Tmax: 329.3 ms
Min: -3.7 mm
Tmin: 156.6 ms
CFC 600

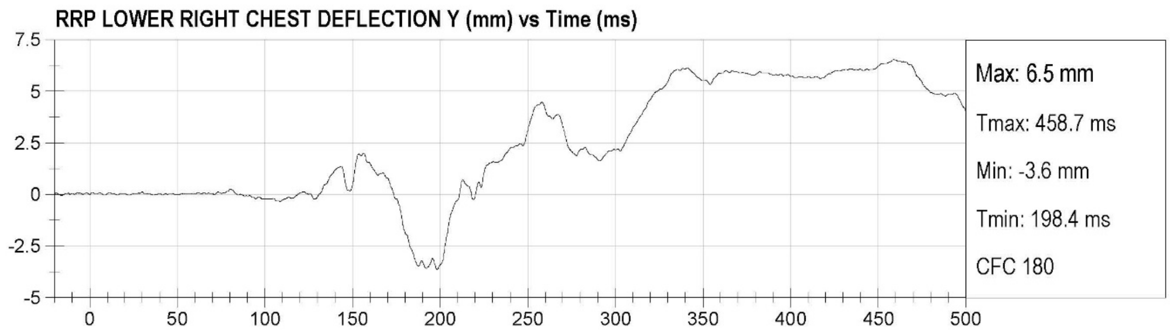

RRP LEFT ABDOMEN DEFLECTION RESULTANT (mm) vs Time (ms)
Max: 97.5 mm
Tmax: 167.3 ms
Min: 0.0 mm
Tmin: 0.0 ms
CFC 600

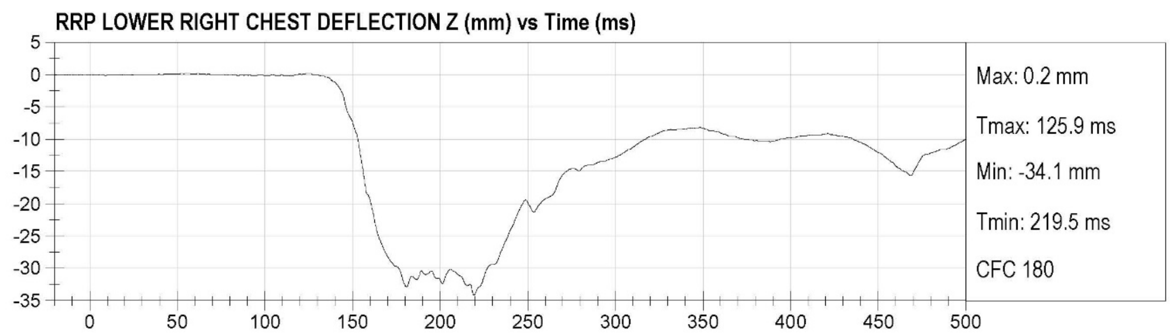

RRP LEFT ABDOMEN IRTRACC (mm) vs Time (ms)
Max: 180.5 mm
Tmax: 127.7 ms
Min: 83.9 mm
Tmin: 167.7 ms
CFC 180

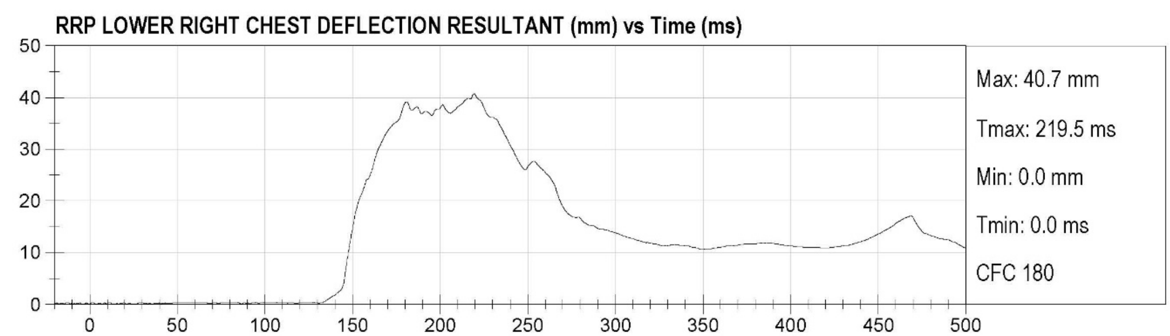

RRP LEFT ABDOMEN POTENTIOMETER Y (deg) vs Time (ms)
Max: 11.3 deg
Tmax: 156.8 ms
Min: 0.3 deg
Tmin: 329.4 ms
CFC 180

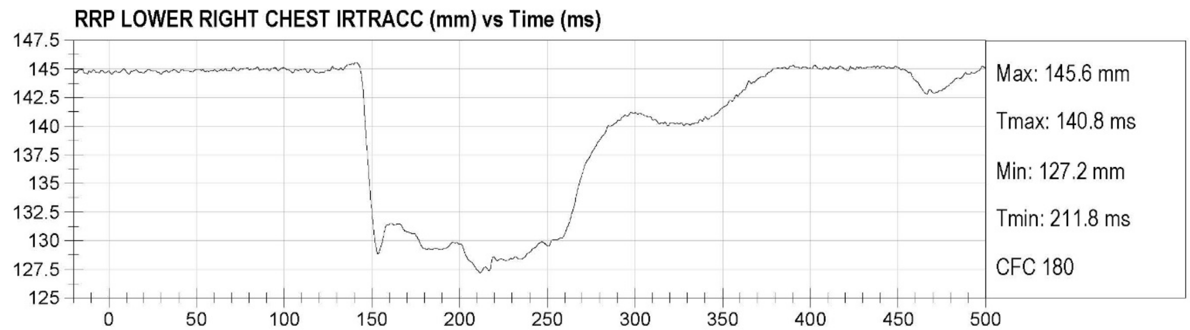

RRP LEFT ABDOMEN POTENTIOMETER Z (deg) vs Time (ms)
Max: -0.2 deg
Tmax: 263.4 ms
Min: -5.6 deg
Tmin: 135.8 ms
CFC 180

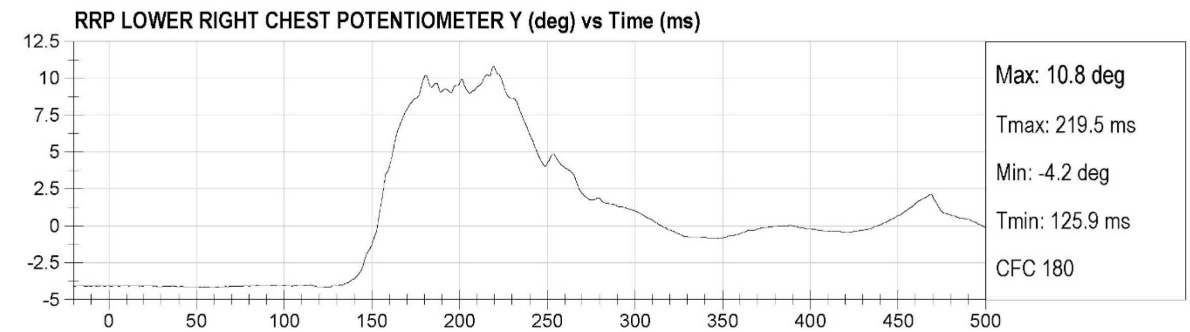

RRP LOWER RIGHT CHEST DEFLECTION X (mm) vs Time (ms)
Max: 0.8 mm
Tmax: 140.8 ms
Min: -22.9 mm
Tmin: 216.6 ms
CFC 180

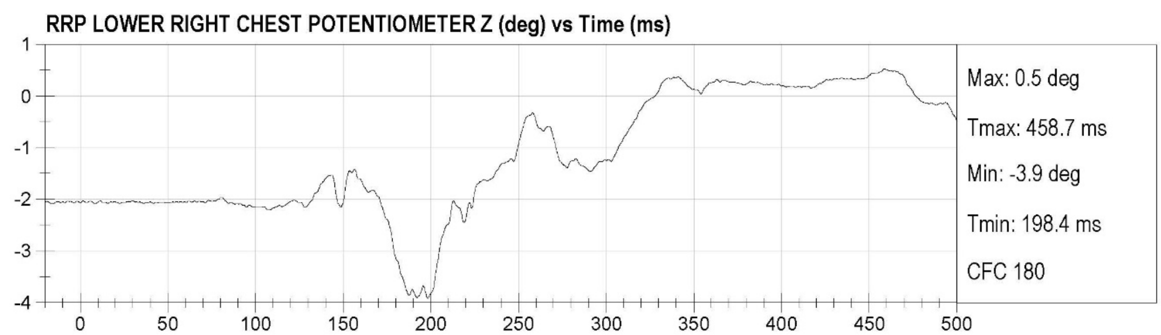

RRP LOWER RIGHT CHEST DEFLECTION Y (mm) vs Time (ms)
Max: 6.5 mm
Tmax: 458.7 ms
Min: -3.6 mm
Tmin: 198.4 ms
CFC 180

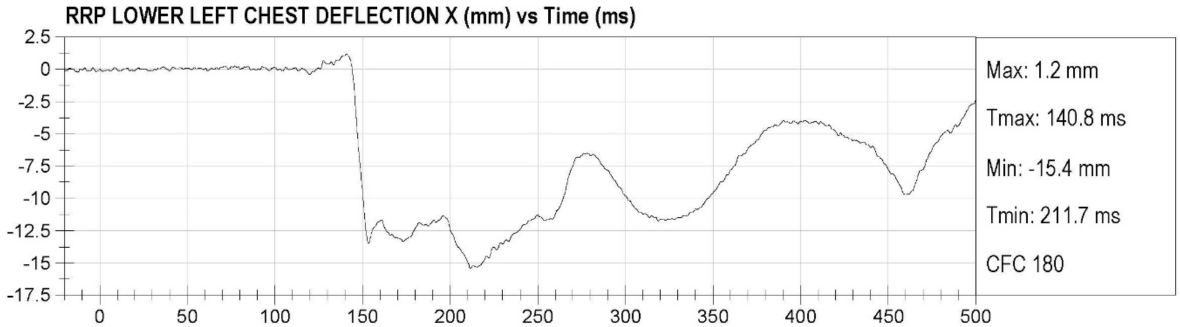

RRP LOWER RIGHT CHEST DEFLECTION Z (mm) vs Time (ms)
Max: 0.2 mm
Tmax: 125.9 ms
Min: -34.1 mm
Tmin: 219.5 ms
CFC 180

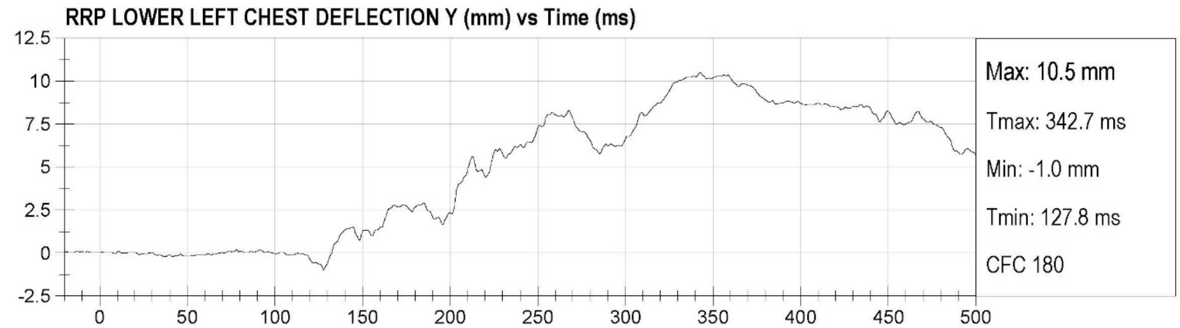

RRP LOWER RIGHT CHEST DEFLECTION RESULTANT (mm) vs Time (ms)
Max: 40.7 mm
Tmax: 219.5 ms
Min: 0.0 mm
Tmin: 0.0 ms
CFC 180

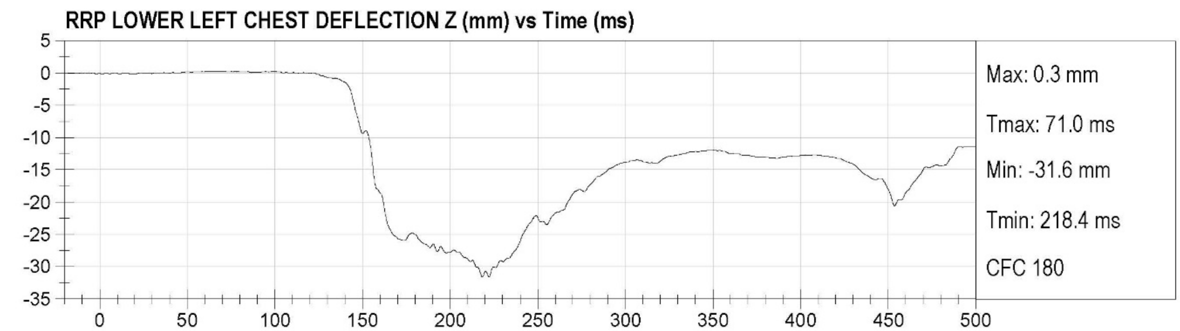

RRP LOWER RIGHT CHEST IRTRACC (mm) vs Time (ms)
Max: 145.6 mm
Tmax: 140.8 ms
Min: 127.2 mm
Tmin: 211.8 ms
CFC 180

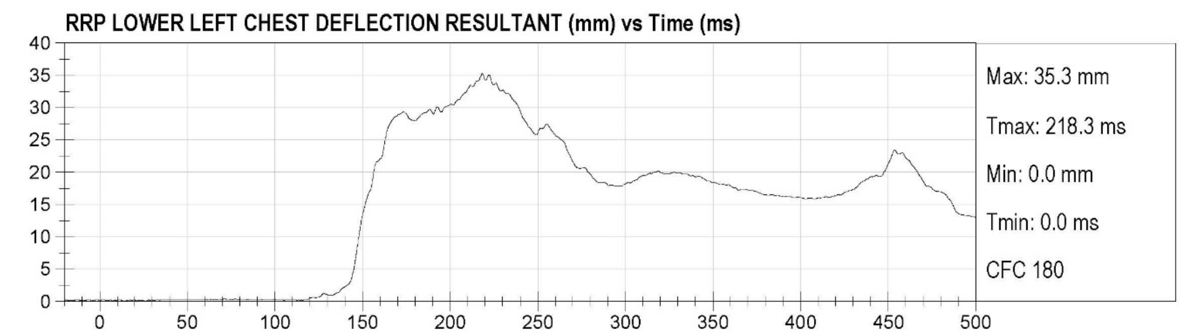

RRP LOWER RIGHT CHEST POTENTIOMETER Y (deg) vs Time (ms)
Max: 10.8 deg
Tmax: 219.5 ms
Min: -4.2 deg
Tmin: 125.9 ms
CFC 180

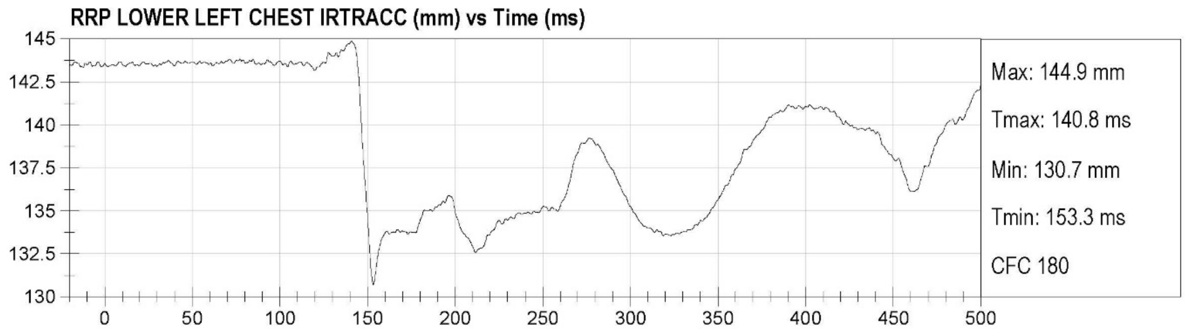

RRP LOWER RIGHT CHEST POTENTIOMETER Z (deg) vs Time (ms)
Max: 0.5 deg
Tmax: 458.7 ms
Min: -3.9 deg
Tmin: 198.4 ms
CFC 180

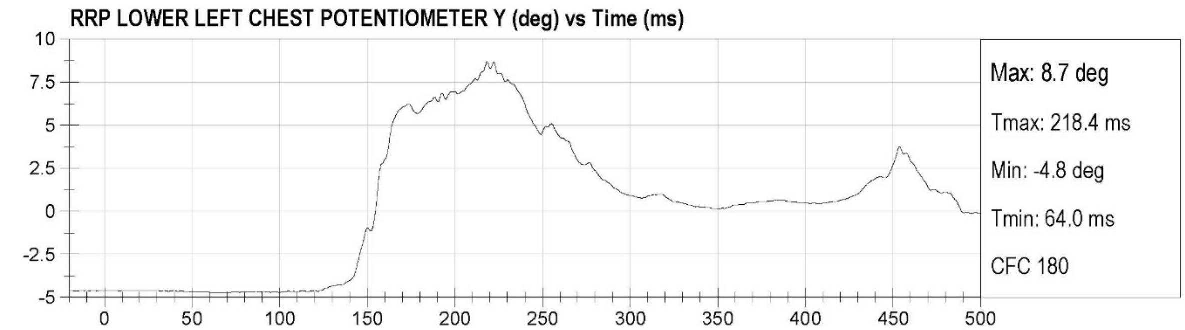

RRP LOWER LEFT CHEST DEFLECTION X (mm) vs Time (ms)
Max: 1.2 mm
Tmax: 140.8 ms
Min: -15.4 mm
Tmin: 211.7 ms
CFC 180

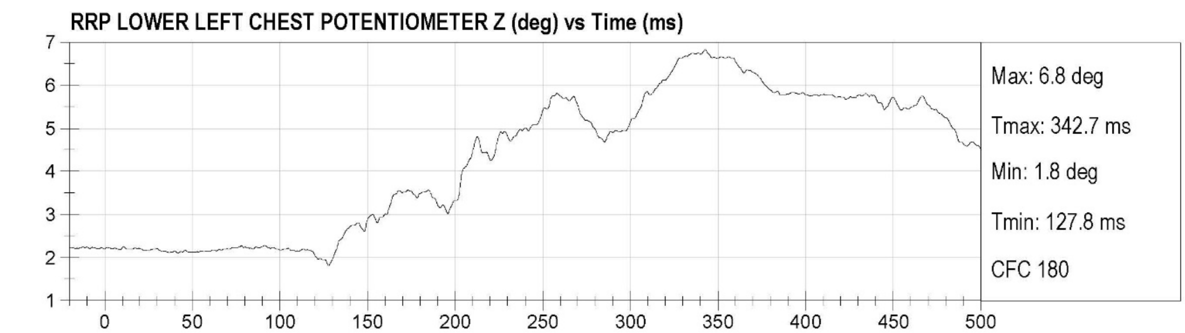

RRP LOWER LEFT CHEST DEFLECTION Y (mm) vs Time (ms)
Max: 10.5 mm
Tmax: 342.7 ms
Min: -1.0 mm
Tmin: 127.8 ms
CFC 180


RRP LOWER LEFT CHEST DEFLECTION Z (mm) vs Time (ms)
Max: 0.3 mm
Tmax: 71.0 ms
Min: -31.6 mm
Tmin: 218.4 ms
CFC 180

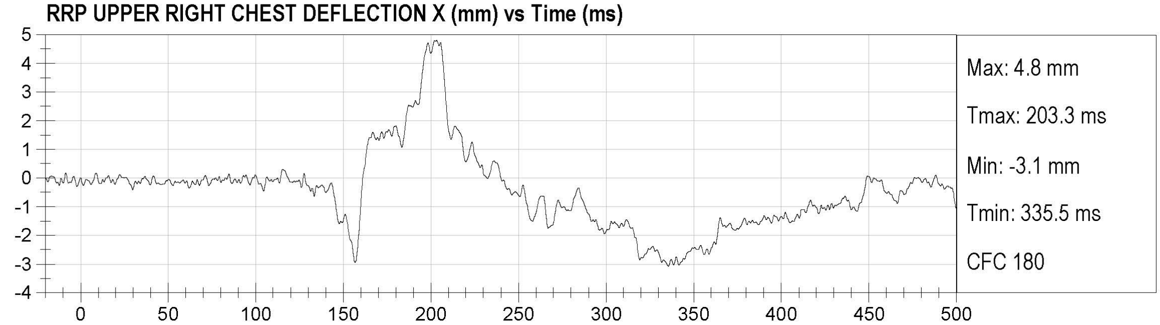

RRP LOWER LEFT CHEST DEFLECTION RESULTANT (mm) vs Time (ms)
Max: 35.3 mm
Tmax: 218.3 ms
Min: 0.0 mm
Tmin: 0.0 ms
CFC 180


RRP LOWER LEFT CHEST IRTRACC (mm) vs Time (ms)
Max: 144.9 mm
Tmax: 140.8 ms
Min: 130.7 mm
Tmin: 153.3 ms
CFC 180

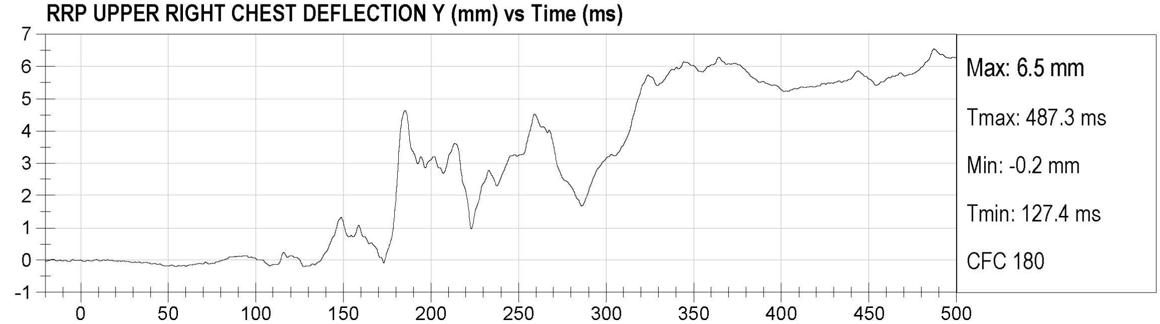

RRP LOWER LEFT CHEST POTENTIOMETER Y (deg) vs Time (ms)
Max: 8.7 deg
Tmax: 218.4 ms
Min: -4.8 deg
Tmin: 64.0 ms
CFC 180


RRP LOWER LEFT CHEST POTENTIOMETER Z (deg) vs Time (ms)
Max: 6.8 deg
Tmax: 342.7 ms
Min: 1.8 deg
Tmin: 127.8 ms
CFC 180

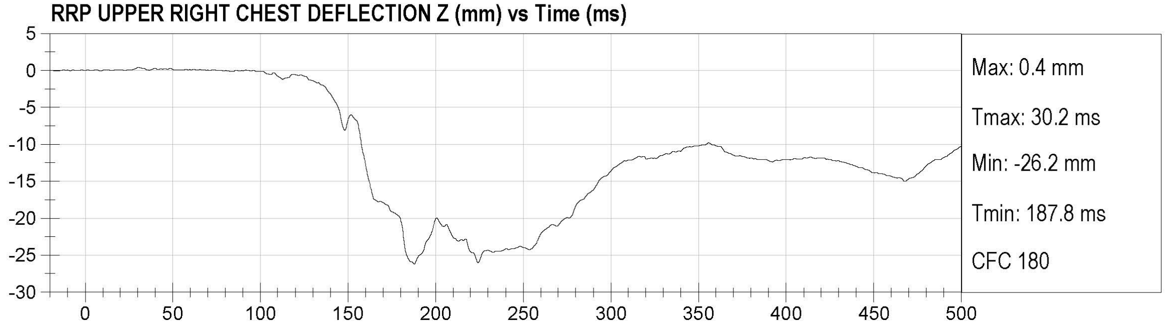
RRP UPPER RIGHT CHEST DEFLECTION X (mm) vs Time (ms)



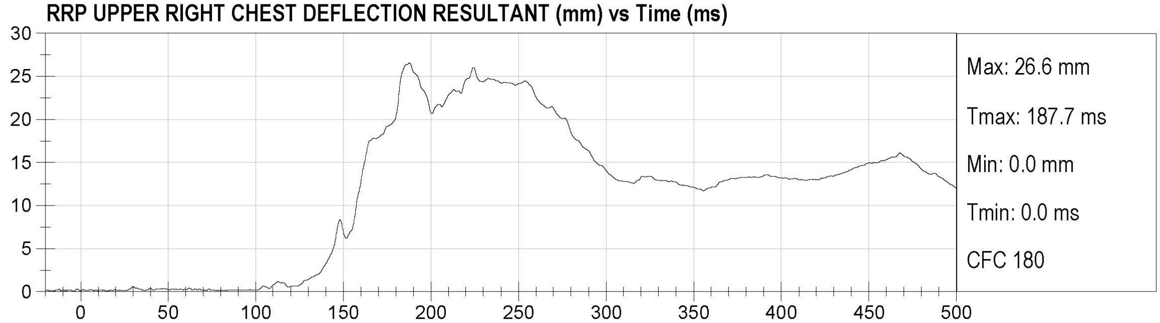

RRP UPPER RIGHT CHEST DEFLECTION Y (mm) vs Time (ms)

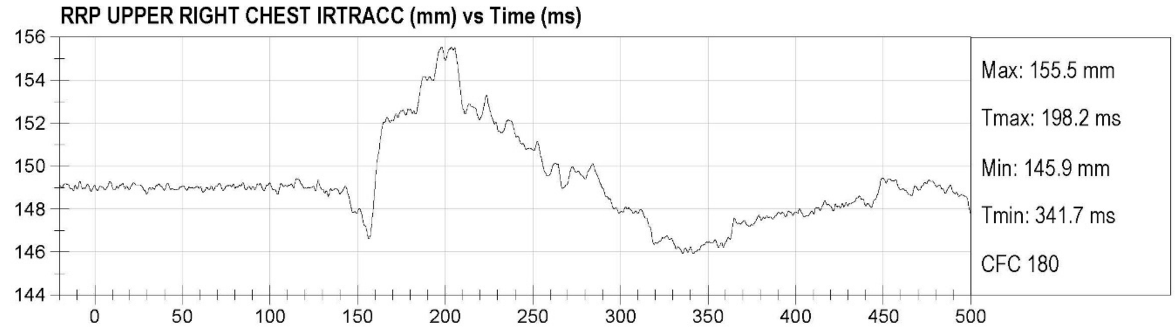


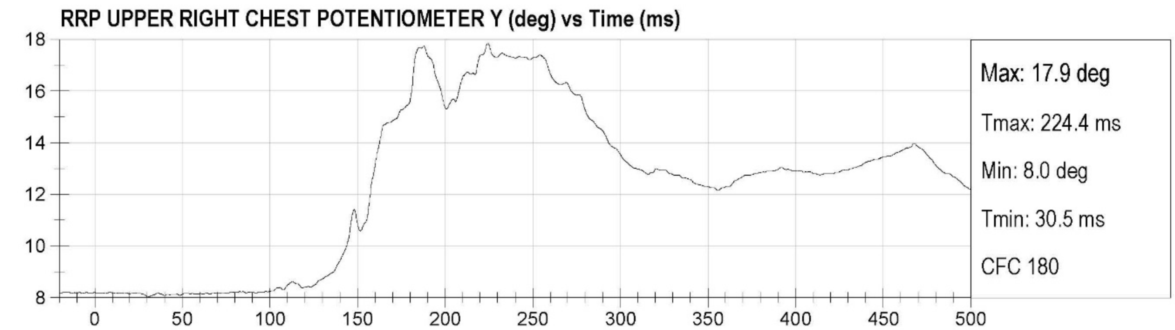

RRP UPPER RIGHT CHEST DEFLECTION Z (mm) vs Time (ms)

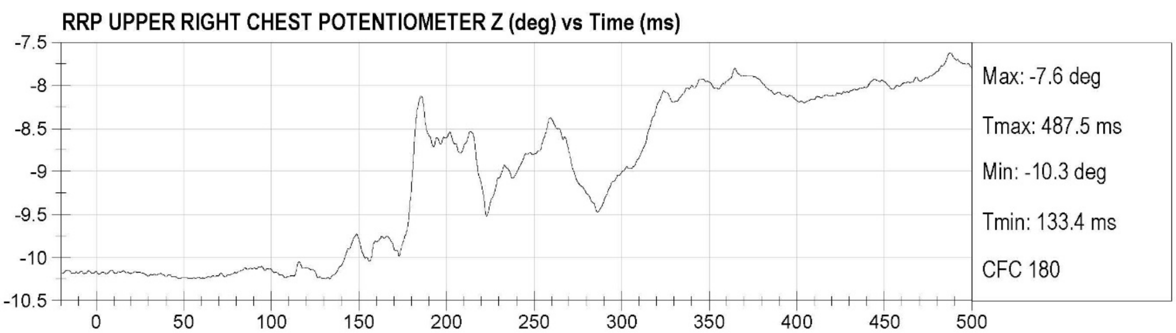


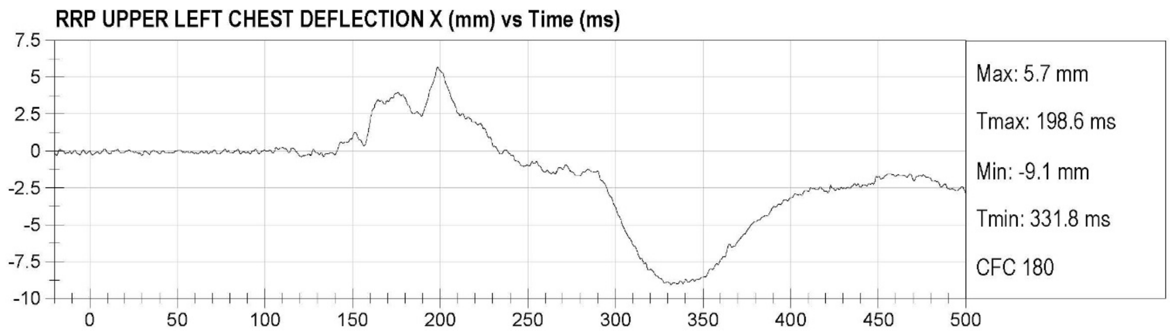

RRP UPPER RIGHT CHEST DEFLECTION RESULTANT (mm) vs Time (ms)

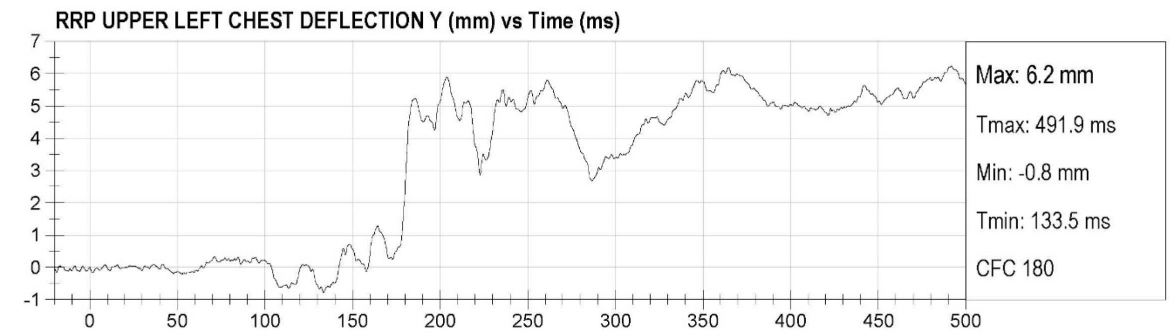


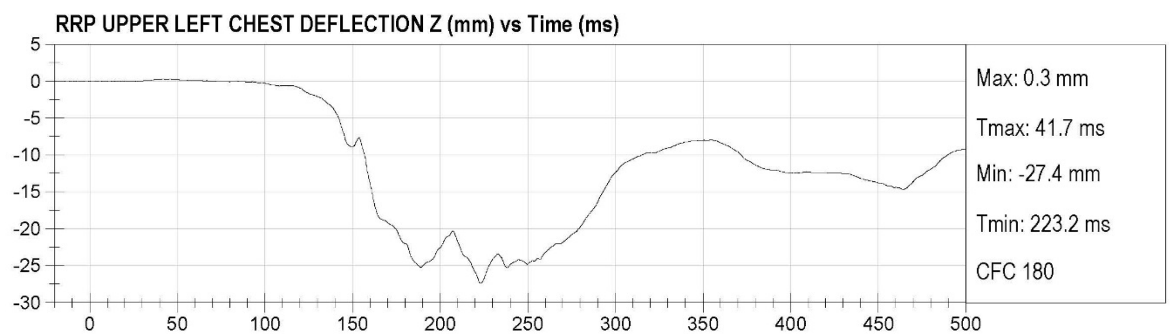

RRP UPPER RIGHT CHEST IRTRACC (mm) vs Time (ms)
Max: 155.5 mm
Tmax: 198.2 ms
Min: 145.9 mm
Tmin: 341.7 ms
CFC 180

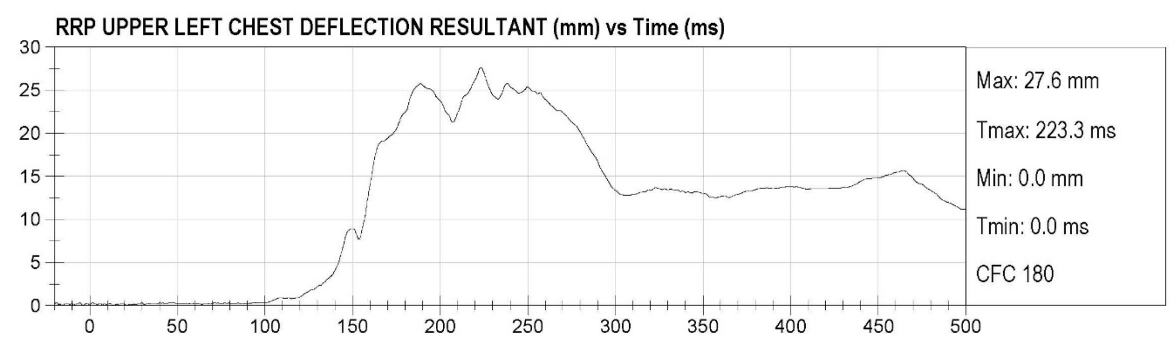

RRP UPPER RIGHT CHEST POTENTIOMETER Y (deg) vs Time (ms)
Max: 17.9 deg
Tmax: 224.4 ms
Min: 8.0 deg
Tmin: 30.5 ms
CFC 180

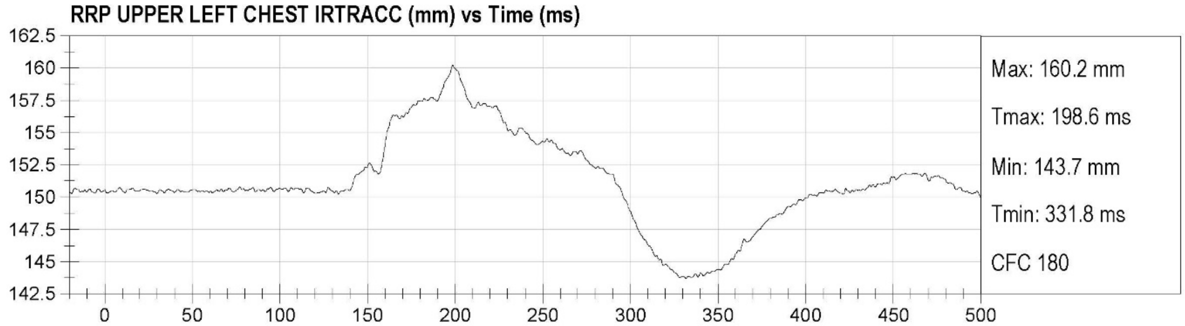

RRP UPPER RIGHT CHEST POTENTIOMETER Z (deg) vs Time (ms)
Max: -7.6 deg
Tmax: 487.5 ms
Min: -10.3 deg
Tmin: 133.4 ms
CFC 180

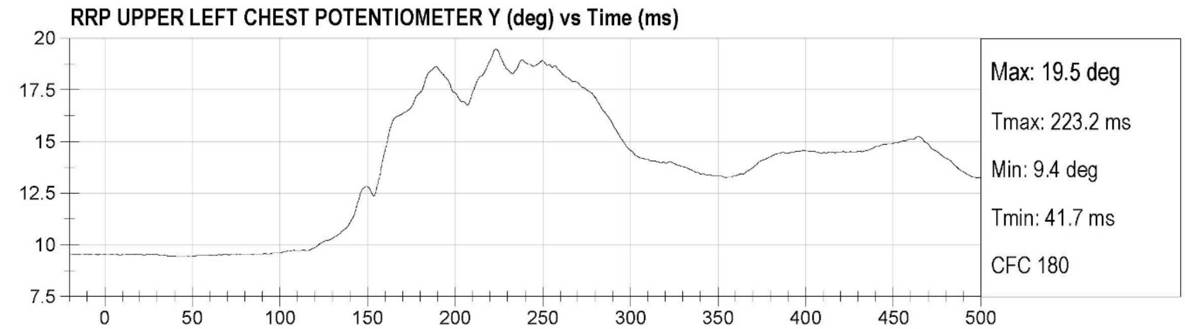

RRP UPPER LEFT CHEST DEFLECTION X (mm) vs Time (ms)
Max: 5.7 mm
Tmax: 198.6 ms
Min: -9.1 mm
Tmin: 331.8 ms
CFC 180

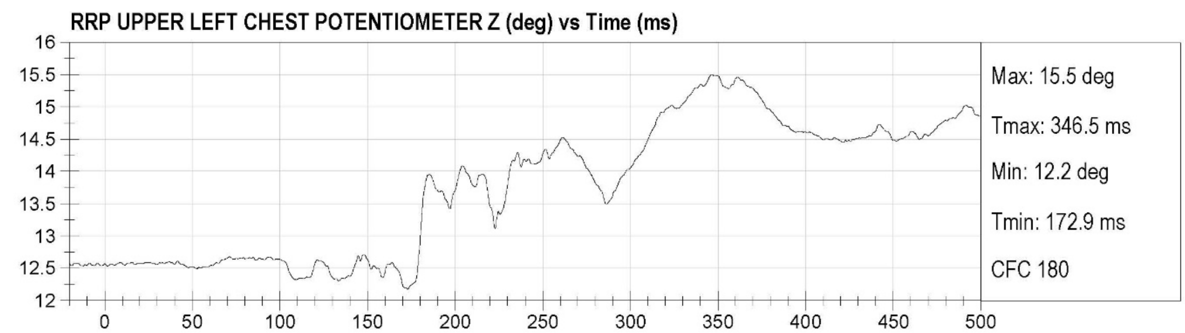

RRP UPPER LEFT CHEST DEFLECTION Y (mm) vs Time (ms)
Max: 6.2 mm
Tmax: 491.9 ms
Min: -0.8 mm
Tmin: 133.5 ms
CFC 180


RRP UPPER LEFT CHEST DEFLECTION Z (mm) vs Time (ms)
Max: 0.3 mm
Tmax: 41.7 ms
Min: -27.4 mm
Tmin: 223.2 ms
CFC 180

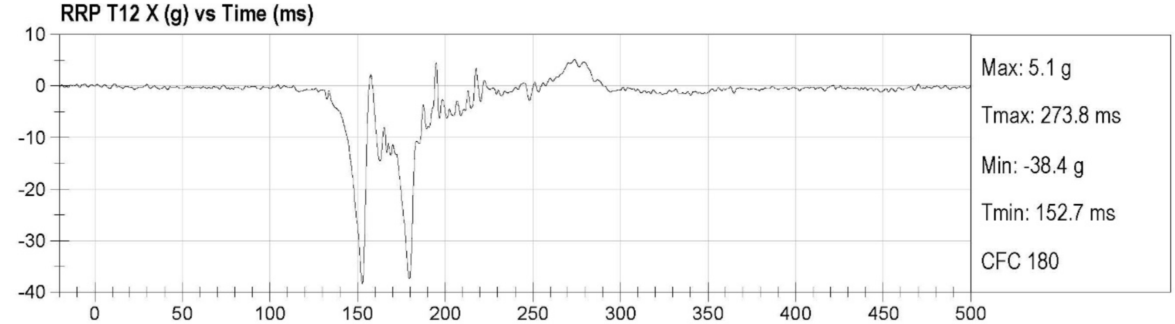

RRP UPPER LEFT CHEST DEFLECTION RESULTANT (mm) vs Time (ms)
Max: 27.6 mm
Tmax: 223.3 ms
Min: 0.0 mm
Tmin: 0.0 ms
CFC 180


RRP UPPER LEFT CHEST IRTRACC (mm) vs Time (ms)
Max: 160.2 mm
Tmax: 198.6 ms
Min: 143.7 mm
Tmin: 331.8 ms
CFC 180

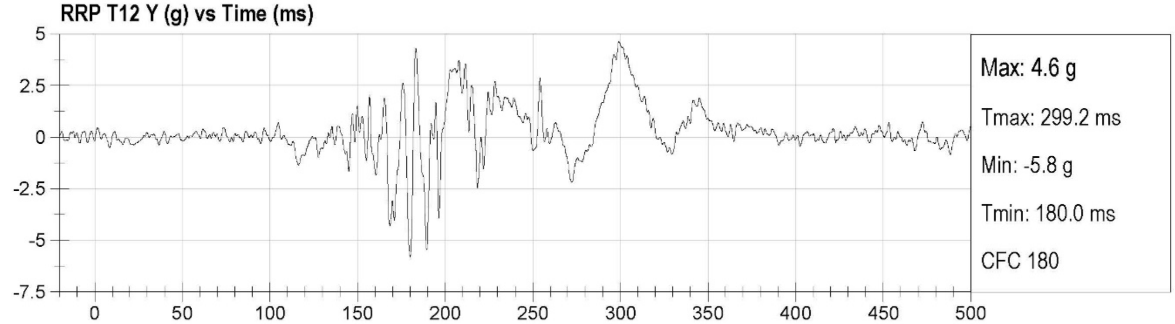

RRP UPPER LEFT CHEST POTENTIOMETER Y (deg) vs Time (ms)
Max: 19.5 deg
Tmax: 223.2 ms
Min: 9.4 deg
Tmin: 41.7 ms
CFC 180


RRP UPPER LEFT CHEST POTENTIOMETER Z (deg) vs Time (ms)
Max: 15.5 deg
Tmax: 346.5 ms
Min: 12.2 deg
Tmin: 172.9 ms
CFC 180

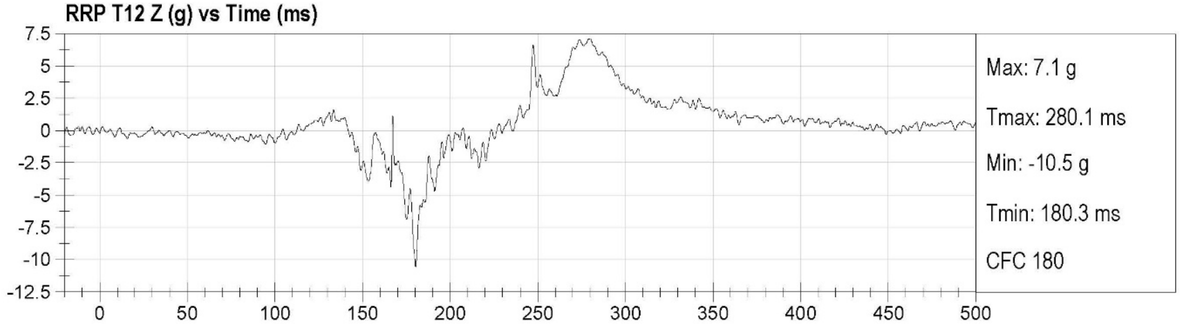
RRP T12 X (g) vs Time (ms)



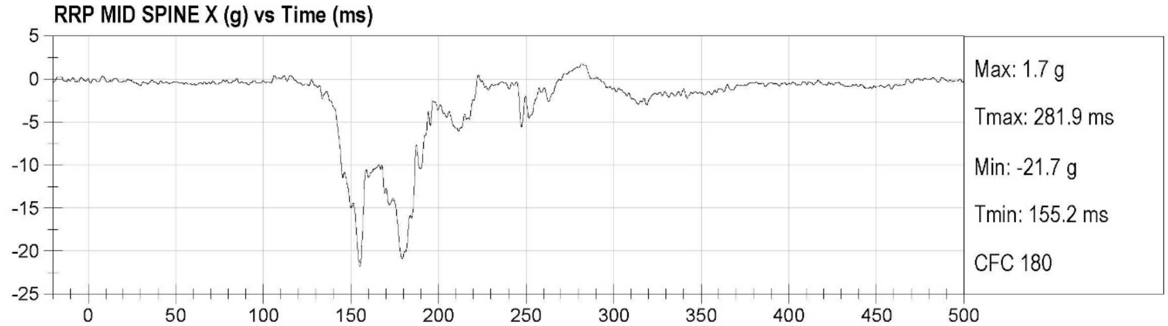

RRP T12 Y (g) vs Time (ms)

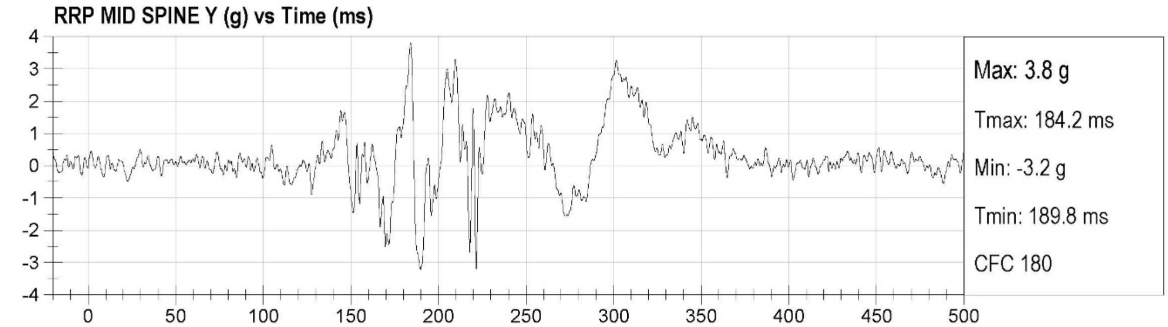


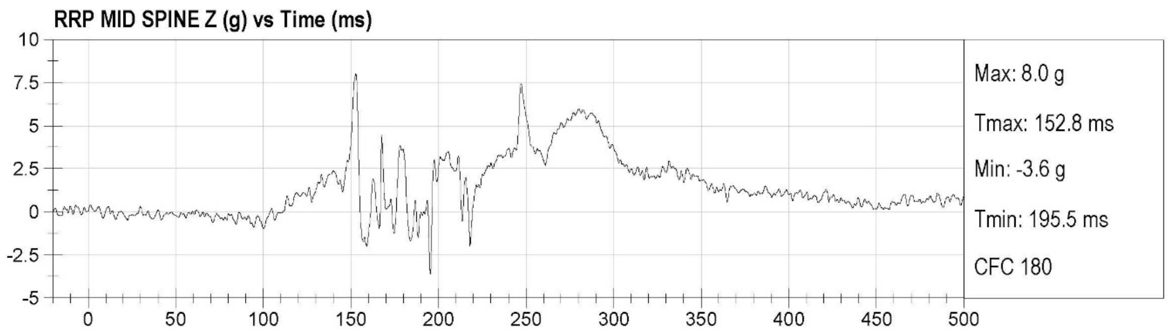

RRP T12 Z (g) vs Time (ms)

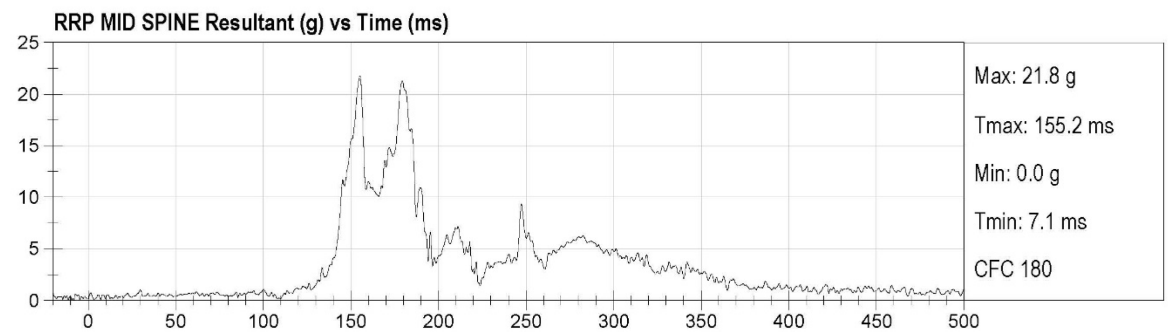


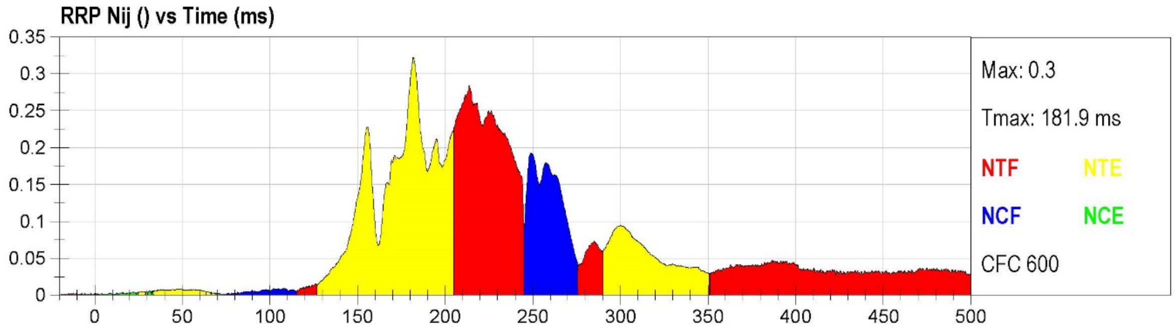

RRP T12 Resultant (g) vs Time (ms)

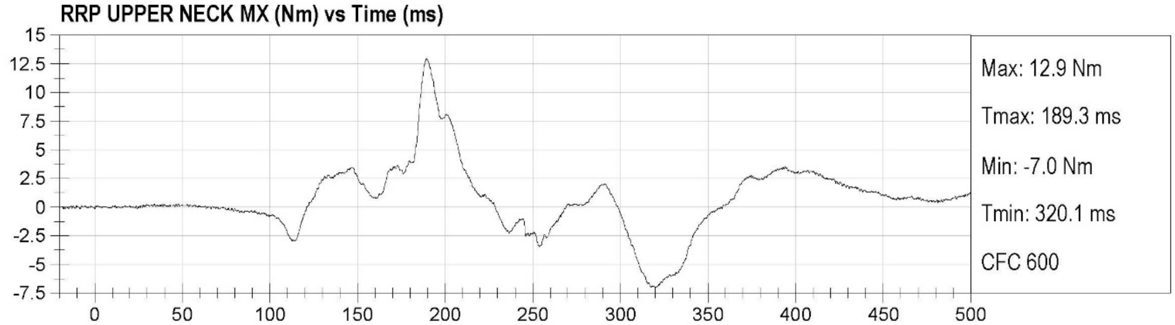

RRP MID SPINE X (g) vs Time (ms)
Max: 1.7 g
Tmax: 281.9 ms
Min: -21.7 g
Tmin: 155.2 ms
CFC 180

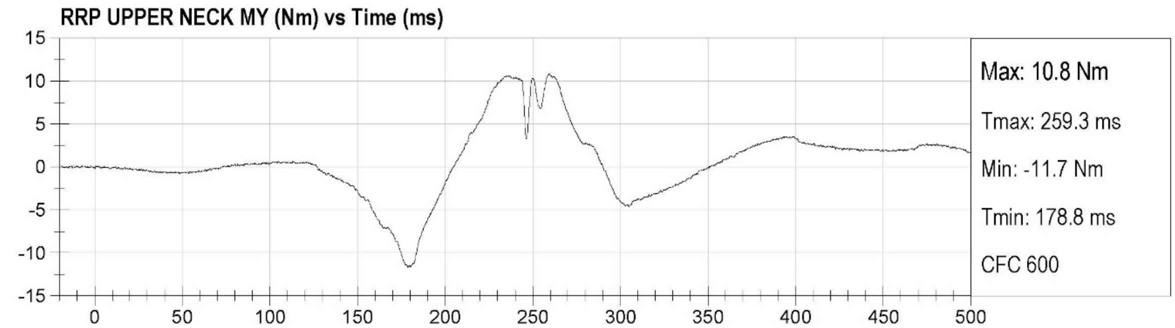

RRP MID SPINE Y (g) vs Time (ms)
Max: 3.8 g
Tmax: 184.2 ms
Min: -3.2 g
Tmin: 189.8 ms
CFC 180

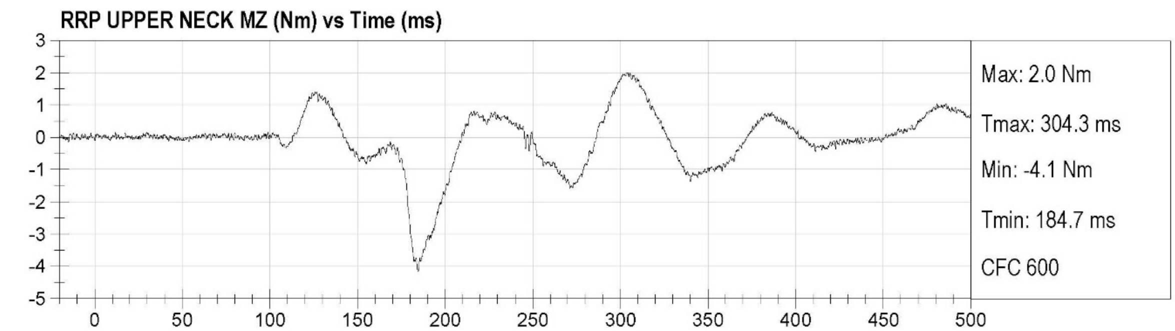

RRP MID SPINE Z (g) vs Time (ms)
Max: 8.0 g
Tmax: 152.8 ms
Min: -3.6 g
Tmin: 195.5 ms
CFC 180

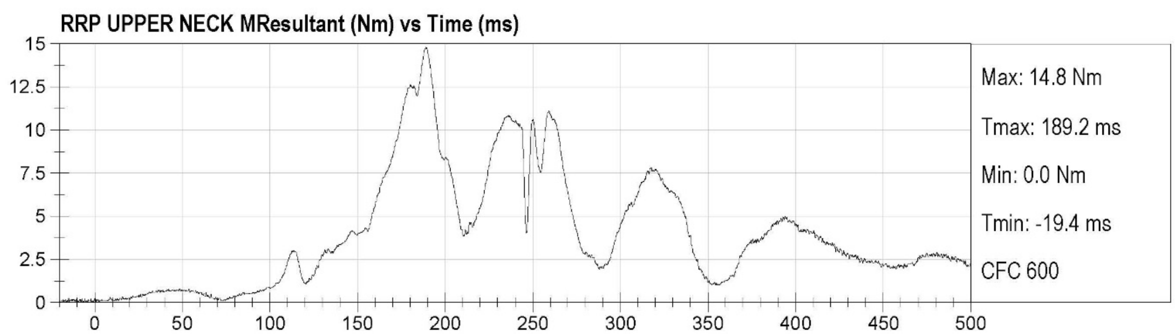

RRP MID SPINE Resultant (g) vs Time (ms)
Max: 21.8 g
Tmax: 155.2 ms
Min: 0.0 g
Tmin: 7.1 ms
CFC 180


