

An Experimental Seat for Measuring External Biofidelity in Rear Impacts and a New Instrumentation Technique for the Cervical Spine of PMHS

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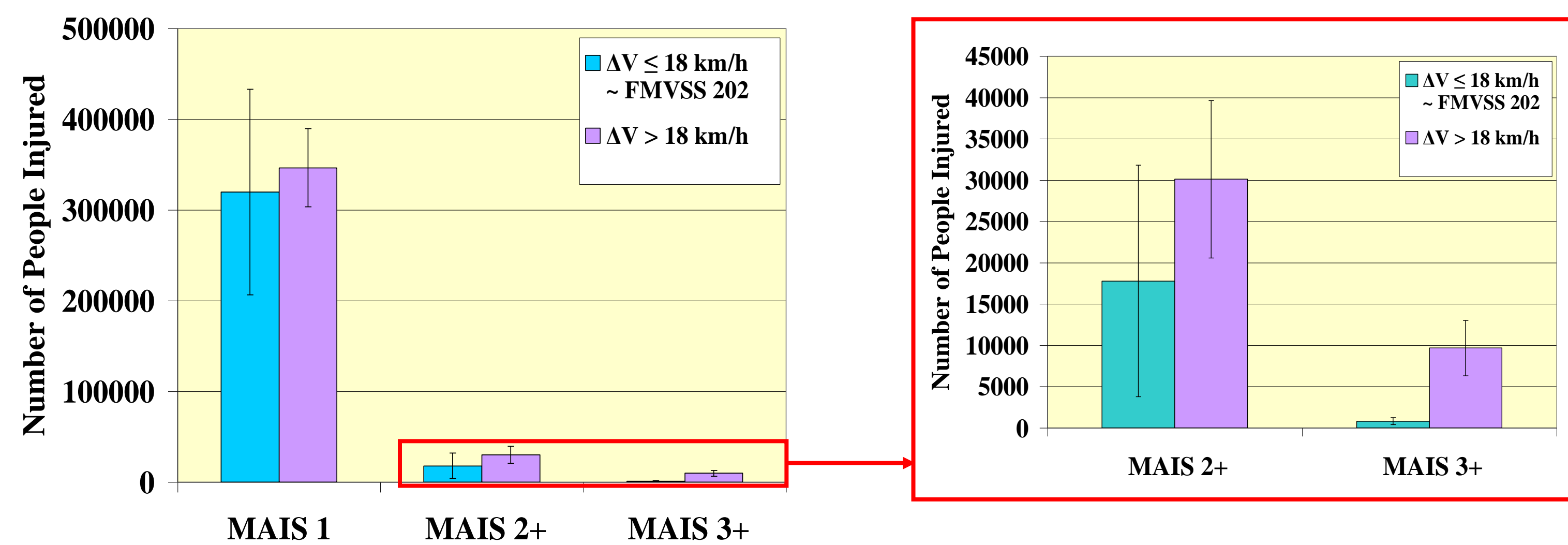
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Introduction

The modern rear impact dummies (BioRID II, RID3D) and their predecessors (BioRID P3, RID2) were designed primarily for low speed testing where whiplash injuries generally occur (at or below FMVSS 202 \approx 18 km/h), also the “internal” biofidelity (i.e., kinematics and internal loads) of the dummies at these low speeds has been evaluated extensively relative to the response of volunteers and PMHS [1-5]. In addition to the internal biofidelity, a few studies also examined the “external” biofidelity (i.e., how the occupant loads the vehicle) of the dummies by measuring the loading on the seat back and/or head restraint using pressure sensing mats or load cells [6-8]. The biofidelity studies above were conducted in many different seat configurations. However, the moderate-to-high speed ($>$ 18 km/h) biofidelity of the rear impact dummies on a modern yielding seat has not been established even though it is important that seat design is optimized to provide sufficient protection to all occupants at all speeds. Moreover, the utilization of a rear impact dummy which is biofidelic at $\Delta V >$ 18 km/h may be important based on the number of people injured in rear impact collisions and the maximum severity of their injuries (Figure 1). Therefore, one of the goals of this study was to develop an experimental seat which could mimic the realistic seat response of a typical OEM seat to evaluate the internal and external biofidelity of the rear impact dummies in moderate-to-high speed rear impacts.

Various instrumentation techniques on the head, neck and spine have been proposed to measure kinematic and kinetic responses during rear impact tests [9-14]. In order to be able to predict neck injuries, it is important to measure the kinematics of the head and the neck. A few studies have used a high speed bi-planar x-ray imaging system to record the motion of the entire cervical spine in low speed rear impact tests [10,14]. However, due to the limited field of view of the machine, it is limited to low speed rear impact tests using rigid seats that are not representative of a modern seat. Therefore, a new instrumentation technique was developed to measure detailed neck kinematics during rear impact testing, that is not limited by field of view or test speed.



NASS/CDS [weighted] Rear Impacts (DOF = 5, 6, 7 O’Clock) between 1999 and 2006. MAIS injuries associated with frontal structure of vehicle excluded.