RRP Nij () vs Time (ms)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
50
100
150
200
250
300
350
400
450
500
Max: 0.3
Tmax: 181.9 ms
NTF
NTE
NCF
NCE
CFC 600

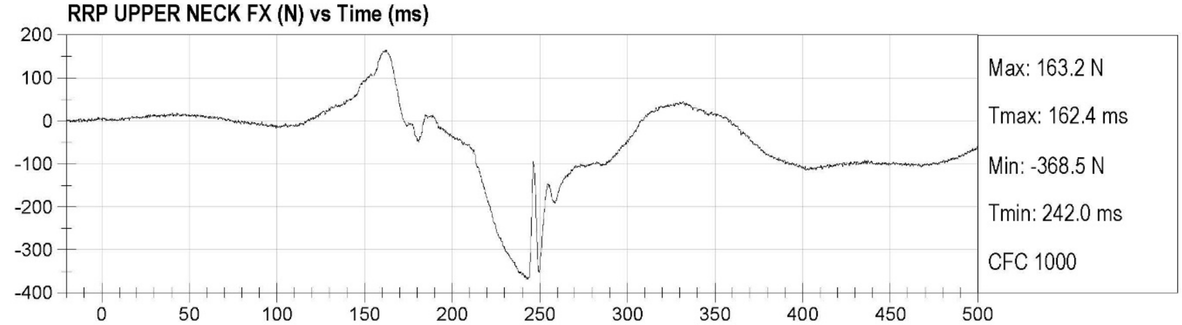

RRP UPPER NECK MX (Nm) vs Time (ms)
Max: 12.9 Nm
Tmax: 189.3 ms
Min: -7.0 Nm
Tmin: 320.1 ms
CFC 600


RRP UPPER NECK MY (Nm) vs Time (ms)
Max: 10.8 Nm
Tmax: 259.3 ms
Min: -11.7 Nm
Tmin: 178.8 ms
CFC 600

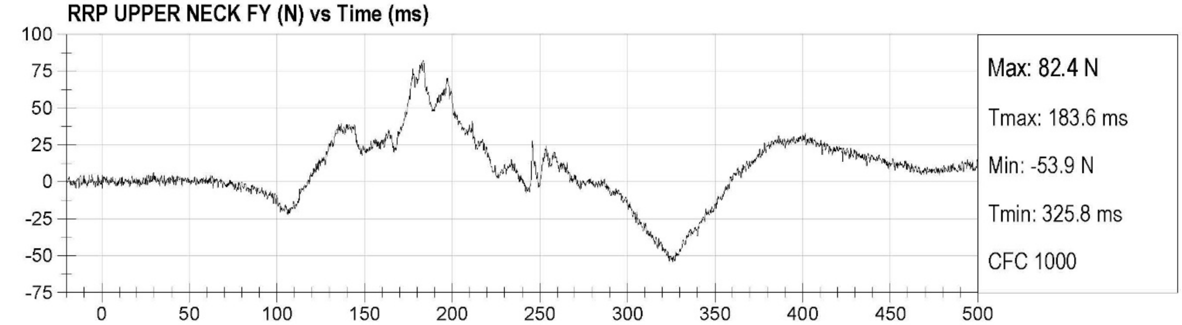

RRP UPPER NECK MZ (Nm) vs Time (ms)
Max: 2.0 Nm
Tmax: 304.3 ms
Min: -4.1 Nm
Tmin: 184.7 ms
CFC 600


RRP UPPER NECK MResultant (Nm) vs Time (ms)
Max: 14.8 Nm
Tmax: 189.2 ms
Min: 0.0 Nm
Tmin: -19.4 ms
CFC 600

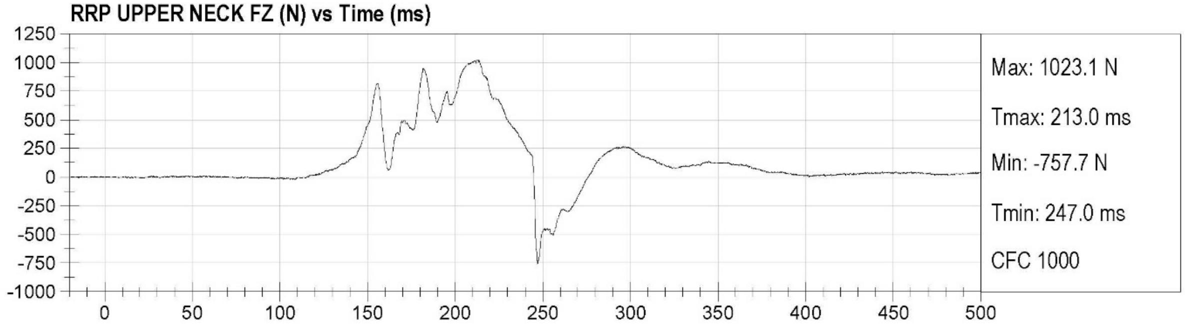
RRP UPPER NECK FX (N) vs Time (ms)



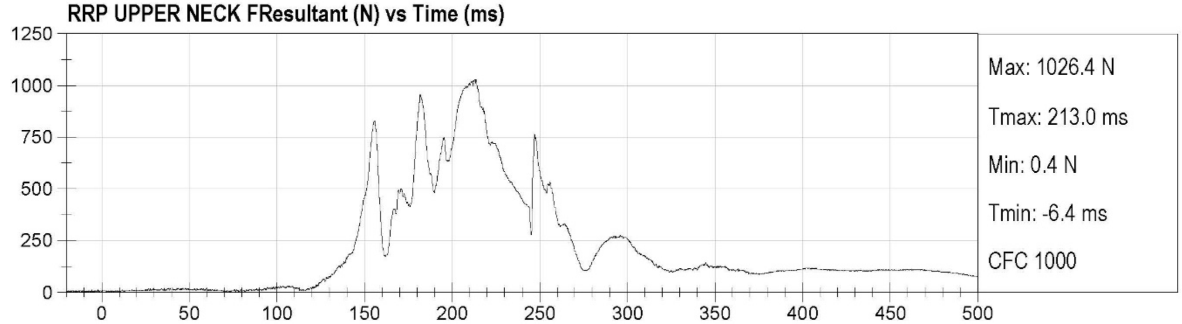

RRP UPPER NECK FY (N) vs Time (ms)



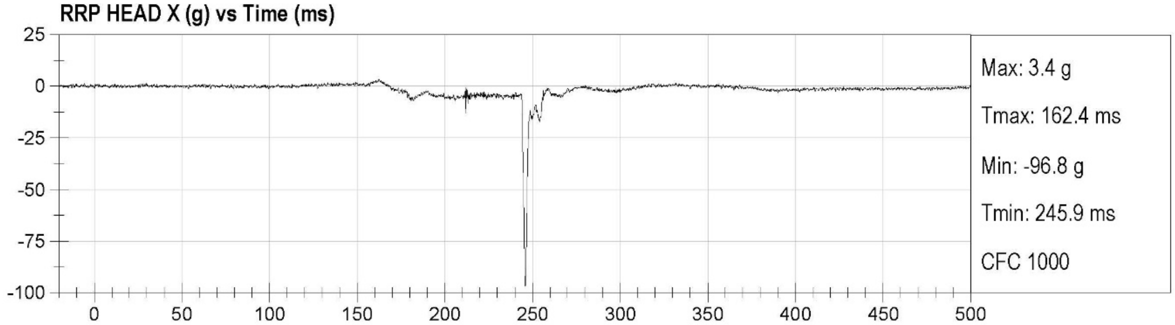

RRP UPPER NECK FZ (N) vs Time (ms)



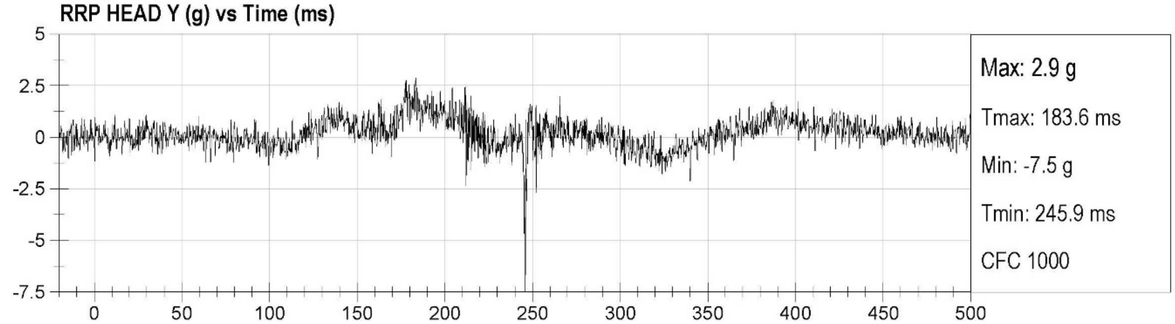

RRP UPPER NECK FResultant (N) vs Time (ms)



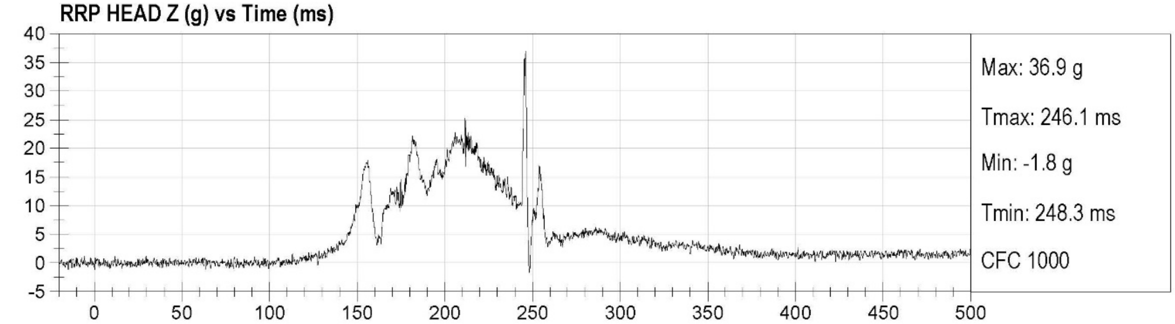
RRP HEAD X (g) vs Time (ms)



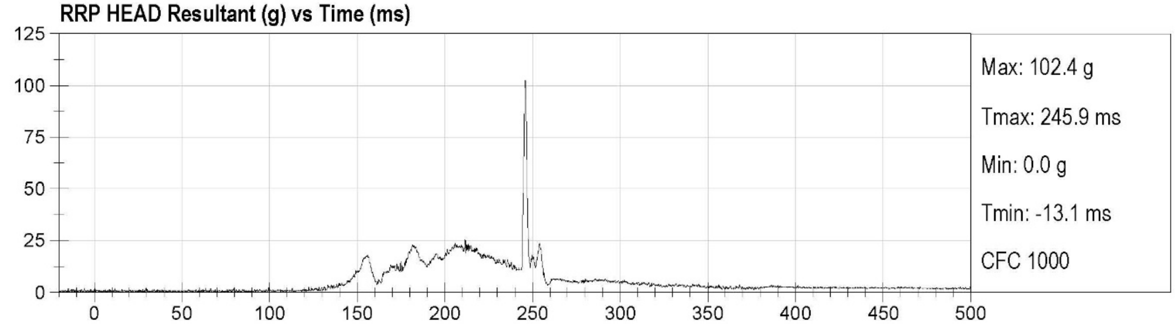

RRP HEAD Y (g) vs Time (ms)

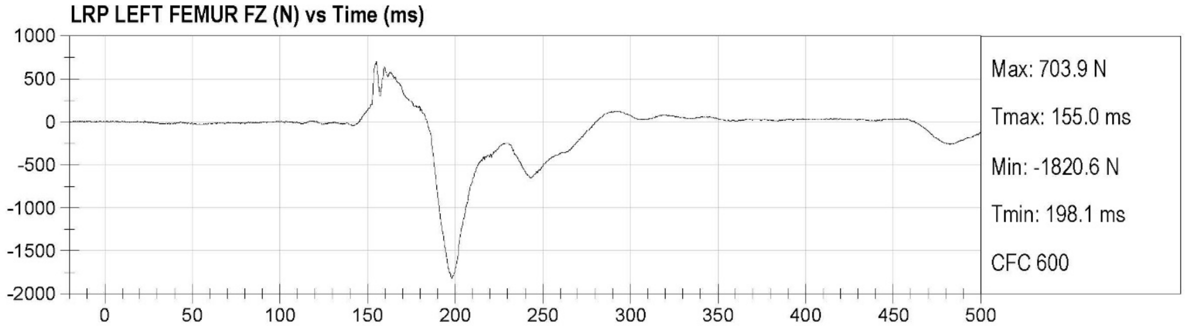


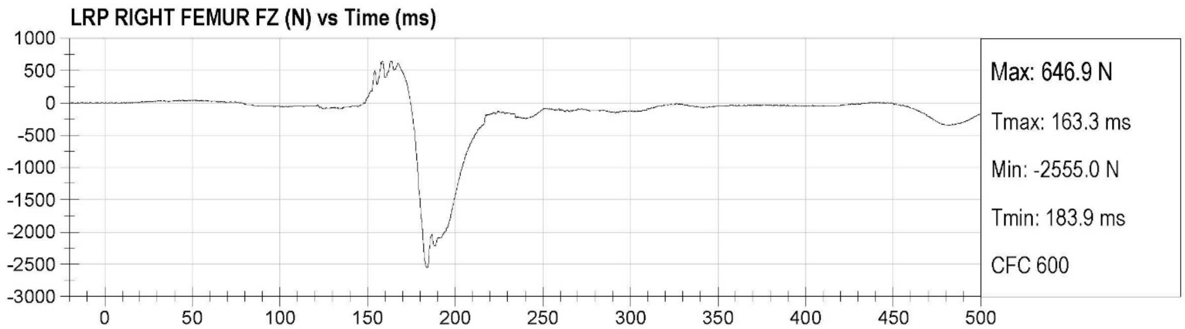

RRP HEAD Z (g) vs Time (ms)

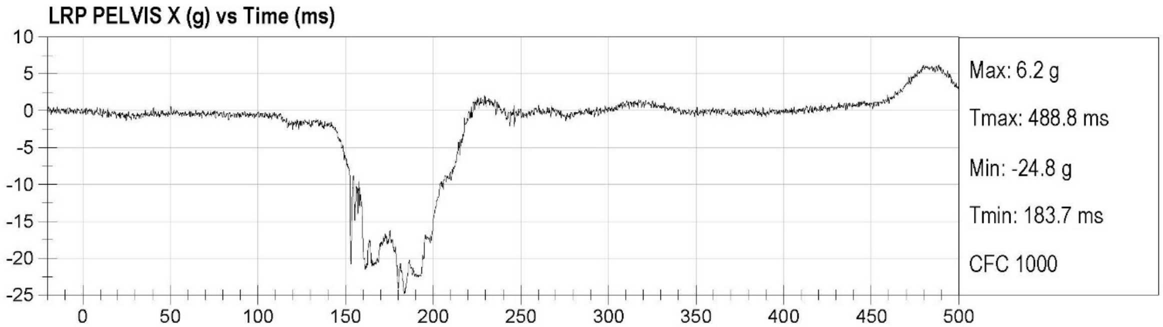


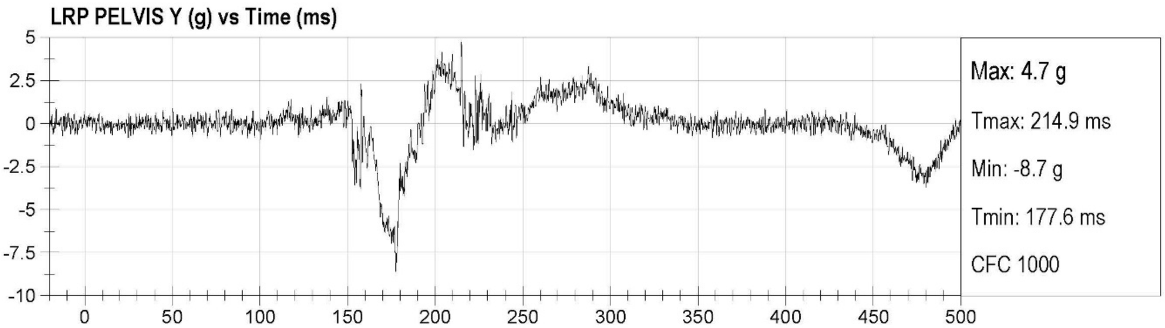

RRP HEAD Resultant (g) vs Time (ms)

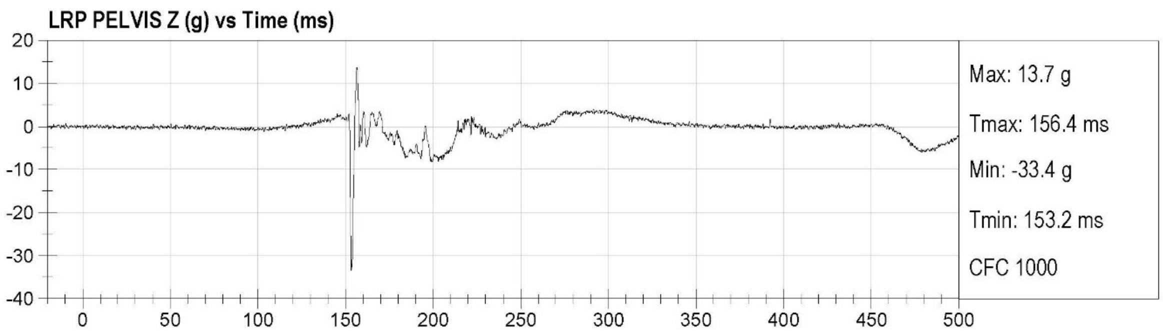


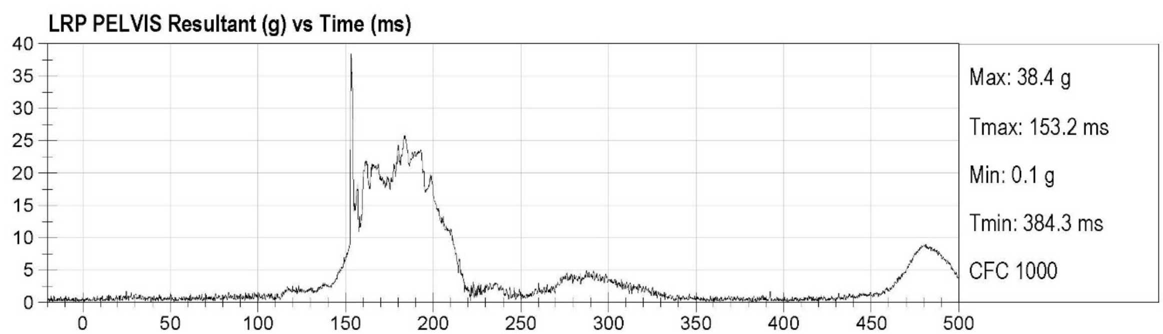

LRP LEFT FEMUR FZ (N) vs Time (ms)
Max: 703.9 N
Tmax: 155.0 ms
Min: -1820.6 N
Tmin: 198.1 ms
CFC 600

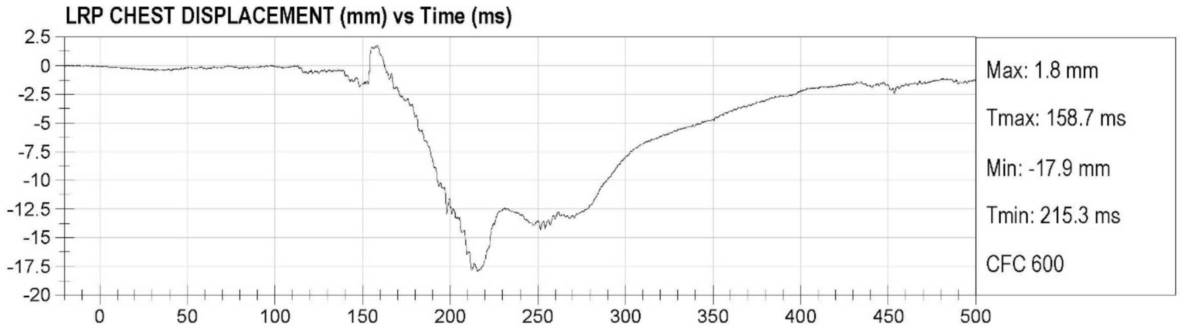

LRP RIGHT FEMUR FZ (N) vs Time (ms)
Max: 646.9 N
Tmax: 163.3 ms
Min: -2555.0 N
Tmin: 183.9 ms
CFC 600


LRP PELVIS X (g) vs Time (ms)
Max: 6.2 g
Tmax: 488.8 ms
Min: -24.8 g
Tmin: 183.7 ms
CFC 1000

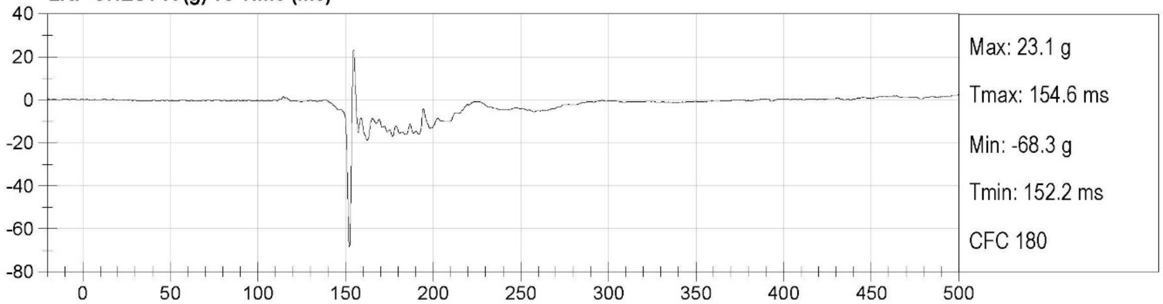

LRP PELVIS Y (g) vs Time (ms)
Max: 4.7 g
Tmax: 214.9 ms
Min: -8.7 g
Tmin: 177.6 ms
CFC 1000


LRP PELVIS Z (g) vs Time (ms)
Max: 13.7 g
Tmax: 156.4 ms
Min: -33.4 g
Tmin: 153.2 ms
CFC 1000

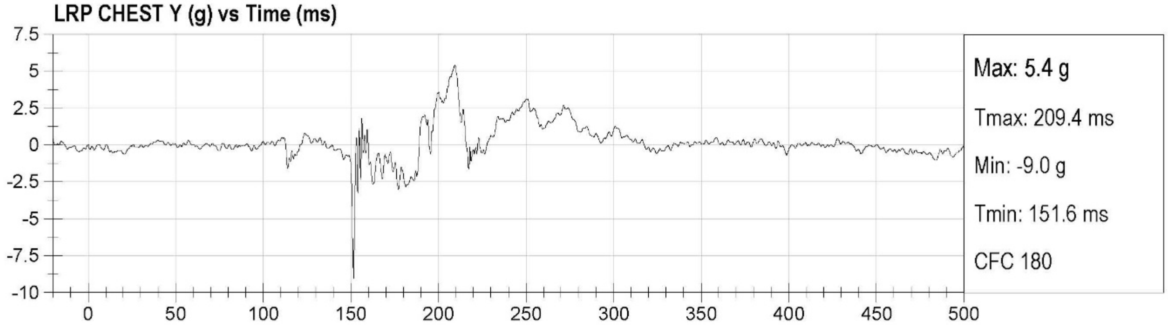

LRP PELVIS Resultant (g) vs Time (ms)
Max: 38.4 g
Tmax: 153.2 ms
Min: 0.1 g
Tmin: 384.3 ms
CFC 1000


LRP CHEST DISPLACEMENT (mm) vs Time (ms)
2.5
0
-2.5
-5
-7.5
-10
-12.5
-15
-17.5
-20
0
50
100
150
200
250
300
350
400
450
500
Max: 1.8 mm
Tmax: 158.7 ms
Min: -17.9 mm
Tmin: 215.3 ms
CFC 600

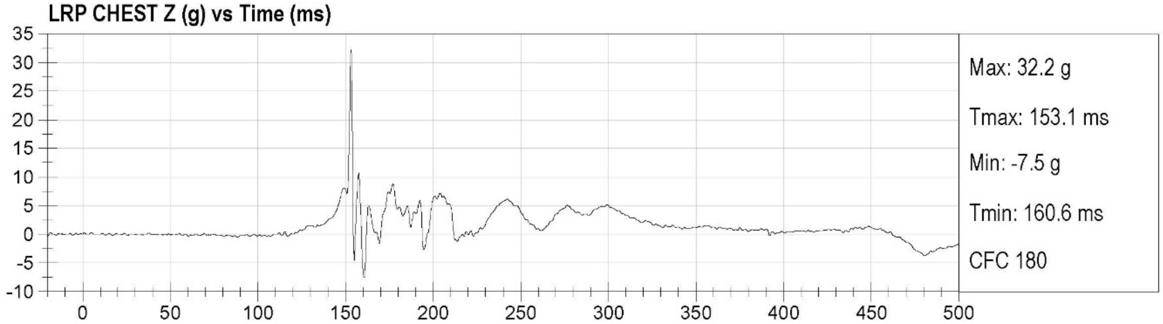
LRP CHEST X (g) vs Time (ms)



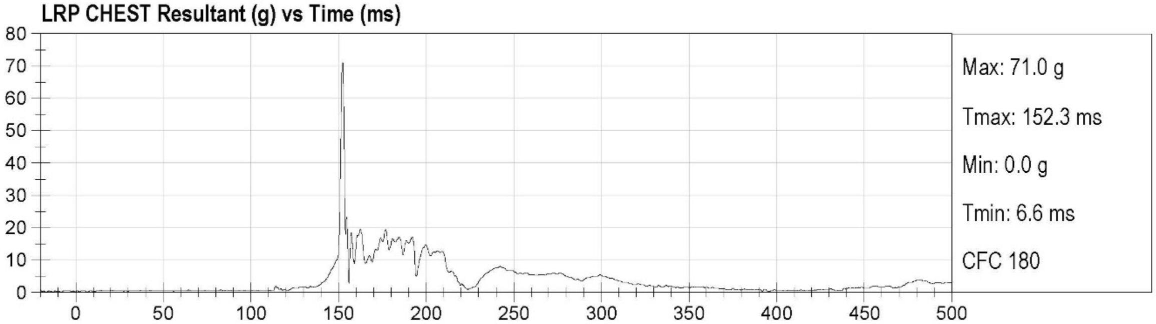

LRP CHEST Y (g) vs Time (ms)

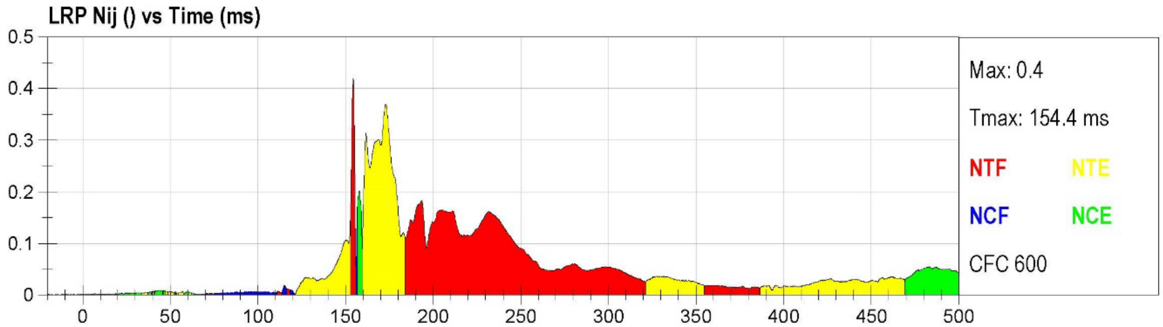



LRP CHEST Z (g) vs Time (ms)

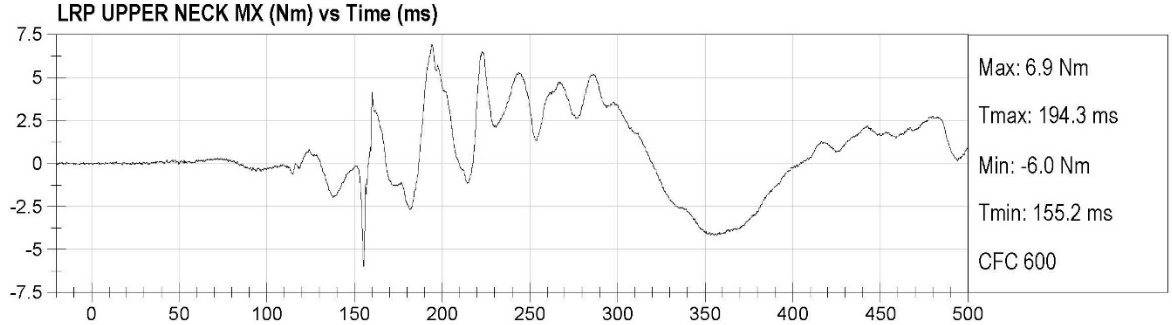



LRP CHEST Resultant (g) vs Time (ms)

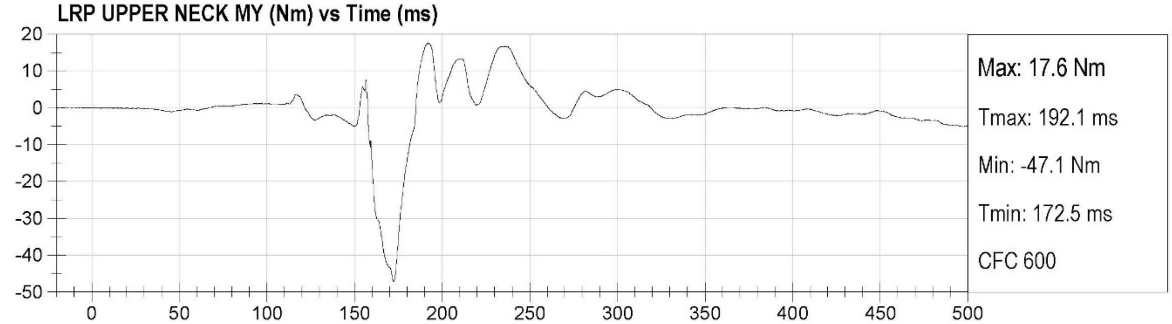



LRP Nij () vs Time (ms)
0.5
0.4
0.3
0.2
0.1
0
0
50
100
150
200
250
300
350
400
450
500
Max: 0.4
Tmax: 154.4 ms
NTF
NTE
NCF
NCE
CFC 600

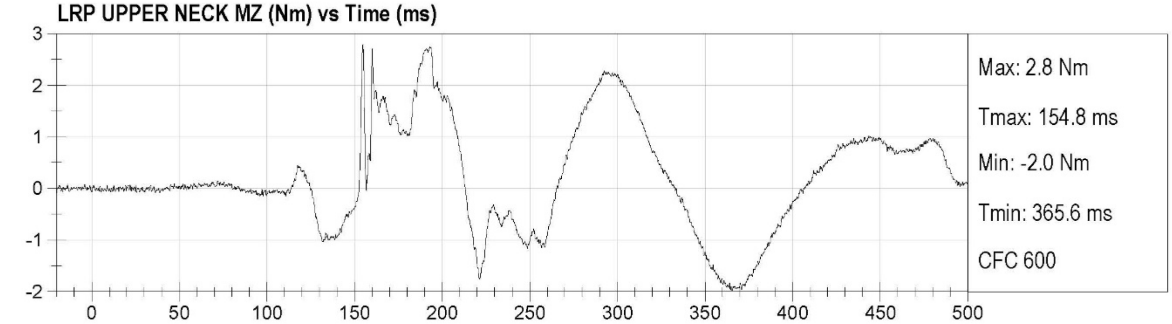
LRP UPPER NECK MX (Nm) vs Time (ms)



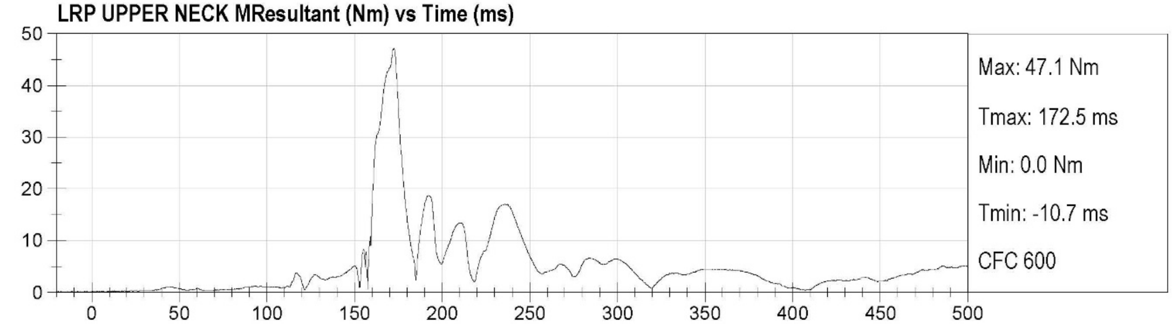

LRP UPPER NECK MY (Nm) vs Time (ms)



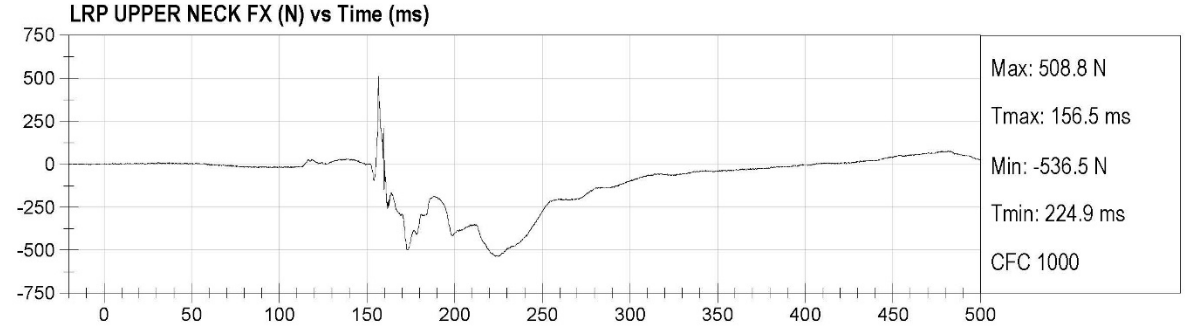

LRP UPPER NECK MZ (Nm) vs Time (ms)



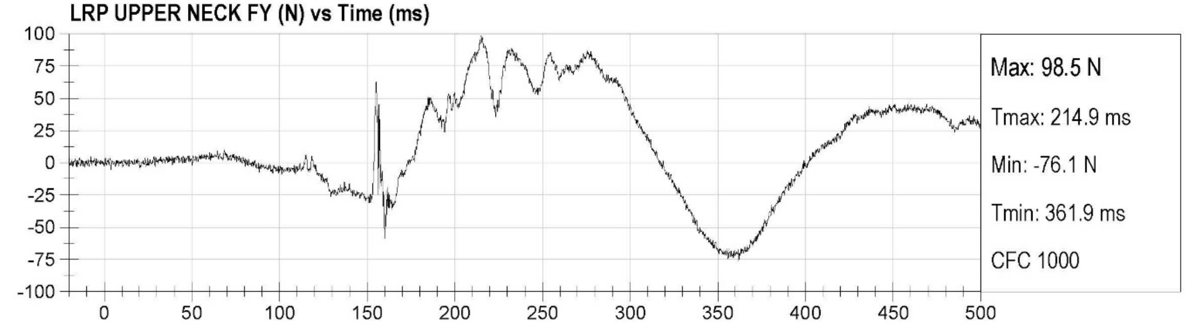

LRP UPPER NECK MResultant (Nm) vs Time (ms)



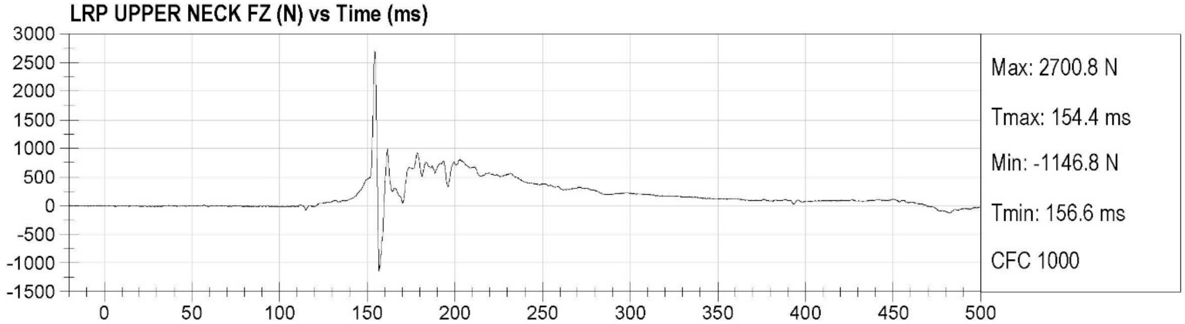
LRP UPPER NECK FX (N) vs Time (ms)



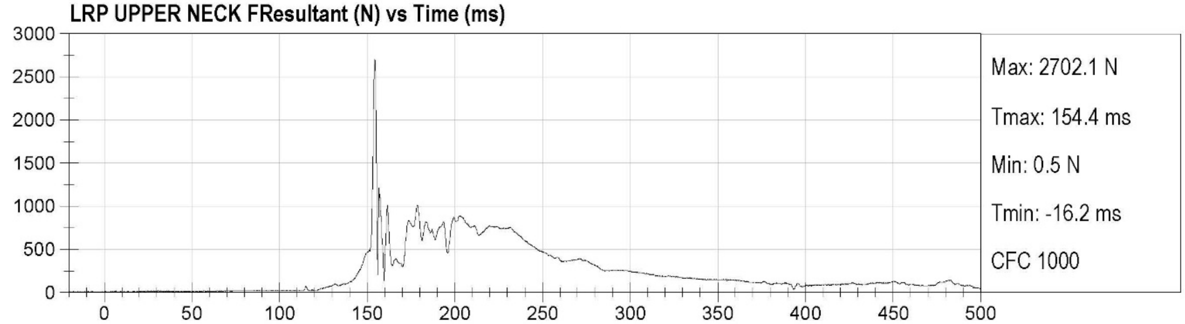

LRP UPPER NECK FY (N) vs Time (ms)

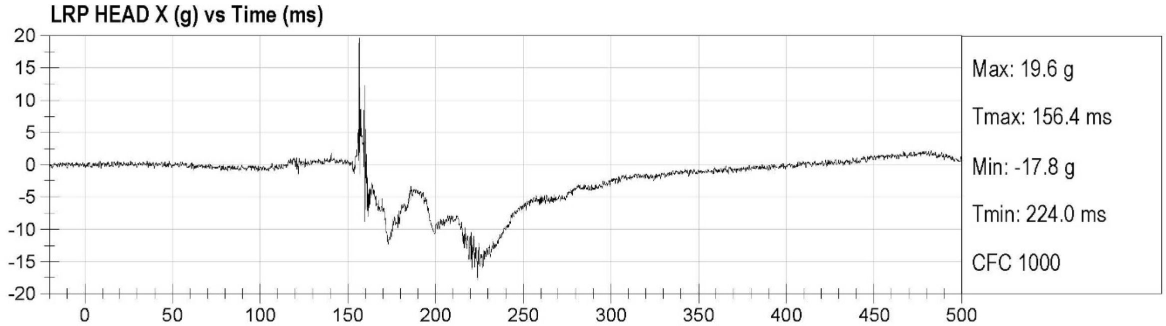


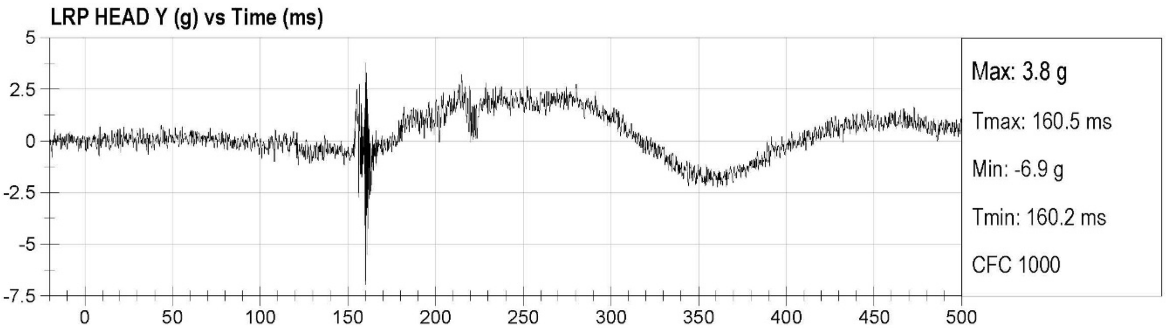

LRP UPPER NECK FZ (N) vs Time (ms)

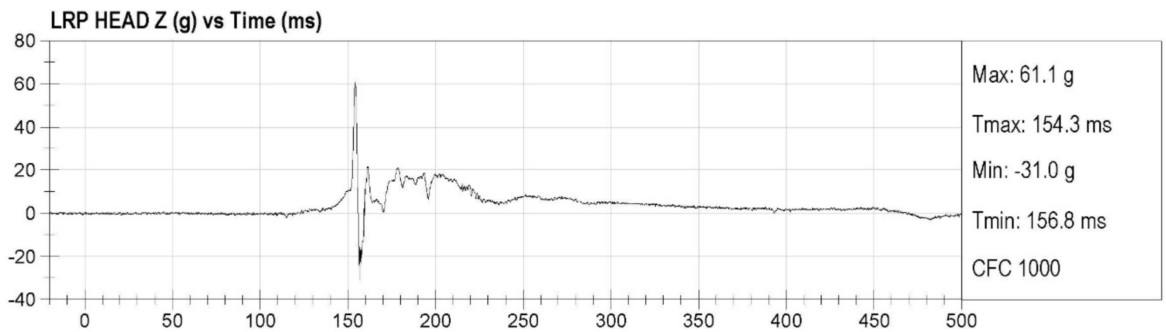



LRP UPPER NECK FResultant (N) vs Time (ms)




LRP HEAD X (g) vs Time (ms)
Max: 19.6 g
Tmax: 156.4 ms
Min: -17.8 g
Tmin: 224.0 ms
CFC 1000


LRP HEAD Y (g) vs Time (ms)
Max: 3.8 g
Tmax: 160.5 ms
Min: -6.9 g
Tmin: 160.2 ms
CFC 1000

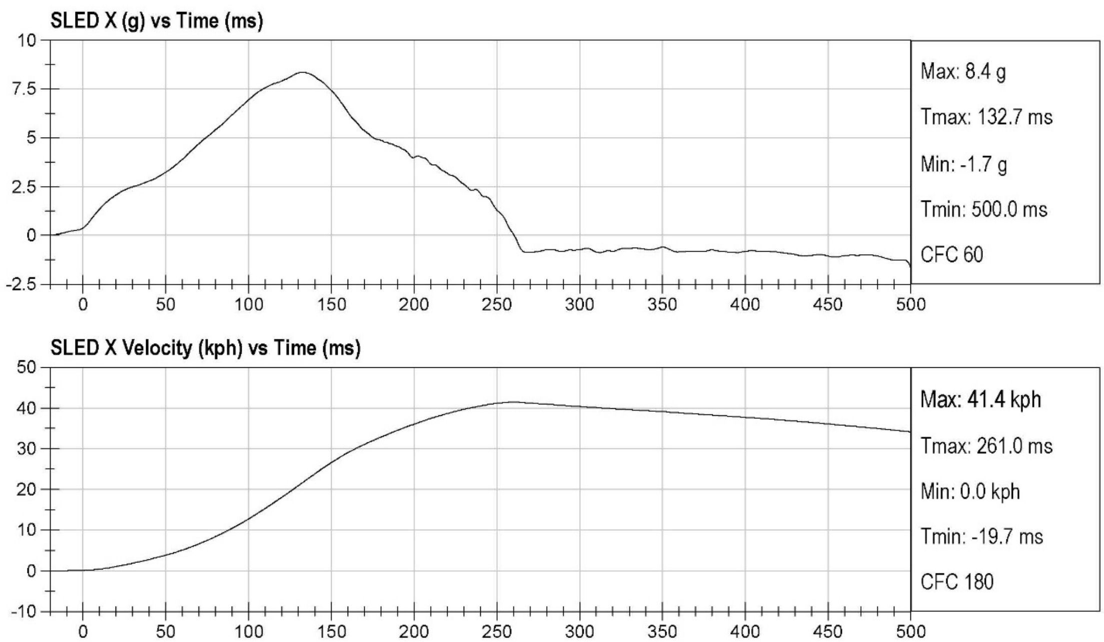

LRP HEAD Z (g) vs Time (ms)
Max: 61.1 g
Tmax: 154.3 ms
Min: -31.0 g
Tmin: 156.8 ms
CFC 1000

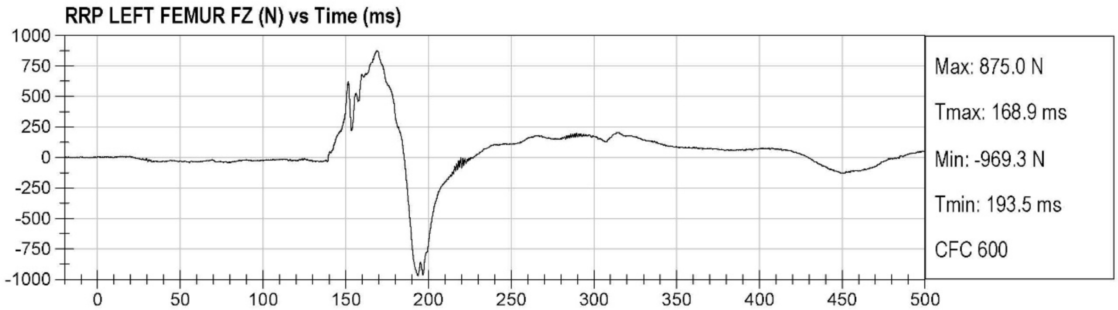

LRP HEAD Resultant (g) vs Time (ms)
Max: 61.1 g
Tmax: 154.3 ms
Min: 0.1 g
Tmin: 9.8 ms
CFC 1000

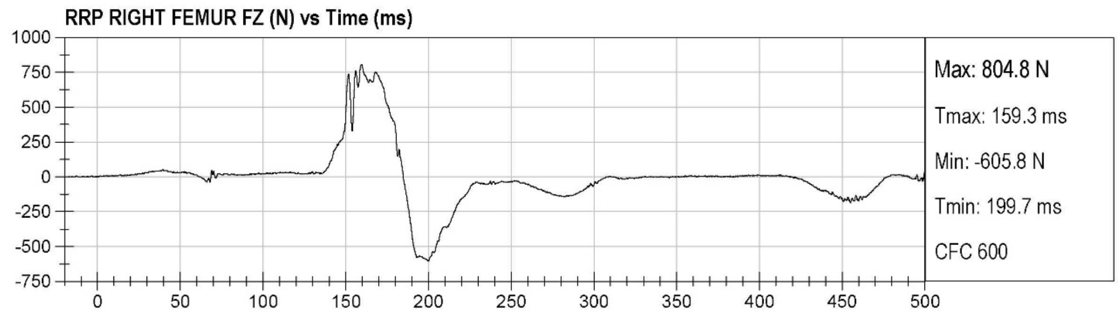
## A.9 Test 3BD Data

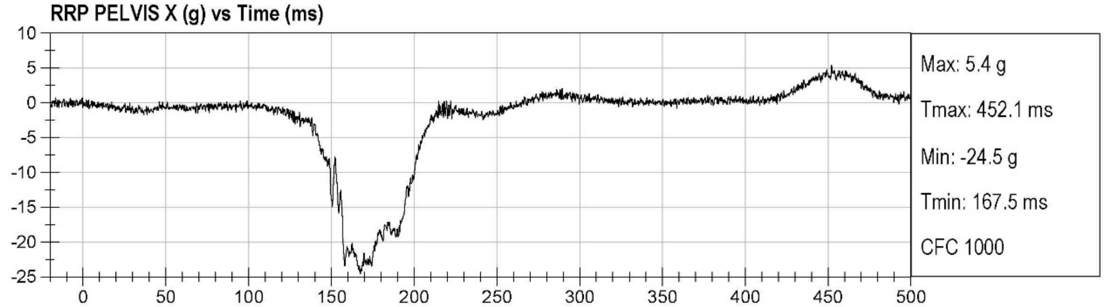
Test Date: 05/10/2021

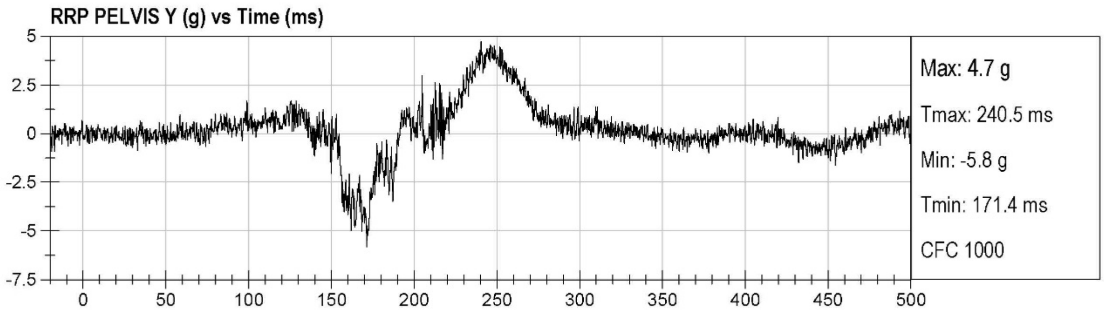
MGA Test ID: S21141

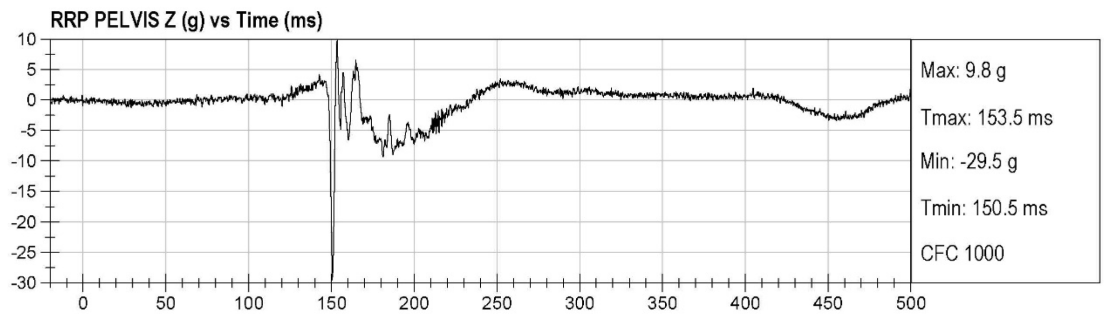


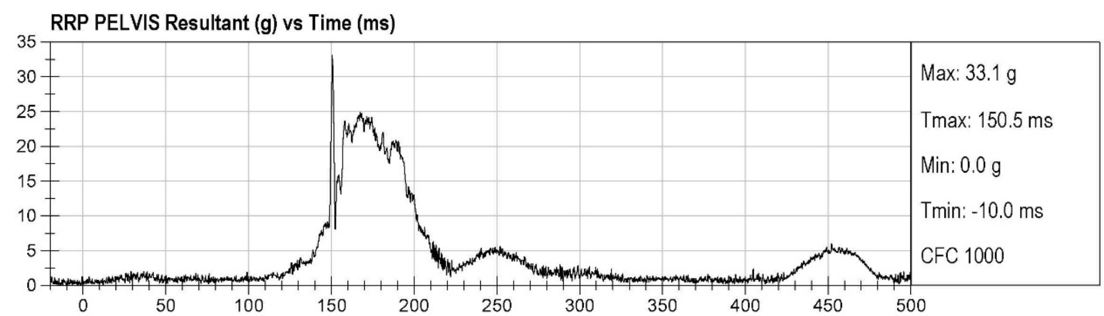

RRP LEFT FEMUR FZ (N) vs Time (ms)
Max: 875.0 N
Tmax: 168.9 ms
Min: -969.3 N
Tmin: 193.5 ms
CFC 600

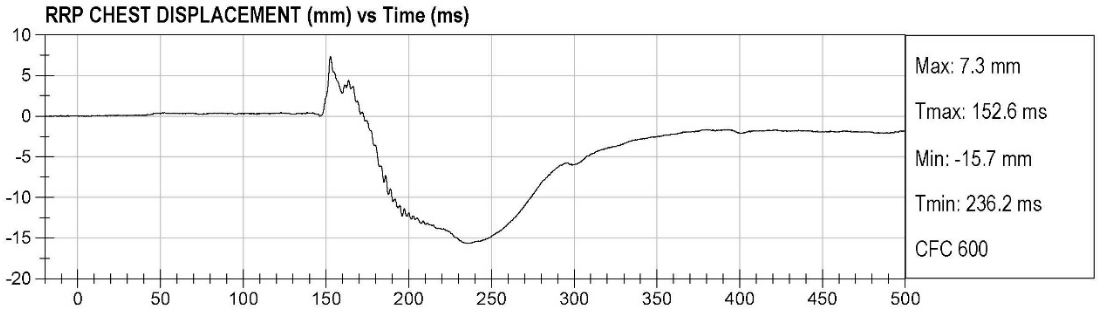

RRP RIGHT FEMUR FZ (N) vs Time (ms)
Max: 804.8 N
Tmax: 159.3 ms
Min: -605.8 N
Tmin: 199.7 ms
CFC 600

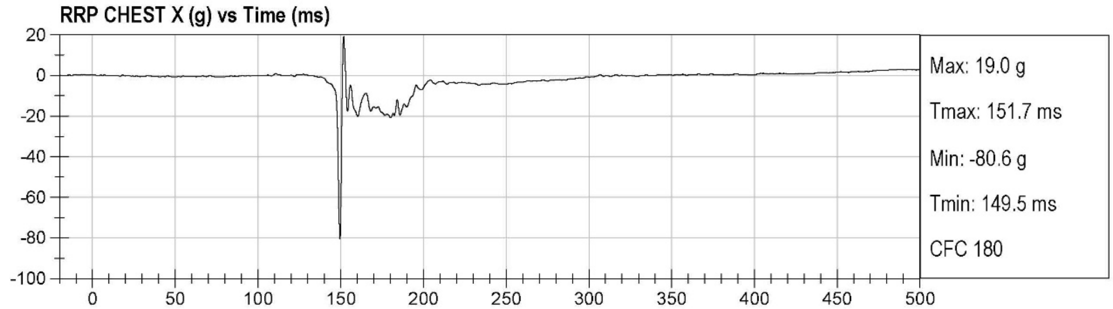

RRP PELVIS X (g) vs Time (ms)
Max: 5.4 g
Tmax: 452.1 ms
Min: -24.5 g
Tmin: 167.5 ms
CFC 1000

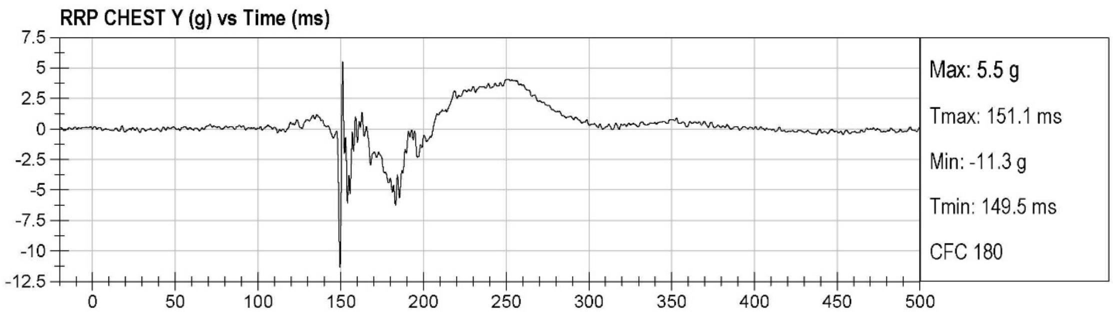

RRP PELVIS Y (g) vs Time (ms)
Max: 4.7 g
Tmax: 240.5 ms
Min: -5.8 g
Tmin: 171.4 ms
CFC 1000


RRP PELVIS Z (g) vs Time (ms)
Max: 9.8 g
Tmax: 153.5 ms
Min: -29.5 g
Tmin: 150.5 ms
CFC 1000

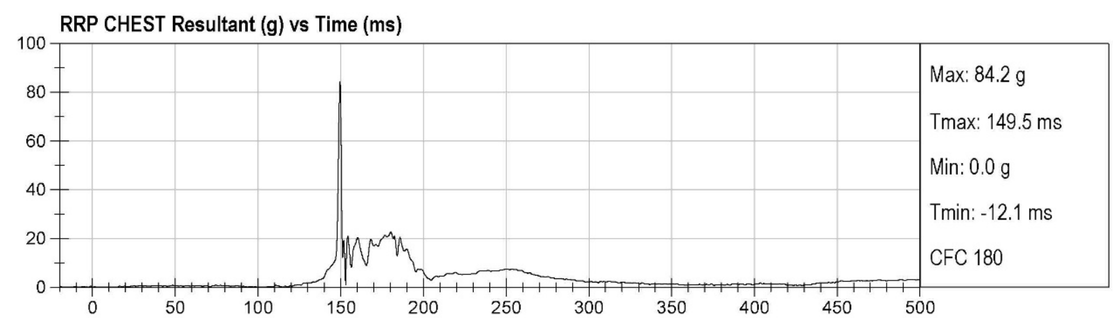

RRP PELVIS Resultant (g) vs Time (ms)
Max: 33.1 g
Tmax: 150.5 ms
Min: 0.0 g
Tmin: -10.0 ms
CFC 1000

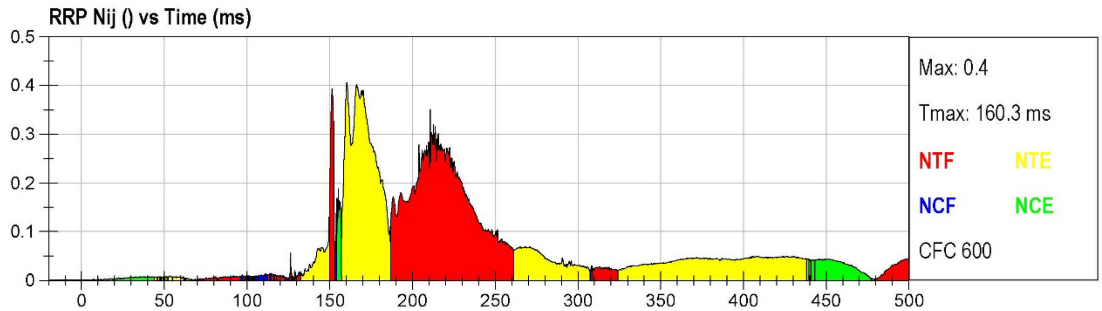

RRP CHEST DISPLACEMENT (mm) vs Time (ms)
Max: 7.3 mm
Tmax: 152.6 ms
Min: -15.7 mm
Tmin: 236.2 ms
CFC 600
10
5
0
-5
-10
-15
-20
0
50
100
150
200
250
300
350
400
450
500


RRP CHEST X (g) vs Time (ms)
Max: 19.0 g
Tmax: 151.7 ms
Min: -80.6 g
Tmin: 149.5 ms
CFC 180

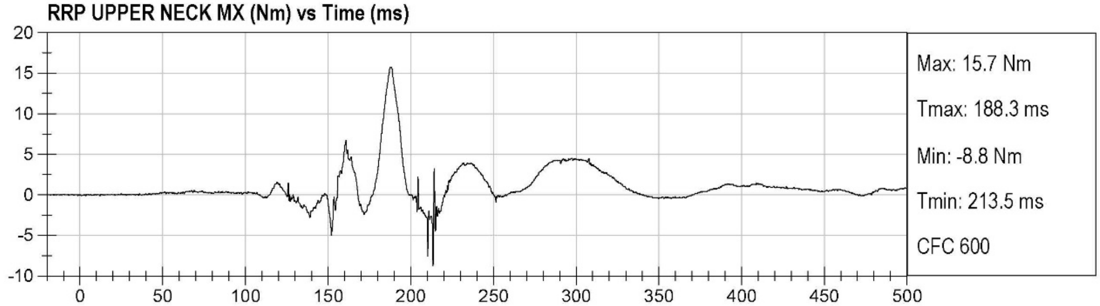

RRP CHEST Y (g) vs Time (ms)
Max: 5.5 g
Tmax: 151.1 ms
Min: -11.3 g
Tmin: 149.5 ms
CFC 180


RRP CHEST Z (g) vs Time (ms)
Max: 24.4 g
Tmax: 150.0 ms
Min: -3.9 g
Tmin: 196.0 ms
CFC 180

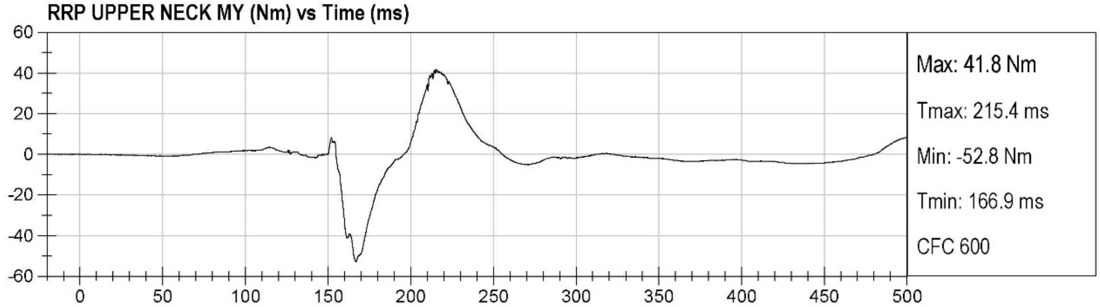

RRP CHEST Resultant (g) vs Time (ms)
Max: 84.2 g
Tmax: 149.5 ms
Min: 0.0 g
Tmin: -12.1 ms
CFC 180


RRP Nij () vs Time (ms)
0.5
0.4
0.3
0.2
0.1
0
0
50
100
150
200
250
300
350
400
450
500
Max: 0.4
Tmax: 160.3 ms
NTF
NTE
NCF
NCE
CFC 600

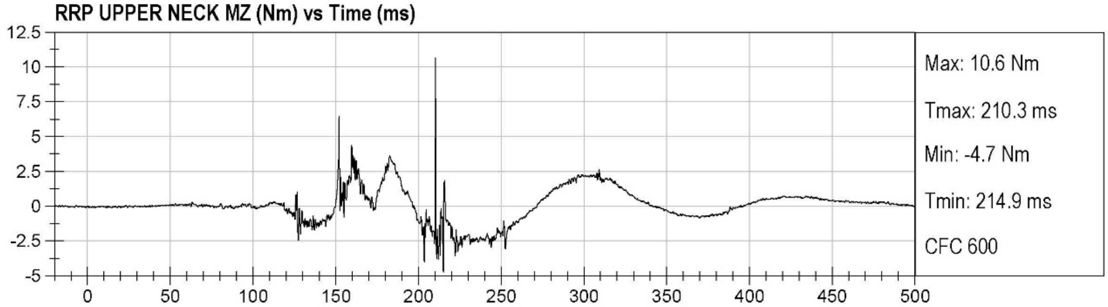
RRP UPPER NECK MX (Nm) vs Time (ms)



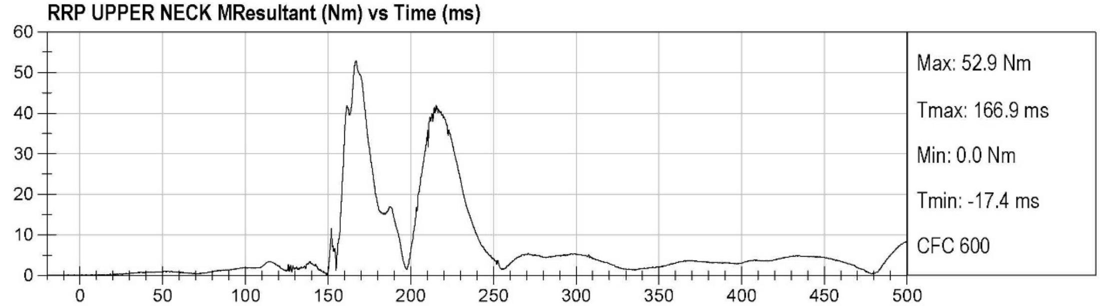

RRP UPPER NECK MY (Nm) vs Time (ms)



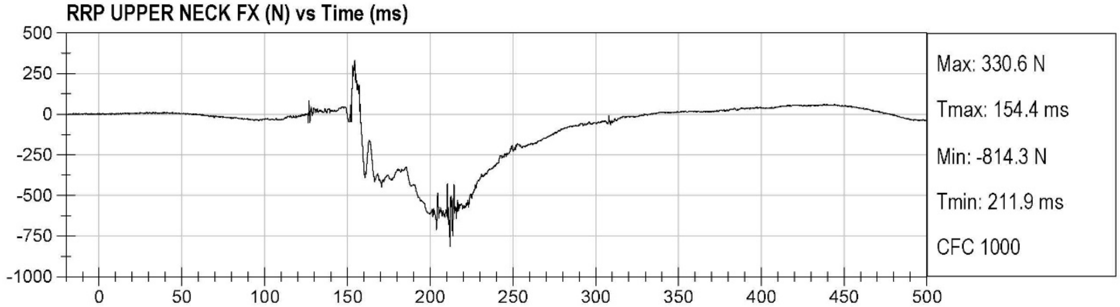

RRP UPPER NECK MZ (Nm) vs Time (ms)



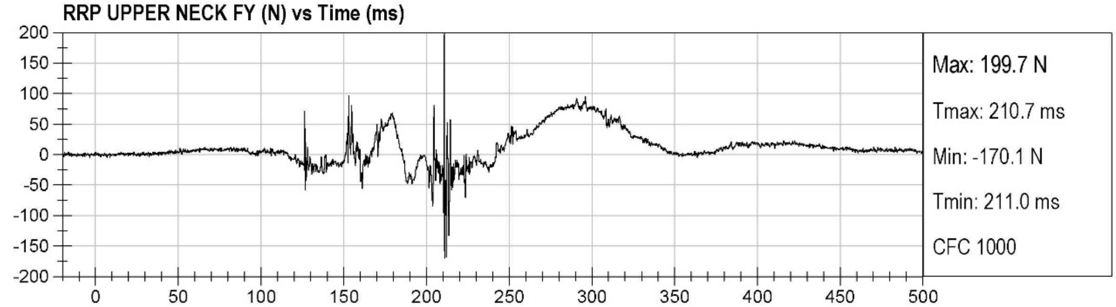

RRP UPPER NECK MResultant (Nm) vs Time (ms)



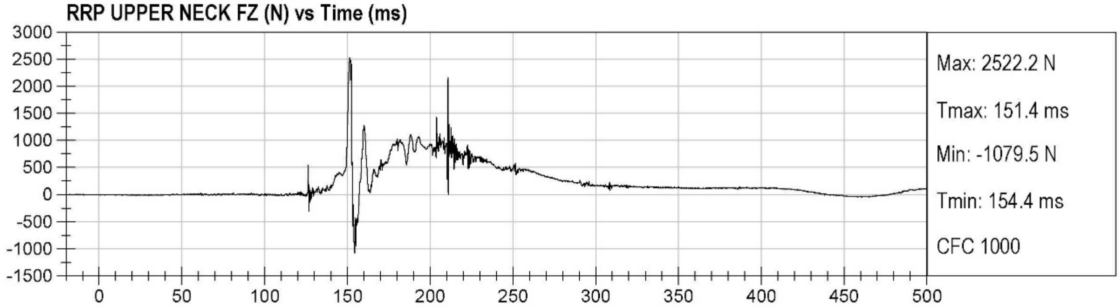
RRP UPPER NECK FX (N) vs Time (ms)



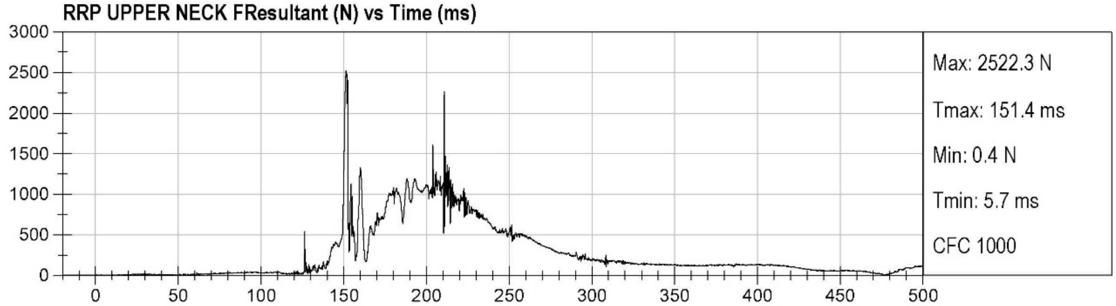

RRP UPPER NECK FY (N) vs Time (ms)

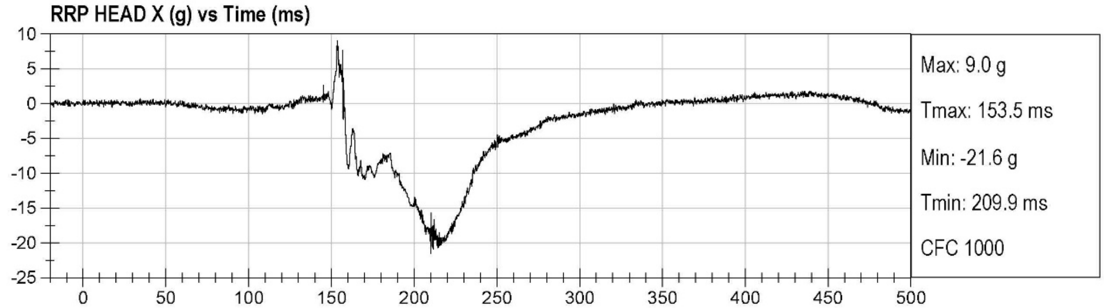


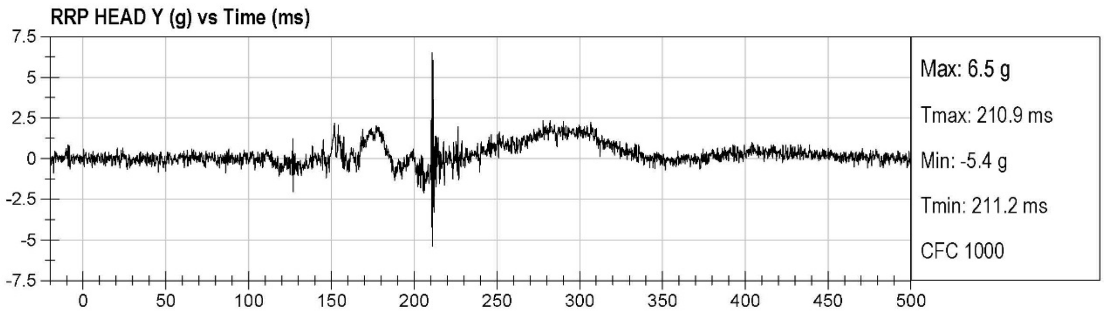

RRP UPPER NECK FZ (N) vs Time (ms)

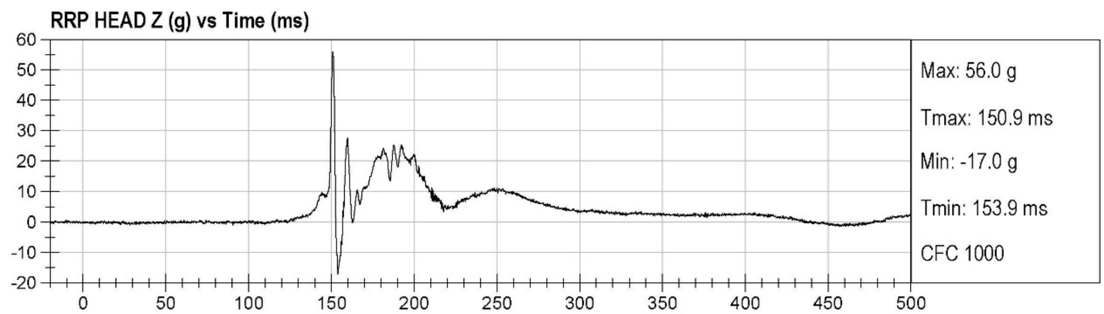


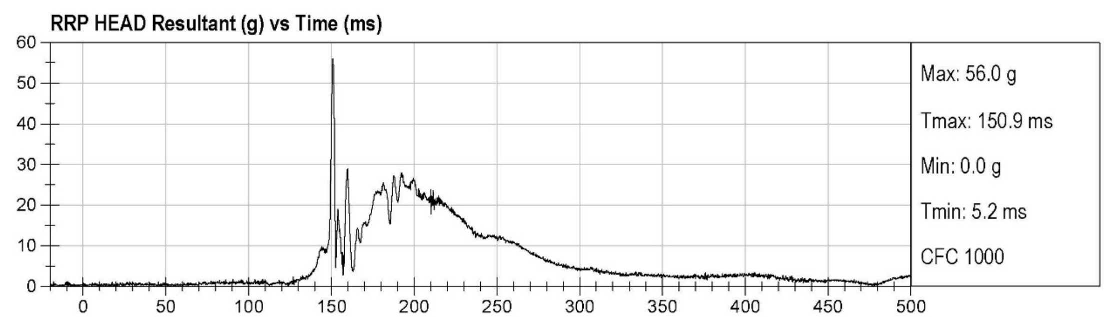

RRP UPPER NECK FResultant (N) vs Time (ms)

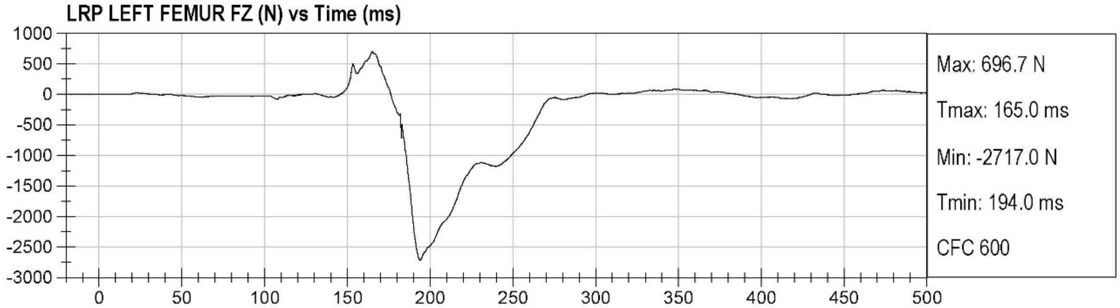


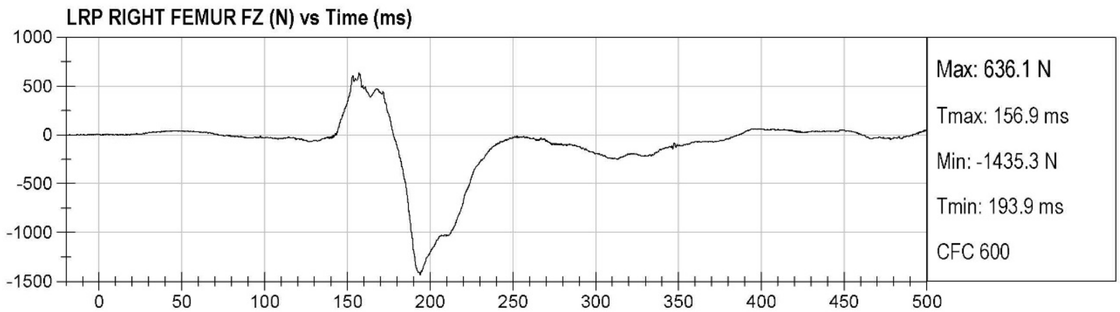

RRP HEAD X (g) vs Time (ms)
Max: 9.0 g
Tmax: 153.5 ms
Min: -21.6 g
Tmin: 209.9 ms
CFC 1000

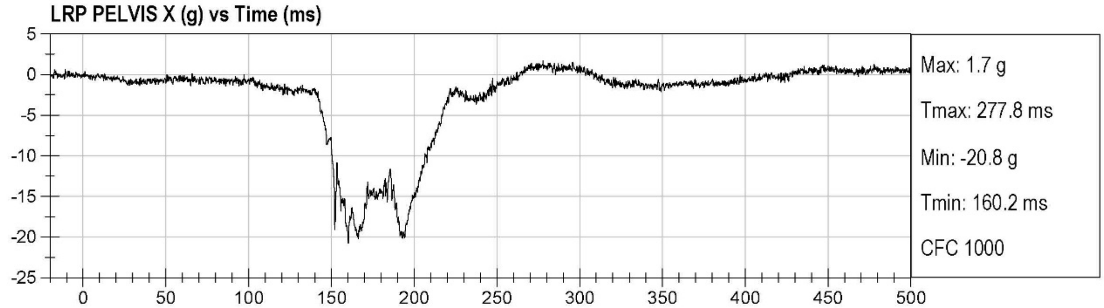

RRP HEAD Y (g) vs Time (ms)
Max: 6.5 g
Tmax: 210.9 ms
Min: -5.4 g
Tmin: 211.2 ms
CFC 1000

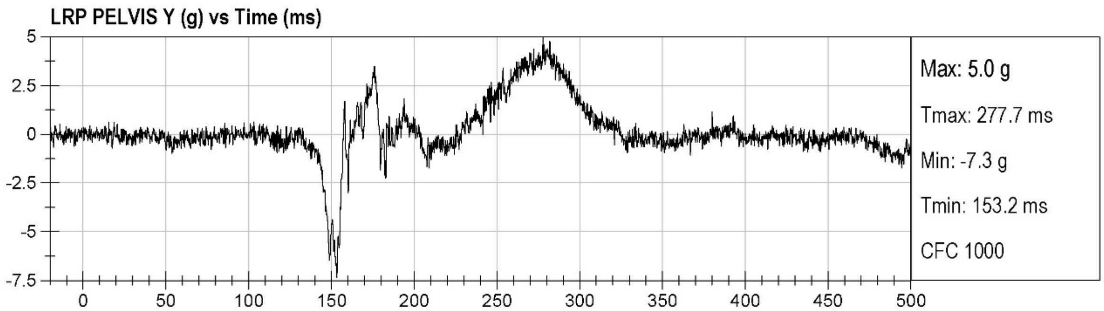

RRP HEAD Z (g) vs Time (ms)
Max: 56.0 g
Tmax: 150.9 ms
Min: -17.0 g
Tmin: 153.9 ms
CFC 1000

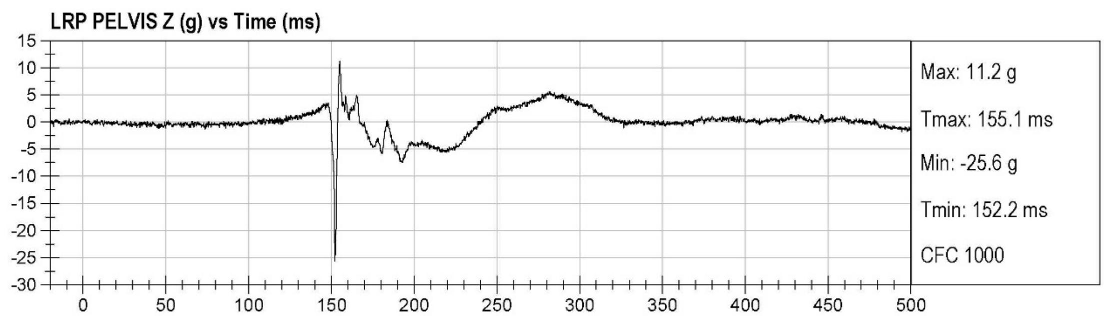

RRP HEAD Resultant (g) vs Time (ms)
Max: 56.0 g
Tmax: 150.9 ms
Min: 0.0 g
Tmin: 5.2 ms
CFC 1000

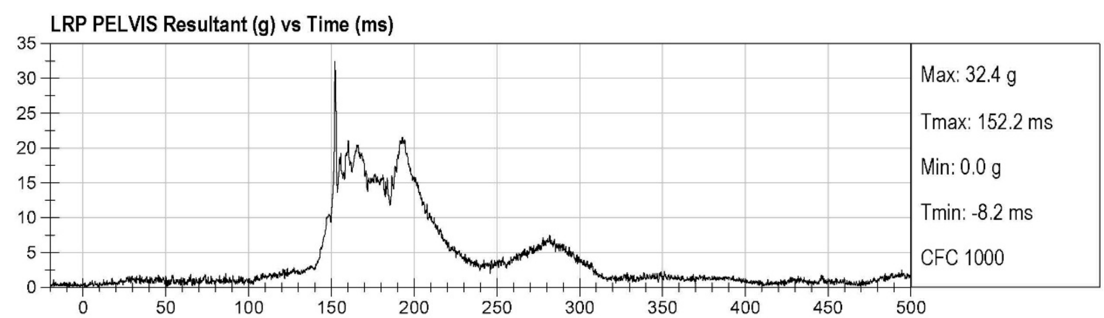

LRP LEFT FEMUR FZ (N) vs Time (ms)
Max: 696.7 N
Tmax: 165.0 ms
Min: -2717.0 N
Tmin: 194.0 ms
CFC 600

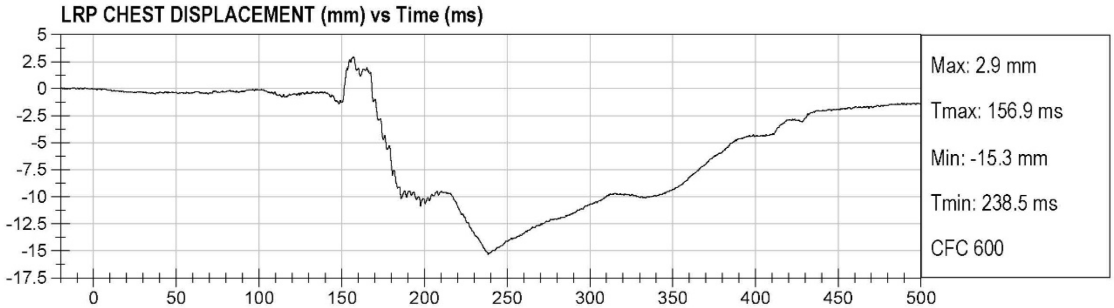

LRP RIGHT FEMUR FZ (N) vs Time (ms)
Max: 636.1 N
Tmax: 156.9 ms
Min: -1435.3 N
Tmin: 193.9 ms
CFC 600

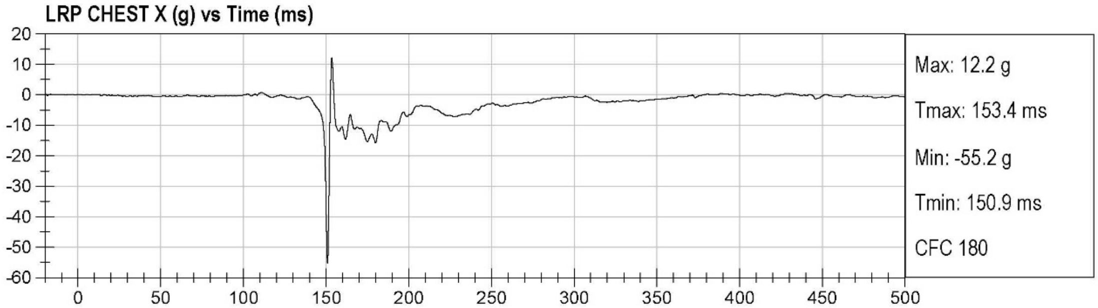

LRP PELVIS X (g) vs Time (ms)
Max: 1.7 g
Tmax: 277.8 ms
Min: -20.8 g
Tmin: 160.2 ms
CFC 1000

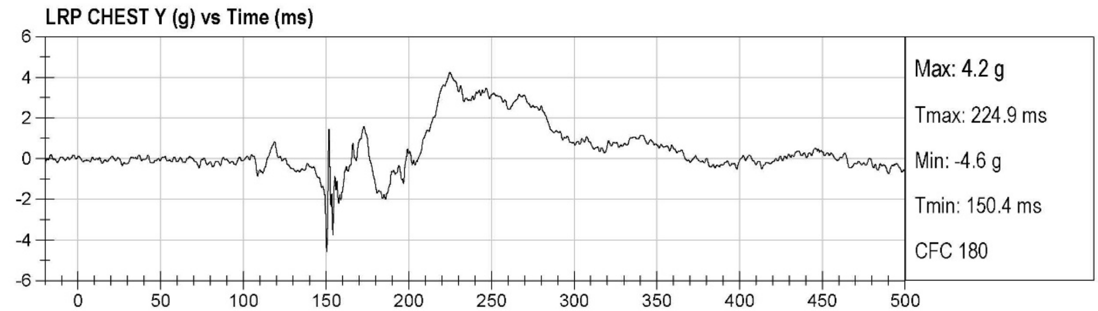

LRP PELVIS Y (g) vs Time (ms)
Max: 5.0 g
Tmax: 277.7 ms
Min: -7.3 g
Tmin: 153.2 ms
CFC 1000

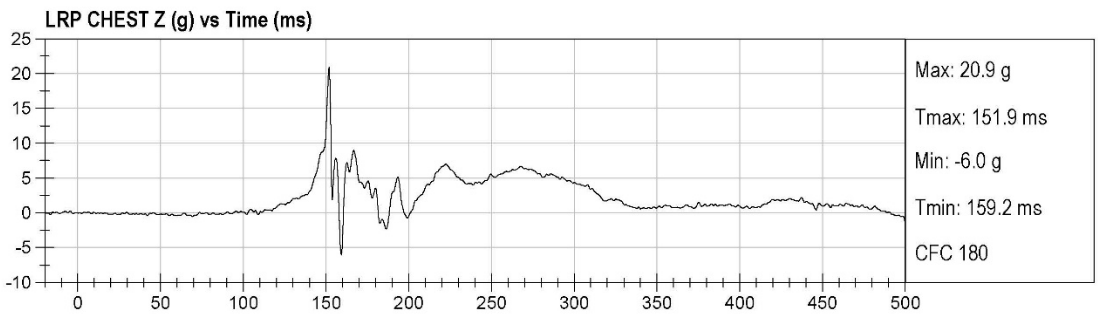

LRP PELVIS Z (g) vs Time (ms)
Max: 11.2 g
Tmax: 155.1 ms
Min: -25.6 g
Tmin: 152.2 ms
CFC 1000


LRP PELVIS Resultant (g) vs Time (ms)
Max: 32.4 g
Tmax: 152.2 ms
Min: 0.0 g
Tmin: -8.2 ms
CFC 1000

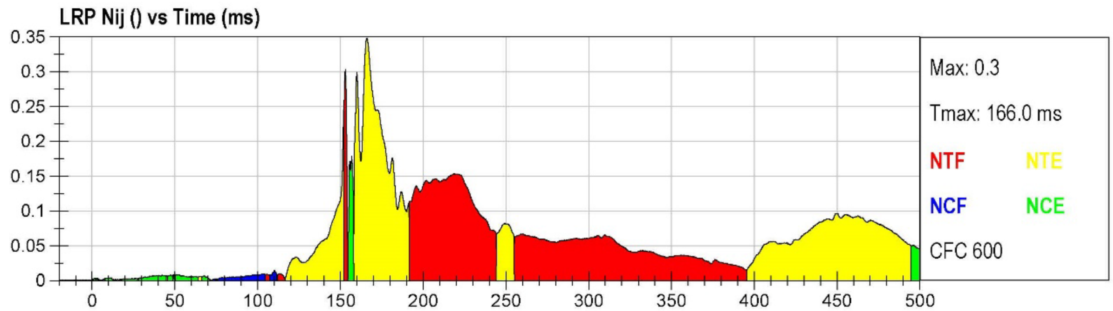

LRP CHEST DISPLACEMENT (mm) vs Time (ms)
Max: 2.9 mm
Tmax: 156.9 ms
Min: -15.3 mm
Tmin: 238.5 ms
CFC 600
5
2.5
0
-2.5
-5
-7.5
-10
-12.5
-15
-17.5
0
50
100
150
200
250
300
350
400
450
500


LRP CHEST X (g) vs Time (ms)
20
10
0
-10
-20
-30
-40
-50
-60
0
50
100
150
200
250
300
350
400
450
500
Max: 12.2 g
Tmax: 153.4 ms
Min: -55.2 g
Tmin: 150.9 ms
CFC 180

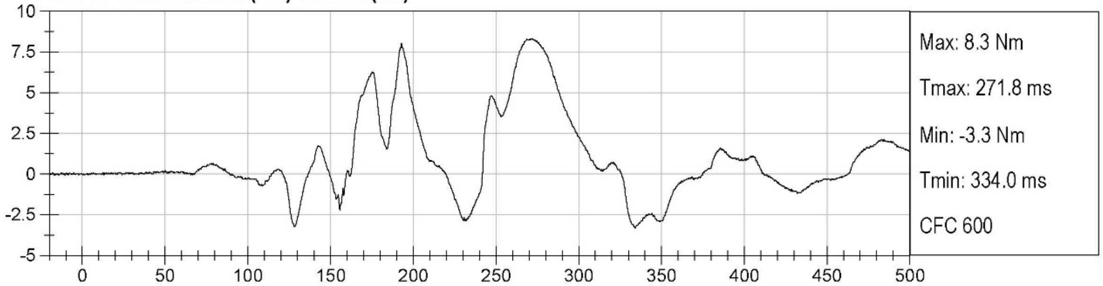

LRP CHEST Y (g) vs Time (ms)
6
4
2
0
-2
-4
-6
0
50
100
150
200
250
300
350
400
450
500
Max: 4.2 g
Tmax: 224.9 ms
Min: -4.6 g
Tmin: 150.4 ms
CFC 180


LRP CHEST Z (g) vs Time (ms)
25
20
15
10
5
0
-5
-10
0
50
100
150
200
250
300
350
400
450
500
Max: 20.9 g
Tmax: 151.9 ms
Min: -6.0 g
Tmin: 159.2 ms
CFC 180

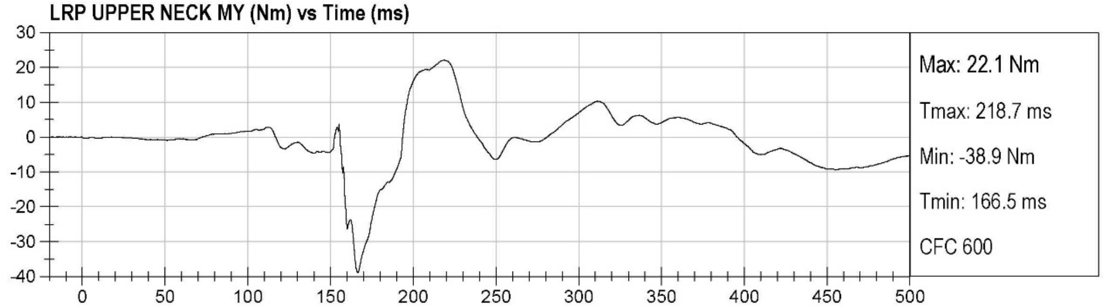

LRP CHEST Resultant (g) vs Time (ms)
60
50
40
30
20
10
0
0
50
100
150
200
250
300
350
400
450
500
Max: 57.8 g
Tmax: 150.9 ms
Min: 0.0 g
Tmin: 101.2 ms
CFC 180


LRP Nij () vs Time (ms)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
50
100
150
200
250
300
350
400
450
500
Max: 0.3
Tmax: 166.0 ms
NTF
NTE
NCF
NCE
CFC 600

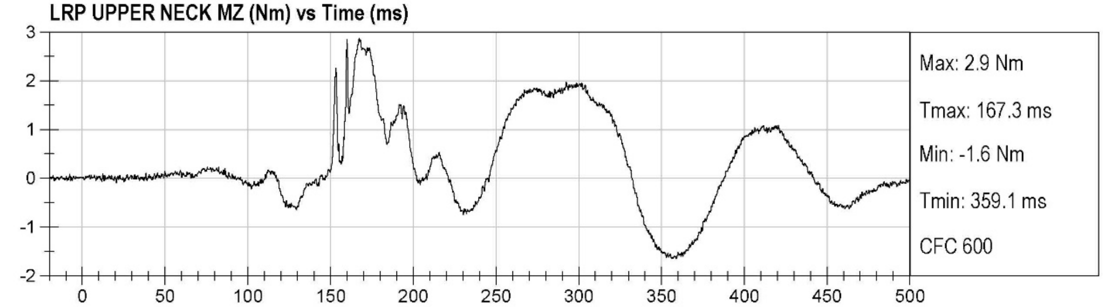
LRP UPPER NECK MX (Nm) vs Time (ms)



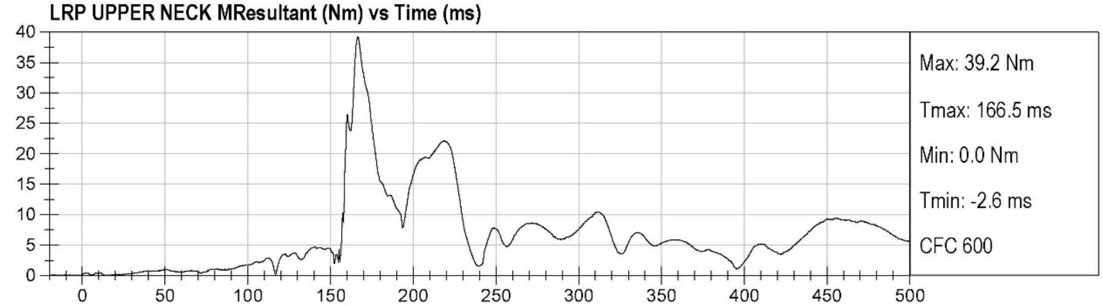

LRP UPPER NECK MY (Nm) vs Time (ms)



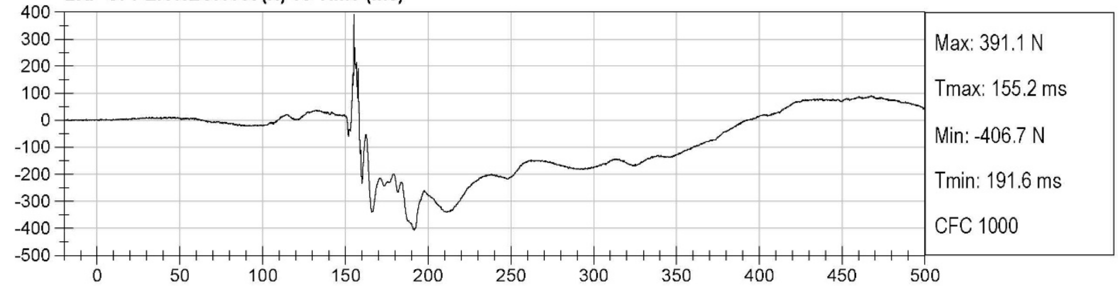

LRP UPPER NECK MZ (Nm) vs Time (ms)



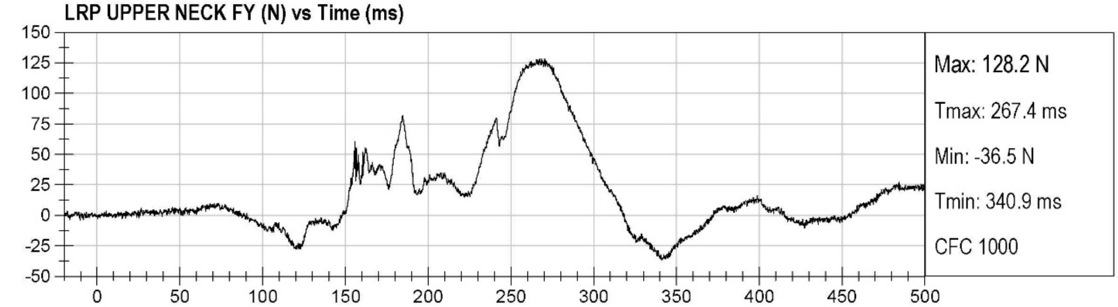

LRP UPPER NECK MResultant (Nm) vs Time (ms)



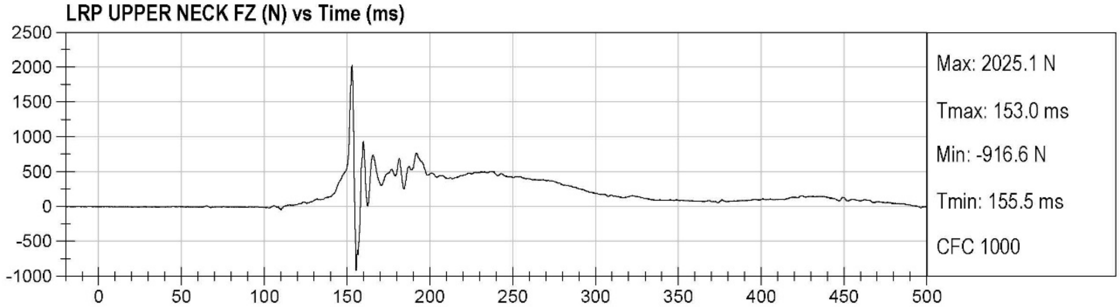
LRP UPPER NECK FX (N) vs Time (ms)



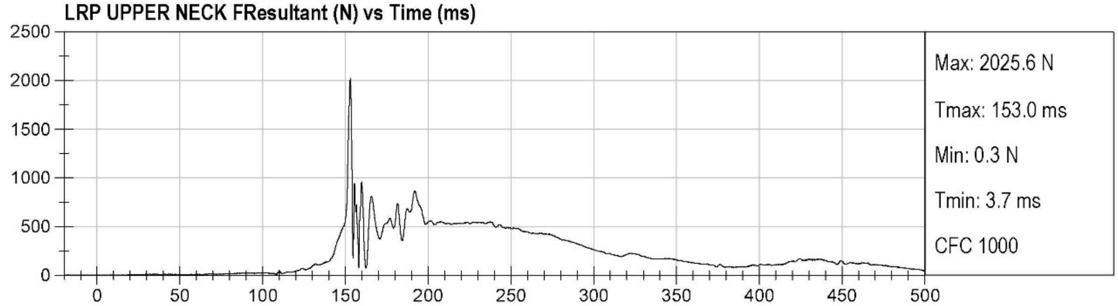

LRP UPPER NECK FY (N) vs Time (ms)



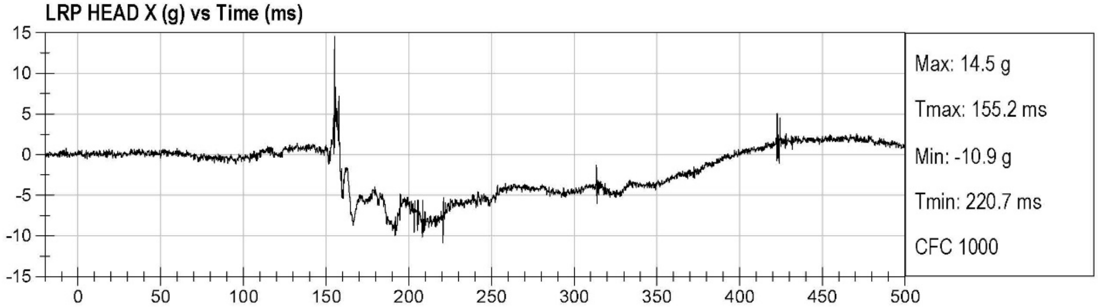

LRP UPPER NECK FZ (N) vs Time (ms)



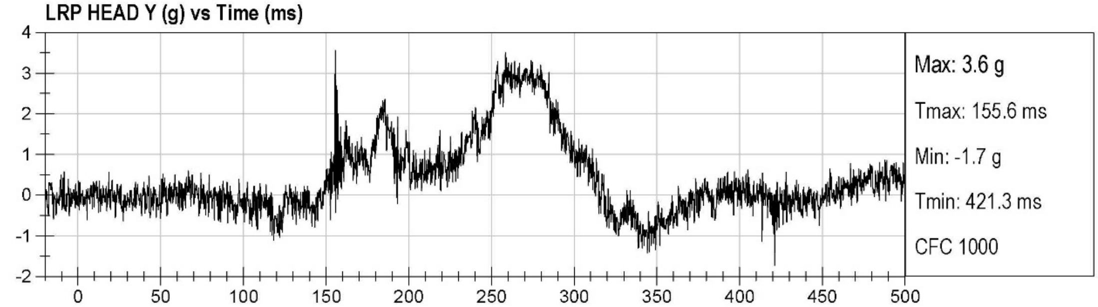

LRP UPPER NECK FResultant (N) vs Time (ms)



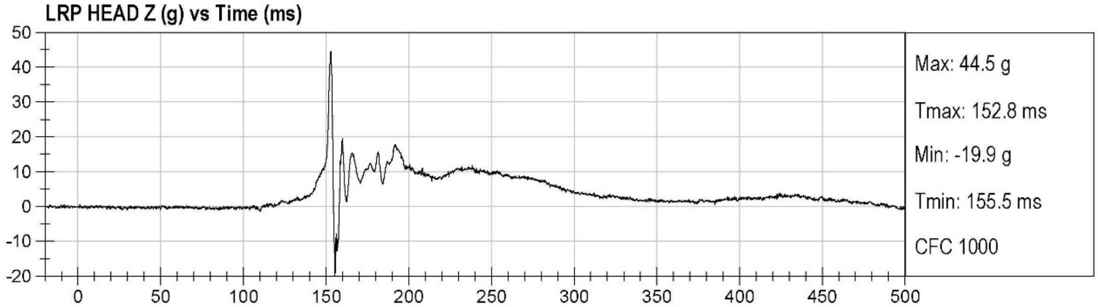
LRP HEAD X (g) vs Time (ms)



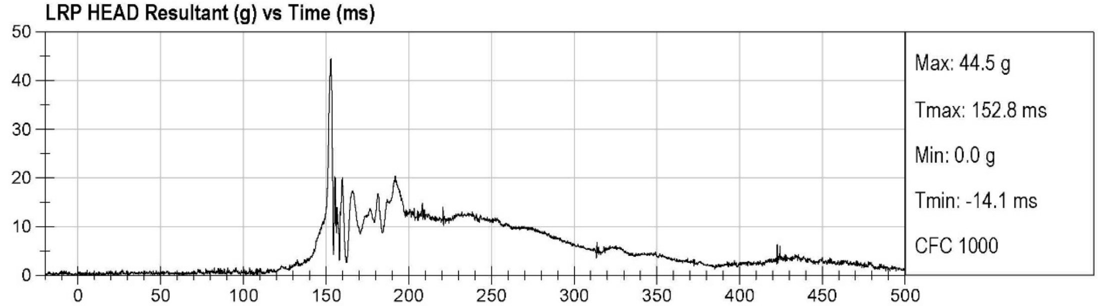

LRP HEAD Y (g) vs Time (ms)




LRP HEAD Z (g) vs Time (ms)




LRP HEAD Resultant (g) vs Time (ms)



## A.10: Test 3BQ Data

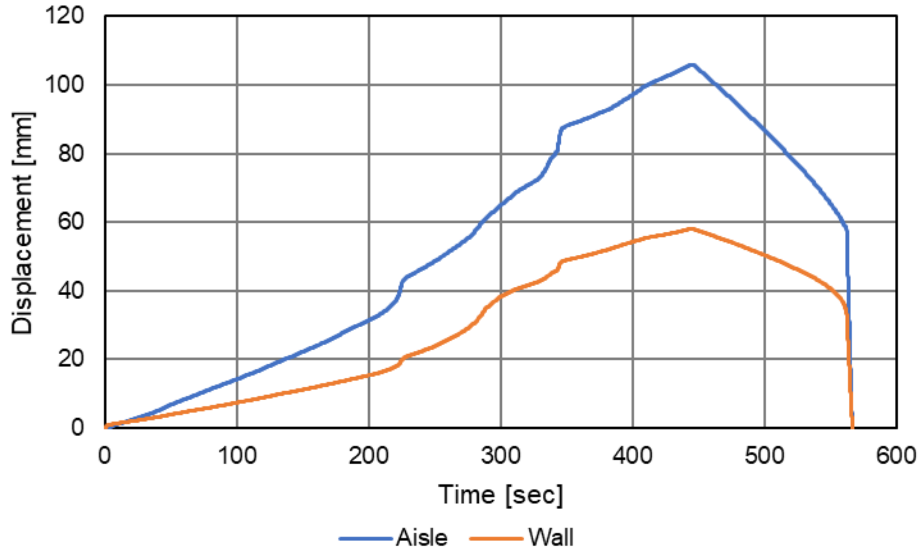



**Figure A9. Test 3BQ Displacement versus Time**

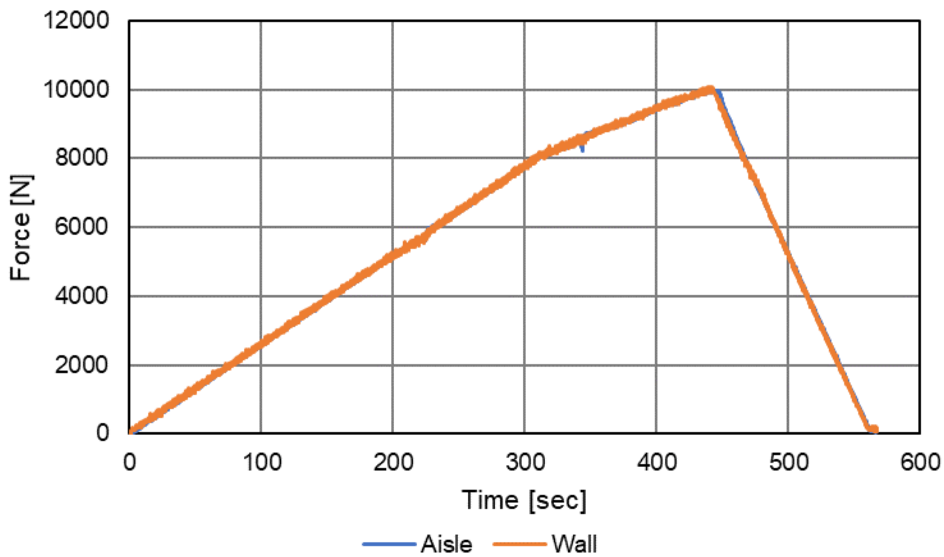



**Figure A10. Test 3BQ Force versus Time**

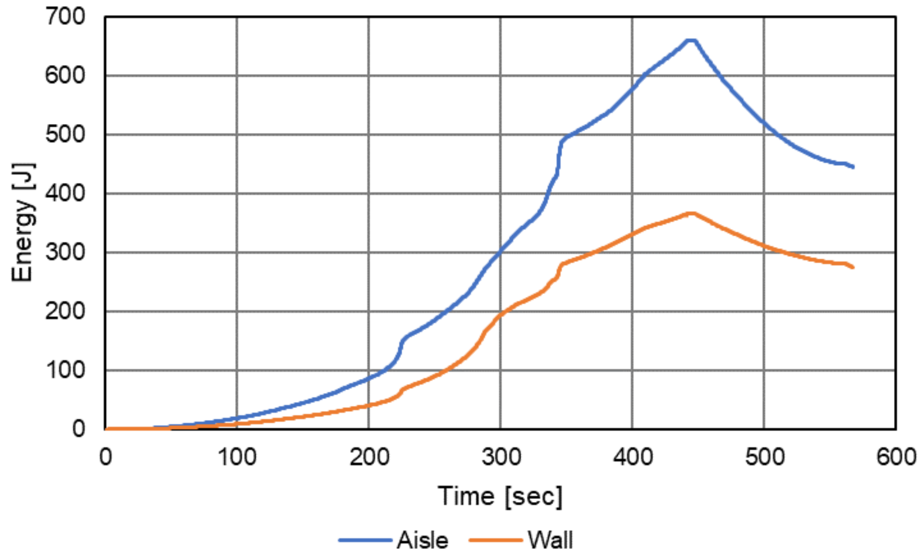



**Figure A11. Test 3BQ Energy-absorption versus Time**

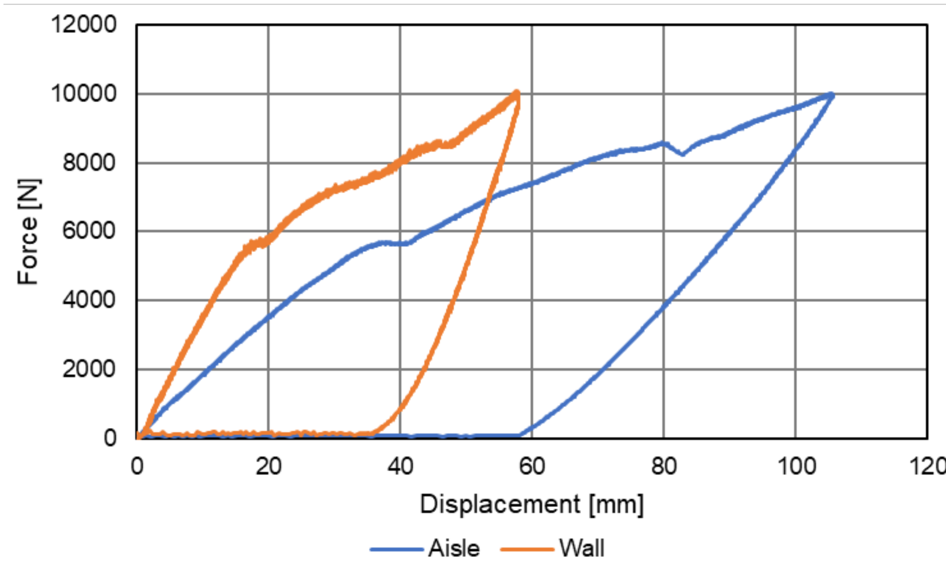
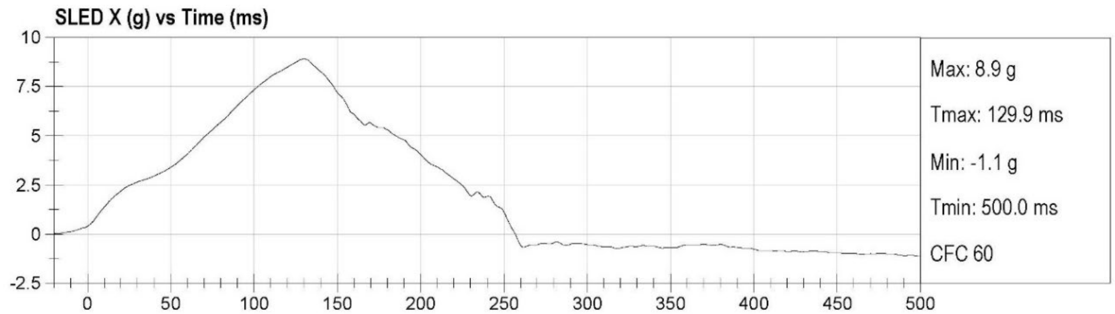


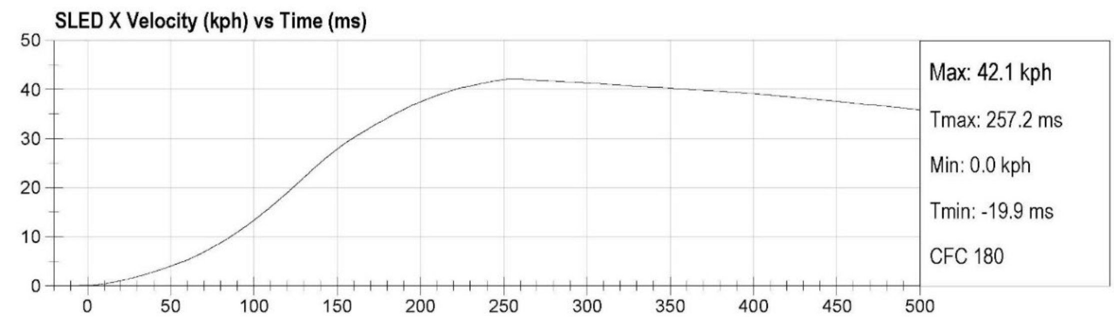

**Figure A12. Test 3BQ Force versus Displacement**

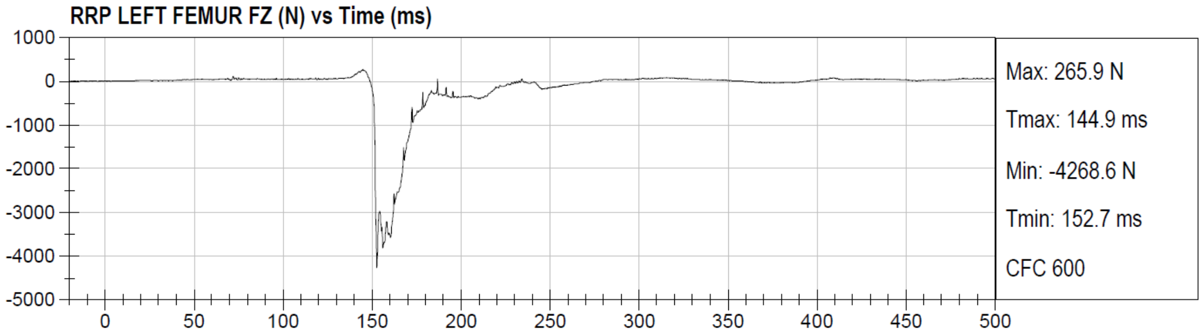
### A.11: Test 4A Data

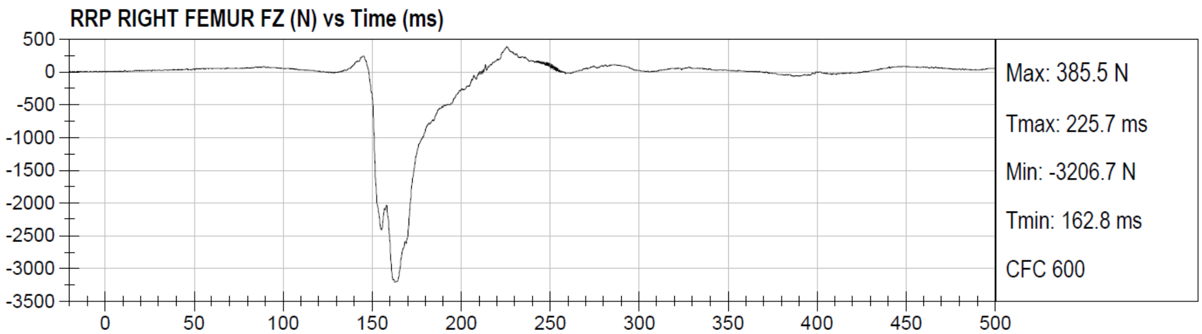
Test Date: 05/12/2021

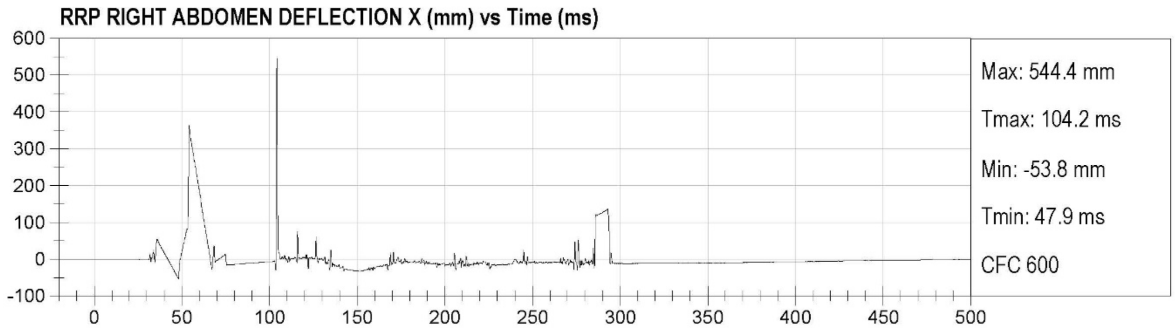
MGA Test ID: S21143

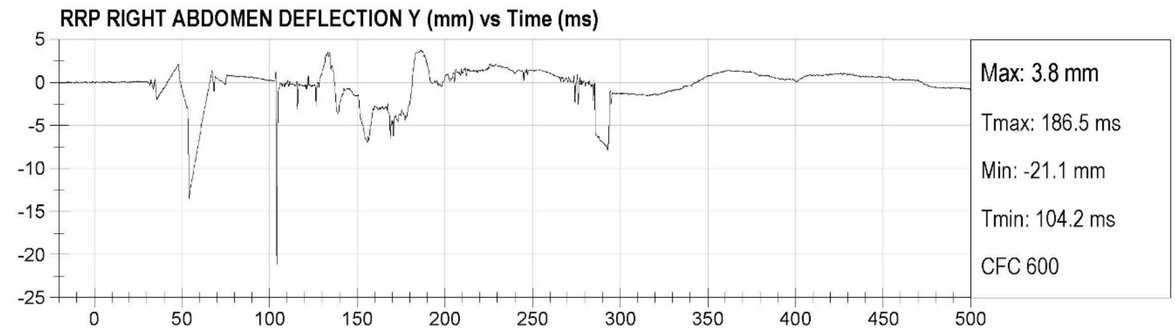


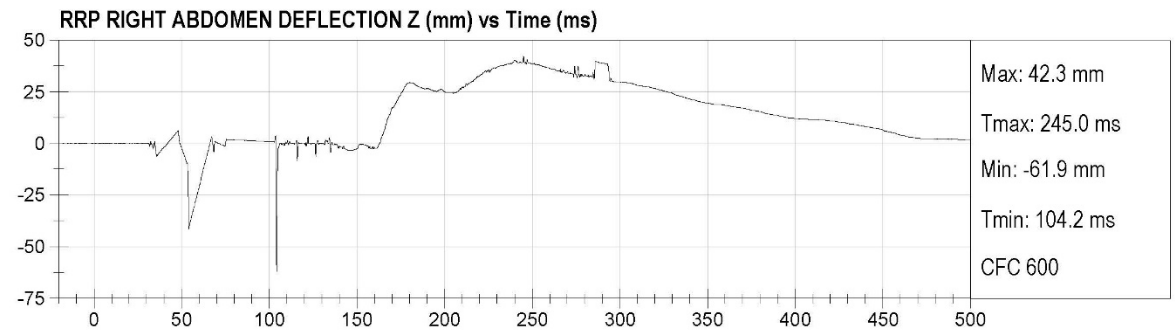



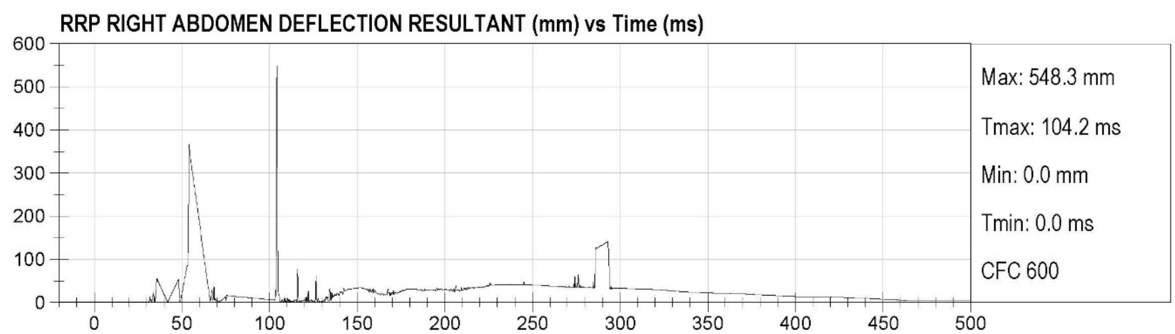

RRP LEFT FEMUR FZ (N) vs Time (ms)
1000
0
-1000
-2000
-3000
-4000
-5000
0
50
100
150
200
250
300
350
400
450
500
Max: 265.9 N
Tmax: 144.9 ms
Min: -4268.6 N
Tmin: 152.7 ms
CFC 600

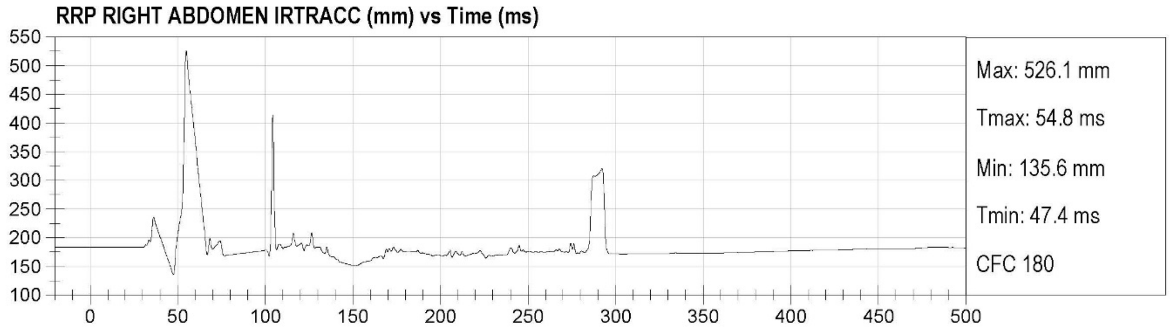

RRP RIGHT FEMUR FZ (N) vs Time (ms)
500
0
-500
-1000
-1500
-2000
-2500
-3000
-3500
0
50
100
150
200
250
300
350
400
450
500
Max: 385.5 N
Tmax: 225.7 ms
Min: -3206.7 N
Tmin: 162.8 ms
CFC 600

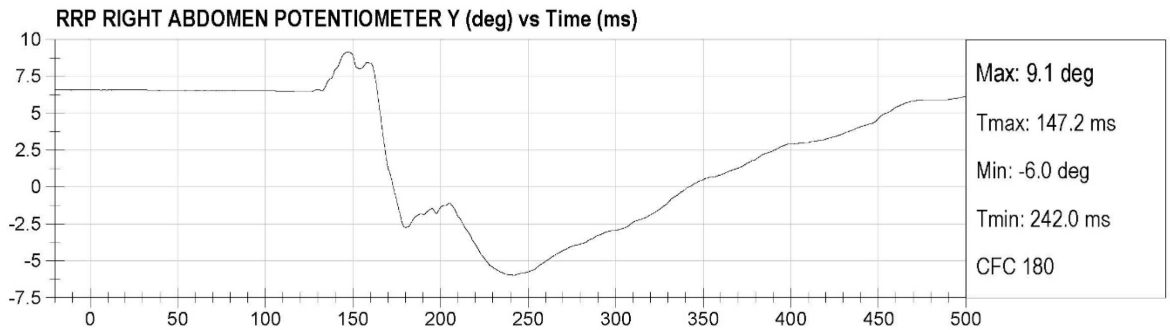

RRP RIGHT ABDOMEN DEFLECTION X (mm) vs Time (ms)
Max: 544.4 mm
Tmax: 104.2 ms
Min: -53.8 mm
Tmin: 47.9 ms
CFC 600

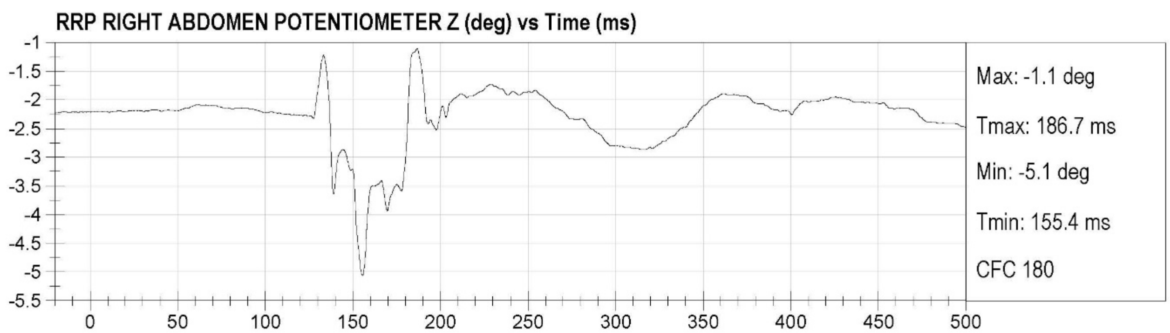

RRP RIGHT ABDOMEN DEFLECTION Y (mm) vs Time (ms)
Max: 3.8 mm
Tmax: 186.5 ms
Min: -21.1 mm
Tmin: 104.2 ms
CFC 600

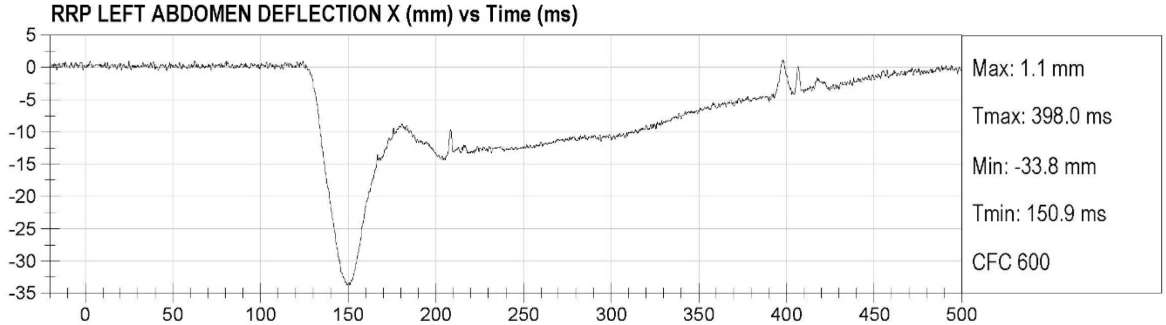

RRP RIGHT ABDOMEN DEFLECTION Z (mm) vs Time (ms)
Max: 42.3 mm
Tmax: 245.0 ms
Min: -61.9 mm
Tmin: 104.2 ms
CFC 600


RRP RIGHT ABDOMEN DEFLECTION RESULTANT (mm) vs Time (ms)
Max: 548.3 mm
Tmax: 104.2 ms
Min: 0.0 mm
Tmin: 0.0 ms
CFC 600

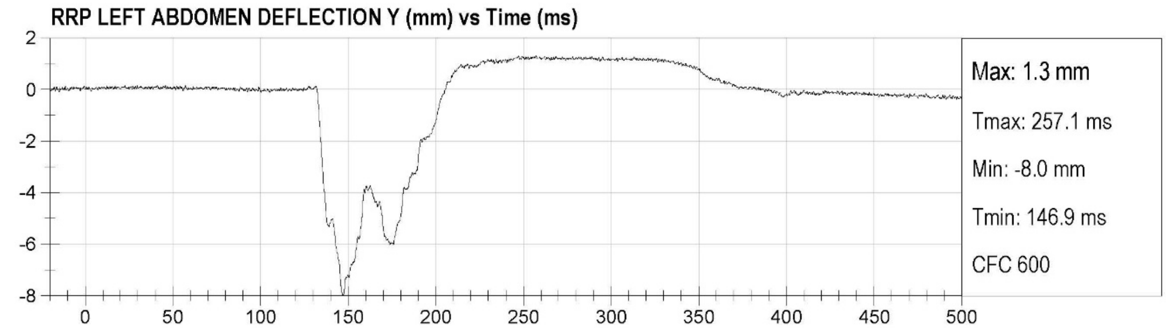

RRP RIGHT ABDOMEN IRTRACC (mm) vs Time (ms)
Max: 526.1 mm
Tmax: 54.8 ms
Min: 135.6 mm
Tmin: 47.4 ms
CFC 180


RRP RIGHT ABDOMEN POTENTIOMETER Y (deg) vs Time (ms)
Max: 9.1 deg
Tmax: 147.2 ms
Min: -6.0 deg
Tmin: 242.0 ms
CFC 180


RRP RIGHT ABDOMEN POTENTIOMETER Z (deg) vs Time (ms)
Max: -1.1 deg
Tmax: 186.7 ms
Min: -5.1 deg
Tmin: 155.4 ms
CFC 180

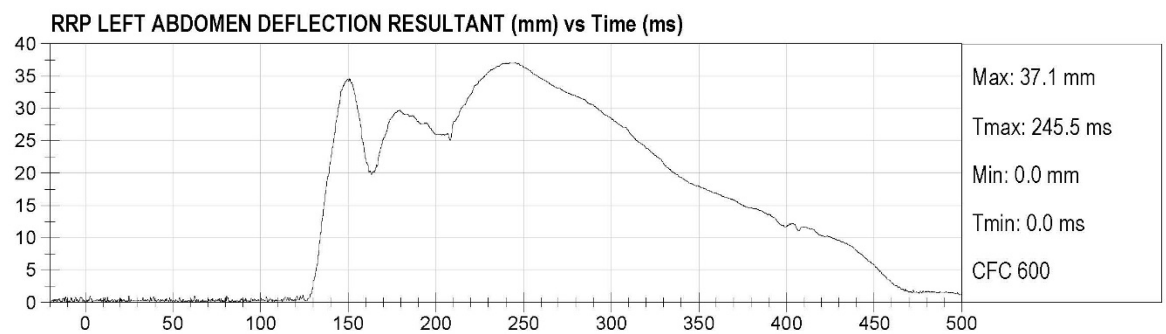


RRP LEFT ABDOMEN DEFLECTION X (mm) vs Time (ms)
Max: 1.1 mm
Tmax: 398.0 ms
Min: -33.8 mm
Tmin: 150.9 ms
CFC 600

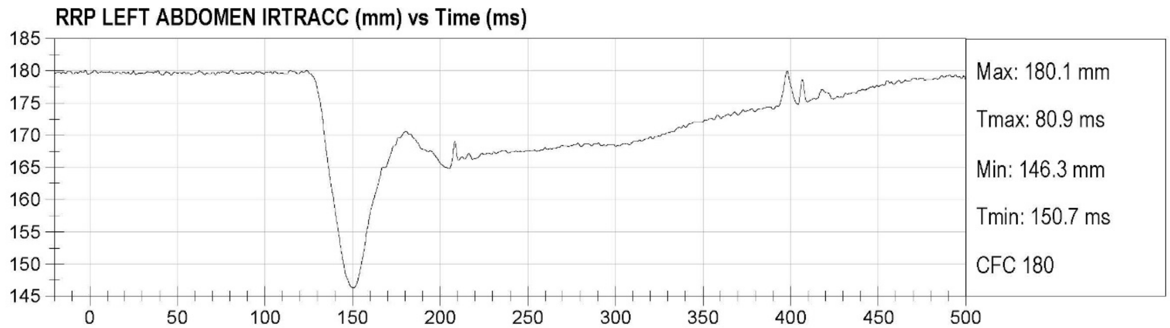



RRP LEFT ABDOMEN DEFLECTION Y (mm) vs Time (ms)
Max: 1.3 mm
Tmax: 257.1 ms
Min: -8.0 mm
Tmin: 146.9 ms
CFC 600

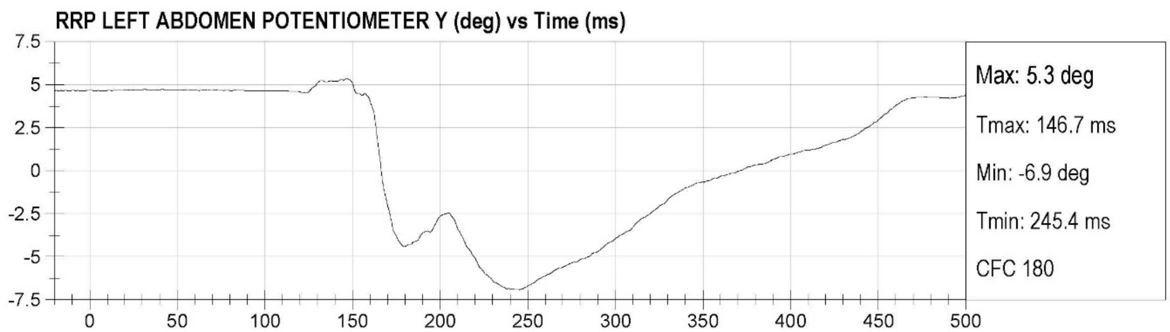

RRP LEFT ABDOMEN DEFLECTION Z (mm) vs Time (ms)
Max: 34.9 mm
Tmax: 245.6 ms
Min: -1.2 mm
Tmin: 131.4 ms
CFC 600

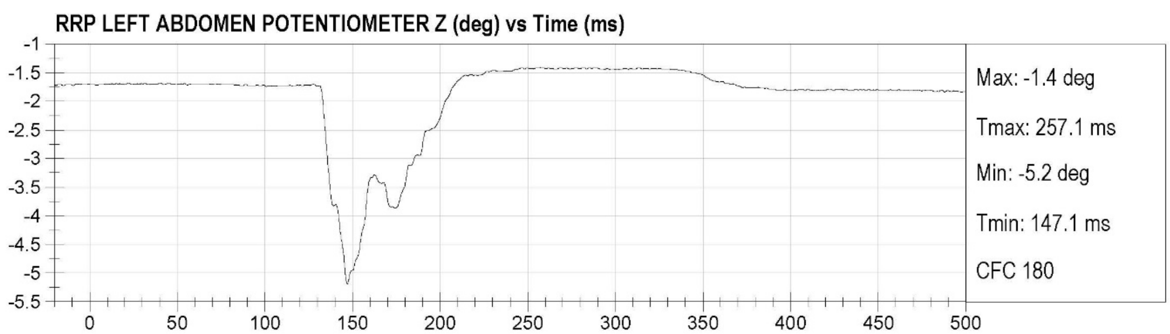
RRP LEFT ABDOMEN DEFLECTION RESULTANT (mm) vs Time (ms)
Max: 37.1 mm
Tmax: 245.5 ms
Min: 0.0 mm
Tmin: 0.0 ms
CFC 600



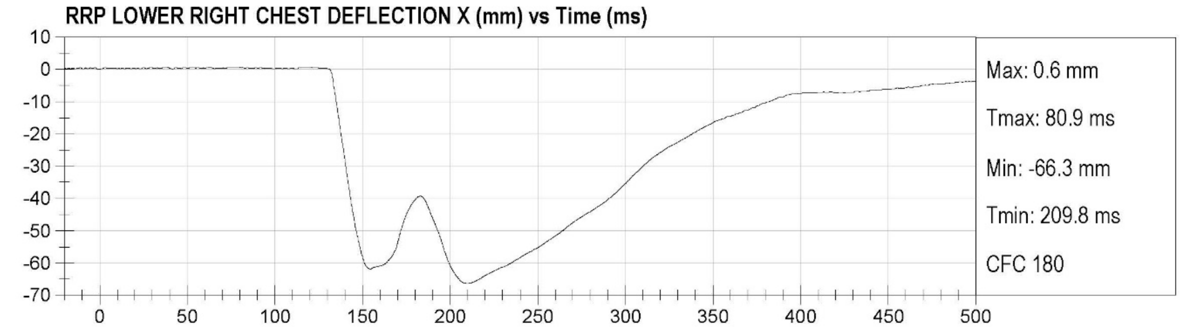
RRP LEFT ABDOMEN IRTRACC (mm) vs Time (ms)
Max: 180.1 mm
Tmax: 80.9 ms
Min: 146.3 mm
Tmin: 150.7 ms
CFC 180

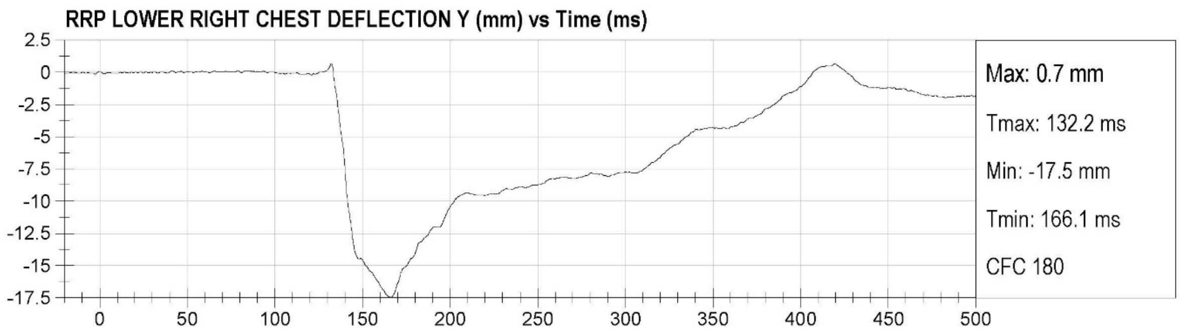



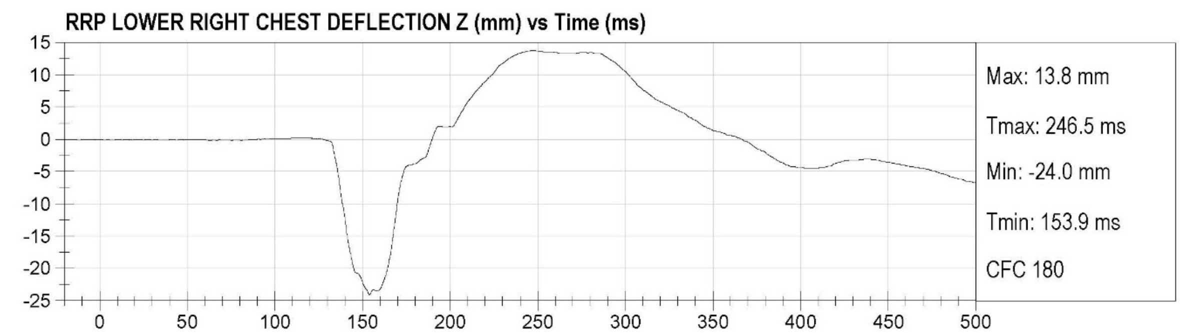
RRP LEFT ABDOMEN POTENTIOMETER Y (deg) vs Time (ms)
Max: 5.3 deg
Tmax: 146.7 ms
Min: -6.9 deg
Tmin: 245.4 ms
CFC 180

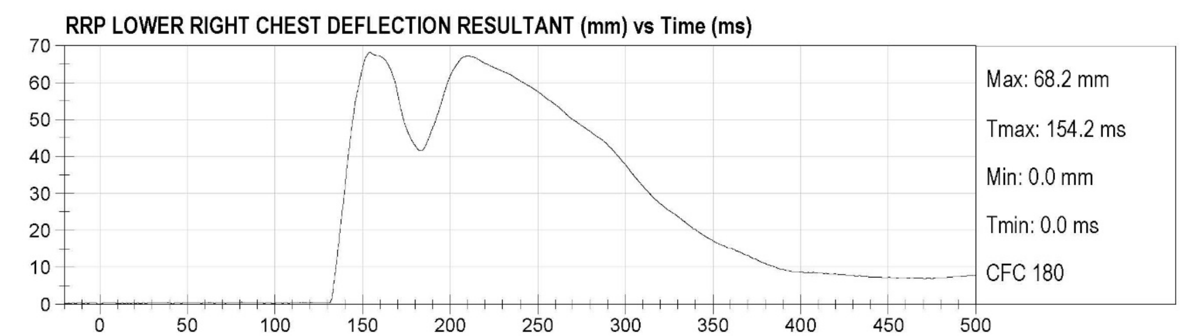



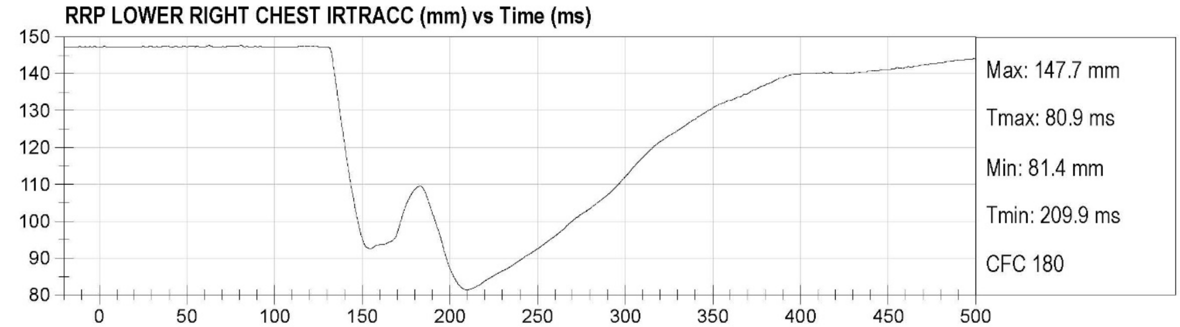
RRP LEFT ABDOMEN POTENTIOMETER Z (deg) vs Time (ms)
Max: -1.4 deg
Tmax: 257.1 ms
Min: -5.2 deg
Tmin: 147.1 ms
CFC 180

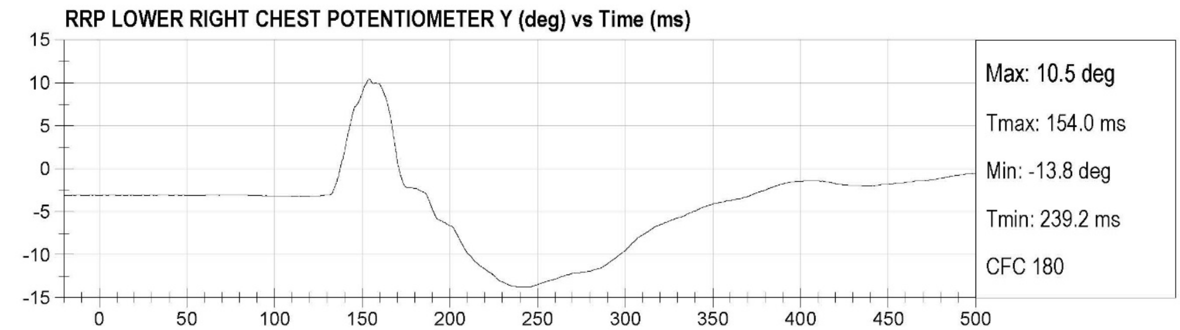

RRP LOWER RIGHT CHEST DEFLECTION X (mm) vs Time (ms)
Max: 0.6 mm
Tmax: 80.9 ms
Min: -66.3 mm
Tmin: 209.8 ms
CFC 180

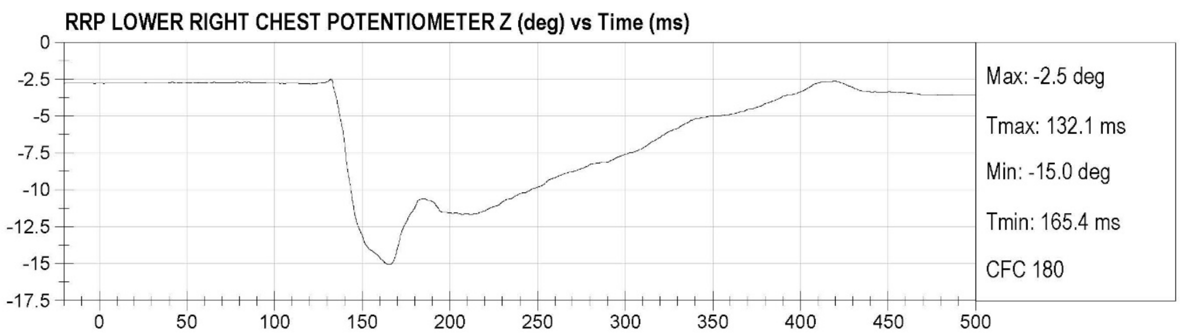

RRP LOWER RIGHT CHEST DEFLECTION Y (mm) vs Time (ms)
Max: 0.7 mm
Tmax: 132.2 ms
Min: -17.5 mm
Tmin: 166.1 ms
CFC 180

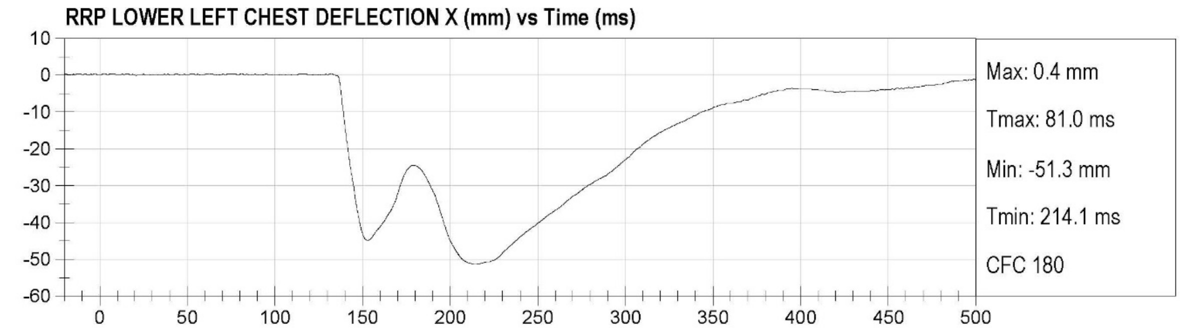

RRP LOWER RIGHT CHEST DEFLECTION Z (mm) vs Time (ms)
Max: 13.8 mm
Tmax: 246.5 ms
Min: -24.0 mm
Tmin: 153.9 ms
CFC 180

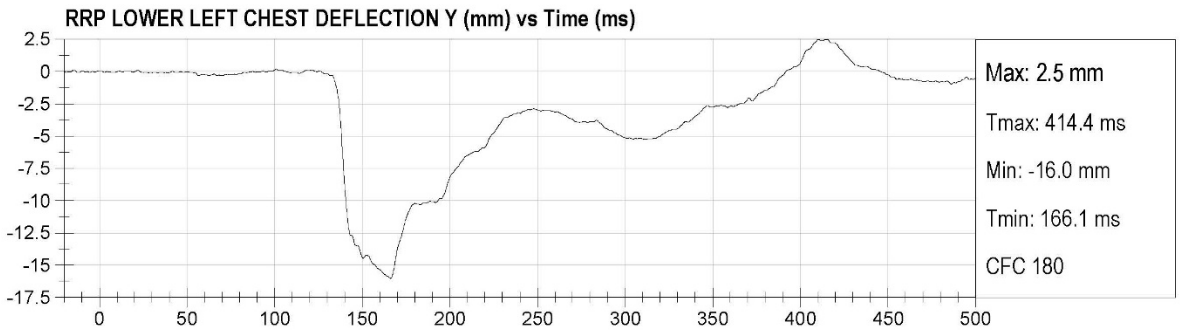

RRP LOWER RIGHT CHEST DEFLECTION RESULTANT (mm) vs Time (ms)
Max: 68.2 mm
Tmax: 154.2 ms
Min: 0.0 mm
Tmin: 0.0 ms
CFC 180


RRP LOWER RIGHT CHEST IRTRACC (mm) vs Time (ms)
Max: 147.7 mm
Tmax: 80.9 ms
Min: 81.4 mm
Tmin: 209.9 ms
CFC 180

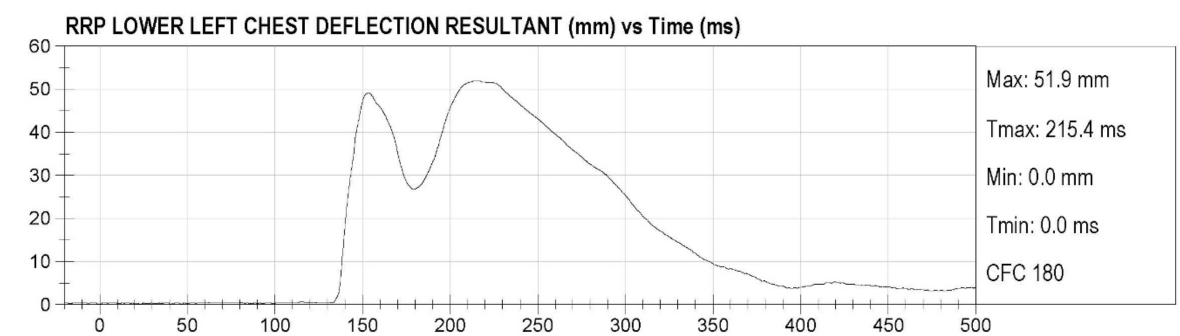

RRP LOWER RIGHT CHEST POTENTIOMETER Y (deg) vs Time (ms)
Max: 10.5 deg
Tmax: 154.0 ms
Min: -13.8 deg
Tmin: 239.2 ms
CFC 180


RRP LOWER RIGHT CHEST POTENTIOMETER Z (deg) vs Time (ms)
Max: -2.5 deg
Tmax: 132.1 ms
Min: -15.0 deg
Tmin: 165.4 ms
CFC 180

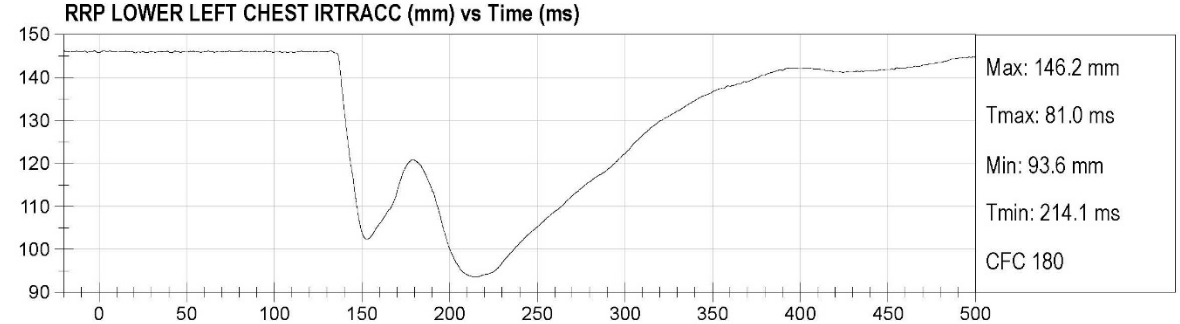

RRP LOWER LEFT CHEST DEFLECTION X (mm) vs Time (ms)
Max: 0.4 mm
Tmax: 81.0 ms
Min: -51.3 mm
Tmin: 214.1 ms
CFC 180


RRP LOWER LEFT CHEST DEFLECTION Y (mm) vs Time (ms)
Max: 2.5 mm
Tmax: 414.4 ms
Min: -16.0 mm
Tmin: 166.1 ms
CFC 180

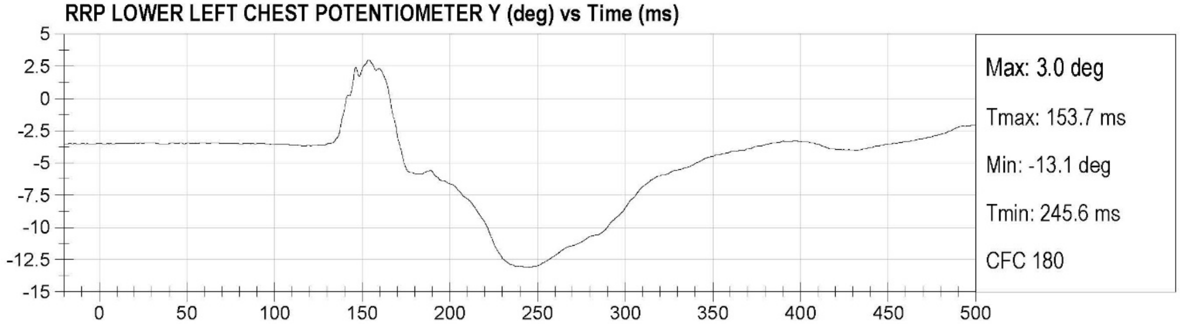

RRP LOWER LEFT CHEST DEFLECTION Z (mm) vs Time (ms)
Max: 15.1 mm
Tmax: 249.0 ms
Min: -14.2 mm
Tmin: 153.7 ms
CFC 180


RRP LOWER LEFT CHEST DEFLECTION RESULTANT (mm) vs Time (ms)
Max: 51.9 mm
Tmax: 215.4 ms
Min: 0.0 mm
Tmin: 0.0 ms
CFC 180

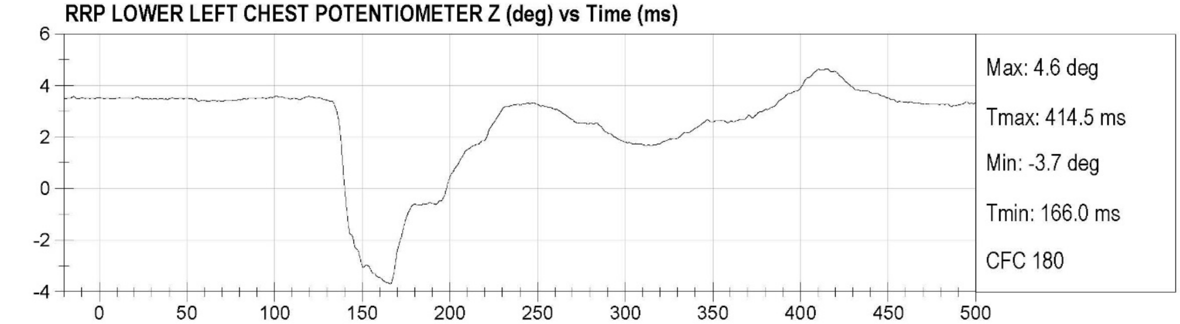
RRP LOWER LEFT CHEST IRTRACC (mm) vs Time (ms)

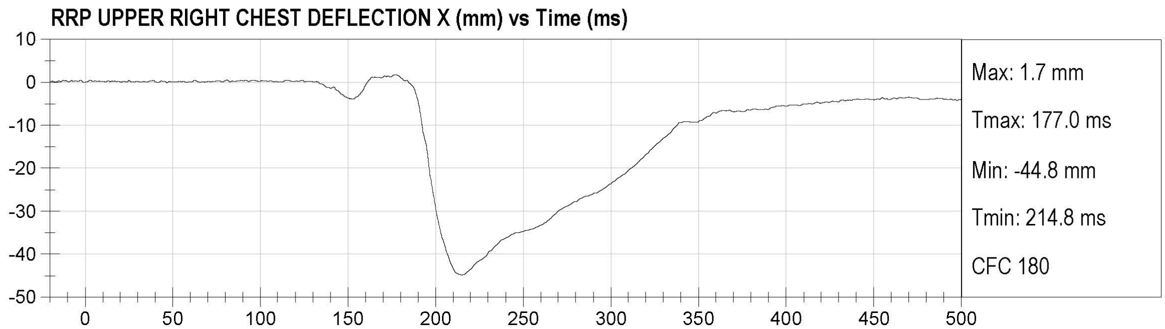


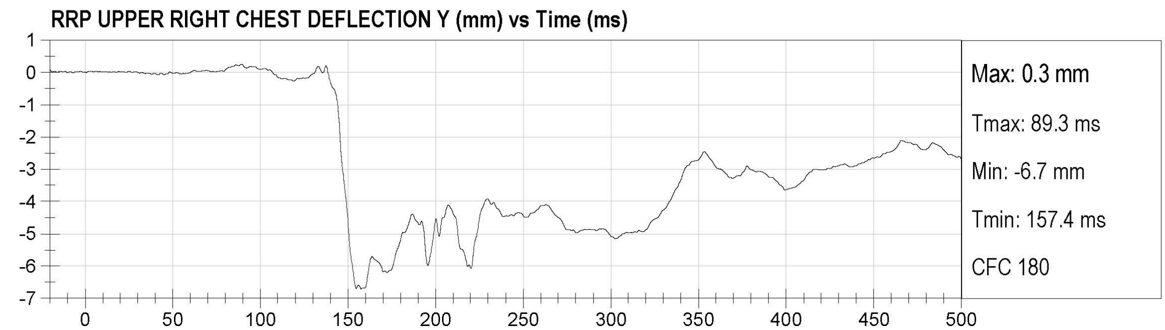

RRP LOWER LEFT CHEST POTENTIOMETER Y (deg) vs Time (ms)

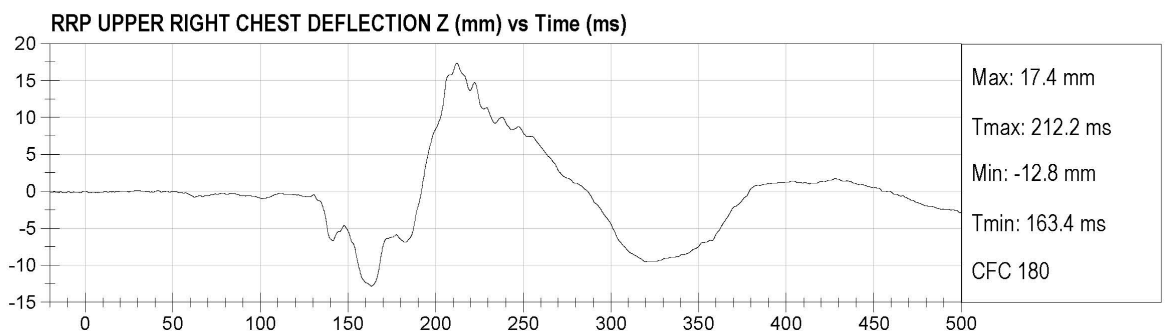


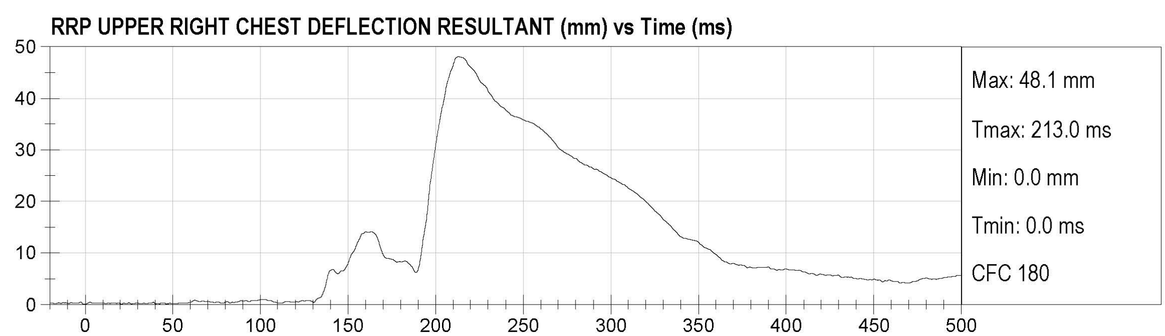

RRP LOWER LEFT CHEST POTENTIOMETER Z (deg) vs Time (ms)

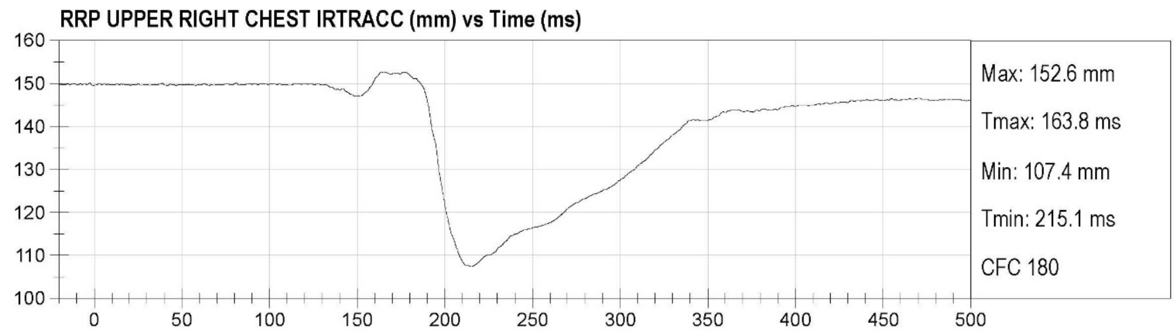


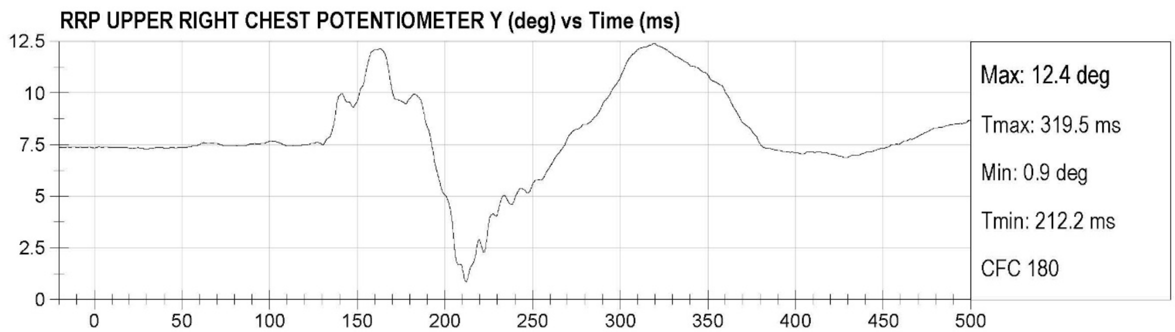

RRP UPPER RIGHT CHEST DEFLECTION X (mm) vs Time (ms)
Max: 1.7 mm
Tmax: 177.0 ms
Min: -44.8 mm
Tmin: 214.8 ms
CFC 180

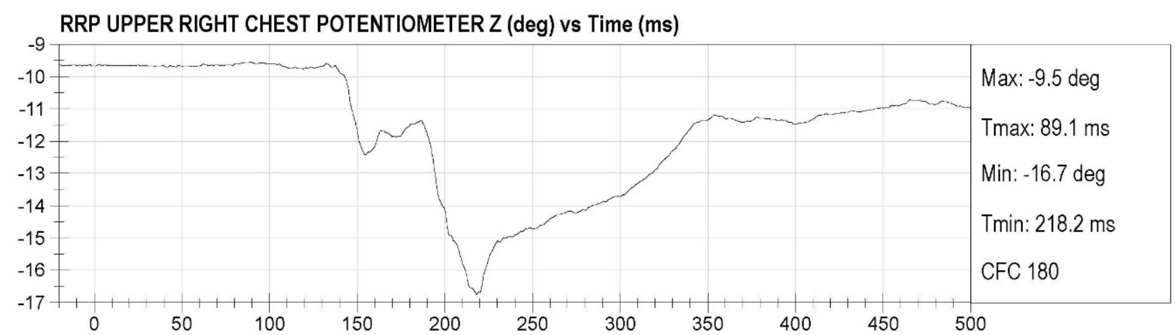

RRP UPPER RIGHT CHEST DEFLECTION Y (mm) vs Time (ms)
Max: 0.3 mm
Tmax: 89.3 ms
Min: -6.7 mm
Tmin: 157.4 ms
CFC 180


RRP UPPER RIGHT CHEST DEFLECTION Z (mm) vs Time (ms)
Max: 17.4 mm
Tmax: 212.2 ms
Min: -12.8 mm
Tmin: 163.4 ms
CFC 180

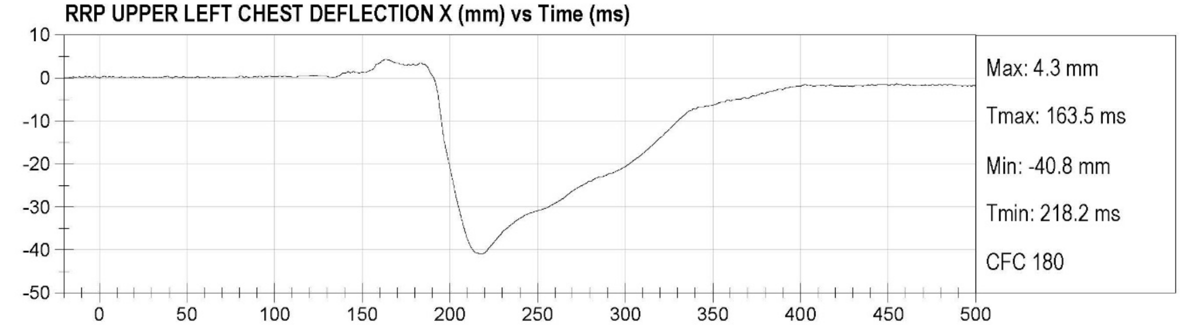

RRP UPPER RIGHT CHEST DEFLECTION RESULTANT (mm) vs Time (ms)
Max: 48.1 mm
Tmax: 213.0 ms
Min: 0.0 mm
Tmin: 0.0 ms
CFC 180


RRP UPPER RIGHT CHEST IRTRACC (mm) vs Time (ms)
Max: 152.6 mm
Tmax: 163.8 ms
Min: 107.4 mm
Tmin: 215.1 ms
CFC 180

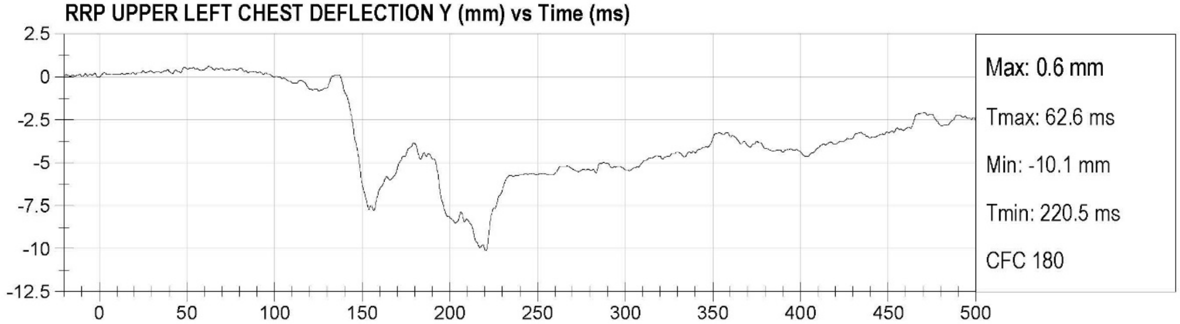

RRP UPPER RIGHT CHEST POTENTIOMETER Y (deg) vs Time (ms)
Max: 12.4 deg
Tmax: 319.5 ms
Min: 0.9 deg
Tmin: 212.2 ms
CFC 180


RRP UPPER RIGHT CHEST POTENTIOMETER Z (deg) vs Time (ms)
Max: -9.5 deg
Tmax: 89.1 ms
Min: -16.7 deg
Tmin: 218.2 ms
CFC 180

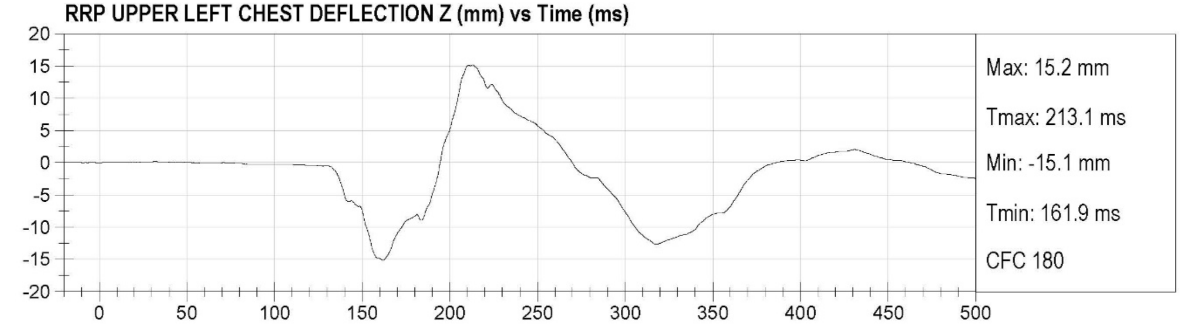
RRP UPPER LEFT CHEST DEFLECTION X (mm) vs Time (ms)



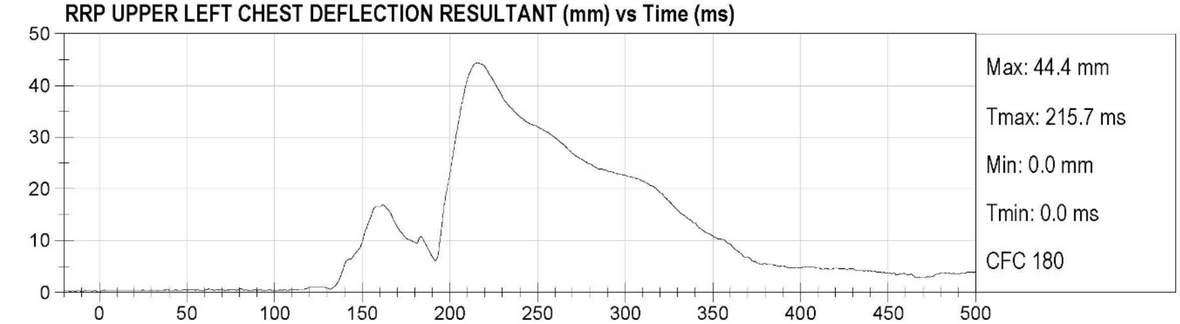

RRP UPPER LEFT CHEST DEFLECTION Y (mm) vs Time (ms)

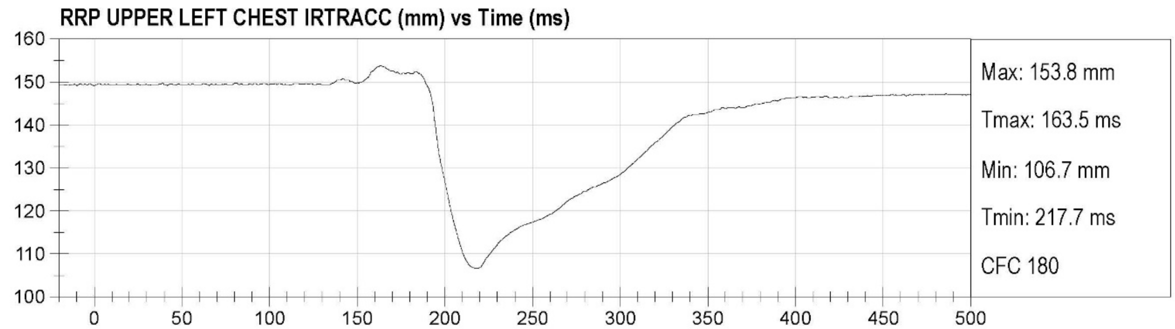


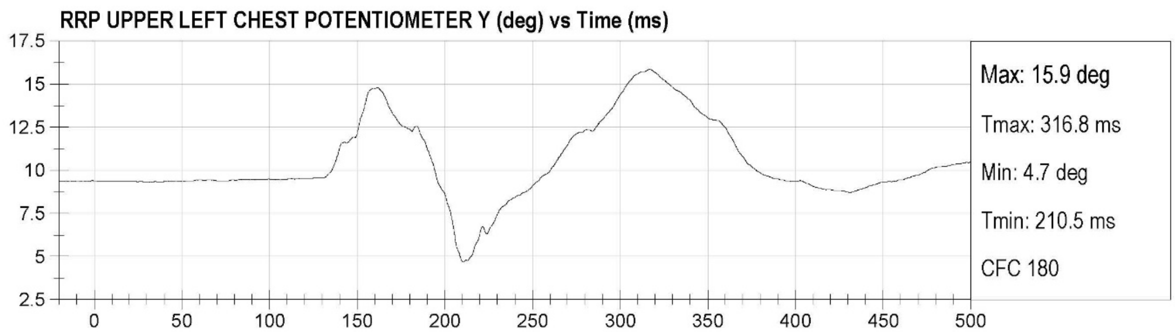

RRP UPPER LEFT CHEST DEFLECTION Z (mm) vs Time (ms)

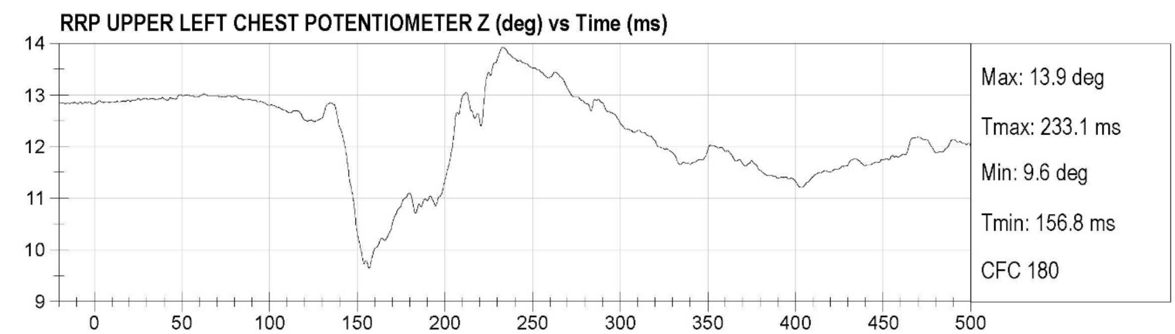


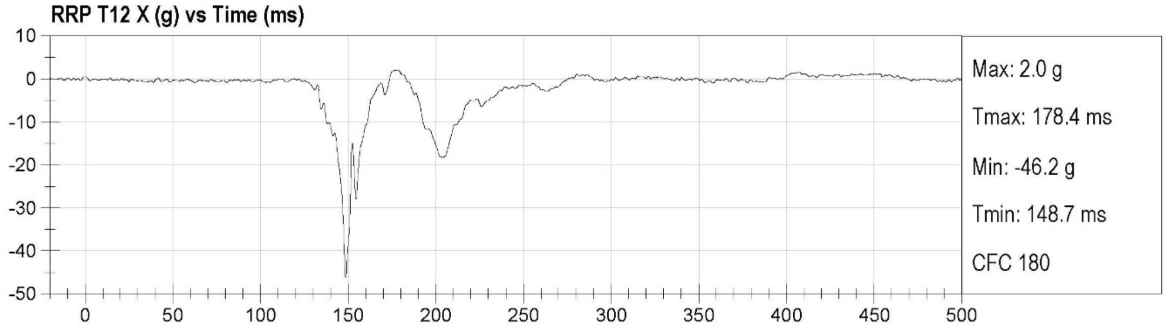

RRP UPPER LEFT CHEST DEFLECTION RESULTANT (mm) vs Time (ms)

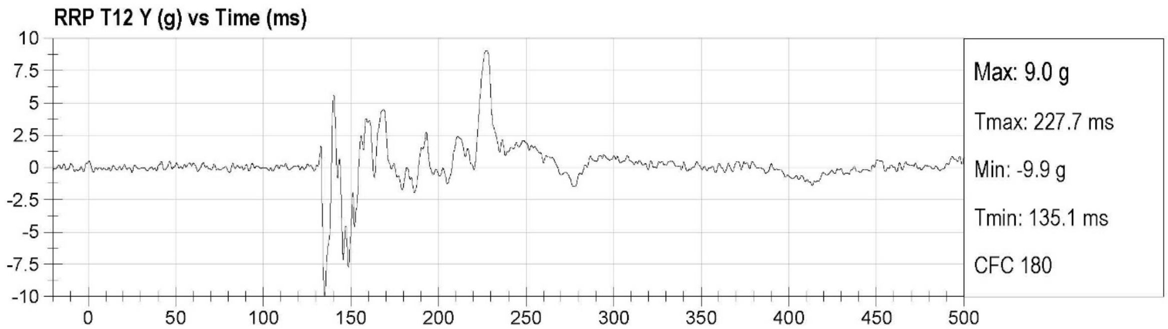


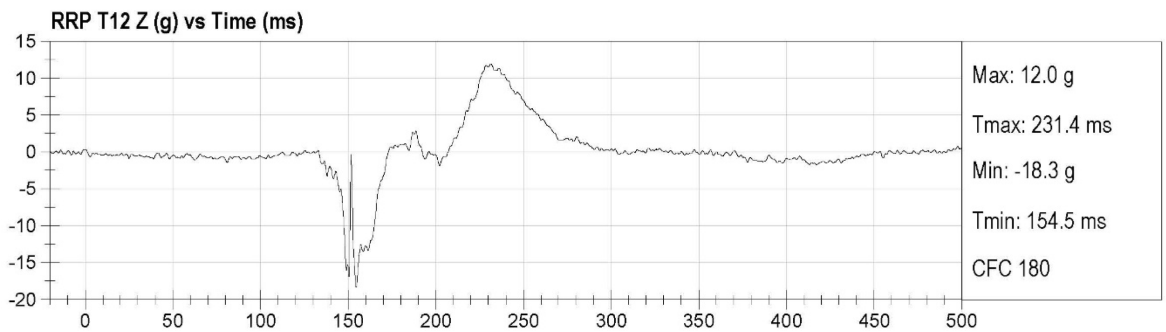

RRP UPPER LEFT CHEST IRTRACC (mm) vs Time (ms)
Max: 153.8 mm
Tmax: 163.5 ms
Min: 106.7 mm
Tmin: 217.7 ms
CFC 180


RRP UPPER LEFT CHEST POTENTIOMETER Y (deg) vs Time (ms)
Max: 15.9 deg
Tmax: 316.8 ms
Min: 4.7 deg
Tmin: 210.5 ms
CFC 180


RRP UPPER LEFT CHEST POTENTIOMETER Z (deg) vs Time (ms)
Max: 13.9 deg
Tmax: 233.1 ms
Min: 9.6 deg
Tmin: 156.8 ms
CFC 180

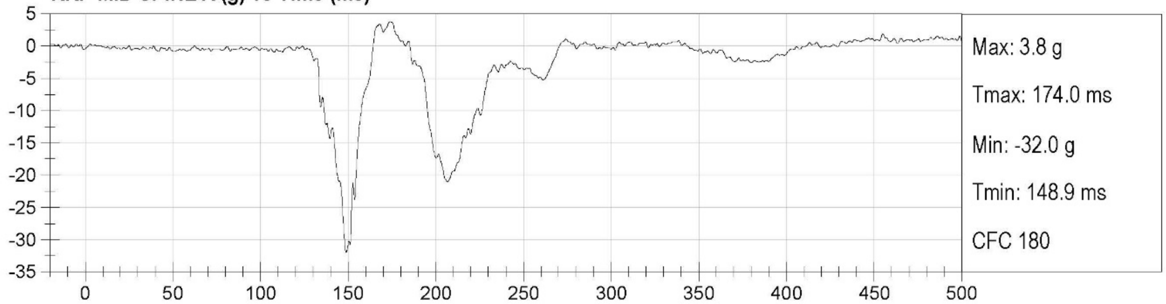

RRP T12 X (g) vs Time (ms)
Max: 2.0 g
Tmax: 178.4 ms
Min: -46.2 g
Tmin: 148.7 ms
CFC 180


RRP T12 Y (g) vs Time (ms)
Max: 9.0 g
Tmax: 227.7 ms
Min: -9.9 g
Tmin: 135.1 ms
CFC 180

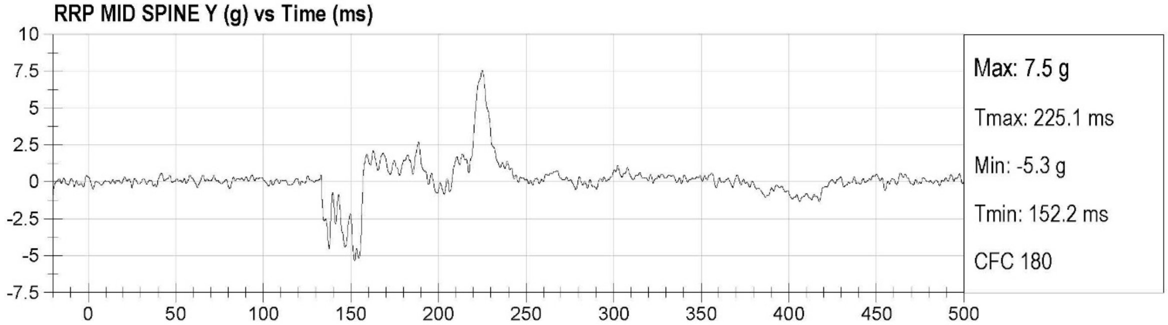

RRP T12 Z (g) vs Time (ms)
Max: 12.0 g
Tmax: 231.4 ms
Min: -18.3 g
Tmin: 154.5 ms
CFC 180


RRP T12 Resultant (g) vs Time (ms)
Max: 49.3 g
Tmax: 148.8 ms
Min: 0.0 g
Tmin: -4.2 ms
CFC 180

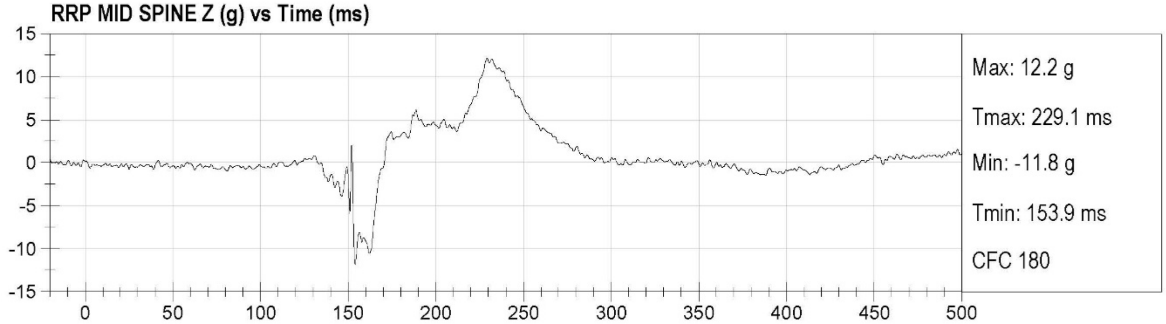
RRP MID SPINE X (g) vs Time (ms)



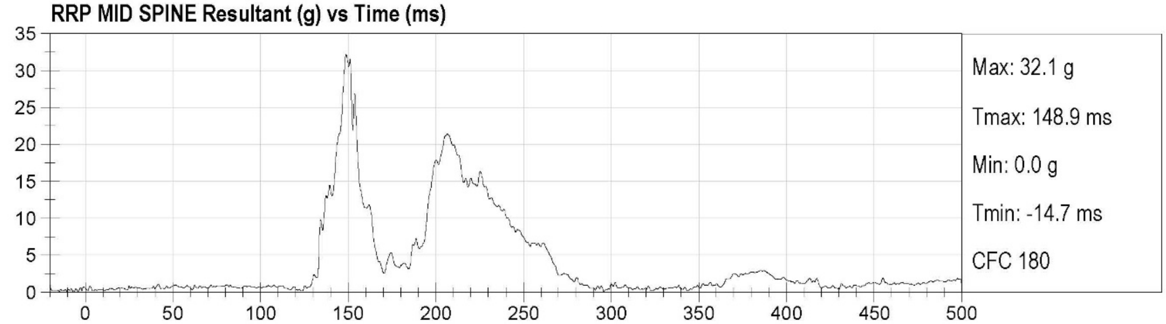

RRP MID SPINE Y (g) vs Time (ms)

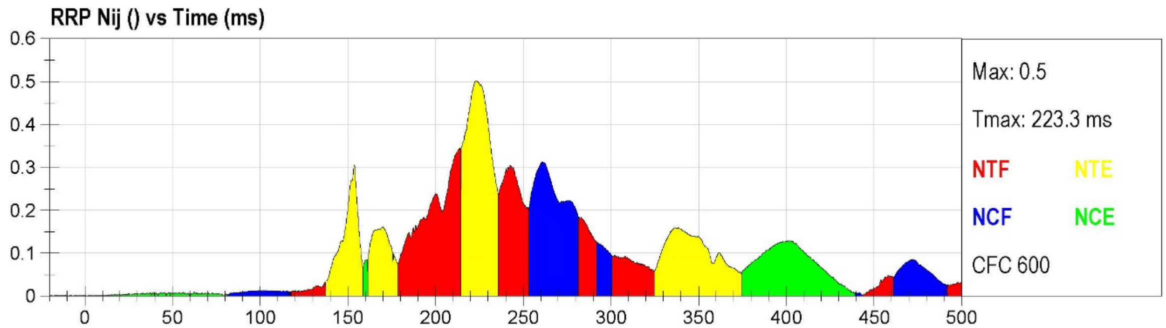



RRP MID SPINE Z (g) vs Time (ms)

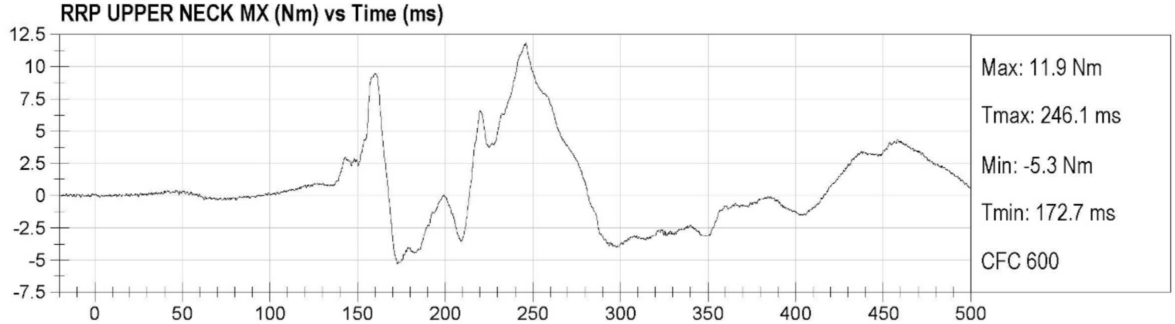



RRP MID SPINE Resultant (g) vs Time (ms)

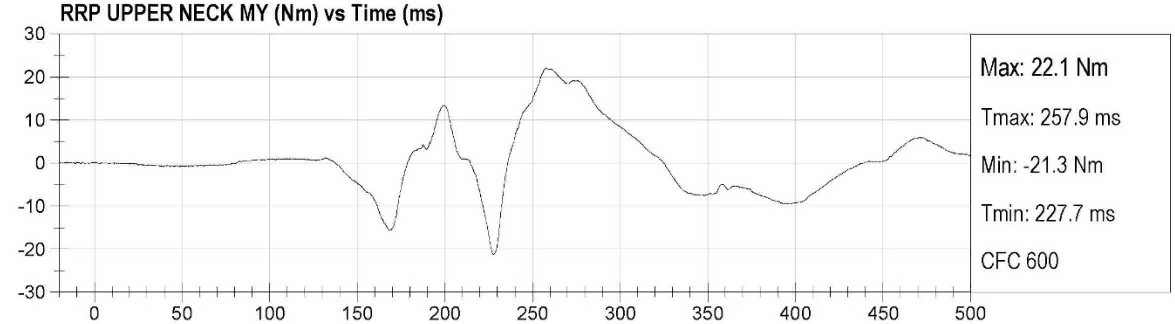



RRP Nij () vs Time (ms)
0.6
0.5
0.4
0.3
0.2
0.1
0
0
50
100
150
200
250
300
350
400
450
500
Max: 0.5
Tmax: 223.3 ms
NTF
NTE
NCF
NCE
CFC 600

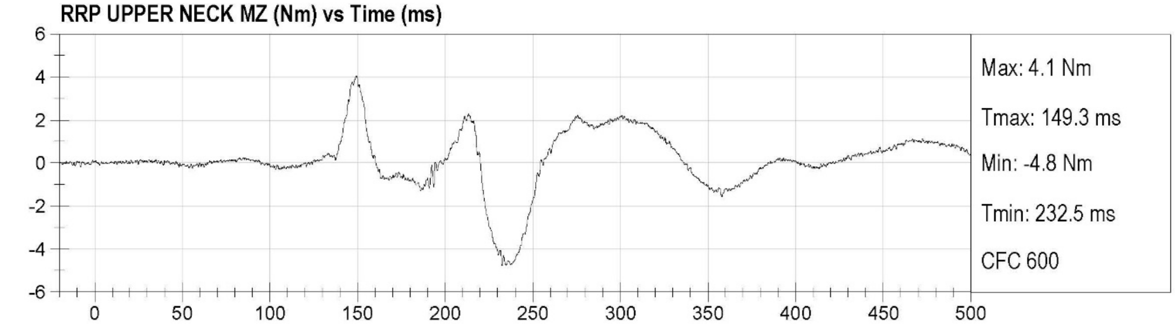
RRP UPPER NECK MX (Nm) vs Time (ms)



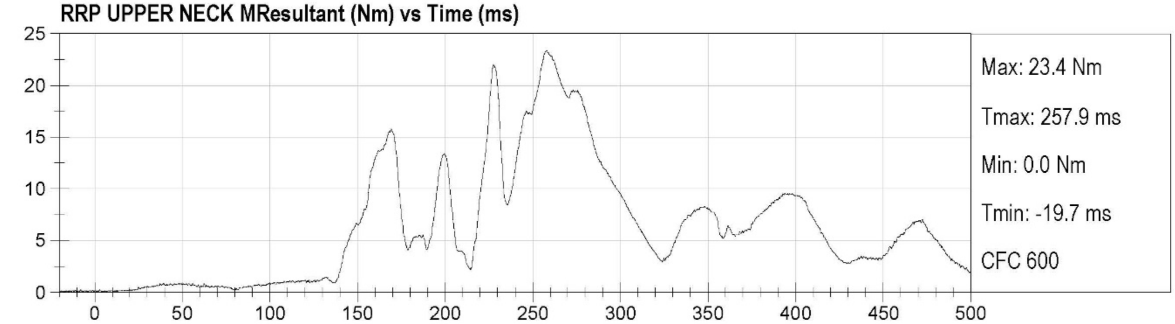

RRP UPPER NECK MY (Nm) vs Time (ms)

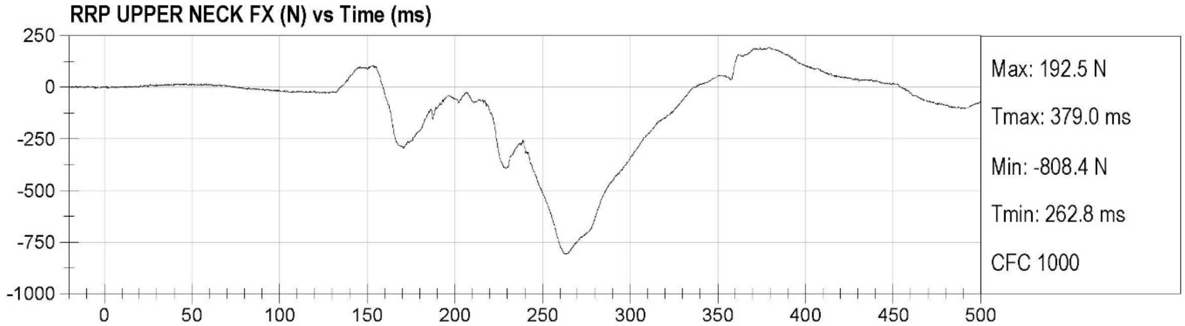



RRP UPPER NECK MZ (Nm) vs Time (ms)

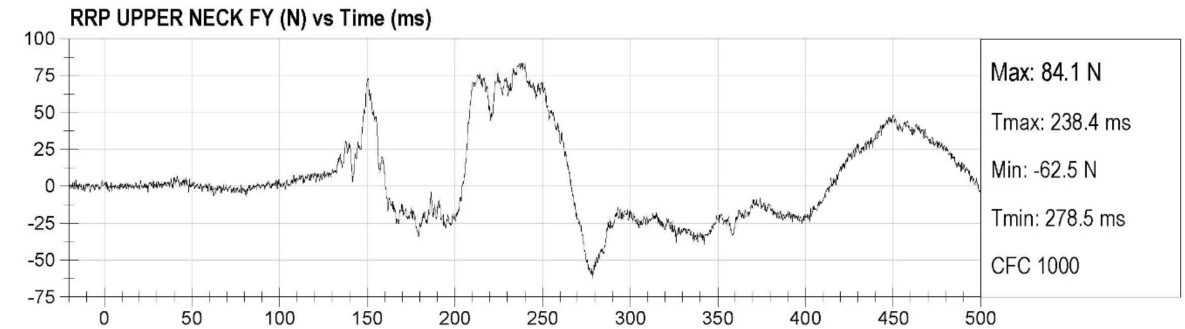



RRP UPPER NECK MResultant (Nm) vs Time (ms)

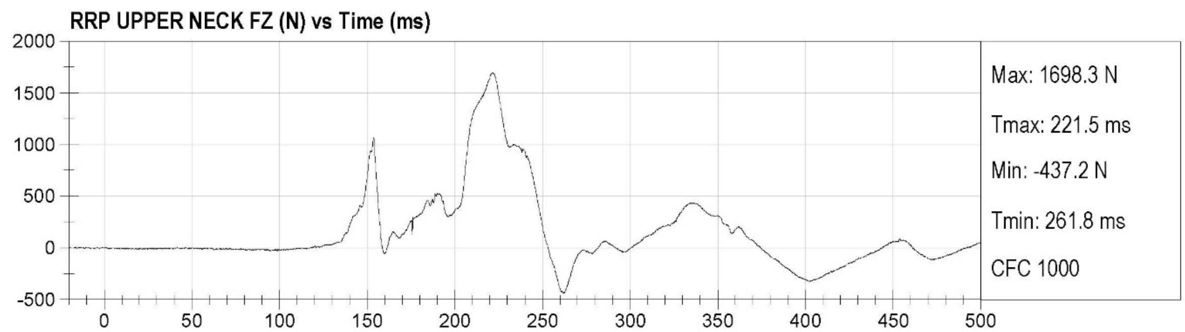




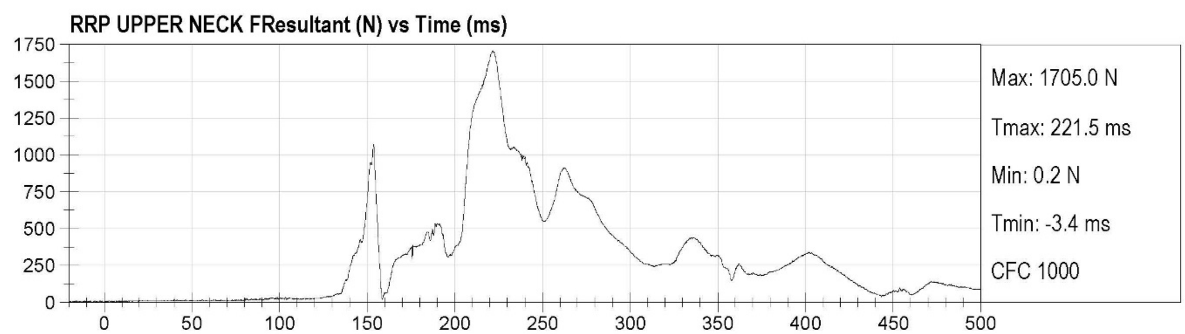
RRP UPPER NECK FX (N) vs Time (ms)
Max: 192.5 N
Tmax: 379.0 ms
Min: -808.4 N
Tmin: 262.8 ms
CFC 1000

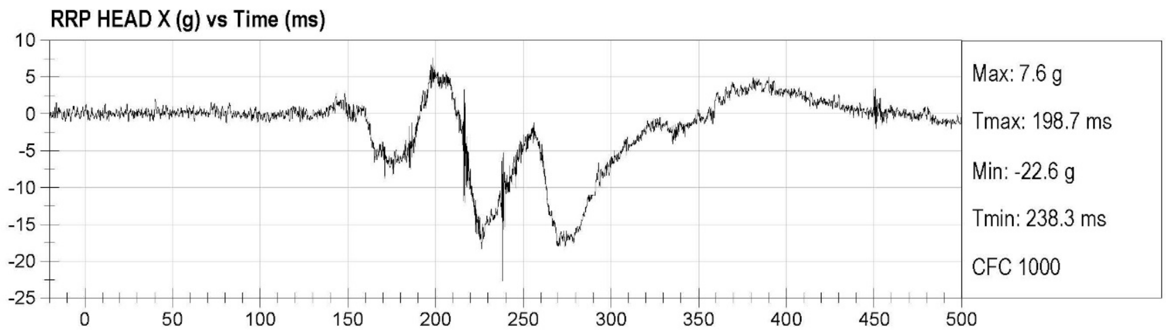
RRP UPPER NECK FY (N) vs Time (ms)
Max: 84.1 N
Tmax: 238.4 ms
Min: -62.5 N
Tmin: 278.5 ms
CFC 1000

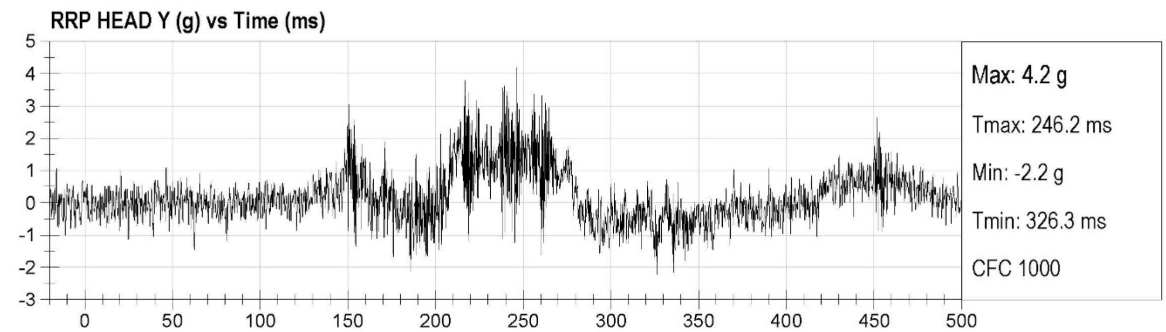



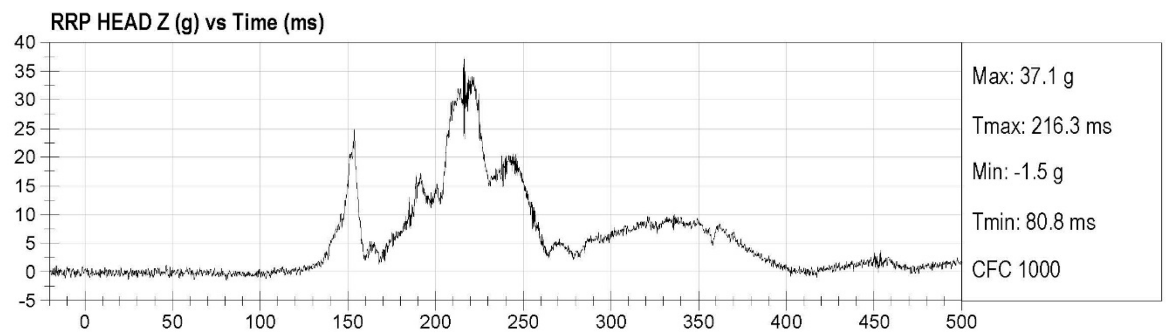
RRP UPPER NECK FZ (N) vs Time (ms)
Max: 1698.3 N
Tmax: 221.5 ms
Min: -437.2 N
Tmin: 261.8 ms
CFC 1000

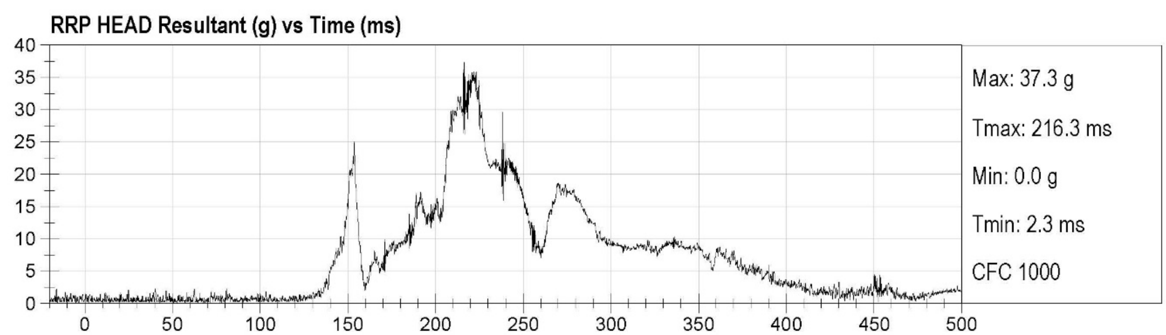



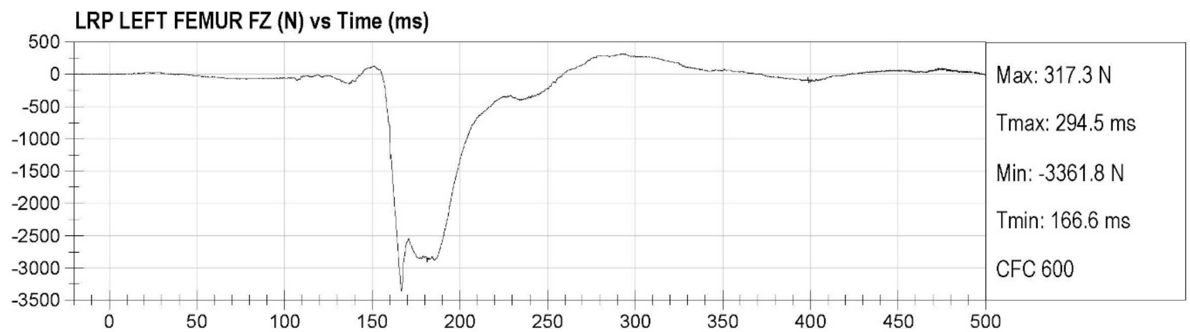
RRP UPPER NECK FResultant (N) vs Time (ms)
Max: 1705.0 N
Tmax: 221.5 ms
Min: 0.2 N
Tmin: -3.4 ms
CFC 1000

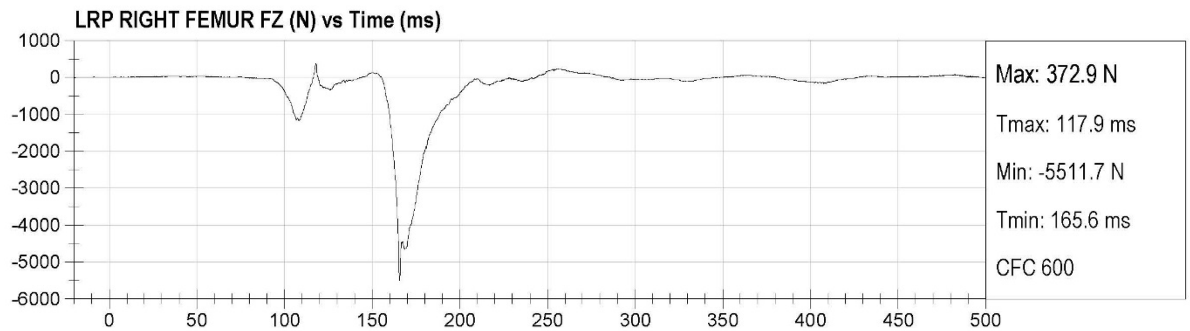

RRP HEAD X (g) vs Time (ms)
Max: 7.6 g
Tmax: 198.7 ms
Min: -22.6 g
Tmin: 238.3 ms
CFC 1000

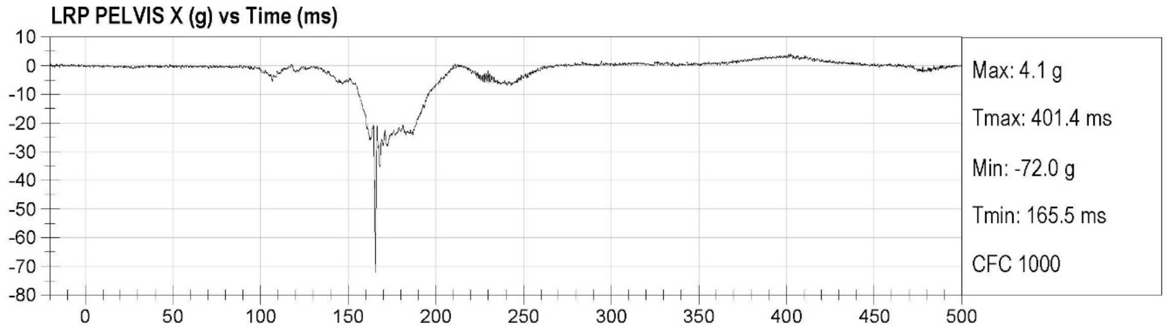

RRP HEAD Y (g) vs Time (ms)
Max: 4.2 g
Tmax: 246.2 ms
Min: -2.2 g
Tmin: 326.3 ms
CFC 1000

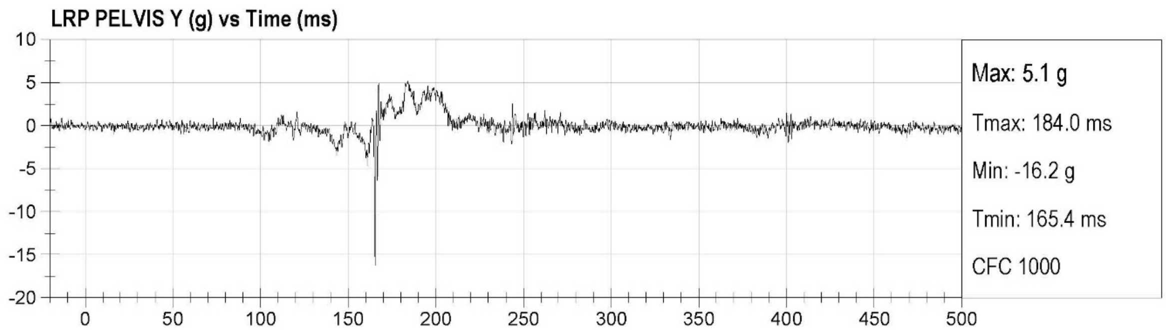

RRP HEAD Z (g) vs Time (ms)
Max: 37.1 g
Tmax: 216.3 ms
Min: -1.5 g
Tmin: 80.8 ms
CFC 1000

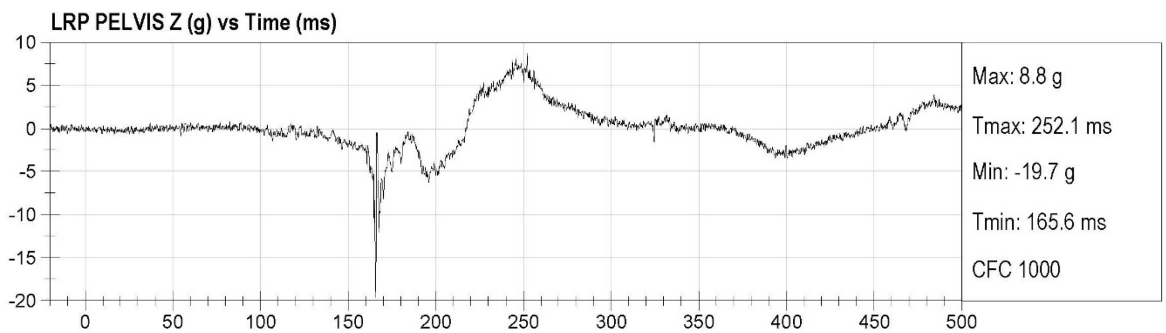

RRP HEAD Resultant (g) vs Time (ms)
Max: 37.3 g
Tmax: 216.3 ms
Min: 0.0 g
Tmin: 2.3 ms
CFC 1000

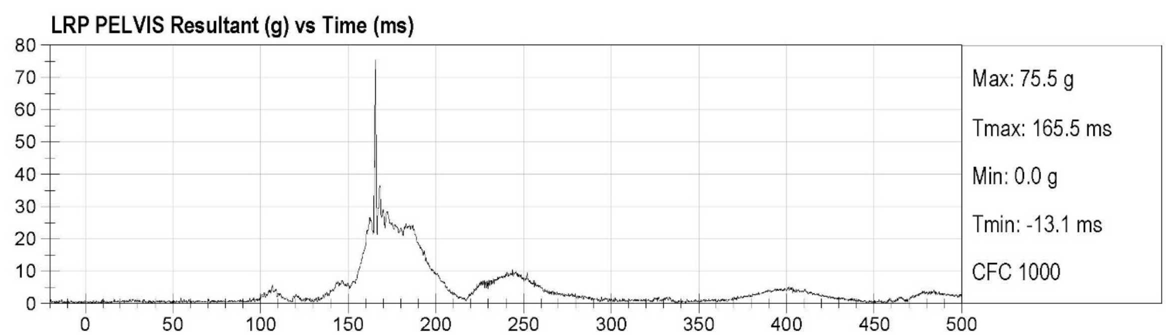

LRP LEFT FEMUR FZ (N) vs Time (ms)
Max: 317.3 N
Tmax: 294.5 ms
Min: -3361.8 N
Tmin: 166.6 ms
CFC 600

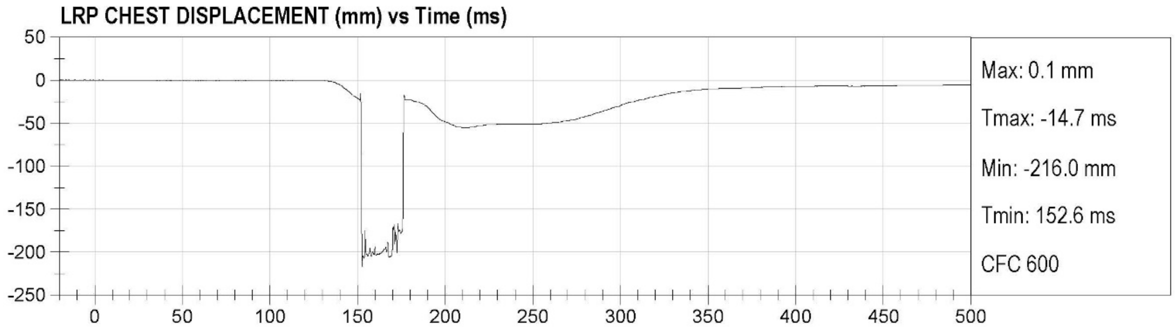

LRP RIGHT FEMUR FZ (N) vs Time (ms)
Max: 372.9 N
Tmax: 117.9 ms
Min: -5511.7 N
Tmin: 165.6 ms
CFC 600

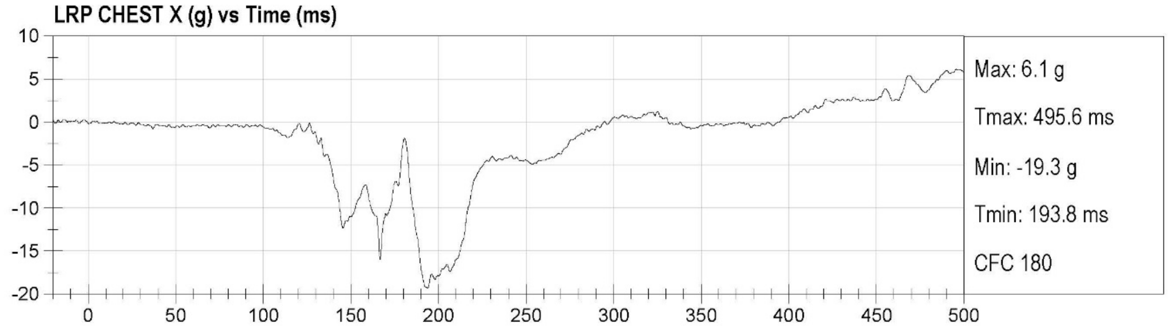

LRP PELVIS X (g) vs Time (ms)
Max: 4.1 g
Tmax: 401.4 ms
Min: -72.0 g
Tmin: 165.5 ms
CFC 1000

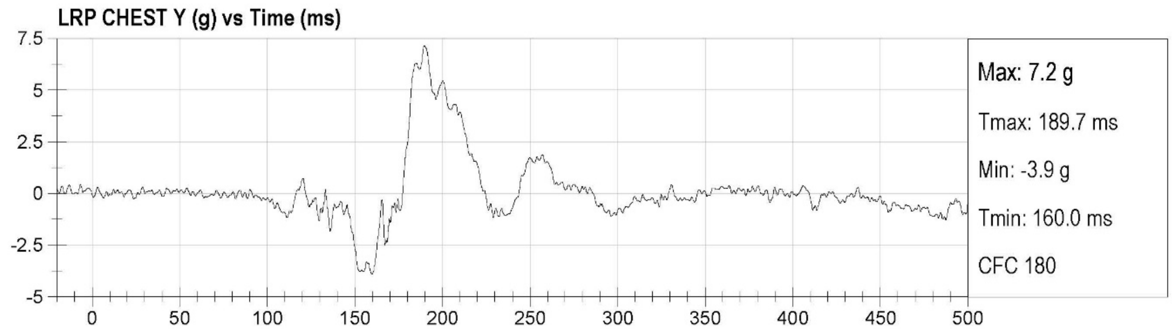

LRP PELVIS Y (g) vs Time (ms)
Max: 5.1 g
Tmax: 184.0 ms
Min: -16.2 g
Tmin: 165.4 ms
CFC 1000

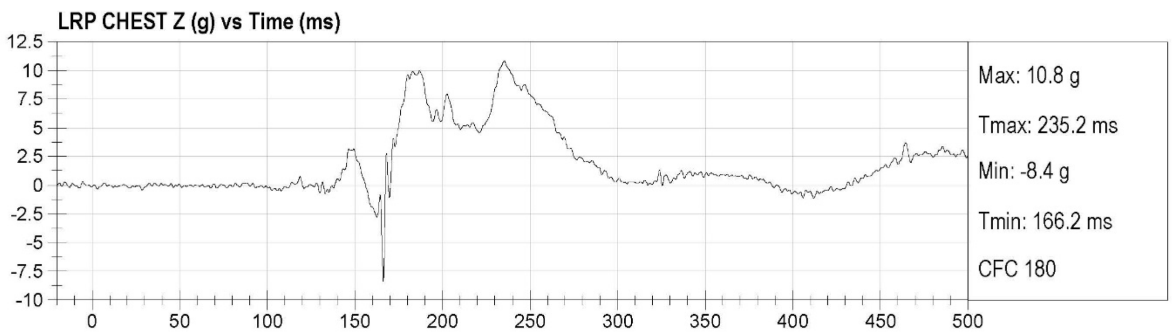

LRP PELVIS Z (g) vs Time (ms)
Max: 8.8 g
Tmax: 252.1 ms
Min: -19.7 g
Tmin: 165.6 ms
CFC 1000

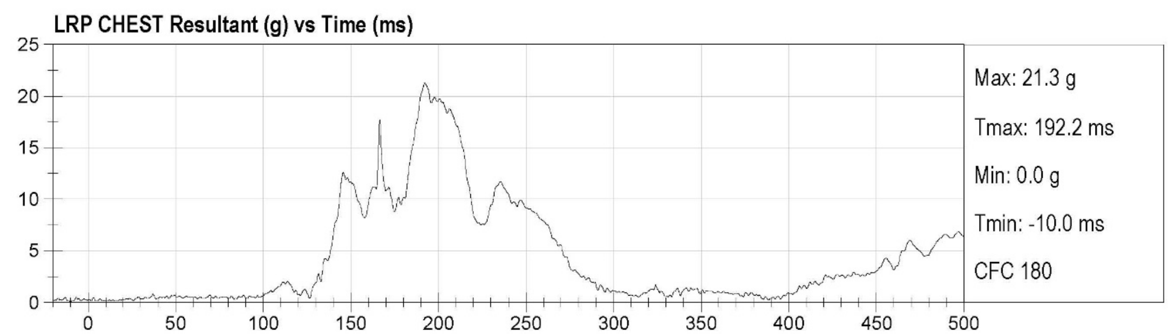

LRP PELVIS Resultant (g) vs Time (ms)
Max: 75.5 g
Tmax: 165.5 ms
Min: 0.0 g
Tmin: -13.1 ms
CFC 1000

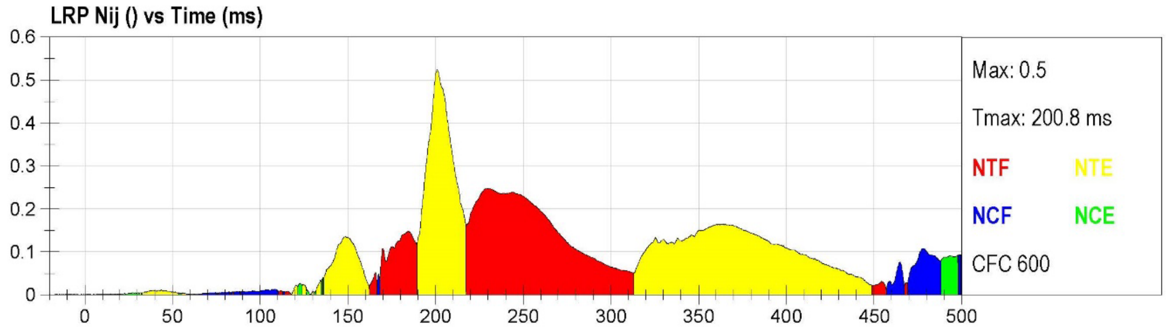

LRP CHEST DISPLACEMENT (mm) vs Time (ms)
50
0
-50
-100
-150
-200
-250
0
50
100
150
200
250
300
350
400
450
500
Max: 0.1 mm
Tmax: -14.7 ms
Min: -216.0 mm
Tmin: 152.6 ms
CFC 600


LRP CHEST X (g) vs Time (ms)
Max: 6.1 g
Tmax: 495.6 ms
Min: -19.3 g
Tmin: 193.8 ms
CFC 180

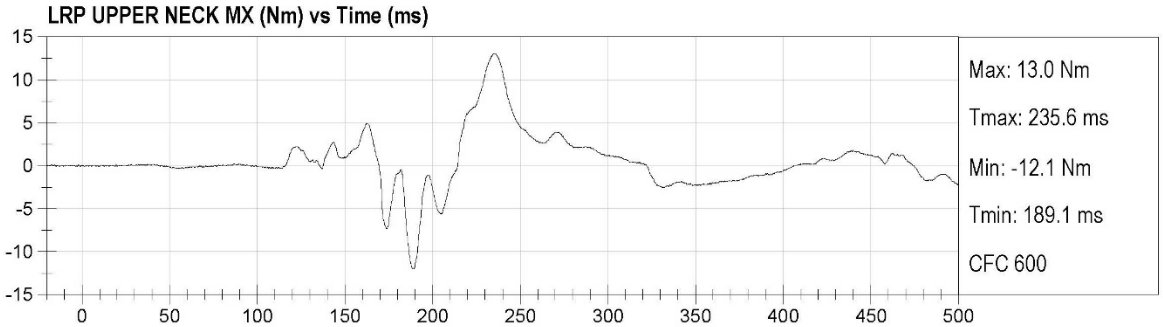

LRP CHEST Y (g) vs Time (ms)
Max: 7.2 g
Tmax: 189.7 ms
Min: -3.9 g
Tmin: 160.0 ms
CFC 180

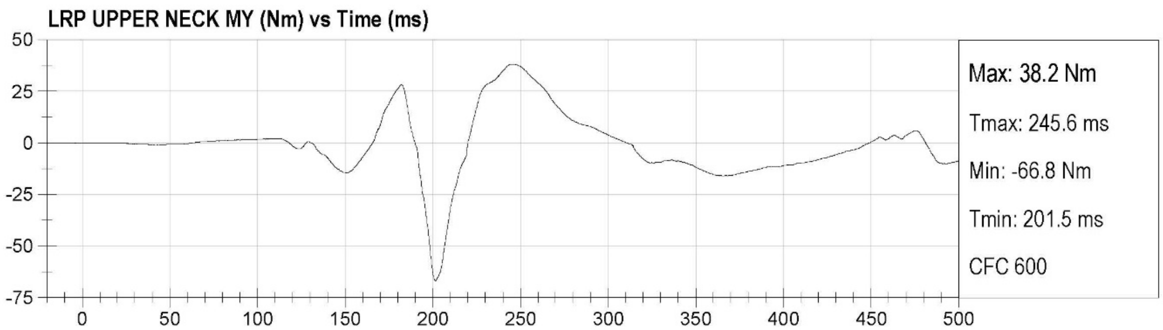

LRP CHEST Z (g) vs Time (ms)
Max: 10.8 g
Tmax: 235.2 ms
Min: -8.4 g
Tmin: 166.2 ms
CFC 180

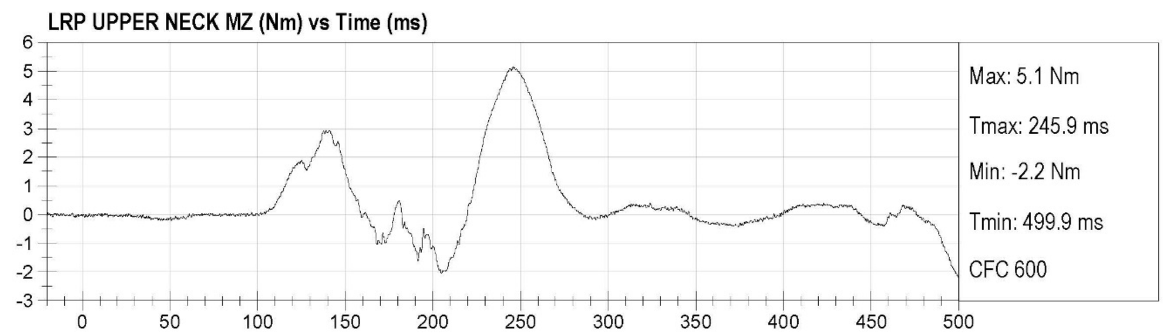

LRP CHEST Resultant (g) vs Time (ms)
Max: 21.3 g
Tmax: 192.2 ms
Min: 0.0 g
Tmin: -10.0 ms
CFC 180

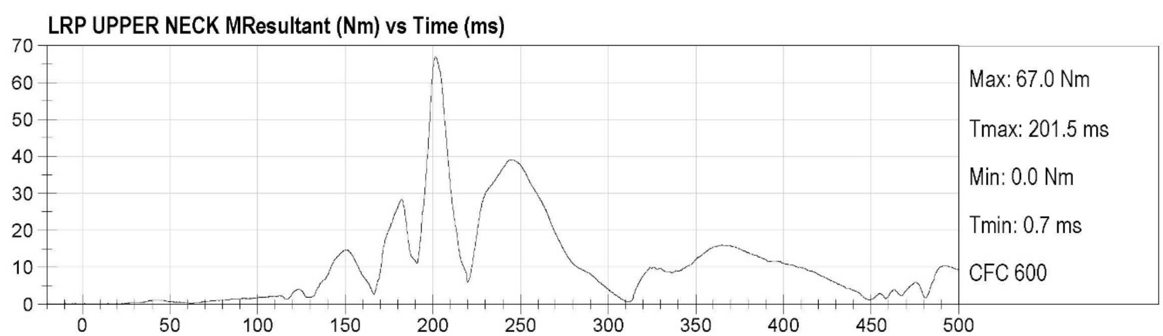


LRP Nij () vs Time (ms)
0.6
0.5
0.4
0.3
0.2
0.1
0
0
50
100
150
200
250
300
350
400
450
500
Max: 0.5
Tmax: 200.8 ms
NTF
NTE
NCF
NCE
CFC 600

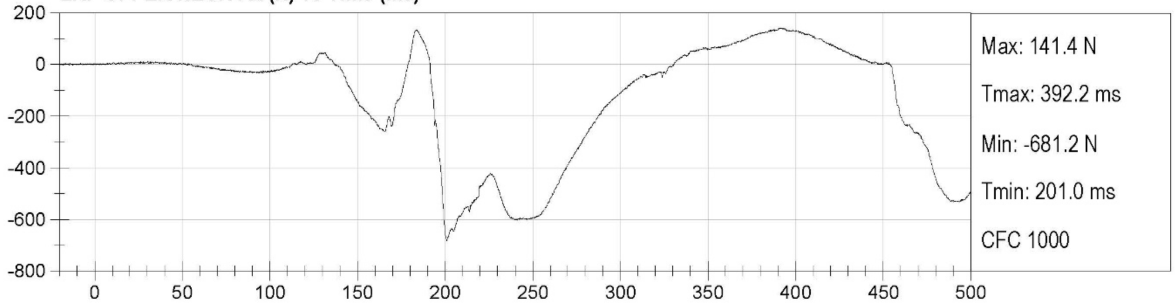

LRP UPPER NECK MX (Nm) vs Time (ms)
Max: 13.0 Nm
Tmax: 235.6 ms
Min: -12.1 Nm
Tmin: 189.1 ms
CFC 600
15
10
5
0
-5
-10
-15
0
50
100
150
200
250
300
350
400
450
500


LRP UPPER NECK MY (Nm) vs Time (ms)
Max: 38.2 Nm
Tmax: 245.6 ms
Min: -66.8 Nm
Tmin: 201.5 ms
CFC 600
50
25
0
-25
-50
-75
0
50
100
150
200
250
300
350
400
450
500

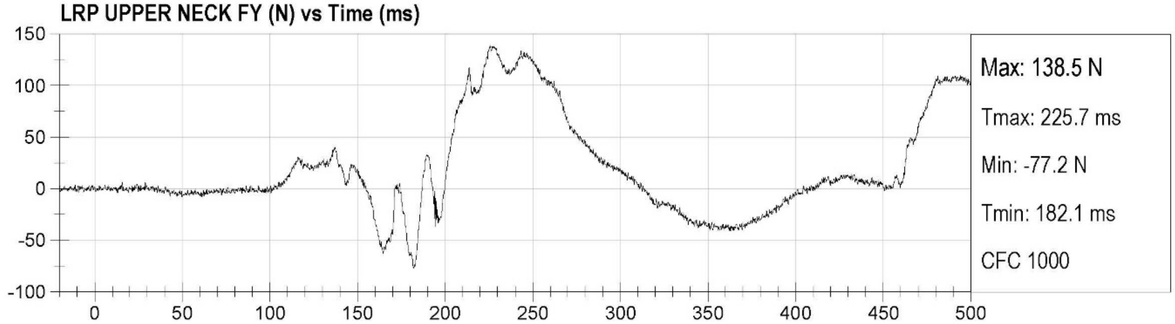

LRP UPPER NECK MZ (Nm) vs Time (ms)
Max: 5.1 Nm
Tmax: 245.9 ms
Min: -2.2 Nm
Tmin: 499.9 ms
CFC 600
6
5
4
3
2
1
0
-1
-2
-3
0
50
100
150
200
250
300
350
400
450
500


LRP UPPER NECK MResultant (Nm) vs Time (ms)
Max: 67.0 Nm
Tmax: 201.5 ms
Min: 0.0 Nm
Tmin: 0.7 ms
CFC 600
70
60
50
40
30
20
10
0
0
50
100
150
200
250
300
350
400
450
500

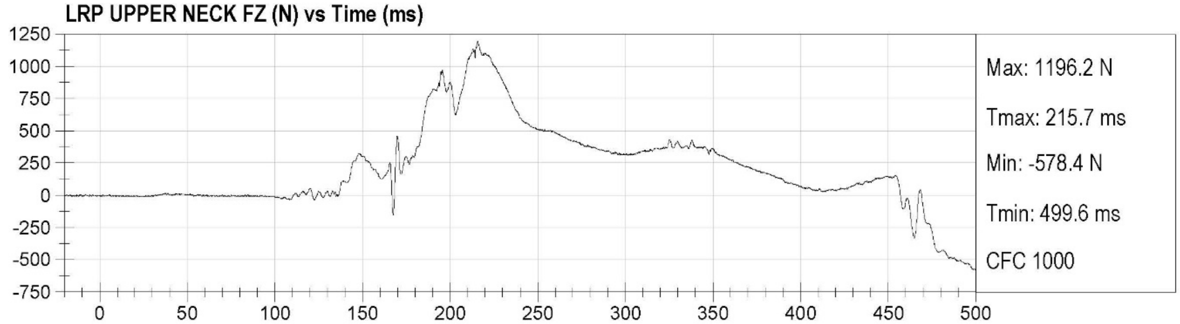
LRP UPPER NECK FX (N) vs Time (ms)



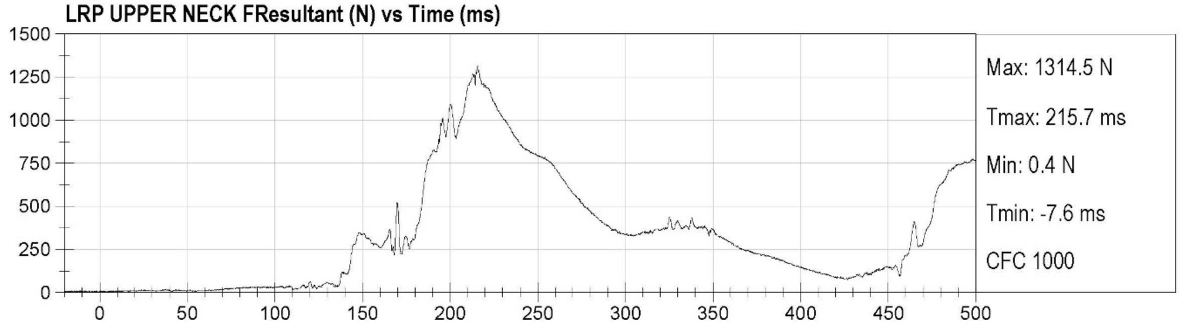

LRP UPPER NECK FY (N) vs Time (ms)



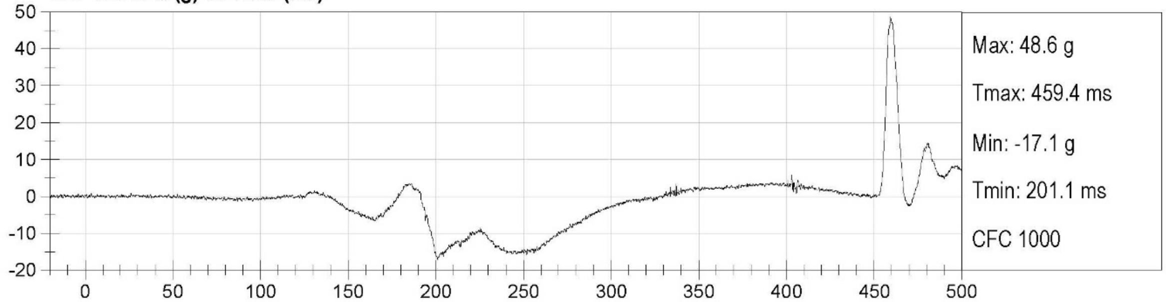

LRP UPPER NECK FZ (N) vs Time (ms)



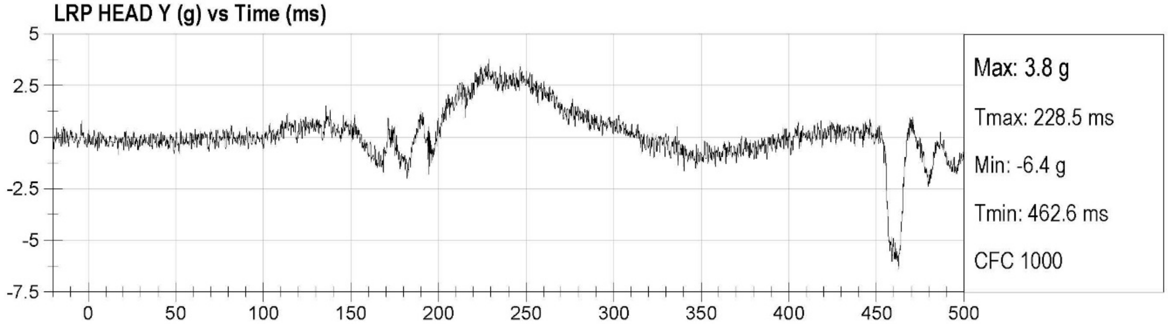

LRP UPPER NECK FResultant (N) vs Time (ms)



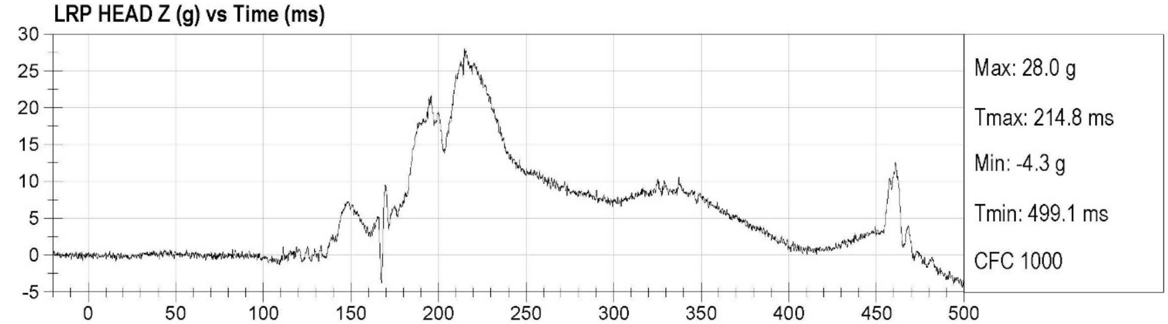
LRP HEAD X (g) vs Time (ms)



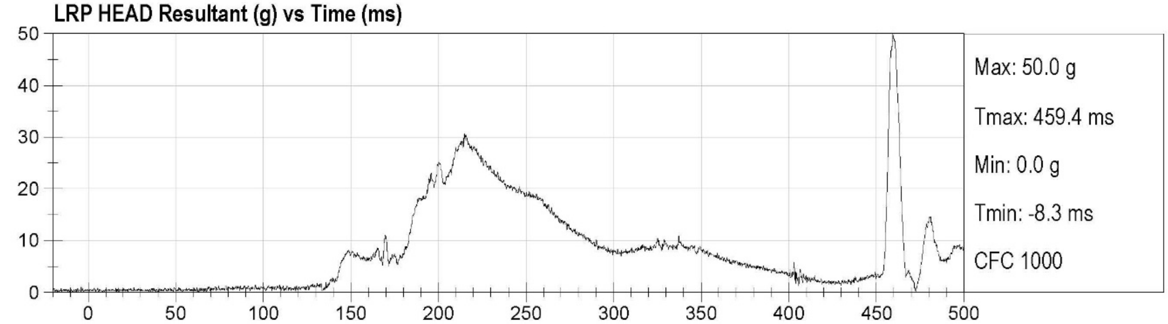

LRP HEAD Y (g) vs Time (ms)




LRP HEAD Z (g) vs Time (ms)



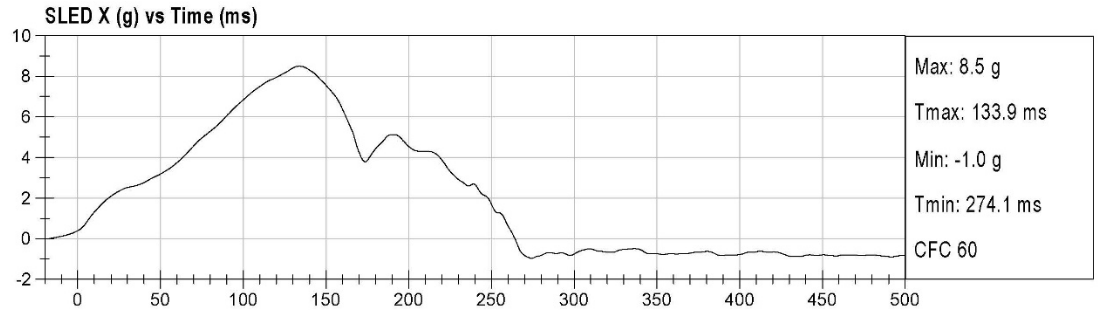

LRP HEAD Resultant (g) vs Time (ms)

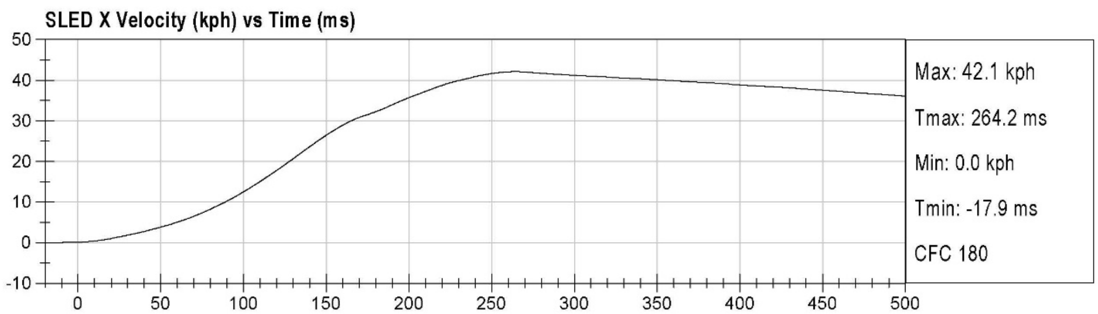


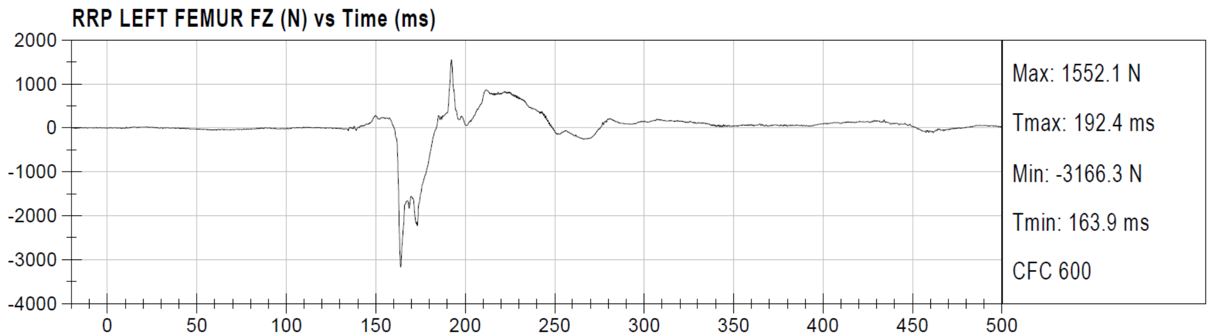
## A.12: Test 5A Data

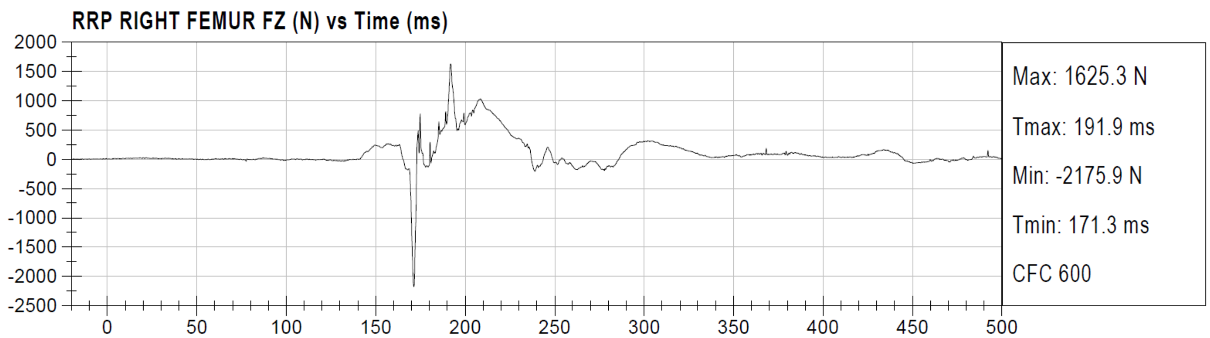
Test Date: 06/09/2021

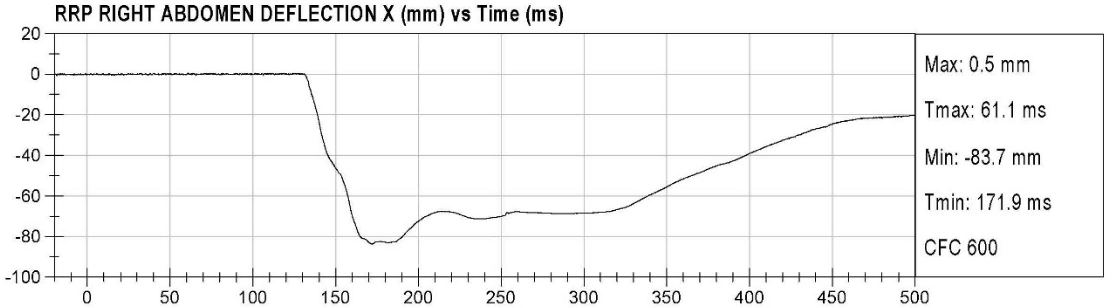
MGA Test ID: S21158

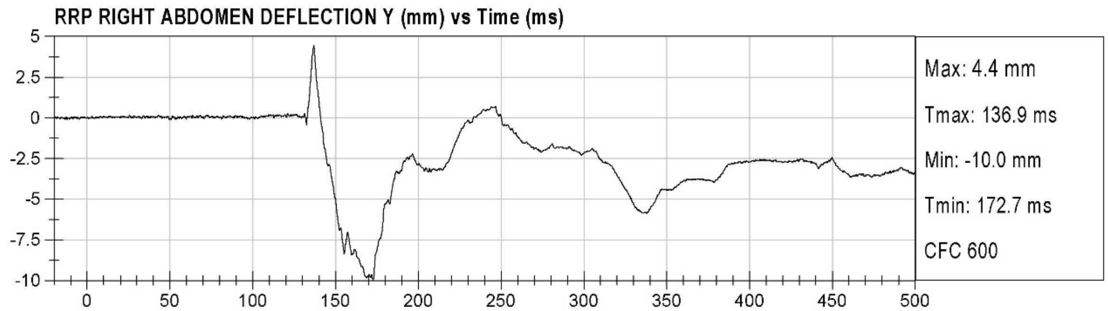


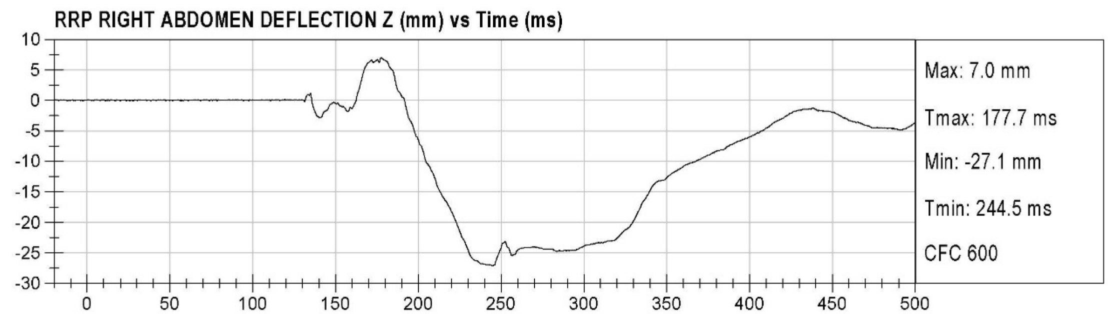



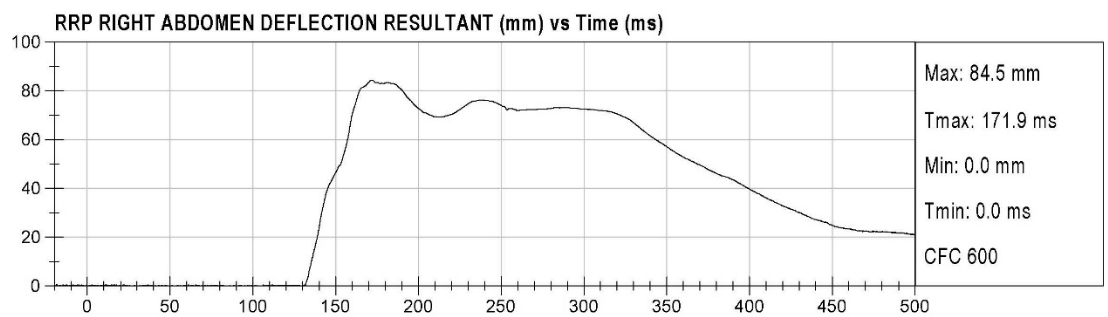

RRP LEFT FEMUR FZ (N) vs Time (ms)
Max: 1552.1 N
Tmax: 192.4 ms
Min: -3166.3 N
Tmin: 163.9 ms
CFC 600

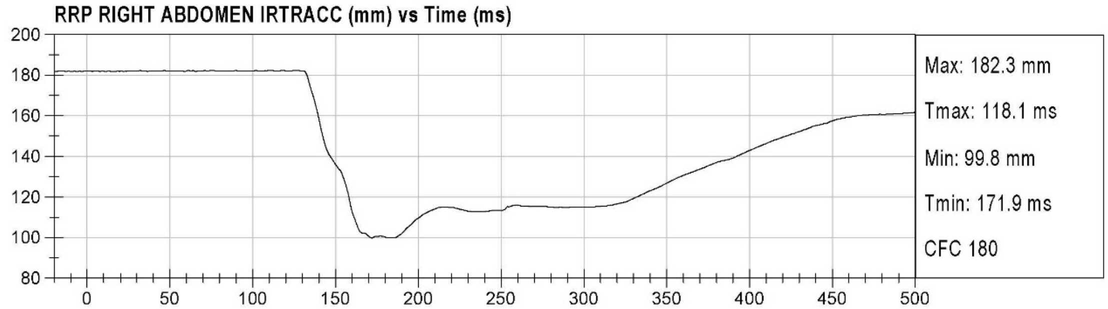

RRP RIGHT FEMUR FZ (N) vs Time (ms)
Max: 1625.3 N
Tmax: 191.9 ms
Min: -2175.9 N
Tmin: 171.3 ms
CFC 600

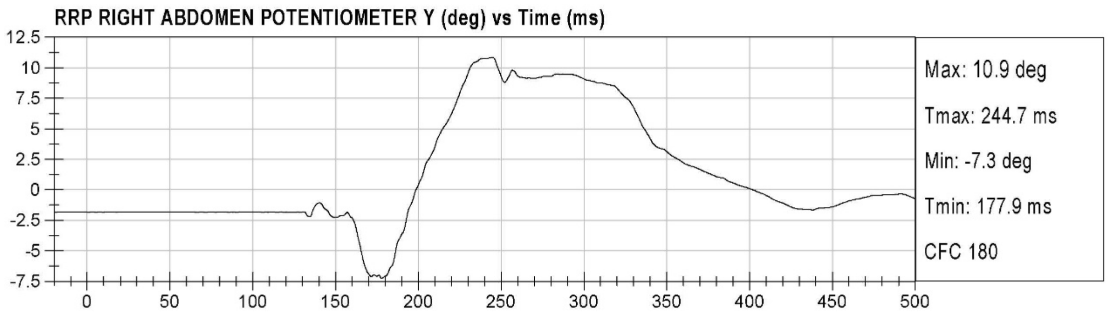

RRP RIGHT ABDOMEN DEFLECTION X (mm) vs Time (ms)
Max: 0.5 mm
Tmax: 61.1 ms
Min: -83.7 mm
Tmin: 171.9 ms
CFC 600

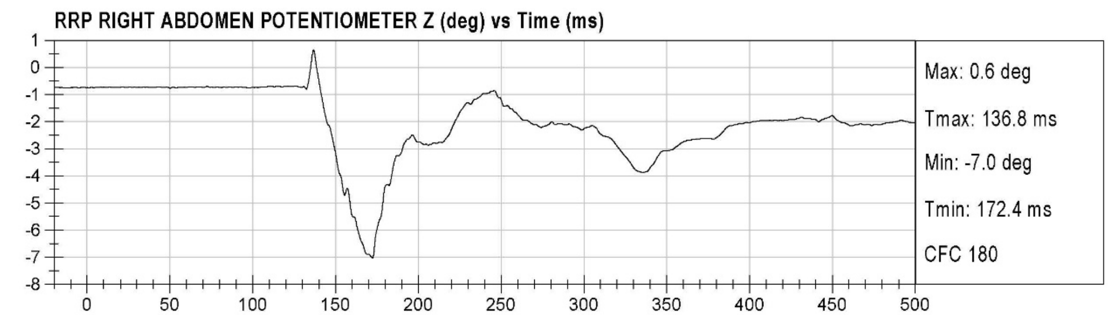

RRP RIGHT ABDOMEN DEFLECTION Y (mm) vs Time (ms)
Max: 4.4 mm
Tmax: 136.9 ms
Min: -10.0 mm
Tmin: 172.7 ms
CFC 600


RRP RIGHT ABDOMEN DEFLECTION Z (mm) vs Time (ms)
Max: 7.0 mm
Tmax: 177.7 ms
Min: -27.1 mm
Tmin: 244.5 ms
CFC 600

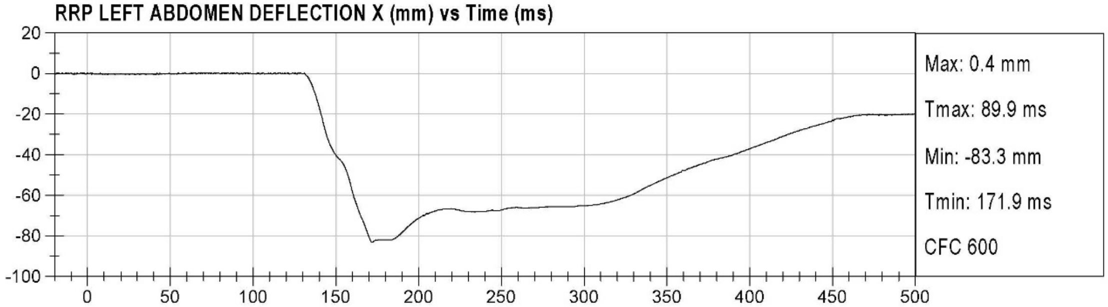

RRP RIGHT ABDOMEN DEFLECTION RESULTANT (mm) vs Time (ms)
Max: 84.5 mm
Tmax: 171.9 ms
Min: 0.0 mm
Tmin: 0.0 ms
CFC 600


RRP RIGHT ABDOMEN IRTRACC (mm) vs Time (ms)
Max: 182.3 mm
Tmax: 118.1 ms
Min: 99.8 mm
Tmin: 171.9 ms
CFC 180

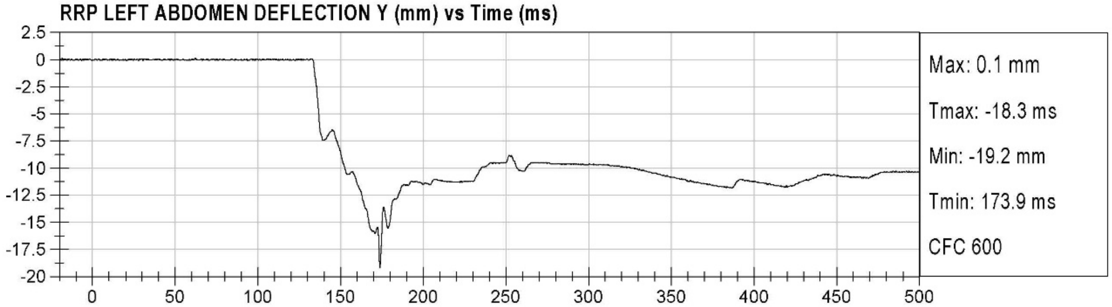

RRP RIGHT ABDOMEN POTENTIOMETER Y (deg) vs Time (ms)
Max: 10.9 deg
Tmax: 244.7 ms
Min: -7.3 deg
Tmin: 177.9 ms
CFC 180


RRP RIGHT ABDOMEN POTENTIOMETER Z (deg) vs Time (ms)
Max: 0.6 deg
Tmax: 136.8 ms
Min: -7.0 deg
Tmin: 172.4 ms
CFC 180

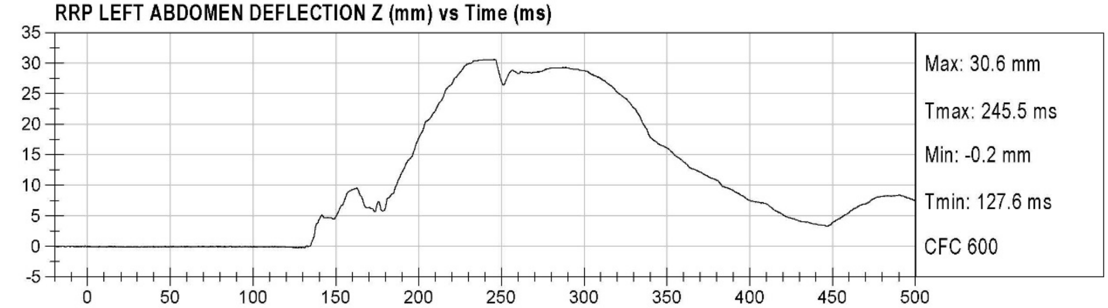
RRP LEFT ABDOMEN DEFLECTION X (mm) vs Time (ms)



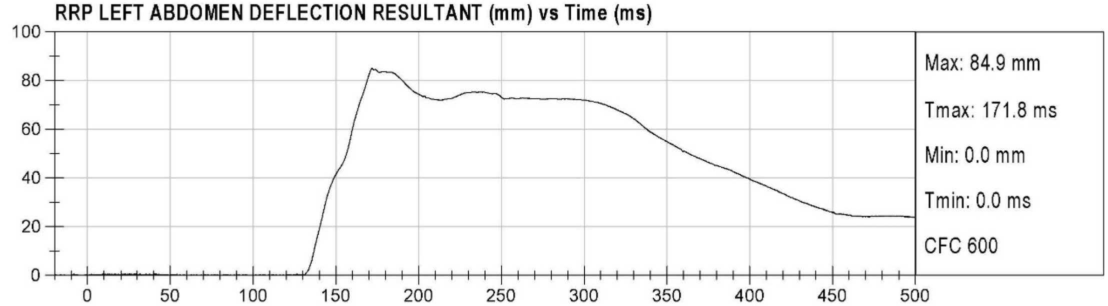

RRP LEFT ABDOMEN DEFLECTION Y (mm) vs Time (ms)

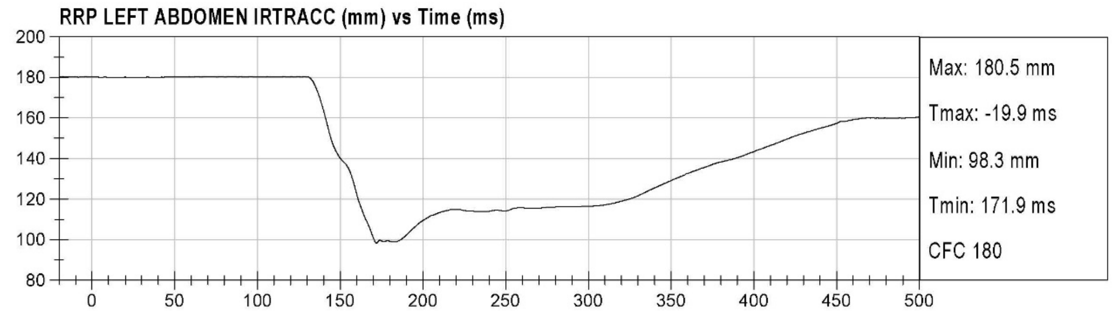


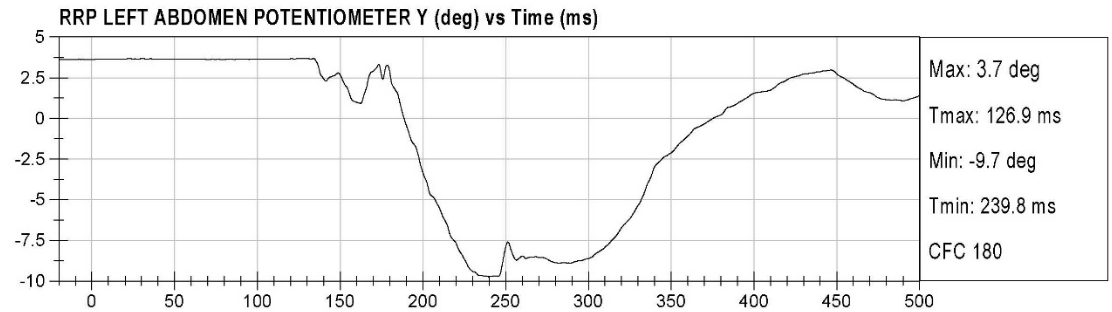

RRP LEFT ABDOMEN DEFLECTION Z (mm) vs Time (ms)

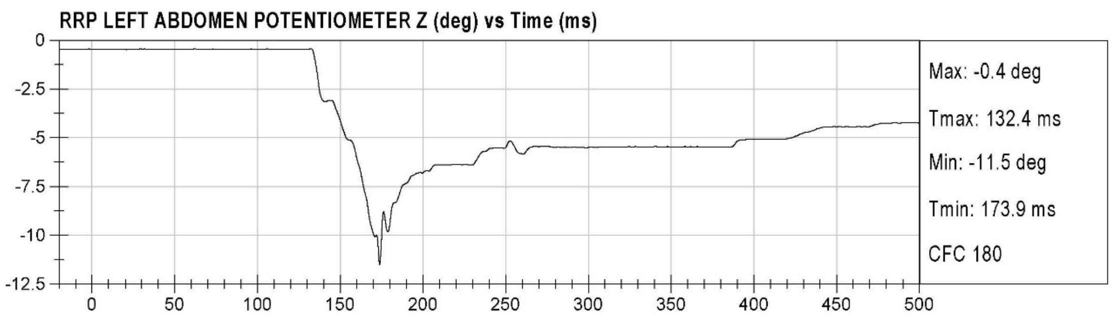



RRP LEFT ABDOMEN DEFLECTION RESULTANT (mm) vs Time (ms)




RRP LEFT ABDOMEN IRTRACC (mm) vs Time (ms)
Max: 180.5 mm
Tmax: -19.9 ms
Min: 98.3 mm
Tmin: 171.9 ms
CFC 180


RRP LEFT ABDOMEN POTENTIOMETER Y (deg) vs Time (ms)
Max: 3.7 deg
Tmax: 126.9 ms
Min: -9.7 deg
Tmin: 239.8 ms
CFC 180


RRP LEFT ABDOMEN POTENTIOMETER Z (deg) vs Time (ms)
Max: -0.4 deg
Tmax: 132.4 ms
Min: -11.5 deg
Tmin: 173.9 ms
CFC 180

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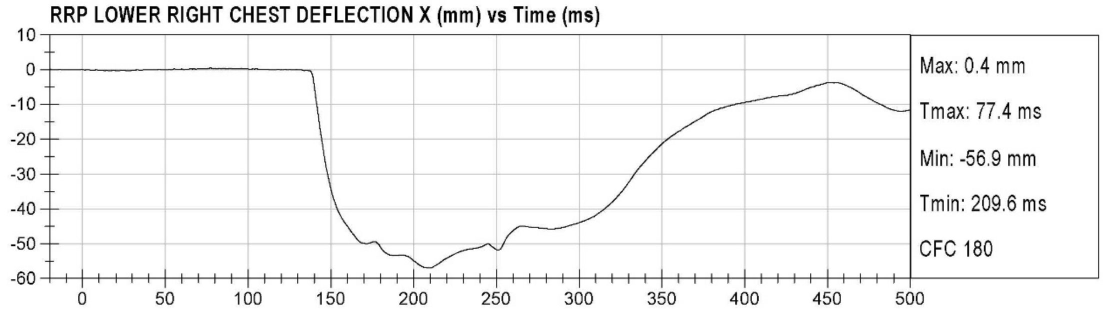
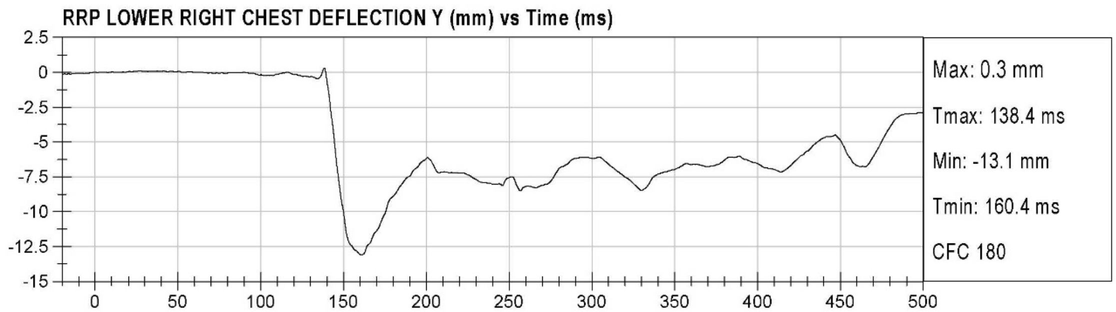
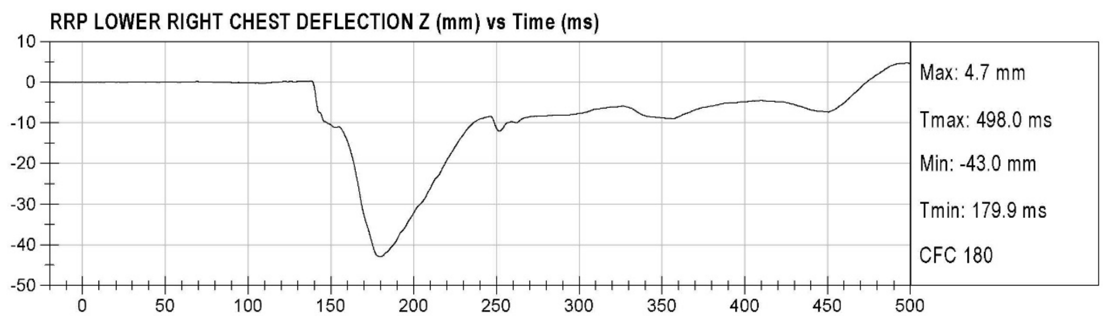
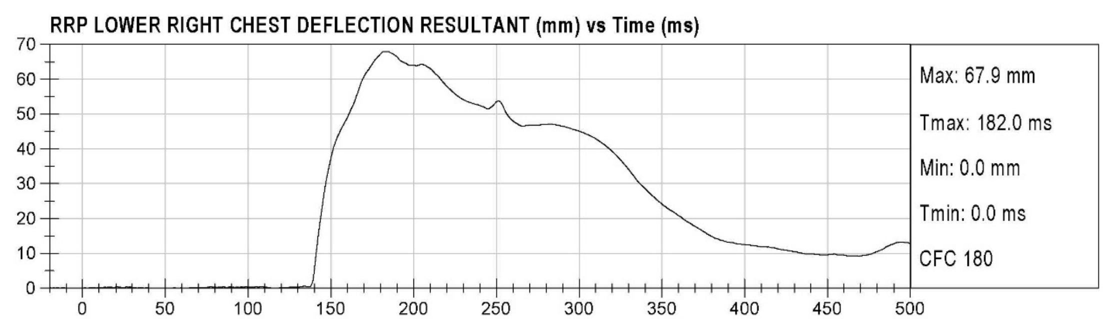

RRP LOWER RIGHT CHEST DEFLECTION X (mm) vs Time (ms)
10
0
-10
-20
-30
-40
-50
-60
0 50 100 150 200 250 300 350 400 450 500
Max: 0.4 mm
Tmax: 77.4 ms
Min: -56.9 mm
Tmin: 209.6 ms
CFC 180


RRP LOWER RIGHT CHEST DEFLECTION Y (mm) vs Time (ms)
2.5
0
-2.5
-5
-7.5
-10
-12.5
-15
0 50 100 150 200 250 300 350 400 450 500
Max: 0.3 mm
Tmax: 138.4 ms
Min: -13.1 mm
Tmin: 160.4 ms
CFC 180


RRP LOWER RIGHT CHEST DEFLECTION Z (mm) vs Time (ms)
10
0
-10
-20
-30
-40
-50
0 50 100 150 200 250 300 350 400 450 500
Max: 4.7 mm
Tmax: 498.0 ms
Min: -43.0 mm
Tmin: 179.9 ms
CFC 180


RRP LOWER RIGHT CHEST DEFLECTION RESULTANT (mm) vs Time (ms)
70
60
50
40
30
20
10
0
0 50 100 150 200 250 300 350 400 450 500
Max: 67.9 mm
Tmax: 182.0 ms
Min: 0.0 mm
Tmin: 0.0 ms
CFC 180

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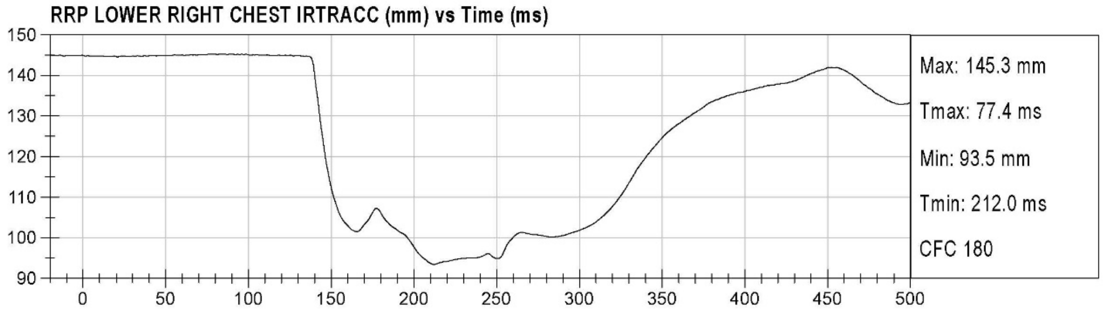
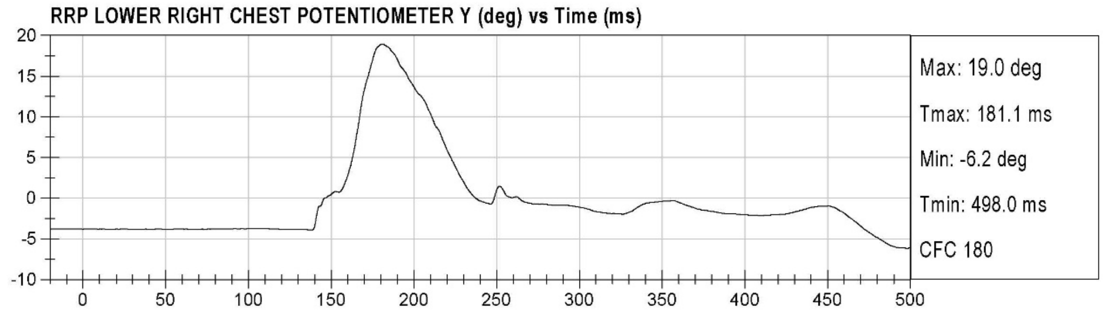
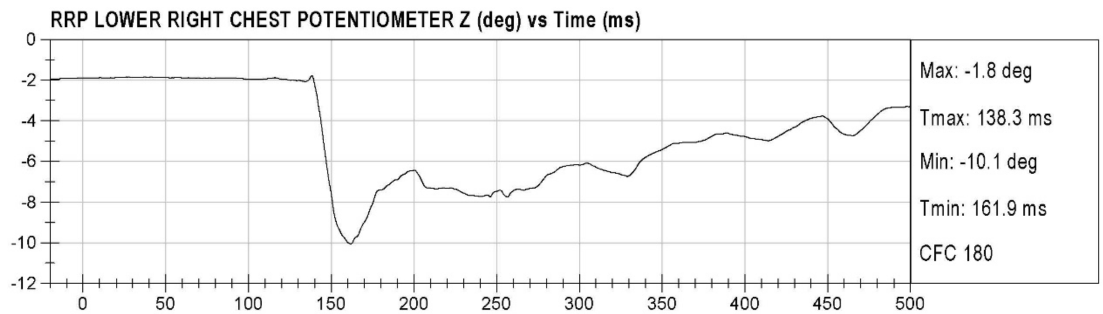
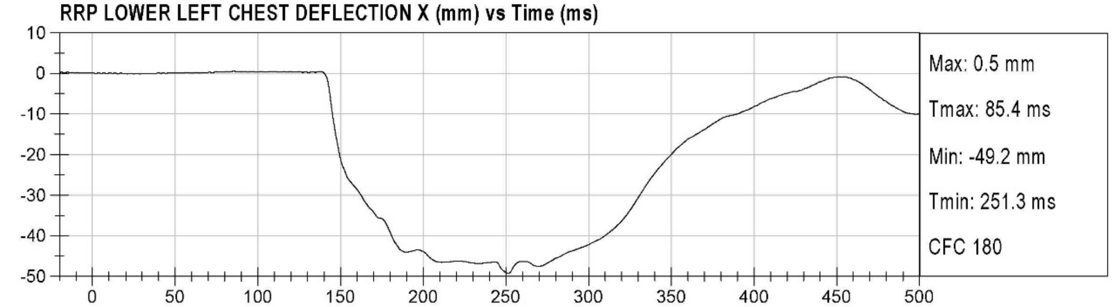

RRP LOWER RIGHT CHEST IRTRACC (mm) vs Time (ms)
Max: 145.3 mm
Tmax: 77.4 ms
Min: 93.5 mm
Tmin: 212.0 ms
CFC 180

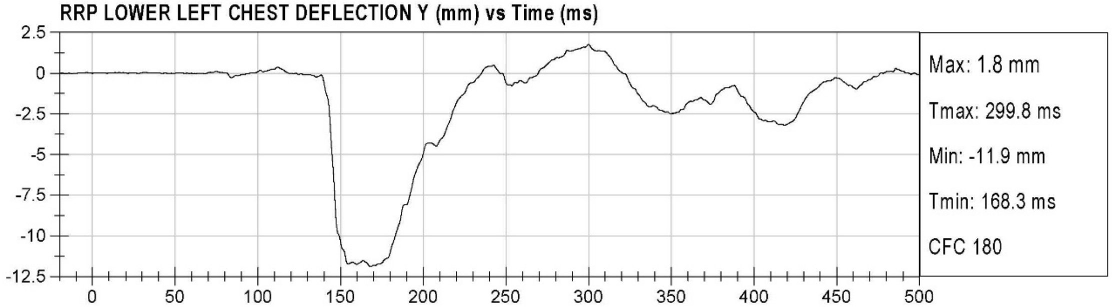

RRP LOWER RIGHT CHEST POTENTIOMETER Y (deg) vs Time (ms)
Max: 19.0 deg
Tmax: 181.1 ms
Min: -6.2 deg
Tmin: 498.0 ms
CFC 180


RRP LOWER RIGHT CHEST POTENTIOMETER Z (deg) vs Time (ms)
Max: -1.8 deg
Tmax: 138.3 ms
Min: -10.1 deg
Tmin: 161.9 ms
CFC 180

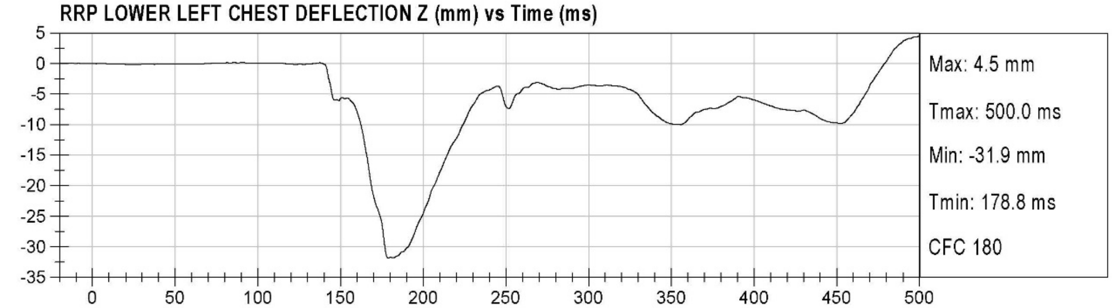
RRP LOWER LEFT CHEST DEFLECTION X (mm) vs Time (ms)



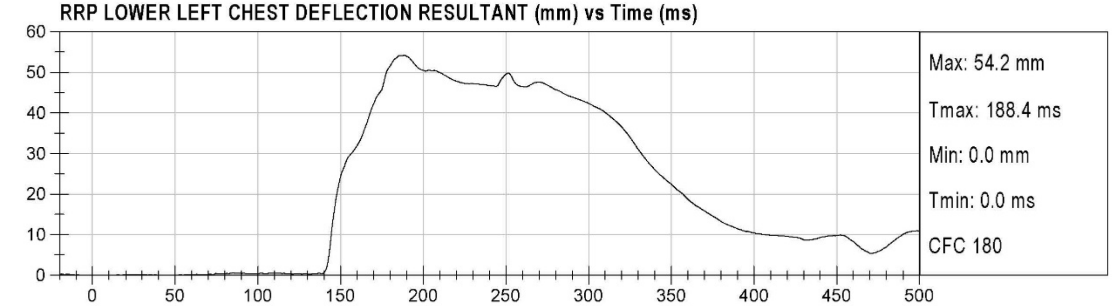

RRP LOWER LEFT CHEST DEFLECTION Y (mm) vs Time (ms)

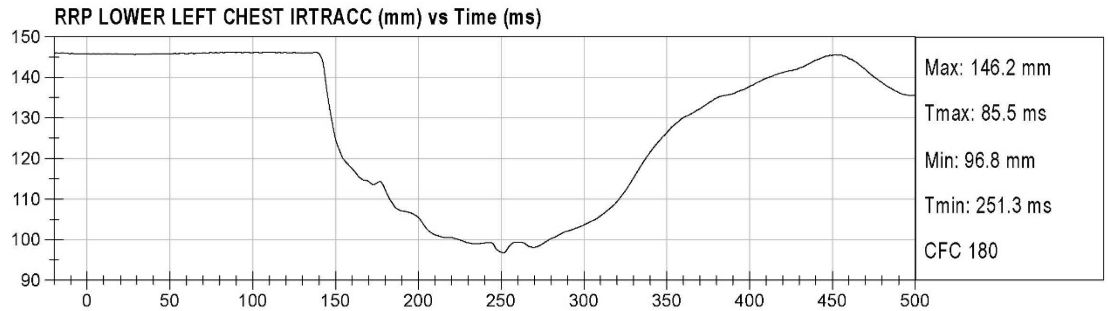


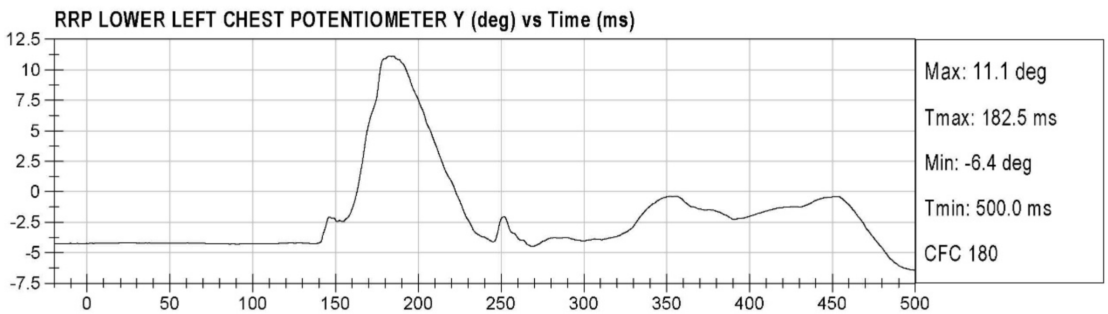

RRP LOWER LEFT CHEST DEFLECTION Z (mm) vs Time (ms)

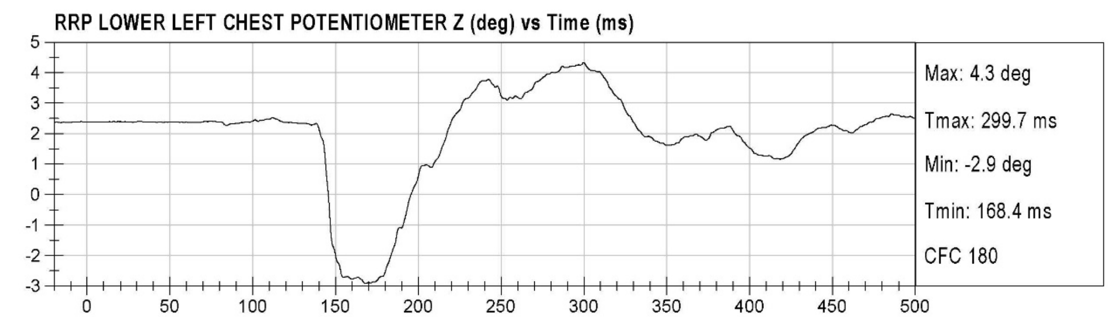



RRP LOWER LEFT CHEST DEFLECTION RESULTANT (mm) vs Time (ms)

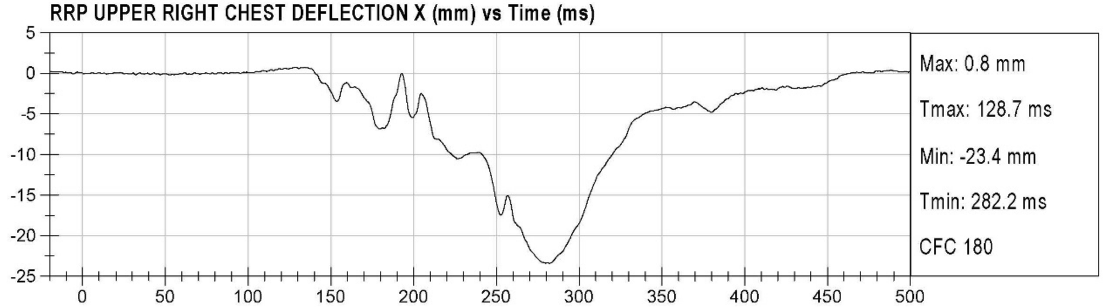



RRP LOWER LEFT CHEST IRTRACC (mm) vs Time (ms)
Max: 146.2 mm
Tmax: 85.5 ms
Min: 96.8 mm
Tmin: 251.3 ms
CFC 180

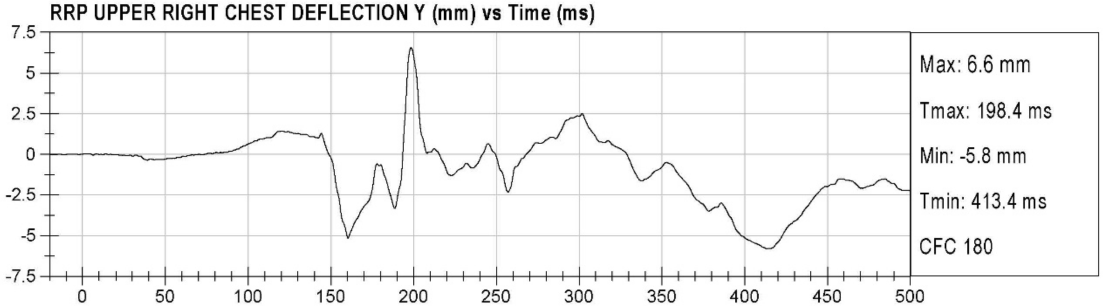

RRP LOWER LEFT CHEST POTENTIOMETER Y (deg) vs Time (ms)
Max: 11.1 deg
Tmax: 182.5 ms
Min: -6.4 deg
Tmin: 500.0 ms
CFC 180


RRP LOWER LEFT CHEST POTENTIOMETER Z (deg) vs Time (ms)
Max: 4.3 deg
Tmax: 299.7 ms
Min: -2.9 deg
Tmin: 168.4 ms
CFC 180

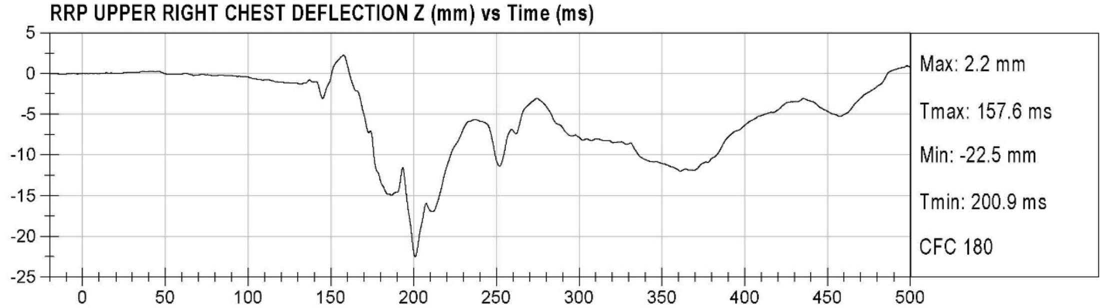
RRP UPPER RIGHT CHEST DEFLECTION X (mm) vs Time (ms)



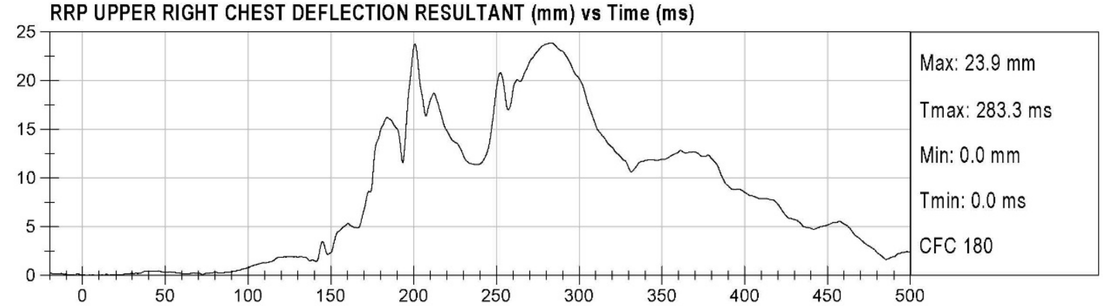

RRP UPPER RIGHT CHEST DEFLECTION Y (mm) vs Time (ms)



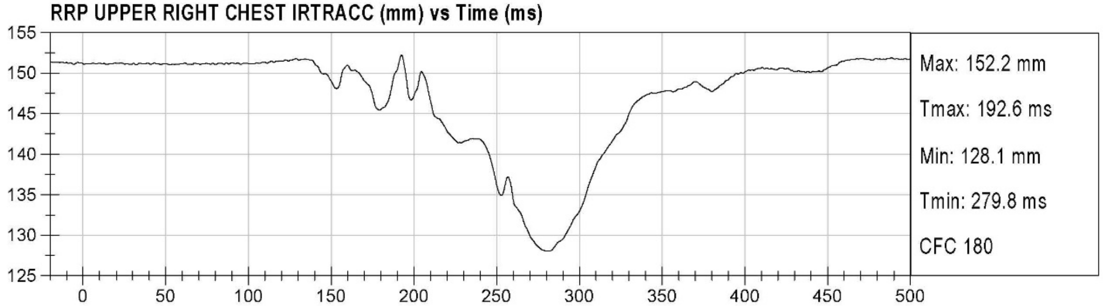

RRP UPPER RIGHT CHEST DEFLECTION Z (mm) vs Time (ms)



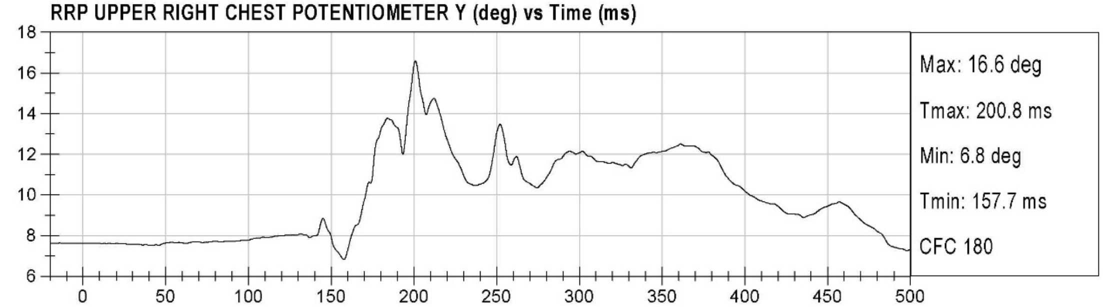

RRP UPPER RIGHT CHEST DEFLECTION RESULTANT (mm) vs Time (ms)



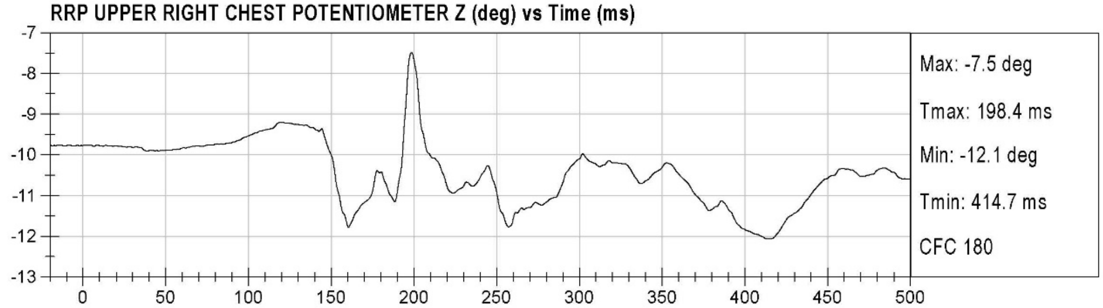
RRP UPPER RIGHT CHEST IRTRACC (mm) vs Time (ms)



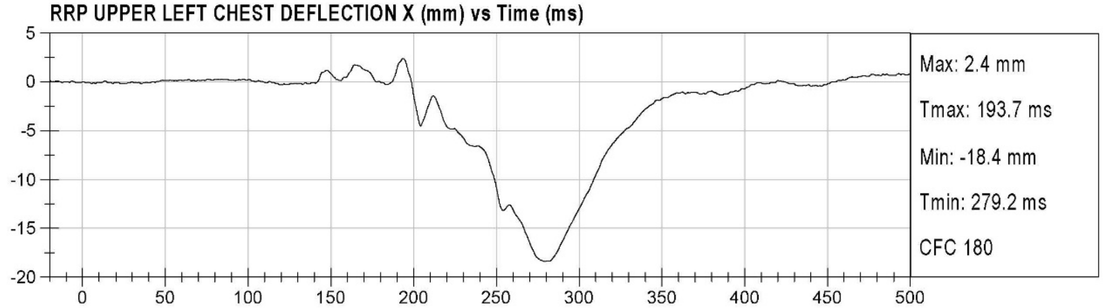

RRP UPPER RIGHT CHEST POTENTIOMETER Y (deg) vs Time (ms)



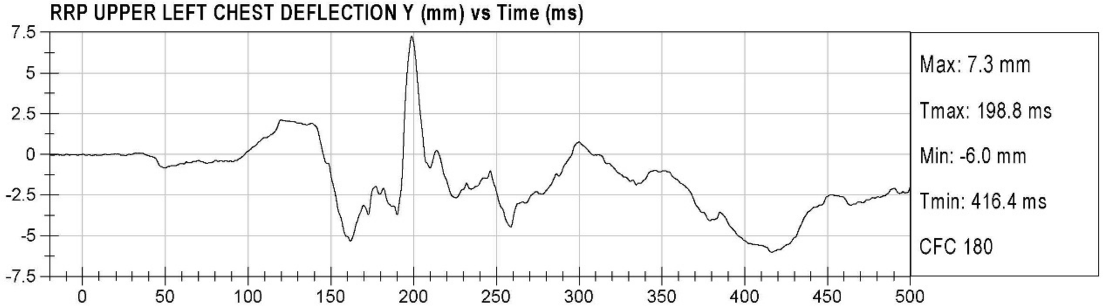

RRP UPPER RIGHT CHEST POTENTIOMETER Z (deg) vs Time (ms)



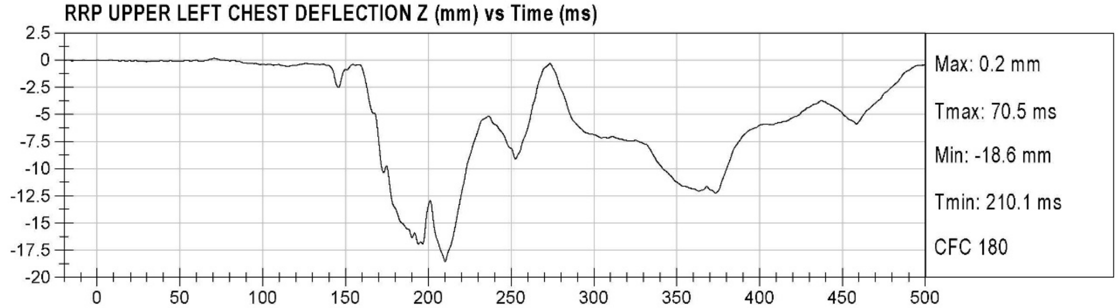
RRP UPPER LEFT CHEST DEFLECTION X (mm) vs Time (ms)



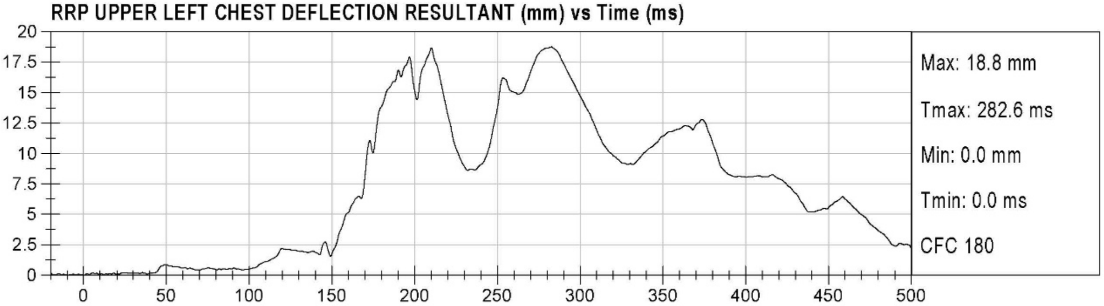

RRP UPPER LEFT CHEST DEFLECTION Y (mm) vs Time (ms)

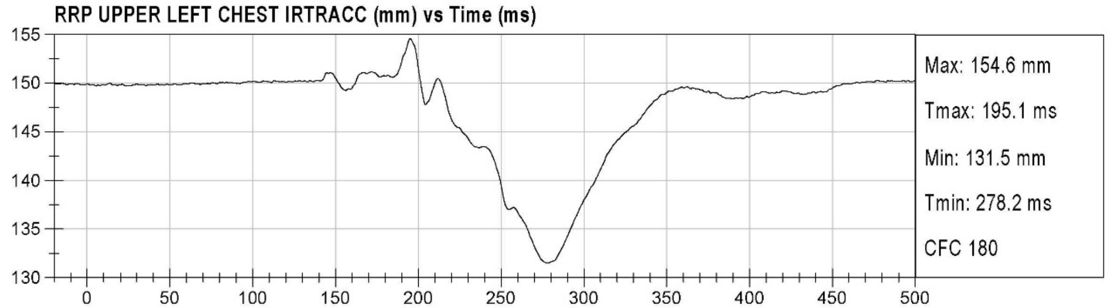


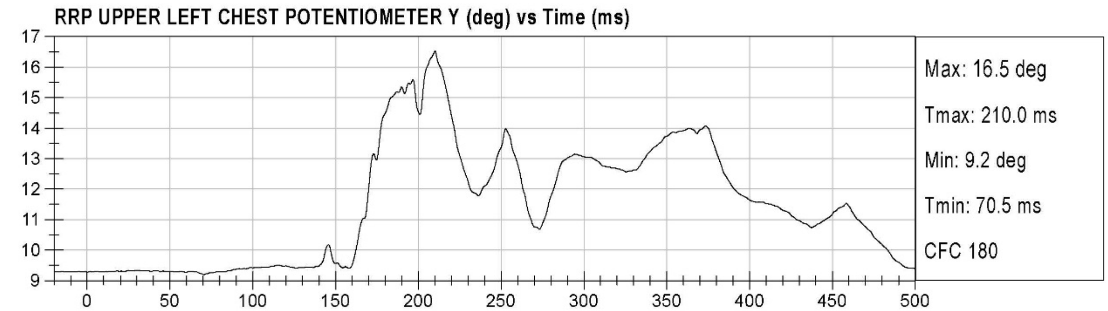

RRP UPPER LEFT CHEST DEFLECTION Z (mm) vs Time (ms)

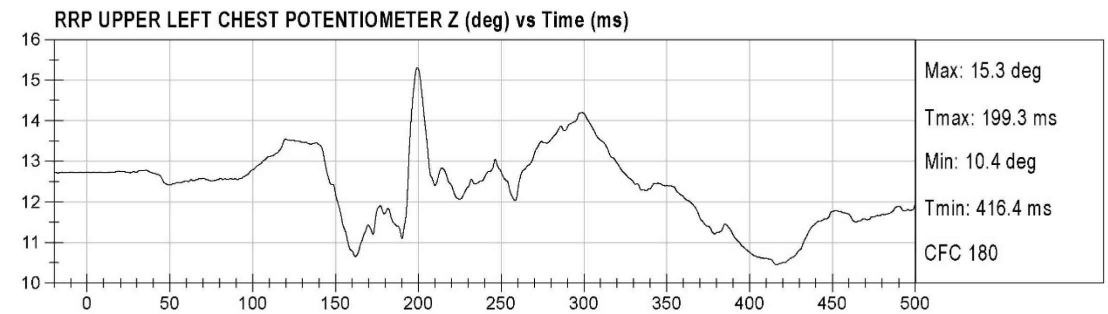


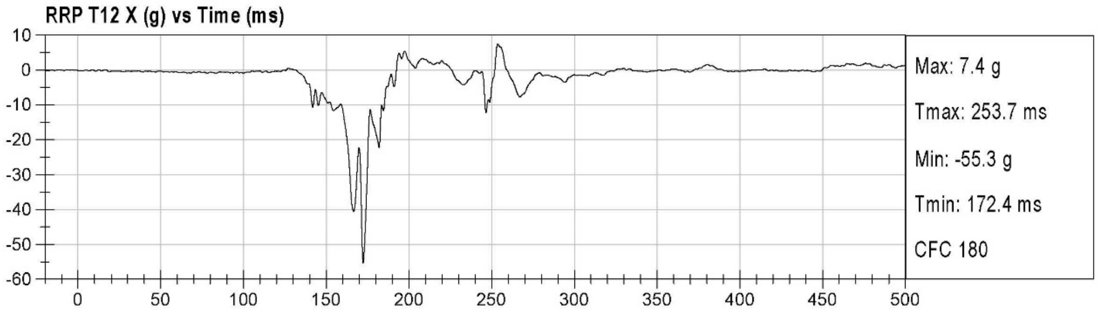

RRP UPPER LEFT CHEST DEFLECTION RESULTANT (mm) vs Time (ms)

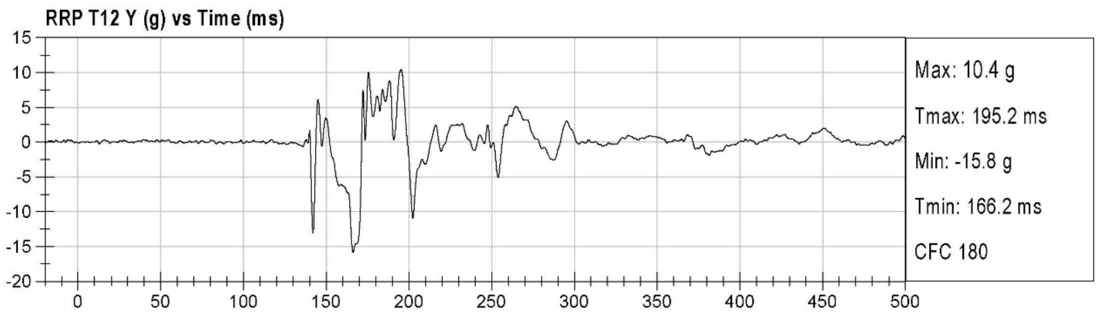


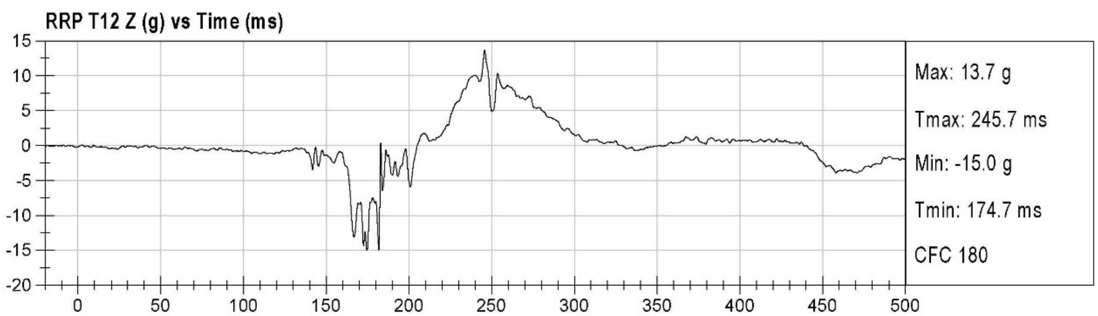

RRP UPPER LEFT CHEST IRTRACC (mm) vs Time (ms)
Max: 154.6 mm
Tmax: 195.1 ms
Min: 131.5 mm
Tmin: 278.2 ms
CFC 180


RRP UPPER LEFT CHEST POTENTIOMETER Y (deg) vs Time (ms)
Max: 16.5 deg
Tmax: 210.0 ms
Min: 9.2 deg
Tmin: 70.5 ms
CFC 180

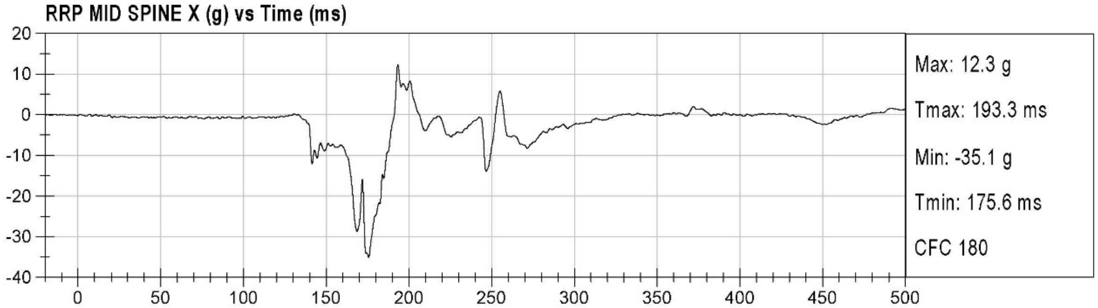

RRP UPPER LEFT CHEST POTENTIOMETER Z (deg) vs Time (ms)
Max: 15.3 deg
Tmax: 199.3 ms
Min: 10.4 deg
Tmin: 416.4 ms
CFC 180

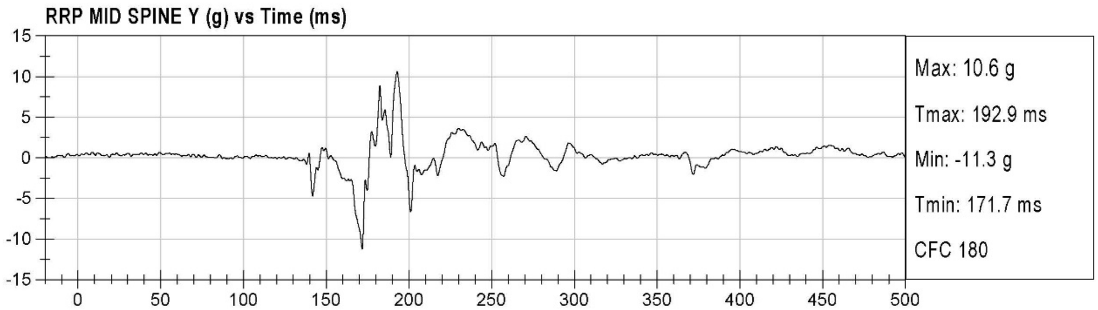

RRP T12 X (g) vs Time (ms)
Max: 7.4 g
Tmax: 253.7 ms
Min: -55.3 g
Tmin: 172.4 ms
CFC 180

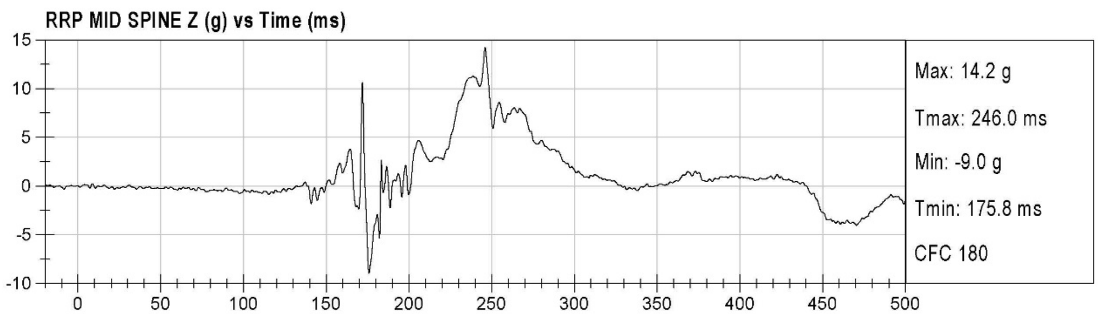

RRP T12 Y (g) vs Time (ms)
Max: 10.4 g
Tmax: 195.2 ms
Min: -15.8 g
Tmin: 166.2 ms
CFC 180

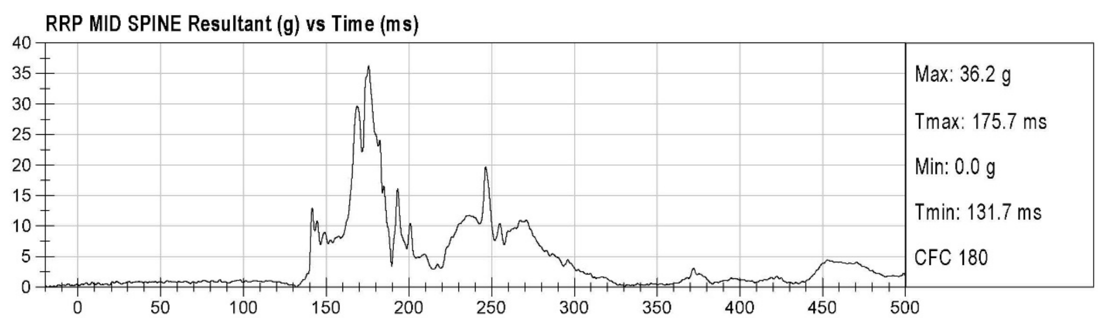

RRP T12 Z (g) vs Time (ms)
Max: 13.7 g
Tmax: 245.7 ms
Min: -15.0 g
Tmin: 174.7 ms
CFC 180

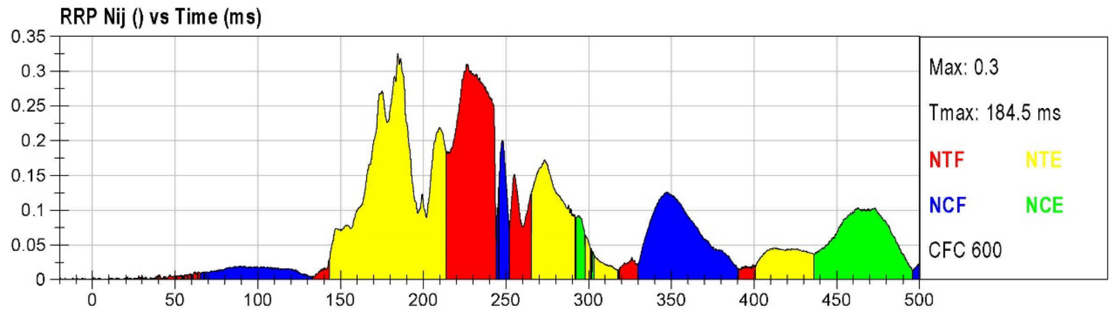

RRP T12 Resultant (g) vs Time (ms)
Max: 57.5 g
Tmax: 172.4 ms
Min: 0.0 g
Tmin: -10.5 ms
CFC 180

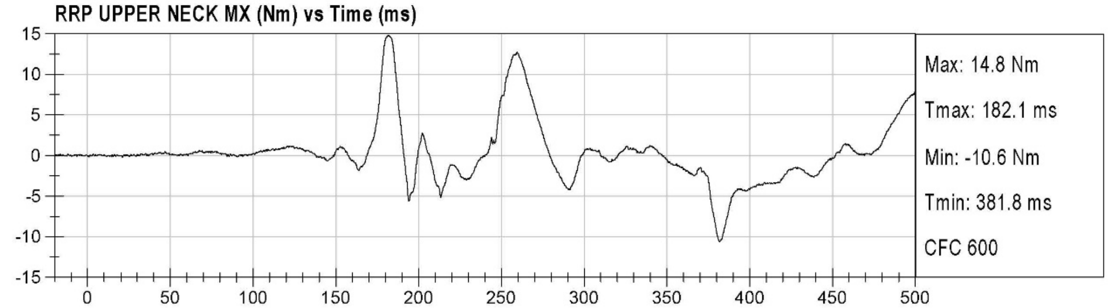

RRP MID SPINE X (g) vs Time (ms)
Max: 12.3 g
Tmax: 193.3 ms
Min: -35.1 g
Tmin: 175.6 ms
CFC 180

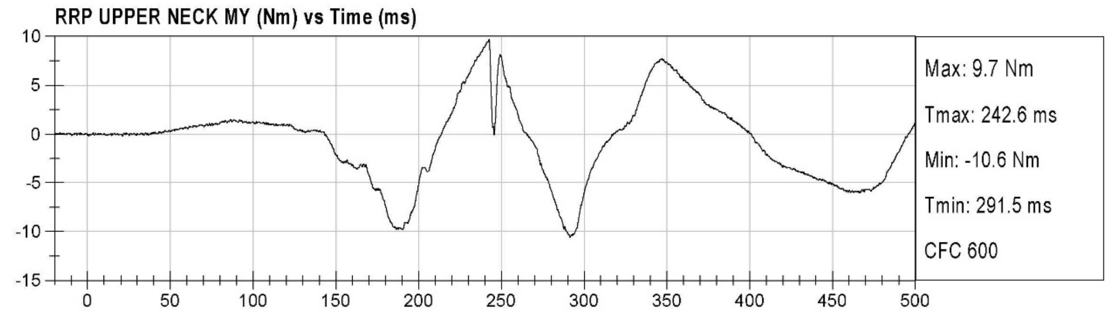

RRP MID SPINE Y (g) vs Time (ms)
Max: 10.6 g
Tmax: 192.9 ms
Min: -11.3 g
Tmin: 171.7 ms
CFC 180

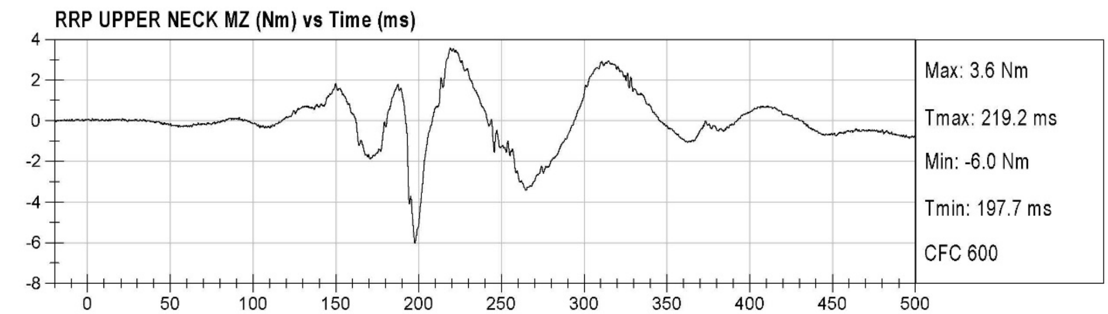

RRP MID SPINE Z (g) vs Time (ms)
Max: 14.2 g
Tmax: 246.0 ms
Min: -9.0 g
Tmin: 175.8 ms
CFC 180

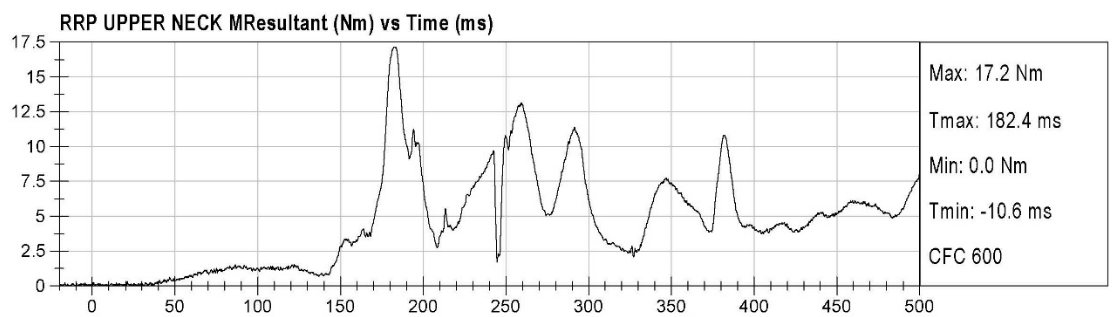

RRP MID SPINE Resultant (g) vs Time (ms)
Max: 36.2 g
Tmax: 175.7 ms
Min: 0.0 g
Tmin: 131.7 ms
CFC 180

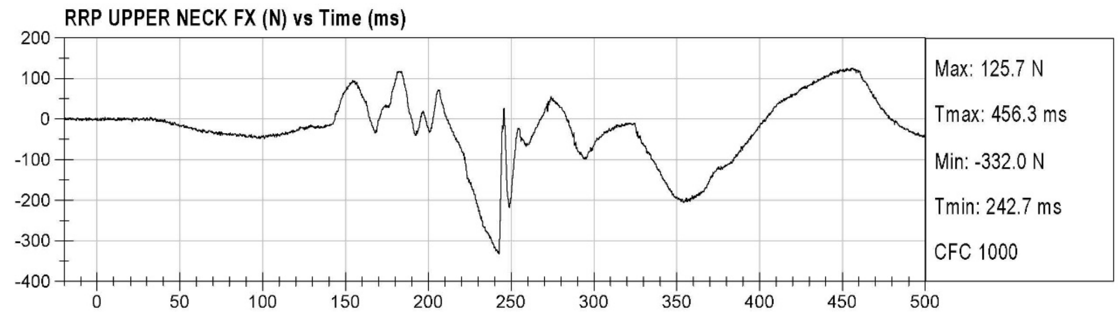

RRP Nij () vs Time (ms)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
50
100
150
200
250
300
350
400
450
500
Max: 0.3
Tmax: 184.5 ms
NTF
NTE
NCF
NCE
CFC 600

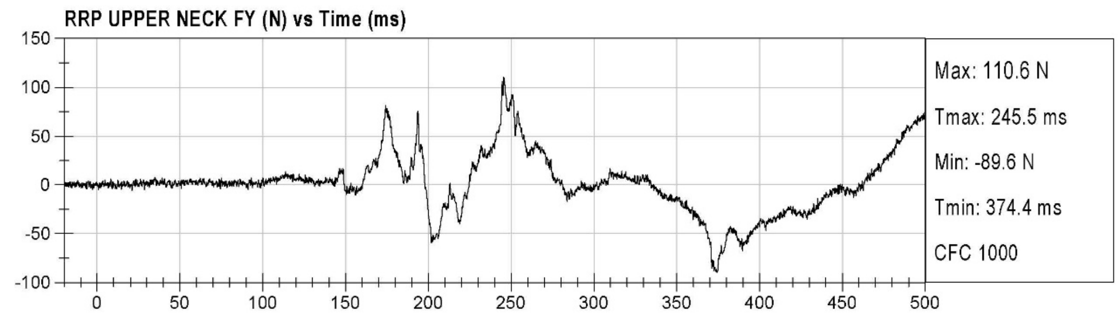

RRP UPPER NECK MX (Nm) vs Time (ms)
Max: 14.8 Nm
Tmax: 182.1 ms
Min: -10.6 Nm
Tmin: 381.8 ms
CFC 600

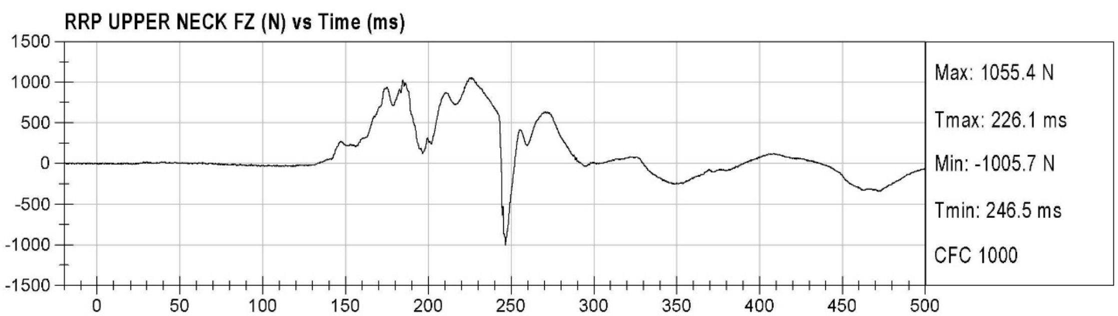

RRP UPPER NECK MY (Nm) vs Time (ms)
Max: 9.7 Nm
Tmax: 242.6 ms
Min: -10.6 Nm
Tmin: 291.5 ms
CFC 600

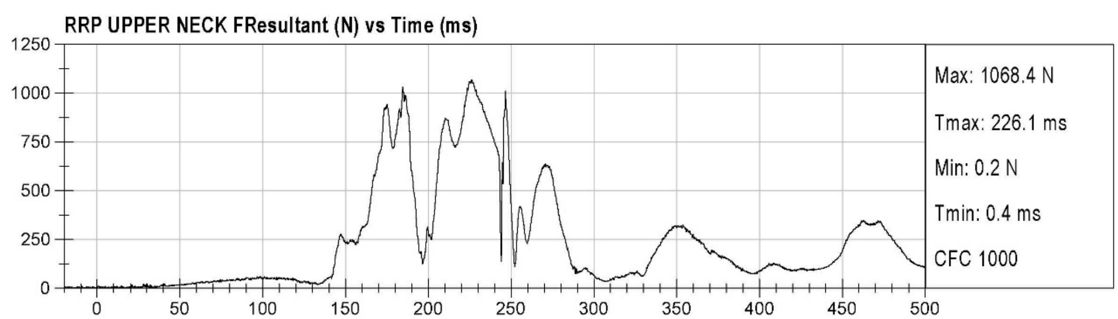

RRP UPPER NECK MZ (Nm) vs Time (ms)
Max: 3.6 Nm
Tmax: 219.2 ms
Min: -6.0 Nm
Tmin: 197.7 ms
CFC 600

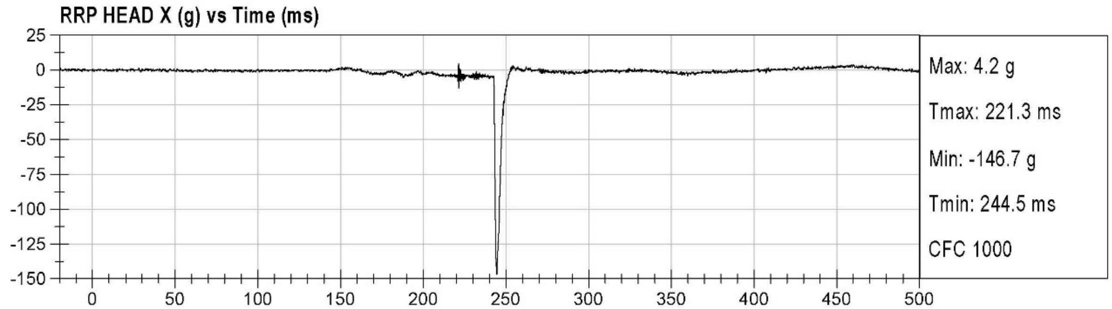

RRP UPPER NECK MResultant (Nm) vs Time (ms)
Max: 17.2 Nm
Tmax: 182.4 ms
Min: 0.0 Nm
Tmin: -10.6 ms
CFC 600

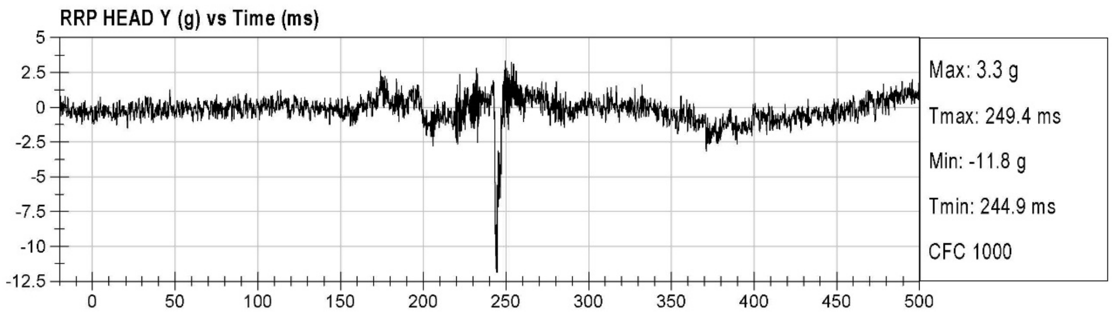

RRP UPPER NECK FX (N) vs Time (ms)
Max: 125.7 N
Tmax: 456.3 ms
Min: -332.0 N
Tmin: 242.7 ms
CFC 1000

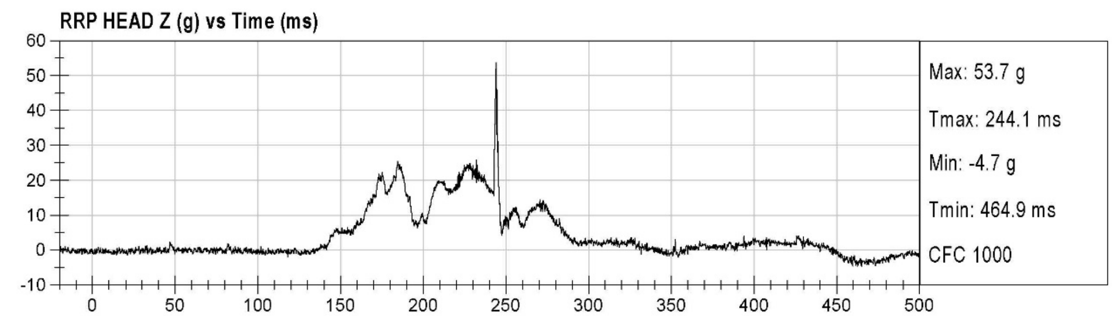

RRP UPPER NECK FY (N) vs Time (ms)
Max: 110.6 N
Tmax: 245.5 ms
Min: -89.6 N
Tmin: 374.4 ms
CFC 1000

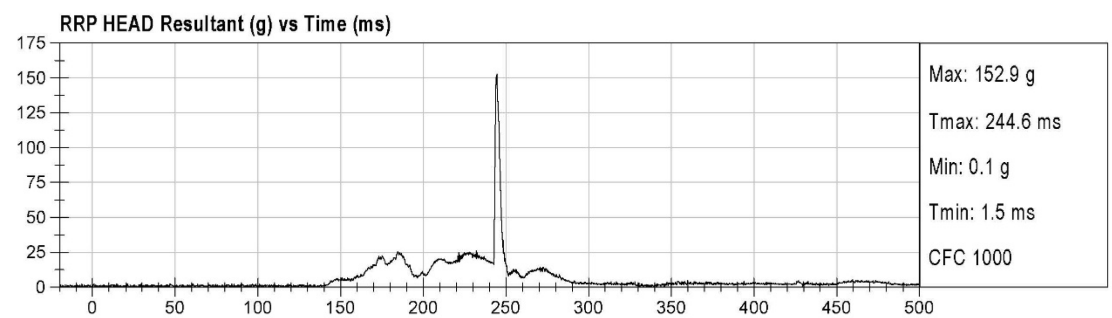

RRP UPPER NECK FZ (N) vs Time (ms)
Max: 1055.4 N
Tmax: 226.1 ms
Min: -1005.7 N
Tmin: 246.5 ms
CFC 1000

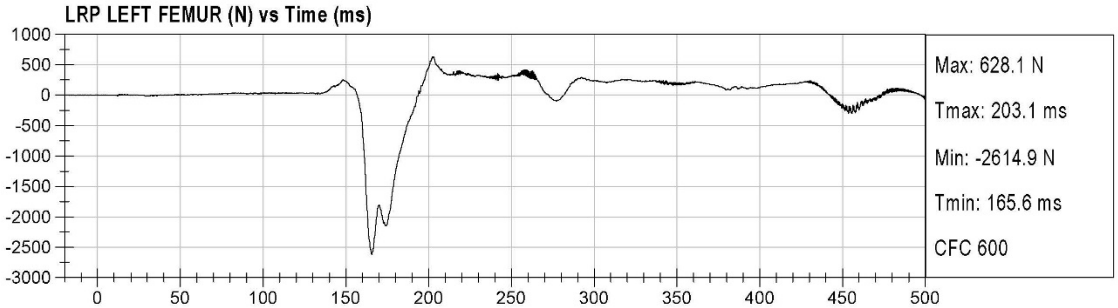

RRP UPPER NECK FResultant (N) vs Time (ms)
Max: 1068.4 N
Tmax: 226.1 ms
Min: 0.2 N
Tmin: 0.4 ms
CFC 1000

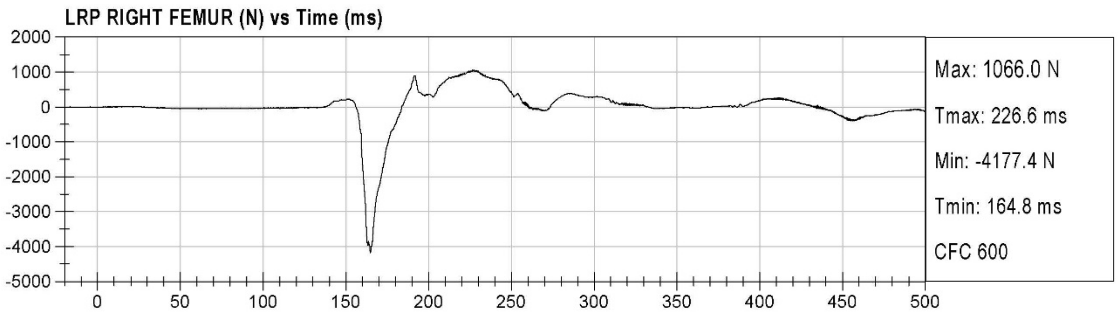

RRP HEAD X (g) vs Time (ms)
Max: 4.2 g
Tmax: 221.3 ms
Min: -146.7 g
Tmin: 244.5 ms
CFC 1000


RRP HEAD Y (g) vs Time (ms)
Max: 3.3 g
Tmax: 249.4 ms
Min: -11.8 g
Tmin: 244.9 ms
CFC 1000

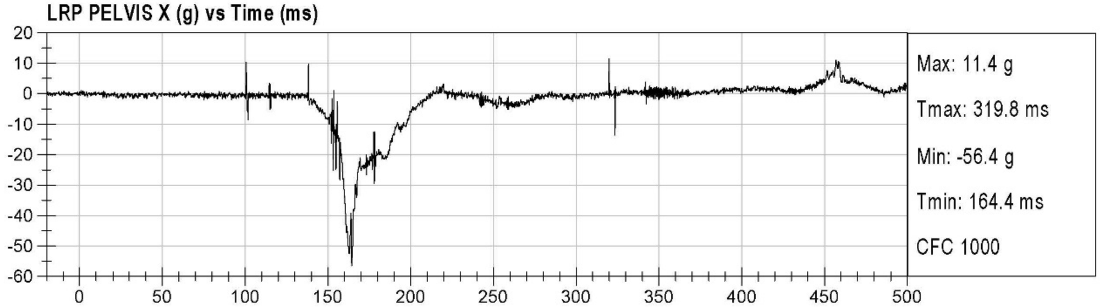

RRP HEAD Z (g) vs Time (ms)
Max: 53.7 g
Tmax: 244.1 ms
Min: -4.7 g
Tmin: 464.9 ms
CFC 1000


RRP HEAD Resultant (g) vs Time (ms)
Max: 152.9 g
Tmax: 244.6 ms
Min: 0.1 g
Tmin: 1.5 ms
CFC 1000

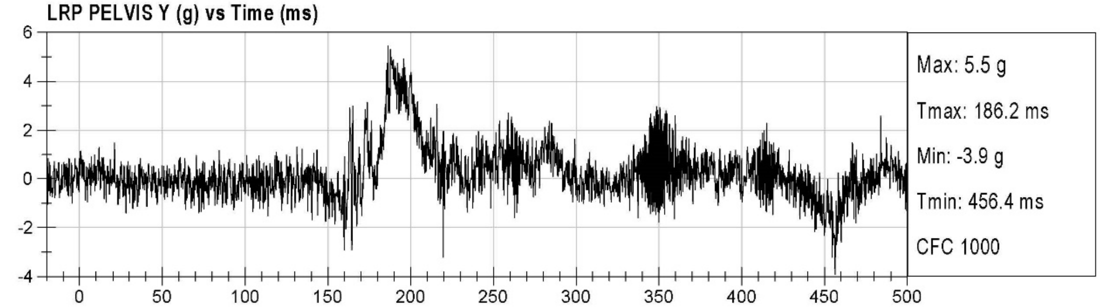

LRP LEFT FEMUR (N) vs Time (ms)
Max: 628.1 N
Tmax: 203.1 ms
Min: -2614.9 N
Tmin: 165.6 ms
CFC 600


LRP RIGHT FEMUR (N) vs Time (ms)
Max: 1066.0 N
Tmax: 226.6 ms
Min: -4177.4 N
Tmin: 164.8 ms
CFC 600

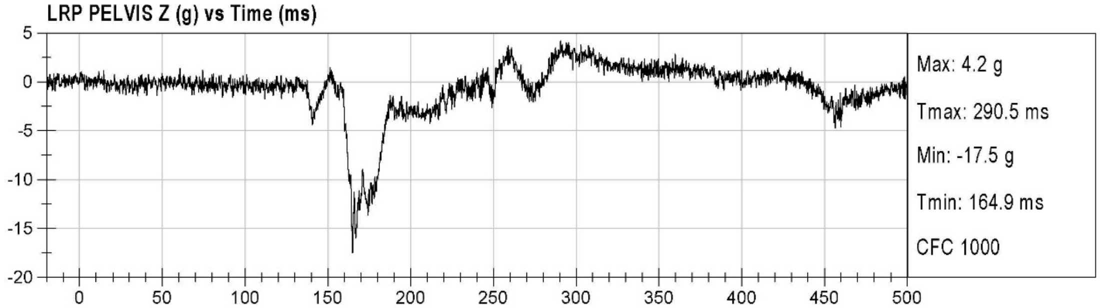
LRP PELVIS X (g) vs Time (ms)



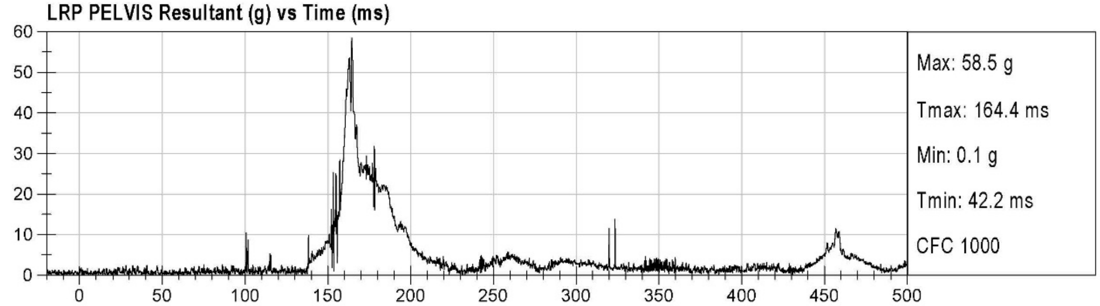

LRP PELVIS Y (g) vs Time (ms)

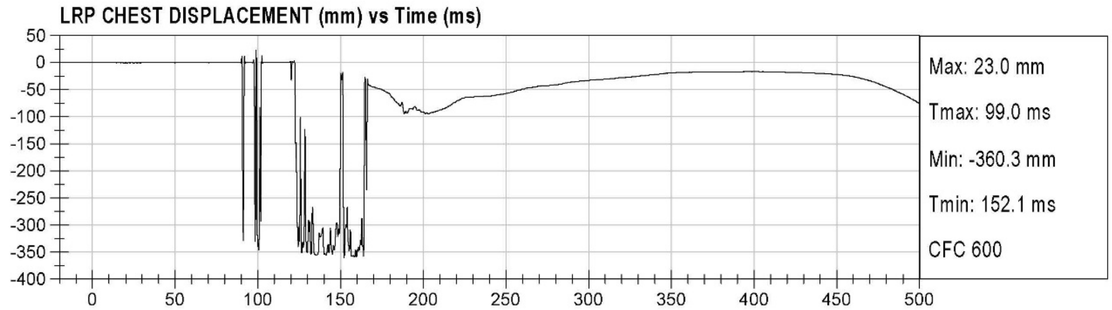


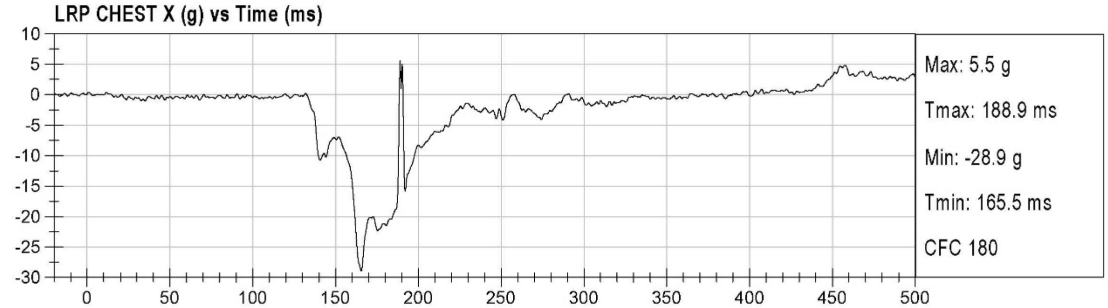

LRP PELVIS Z (g) vs Time (ms)

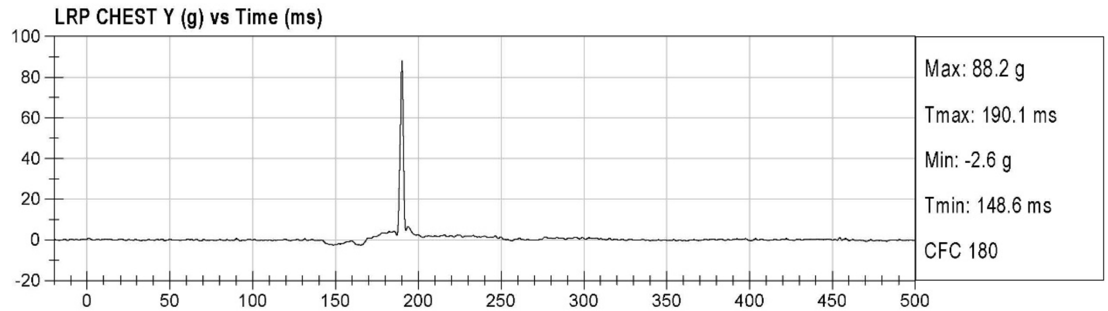


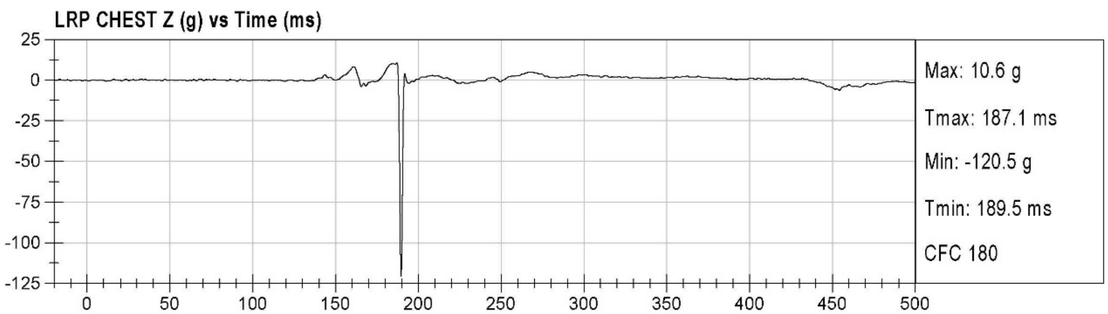

LRP PELVIS Resultant (g) vs Time (ms)

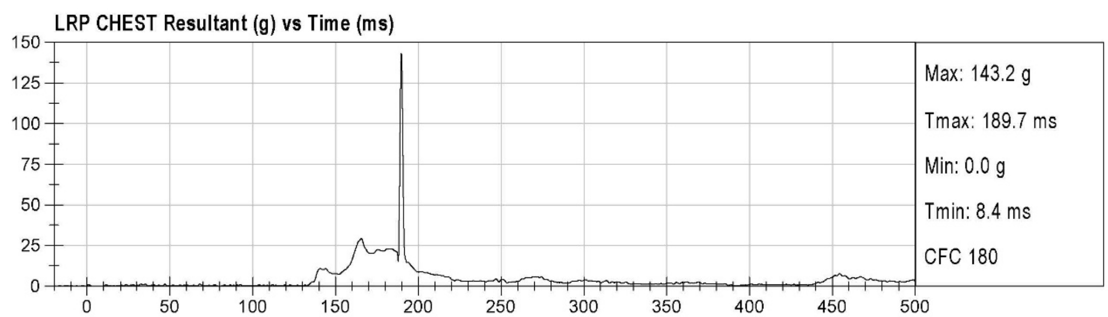


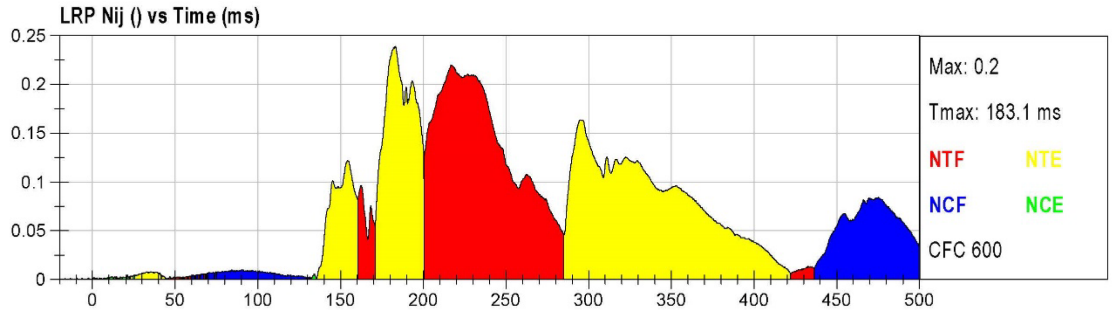

LRP CHEST DISPLACEMENT (mm) vs Time (ms)
50
0
-50
-100
-150
-200
-250
-300
-350
-400
0
50
100
150
200
250
300
350
400
450
500
Max: 23.0 mm
Tmax: 99.0 ms
Min: -360.3 mm
Tmin: 152.1 ms
CFC 600


LRP CHEST X (g) vs Time (ms)
Max: 5.5 g
Tmax: 188.9 ms
Min: -28.9 g
Tmin: 165.5 ms
CFC 180

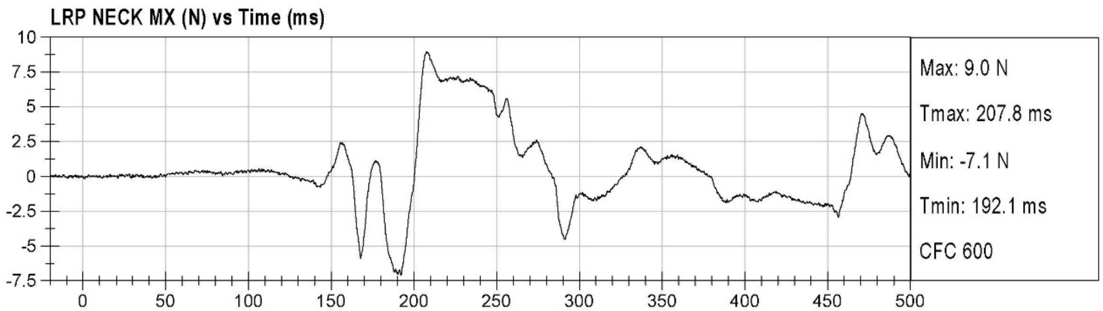

LRP CHEST Y (g) vs Time (ms)
Max: 88.2 g
Tmax: 190.1 ms
Min: -2.6 g
Tmin: 148.6 ms
CFC 180

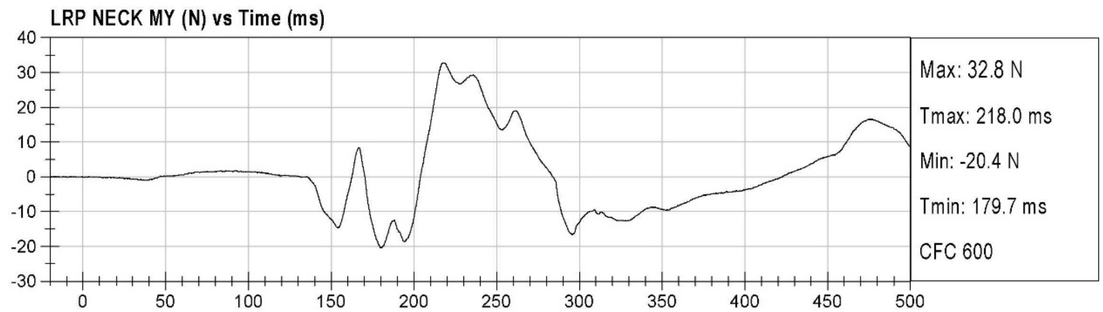

LRP CHEST Z (g) vs Time (ms)
Max: 10.6 g
Tmax: 187.1 ms
Min: -120.5 g
Tmin: 189.5 ms
CFC 180

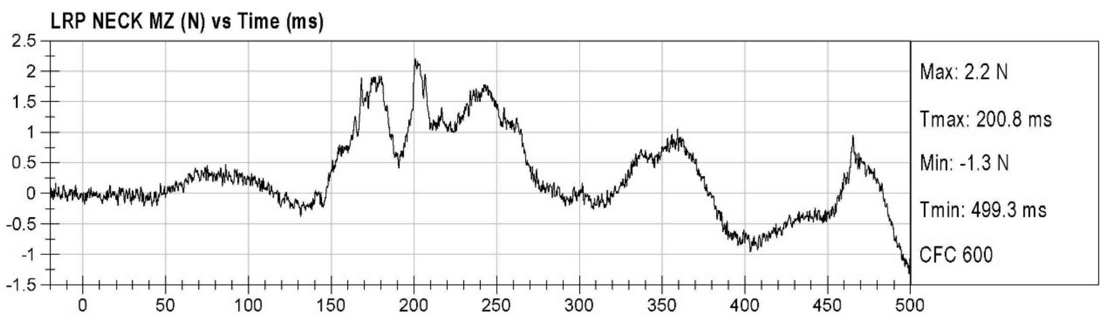

LRP CHEST Resultant (g) vs Time (ms)
Max: 143.2 g
Tmax: 189.7 ms
Min: 0.0 g
Tmin: 8.4 ms
CFC 180

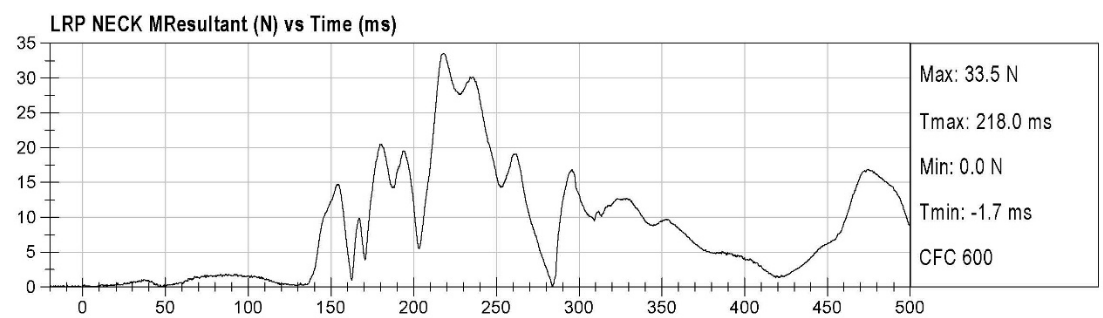


LRP Nij () vs Time (ms)
0.25
0.2
0.15
0.1
0.05
0
0
50
100
150
200
250
300
350
400
450
500
Max: 0.2
Tmax: 183.1 ms
NTF
NTE
NCF
NCE
CFC 600

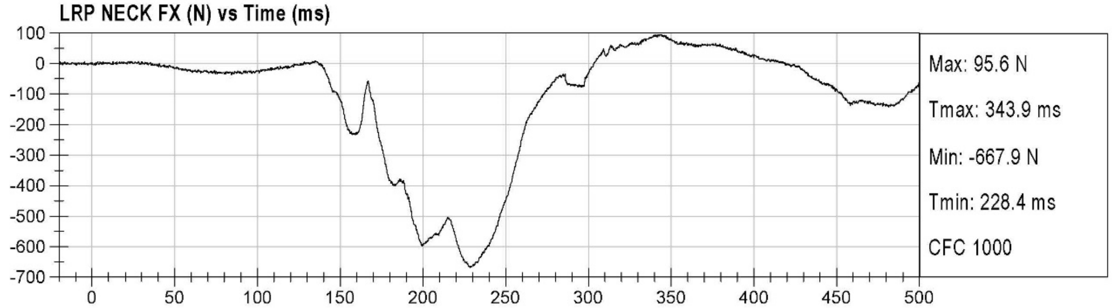

LRP NECK MX (N) vs Time (ms)
Max: 9.0 N
Tmax: 207.8 ms
Min: -7.1 N
Tmin: 192.1 ms
CFC 600


LRP NECK MY (N) vs Time (ms)
Max: 32.8 N
Tmax: 218.0 ms
Min: -20.4 N
Tmin: 179.7 ms
CFC 600

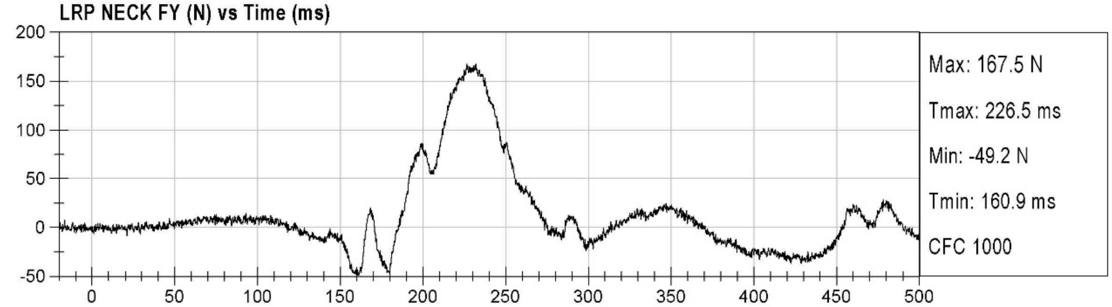

LRP NECK MZ (N) vs Time (ms)
Max: 2.2 N
Tmax: 200.8 ms
Min: -1.3 N
Tmin: 499.3 ms
CFC 600


LRP NECK MResultant (N) vs Time (ms)
Max: 33.5 N
Tmax: 218.0 ms
Min: 0.0 N
Tmin: -1.7 ms
CFC 600

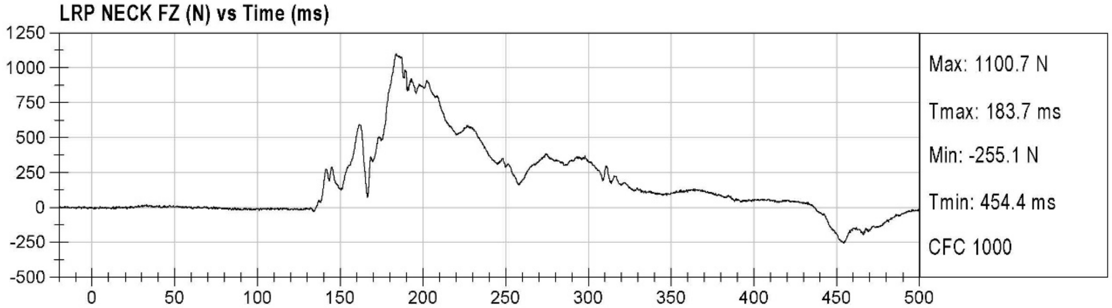
LRP NECK FX (N) vs Time (ms)



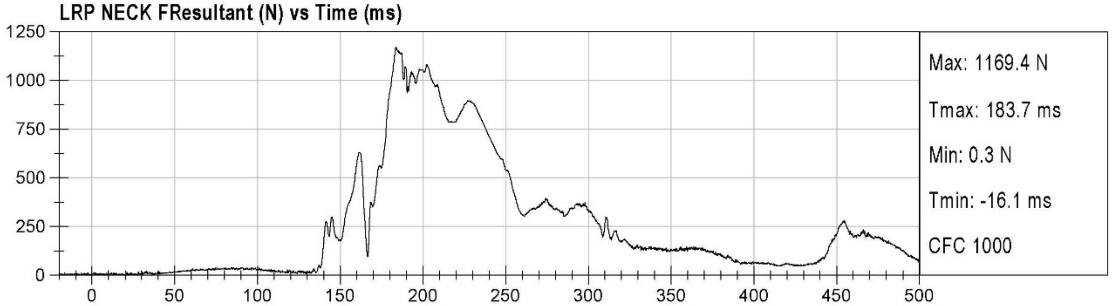

LRP NECK FY (N) vs Time (ms)

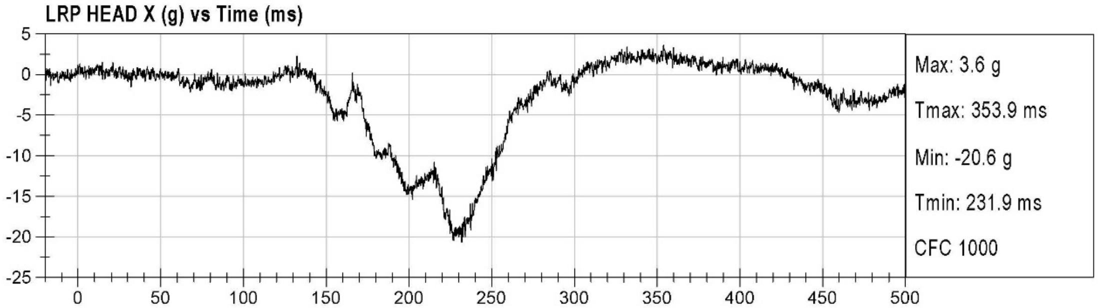


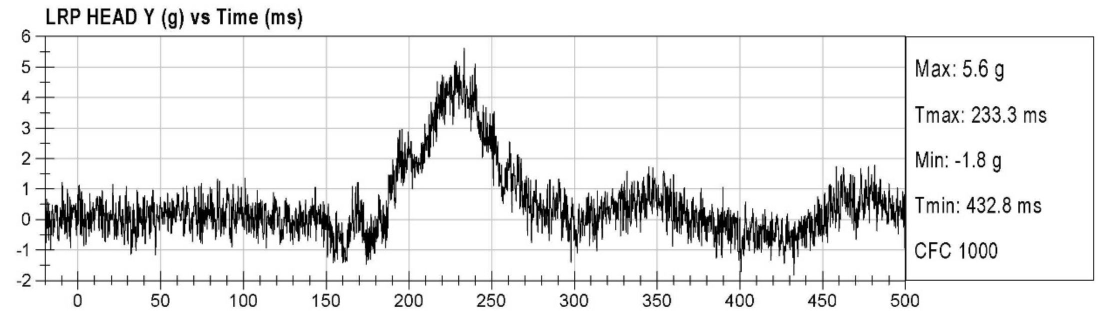

LRP NECK FZ (N) vs Time (ms)

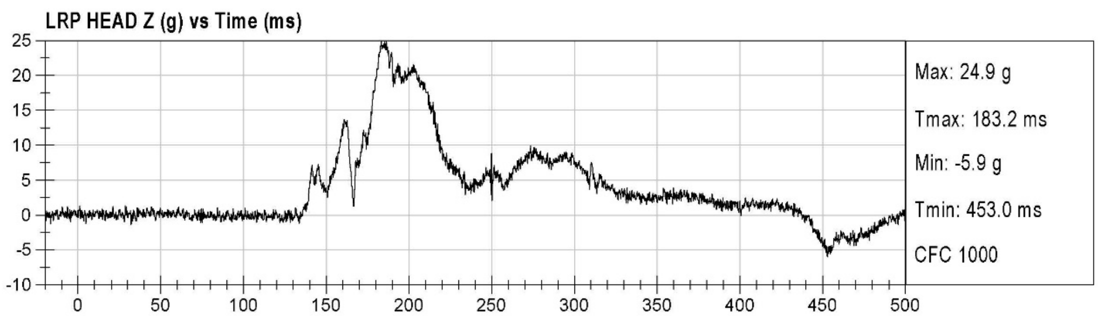


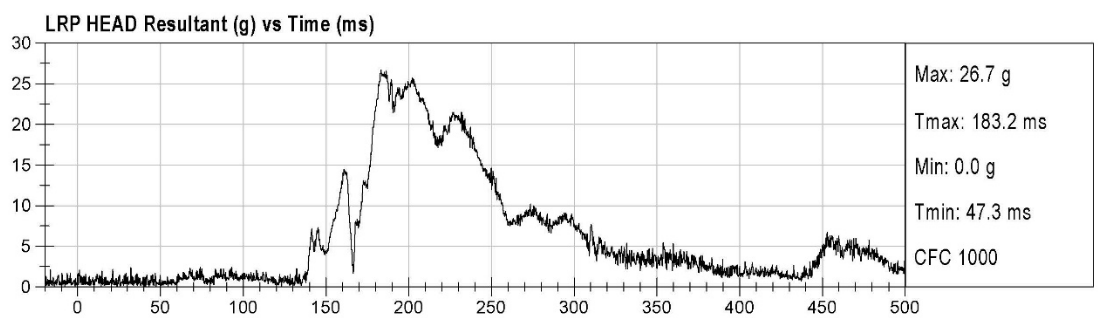

LRP NECK FResultant (N) vs Time (ms)




LRP HEAD X (g) vs Time (ms)
Max: 3.6 g
Tmax: 353.9 ms
Min: -20.6 g
Tmin: 231.9 ms
CFC 1000


LRP HEAD Y (g) vs Time (ms)
Max: 5.6 g
Tmax: 233.3 ms
Min: -1.8 g
Tmin: 432.8 ms
CFC 1000


LRP HEAD Z (g) vs Time (ms)
Max: 24.9 g
Tmax: 183.2 ms
Min: -5.9 g
Tmin: 453.0 ms
CFC 1000


LRP HEAD Resultant (g) vs Time (ms)
Max: 26.7 g
Tmax: 183.2 ms
Min: 0.0 g
Tmin: 47.3 ms
CFC 1000

## Appendix B. Survival Space Evaluations

MGA evaluated survival space in the dynamic sled tests per Section 5.1.3 of APTA S-018, Revision 2. MGA took screenshots from the high-speed video taken at the point of maximum table encroachment on the survival space. Measurements were taken (in millimeters) at the shortest distance between the table and rear-facing seatback. All tests met the survival space requirements except for Test 3BD. The table in Test 3BD was attached to the sidewall by rivets. The rivets pulled out during the test because only four out of the intended six rivets were installed.

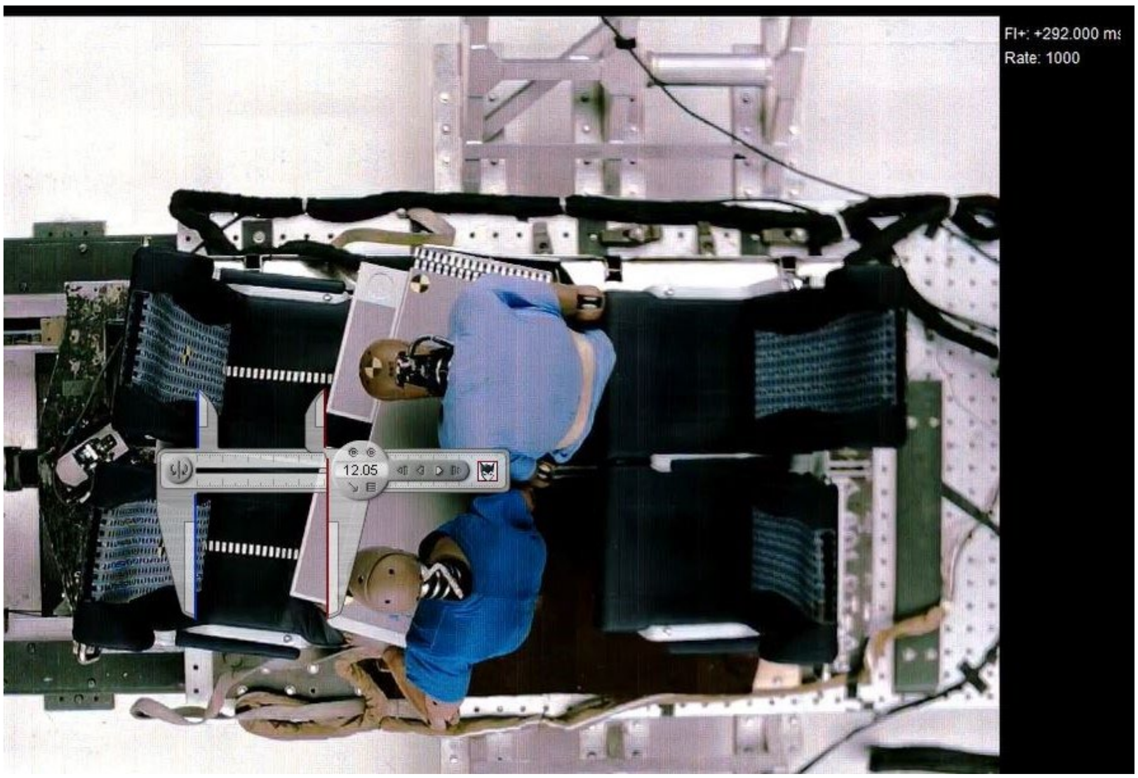



**Figure B13. Test 1A Survival Space Screenshot**

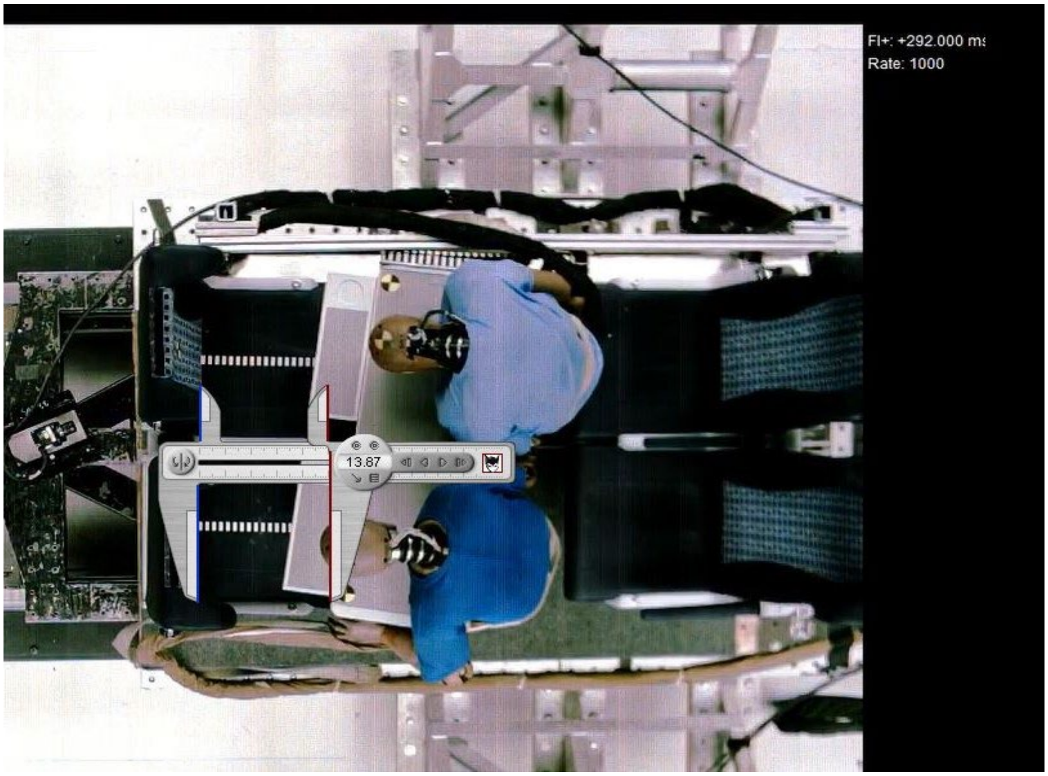



**Figure B14. Test 1A* Survival Space Screenshot**

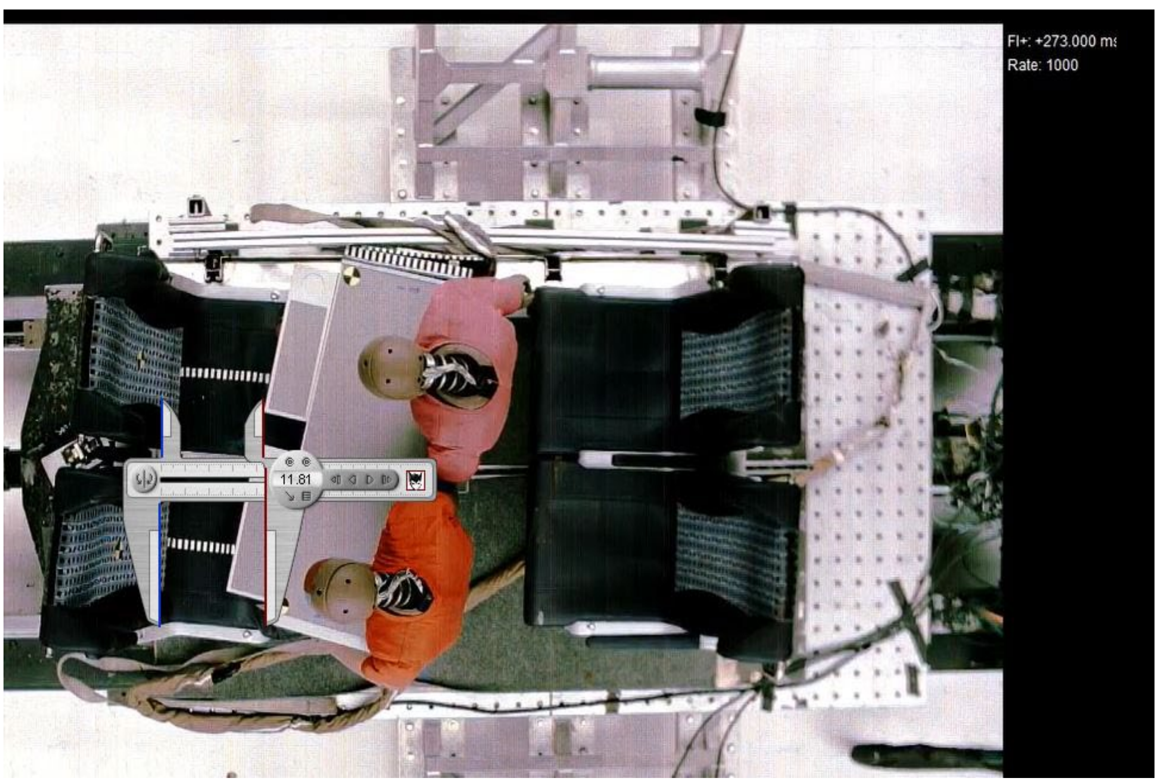



**Figure B15. Test 1BD Survival Space Screenshot**

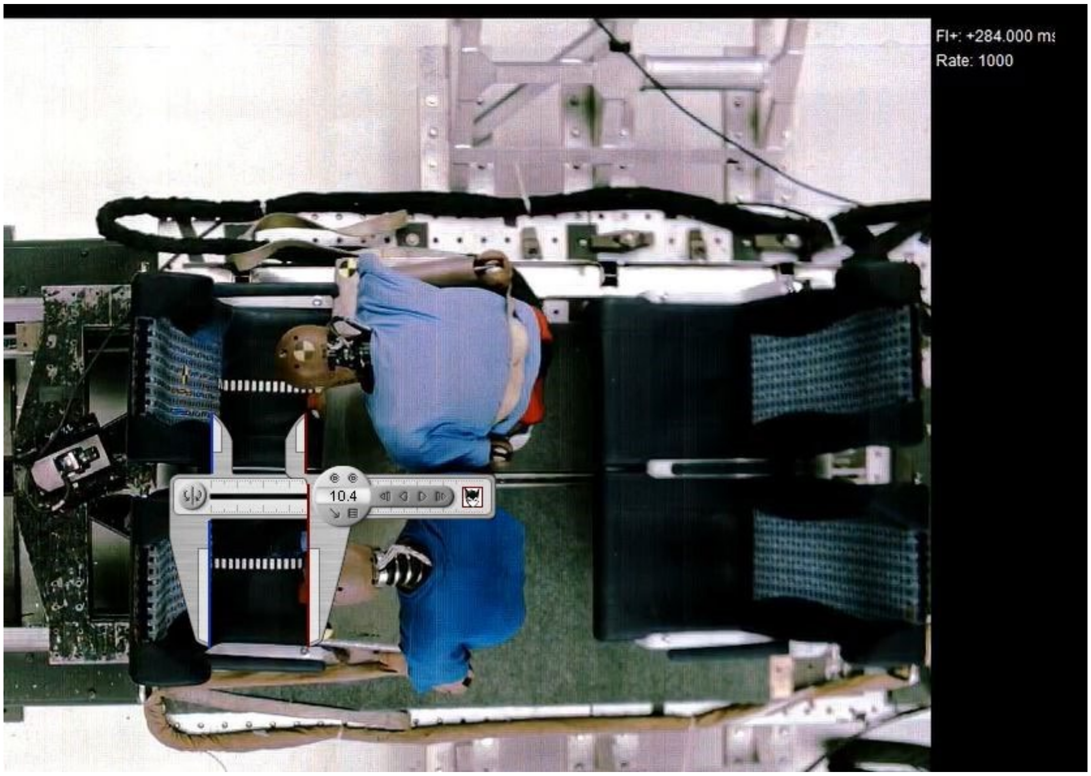



**Figure B16. Test 2A Survival Space Screenshot**

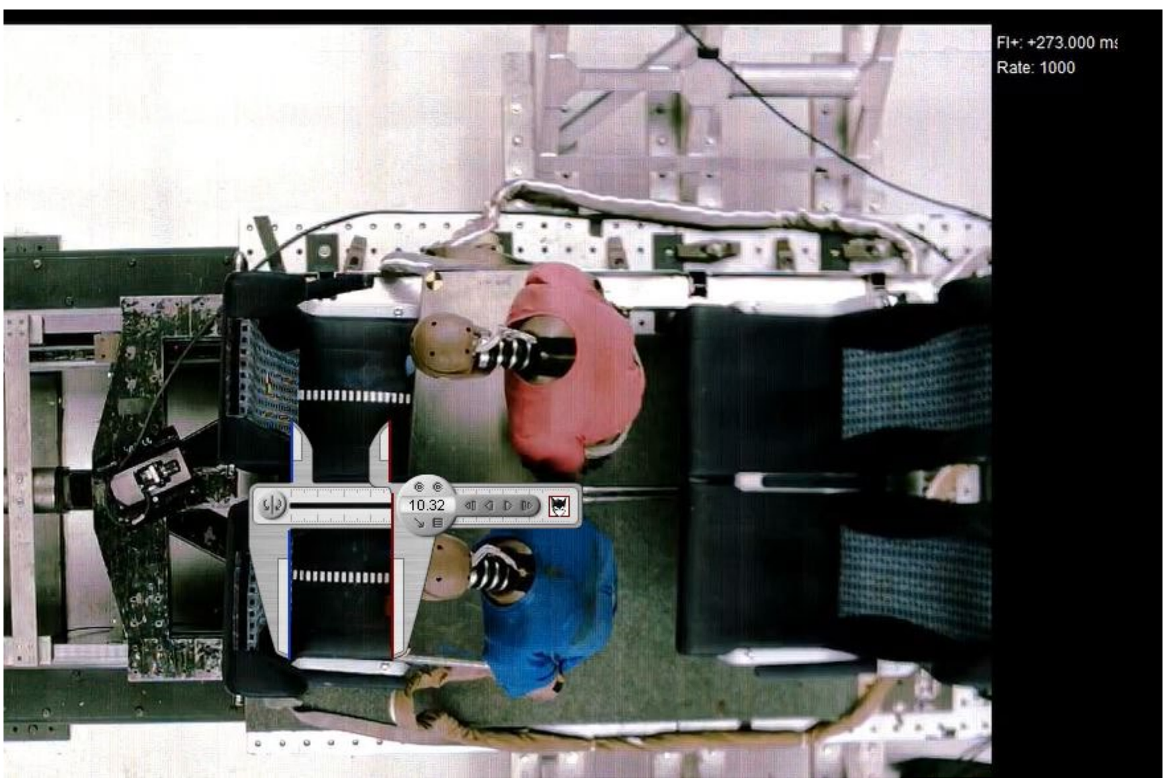



**Figure B17. Test 2BD Survival Space Screenshot**

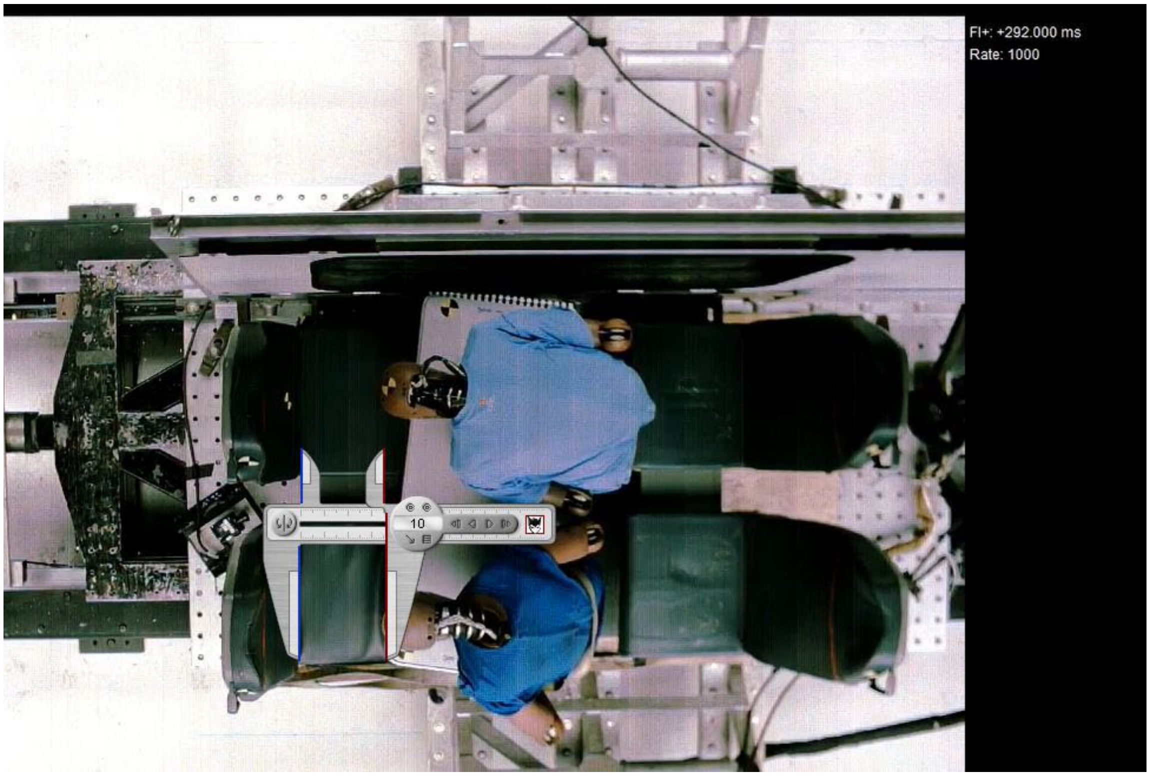



**Figure B18. Test 3A Survival Space Screenshot**

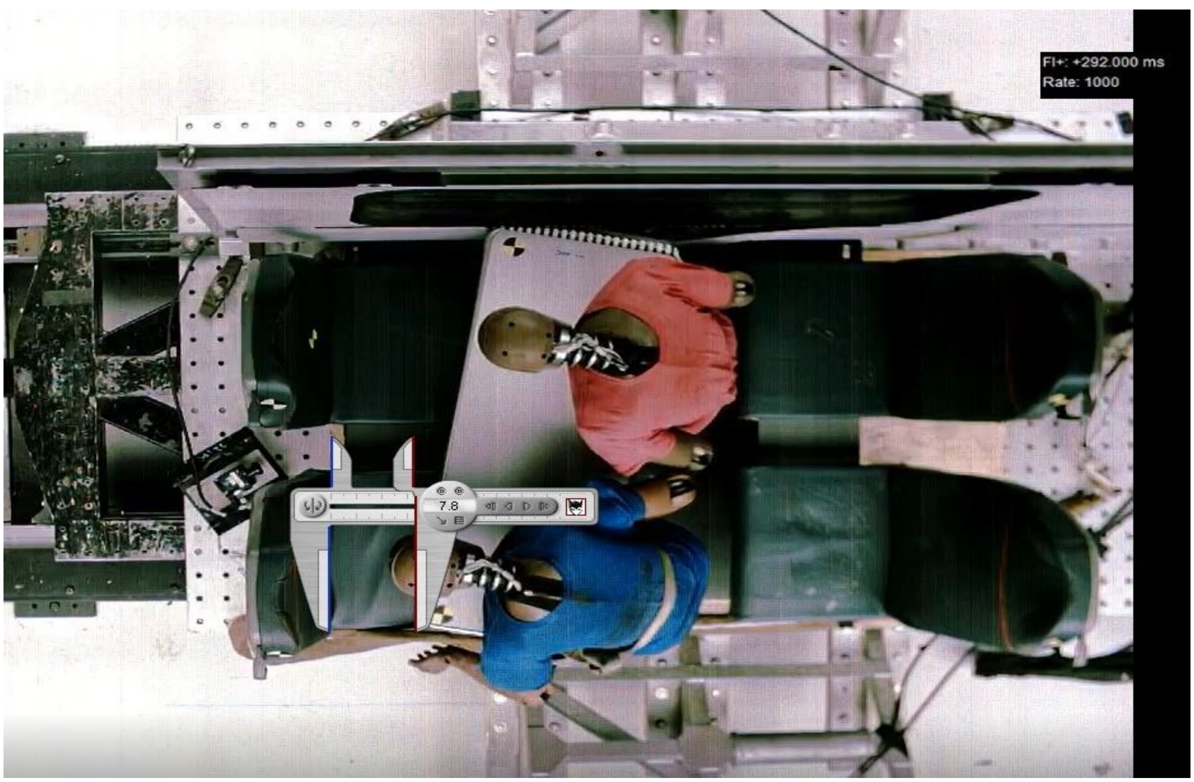



**Figure B19. Test 3BD Survival Space Screenshot**

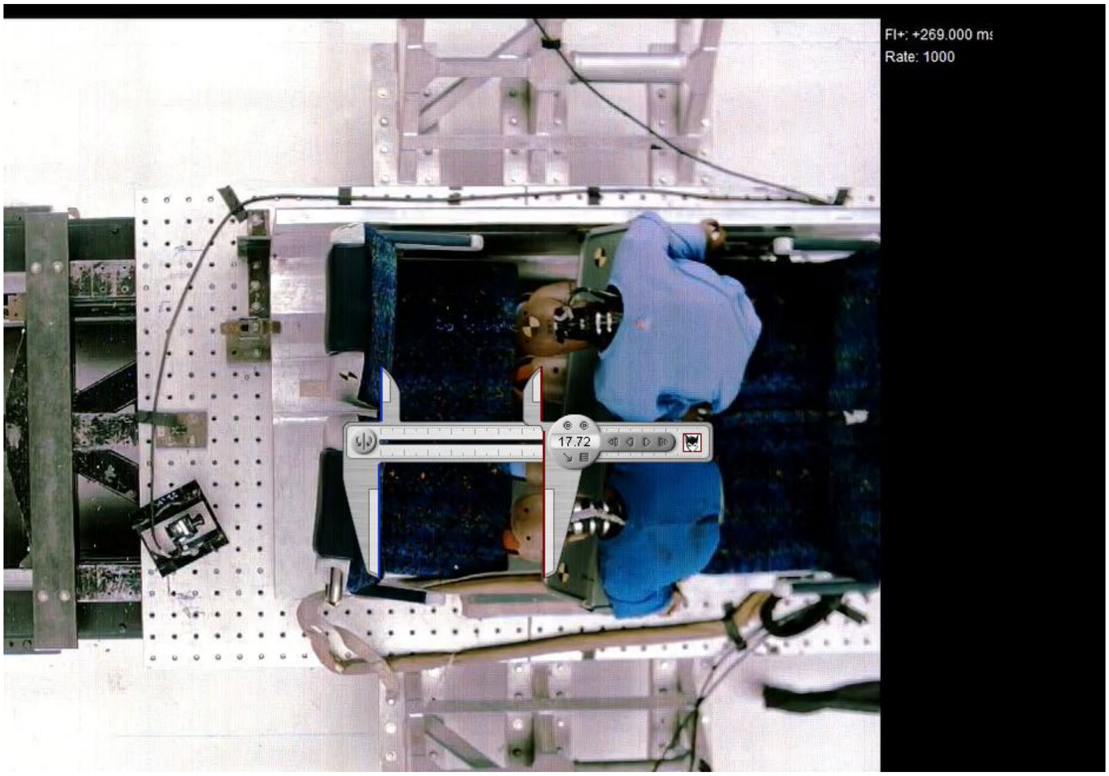



**Figure B20. Test 4A Survival Space Screenshot**

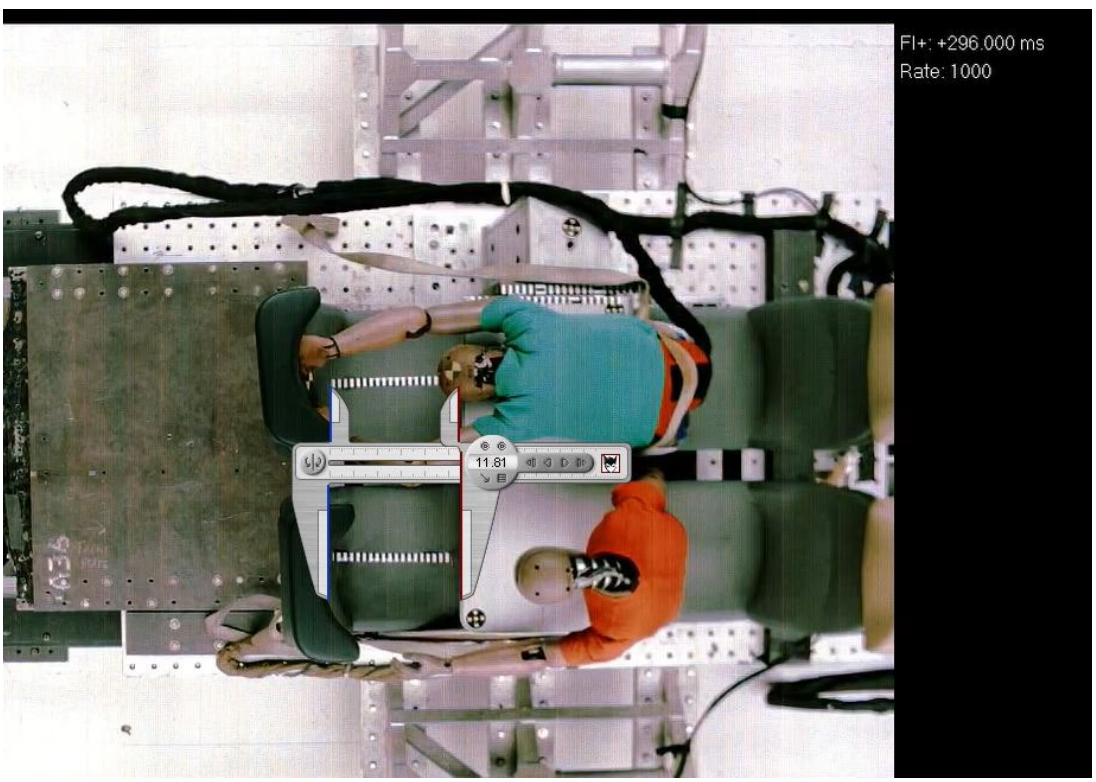



**Figure B21. Test 5A Survival Space Screenshot**

## Appendix C. Pre- and Post-test Measurements

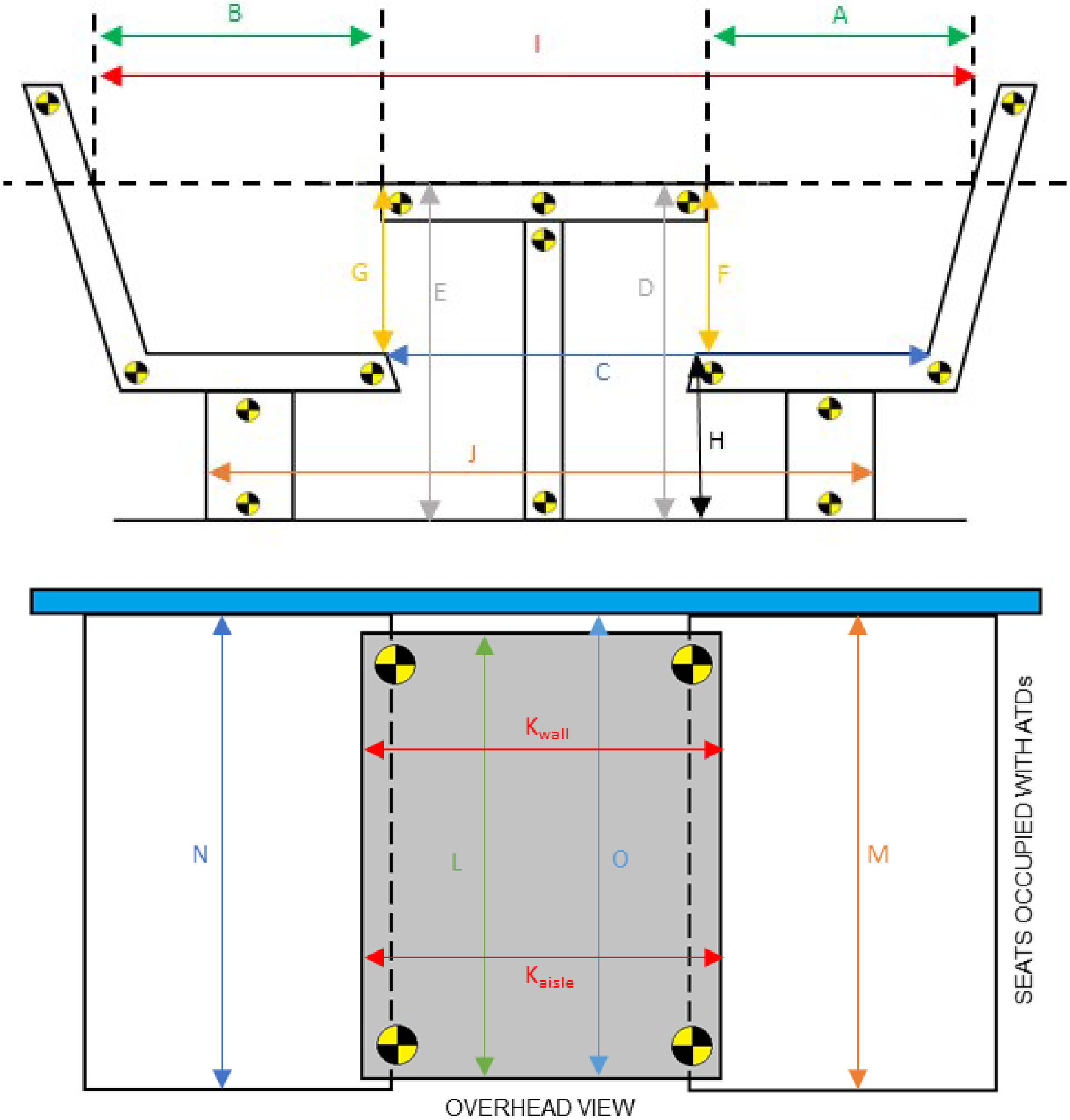



**Figure C1. Schematic of Pre- and Post-test Measurements**

## Test 1A: Pre and Post-test Measurements

**Table C1. Test 1A Pre- and Post-test Measurement by ATD**

| ID | Pre- test | | Post- test | |
|---|---|---|---|---|
| | Wall [mm] | Aisle [mm] | Wall [mm] | Aisle [mm] |
| A | 673 | 663 | 935 | 812 |
| B | 660 | 665 | 486 | 544 |
| C | 1063 | 1065 | 1370 | 1220 |
| D | 746 | 732 | 781 | 770 |
| E | 748 | 733 | 718 | 710 |
| F | 313 | 302 | 330 | 325 |
| G | 300 | 290 | 272 | 276 |
| H | 310 | 311 | 310 | 318 |
| I | 1703 | 1698 | 1789 | 1724 |
| J | 1,554 | | 1,615 | |
| K | 370 | 370 | 368 | 368 |
| L | 1,052 | | 1,065 | |
| M | 1,140 | | 1,145 | |
| N | 1,143 | | 1,148 | |
| O | 1,126 | | 1,145 | |

### Test 1A*: Pre and Post-test Measurements

**Table C2. Test 1A* Pre and Post-test Measurement by Occupant**

| ID | Pre- test | | Post- test | |
|---|---|---|---|---|
| | Wall [mm] | Aisle [mm] | Wall [mm] | Aisle [mm] |
| A | 635 | 646 | 960 | 935 |
| B | 652 | 657 | 377 | 365 |
| C | 1080 | 1072 | 1095 | 1065 |
| D | 755 | 748 | 780 | 743 |
| E | 759 | 752 | 695 | 743 |
| F | 315 | 320 | 365 | 295 |
| G | 320 | 322 | 245 | 198 |
| H | 308 | 305 | 305 | 303 |
| I | 1671 | 1687 | 1721 | 1684 |
| J | 1,548 | | 1,560 | |
| K | 384 | 384 | 384 | 384 |
| L | 1,032 | | 1,155 | |
| M | 1,155 | | 1,150 | |
| N | 1,145 | | 1,150 | |
| O | 1,103 | | 1,092 | |

## Test 1BD: Pre and Post-test Measurements

**Table C3. Test 1BD Pre and Post-test Measurement by Occupant**

| ID | Pre- test | | Post- test | |
|---|---|---|---|---|
| | Wall [mm] | Aisle [mm] | Wall [mm] | Aisle [mm] |
| A | 653 | 669 | 910 | 811 |
| B | 673 | 661 | 466 | 528 |
| C | 1087 | 1085 | 1123 | 1085 |
| D | 755 | 738 | 788 | 774 |
| E | 758 | 740 | 741 | 705 |
| F | 315 | 310 | 325 | 327 |
| G | 310 | 328 | 296 | 281 |
| H | 276 | 276 | 278 | 278 |
| I | 1696 | 1703 | 1746 | 1708 |
| J | 860 | | 885 | |
| K | 370 | 373 | 370 | 369 |
| L | 1,054 | | 1,044 | |
| M | 1,033 | | 1,141 | |
| N | 1,039 | | 1,038 | |
| O | 1,008 | | 1,063 | |

## Test 2A: Pre and Post-test Measurements

**Table C4. Test 2A Pre and Post-test Measurement by ATD**

| ID | Pre- test | | Post- test | |
|---|---|---|---|---|
| | Wall [mm] | Aisle [mm] | Wall [mm] | Aisle [mm] |
| A | 635 | 646 | 960 | 935 |
| B | 652 | 657 | 377 | 365 |
| C | 1080 | 1072 | 1095 | 1065 |
| D | 755 | 748 | 780 | 743 |
| E | 759 | 752 | 695 | 743 |
| F | 315 | 320 | 365 | 295 |
| G | 320 | 322 | 245 | 198 |
| H | 308 | 305 | 305 | 303 |
| I | 1671 | 1687 | 1721 | 1684 |
| J | 1,548 | | 1,560 | |
| K | 384 | 384 | 384 | 384 |
| L | 1,032 | | 1,155 | |
| M | 1,155 | | 1,150 | |
| N | 1,145 | | 1,150 | |
| O | 1,103 | | 1,092 | |

## Test 2BD: Pre and Post-test Measurements

**Table C5. Test 2BD Pre and Post-test Measurement by Occupant**

| | Pre- test | | Post- test | |
|---|---|---|---|---|
| **ID** | **Wall [mm]** | **Aisle [mm]** | **Wall [mm]** | **Aisle [mm]** |
| A | 652 | 665 | 990 | 960 |
| B | 663 | 660 | 395 | 375 |
| C | 1077 | 1088 | 1100 | 1090 |
| D | 757 | 754 | 780 | 732 |
| E | 756 | 753 | 685 | 565 |
| F | 317 | 321 | 345 | 285 |
| G | 318 | 320 | 230 | 190 |
| H | 315 | 305 | 315 | 312 |
| I | 1697 | 1707 | 1767 | 1717 |
| J | 1,547 | | 1,564 | |
| K | 382 | 382 | 382 | 382 |
| L | 1,038 | | 1,036 | |
| M | 1,145 | | 1,135 | |
| N | 1,135 | | 1,142 | |
| O | 1,098 | | 1,080 | |

## Test 3A: Pre and Post-test Measurements

**Table C6. Test 3A Pre and Post-test Measurement by Occupant**

| | Pre- test | | Post- test | |
|---|---|---|---|---|
| **ID** | **Wall [mm]** | **Aisle [mm]** | **Wall [mm]** | **Aisle [mm]** |
| A | 514 | 497 | 650 | 620 |
| B | 501 | 493 | 375 | 390 |
| C | 1008 | 1003 | 1020 | 1016 |
| D | 729 | 733 | 732 | 739 |
| E | 728 | 726 | 717 | 720 |
| F | 254 | 258 | 259 | 261 |
| G | 250 | 252 | 242 | 247 |
| H | 360 | 360 | 369 | 366 |
| I | 1448 | 1440 | 1458 | 1459 |
| J | 1,165 | | 1,186 | |
| K | 433 | 450 | 433 | 449 |
| L | 1,095 | | 1,095 | |
| M | 1,151 | | 1,152 | |
| N | 1,150 | | 1,152 | |
| O | 1,105 | | 1,108 | |

## Test 3BD: Pre and Post-test Measurements

**Table C7. Test 3BD Pre and Post-test Measurement by Occupant**

| ID | Pre- test | | Post- test | |
|---|---|---|---|---|
| | Wall [mm] | Aisle [mm] | Wall [mm] | Aisle [mm] |
| A | 498 | 491 | 675 | 610 |
| B | 500 | 492 | 347 | 382 |
| C | 988 | 995 | 1014 | 1007 |
| D | 725 | 725 | 721 | 728 |
| E | 720 | 720 | 714 | 723 |
| F | 255 | 253 | 230 | 240 |
| G | 234 | 238 | 234 | 248 |
| H | 355 | 362 | 365 | 362 |
| I | 1433 | 1433 | 1456 | 1444 |
| J | 1,155 | | 1,187 | |
| K | 435 | 450 | 434 | 452 |
| L | 1,095 | | 1,095 | |
| M | 1,107 | | 1,105 | |
| N | 1,107 | | 1,105 | |
| O | 1,110 | | 1,115 | |

## Test 4A: Pre and Post-test Measurements

**Table C8. Test 4A Pre- and Post-Test Measurement by Occupant**

| | Pre- test | | Post- test | |
|---|---|---|---|---|
| ID | Wall [mm] | Aisle [mm] | Wall [mm] | Aisle [mm] |
| A | 466 | 467 | 543 | 545 |
| B | 452 | 451 | 466 | 464 |
| C | 928 | 944 | 990 | 973 |
| D | 799 | 795 | 792 | 786 |
| E | 802 | 797 | 733 | 730 |
| F | 304 | 306 | 298 | 298 |
| G | 307 | 306 | 215 | 215 |
| H | 364 | 355 | 368 | 352 |
| I | 1432 | 1432 | 1419 | 1404 |
| J | 1,212 | | 1,262 | |
| K | 514 | 514 | 410 | 395 |
| L | 1,017 | | 1,054 | |
| M | 1,016 | | 1,016 | |
| N | 1,027 | | 1,028 | |
| O | 1,057 | | 1,075 | |

## Test 5A: Pre and Post-test Measurements

**Table C9. Test 5A Pre and Post-test Measurement by Occupant**

| ID | Pre- test | | Post- test | |
|---|---|---|---|---|
| | Wall [mm] | Aisle [mm] | Wall [mm] | Aisle [mm] |
| A | 491 | 488 | 531 | 523 |
| B | 491 | 495 | 489 | 496 |
| C | 952 | 952 | 995 | 975 |
| D | 765 | 765 | 777 | 773 |
| E | 766 | 766 | 763 | 761 |
| F | 304 | 309 | 311 | 311 |
| G | 310 | 309 | 284 | 301 |
| H | 357 | 357 | 368 | 368 |
| I | 1463 | 1463 | 1500 | 1499 |
| J | 808 | | 807 | |
| K | 481 | 480 | 480 | 480 |
| L | 970 | | 974 | |
| M | 1,056 | | 1,066 | |
| N | 1,061 | | 1,093 | |
| O | 1,036 | | 1,036 | |

## Abbreviations and Acronyms

| ACRONYM | EXPLANATION |
|---|---|
| 50M | $50^{th}$ Percentile Male |
| APTA | American Public Transportation Association |
| ATD | Anthropomorphic Test Device |
| CFC | Channel Frequency Class |
| FMVSS | Federal Motor Vehicle Safety Standard |
| FRA | Federal Railroad Administration |
| H3 | Hybrid-III |
| HIC | Head Injury Criteria |
| MGA | MGA Research Corporation |
| N/A | Not Applicable |
| Nij | Neck Injury Criterion |
| NVD | No Value Declared |
| RS | Rail Safety |
| THOR | Test device for Human Occupant Restraint |
| TRL | Transport Research Laboratory |