Figure 1. Number and severity of injuries associated with rear impact accidents

Objectives

- Design, construct, and evaluate a seat for rear impact testing of PMHS and ATDs on a HYPE sled
 - Match seat back rotational response, geometry, and padding/upholstery characteristics of a typical OEM seat
 - Instrumentation to measure occupant loading on the seat so external biofidelity of the ATDs may be assessed
 - Reusable - opposed to typical OEM seats which must be replaced after moderate or high speed impacts
 - Repeatable and reproducible
- Develop and verify a new technique to instrument the anterior aspect of cervical vertebral bodies to measure detail neck kinematics during rear impacts
 - Minimize damage to soft tissue, muscles and ligaments of the subjects
 - Capable of measuring kinematics of vertebral bodies C2 ~ T1

Methods

Experimental seat design: The dimensions of the head restraint are representative of a typical OEM seat and has a mass of 5.5 kg. The head restraint height is infinitely adjustable using set screws along the length of the two 17 mm diameter support bars. Two parallel adjustable one-way dampers (Ace Controls, Inc., Farmington, MI) and two parallel springs (The Yost Superior Co., Springfield, OH) with stiffness values of 13,500 N/m (i.e., half of 27000 N/m, which was determined by analyzing data of seat back rotational stiffness from the previous study [17]) were installed. The geometry of the seat is similar to that of a typical OEM seat, and the padding, cushions and seat cover are from a 1999 Toyota Camry. As previously discussed, the seat includes a total of 12 uni-axial load cells (Transducer Techniques, Temecula, CA) to measure the occupant loading on the seat (two in the head restraint, six in the seat back, and four in the seat base). Figure 2 shows the sled buck configuration chosen for the testing. It contains two seats placed side-by-side so that each sled test could produce two similar occupant exposures.

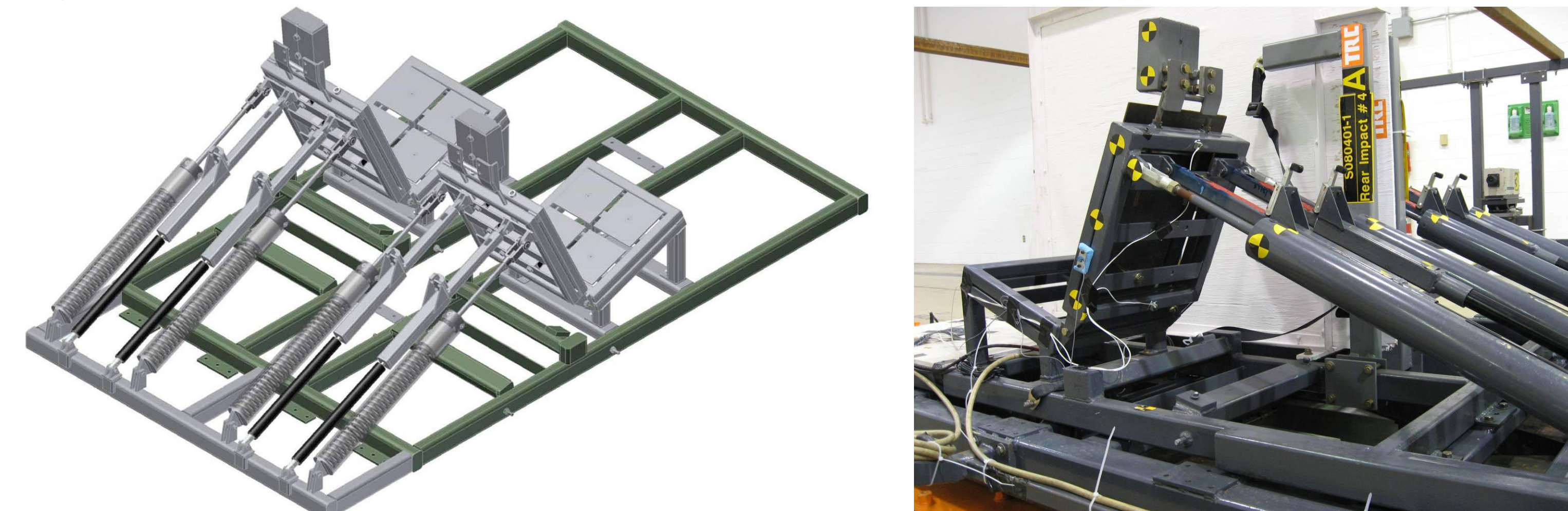


Figure 2. Sled buck and designed seat configuration for the experimental seats

Instrumentation technique: A new technique for instrumenting the anterior aspect of the bodies of the cervical vertebrae and the first thoracic vertebra (T1) was developed and proposed to measure detailed neck kinematics during the event. The proposed technique allowed for installation of two accelerometers and an angular rate sensor on each anterior aspect of the vertebral bodies without disrupting the musculature of the neck (Figure 3). The accelerometers (Endevco model 7264, 2000 G limit) and the angular rate sensors (DTS ARS-1500/12K, \pm 1500/12K deg/sec) were installed at each cervical vertebra by accessing the retropharyngeal space through lateral incisions posterior to the sternocleidomastoid muscle, to determine kinematics of the cervical vertebrae during the event. To measure head kinematics, an aluminum tetrahedron fixture with 6 accelerometers and 3 angular rate sensors (6ω) was placed on the vertex of the head. Initial positions of the instrumentation and required skeletal landmarks were digitized using FaroArm (Faro Arm Technologies, Lake Mary FL).

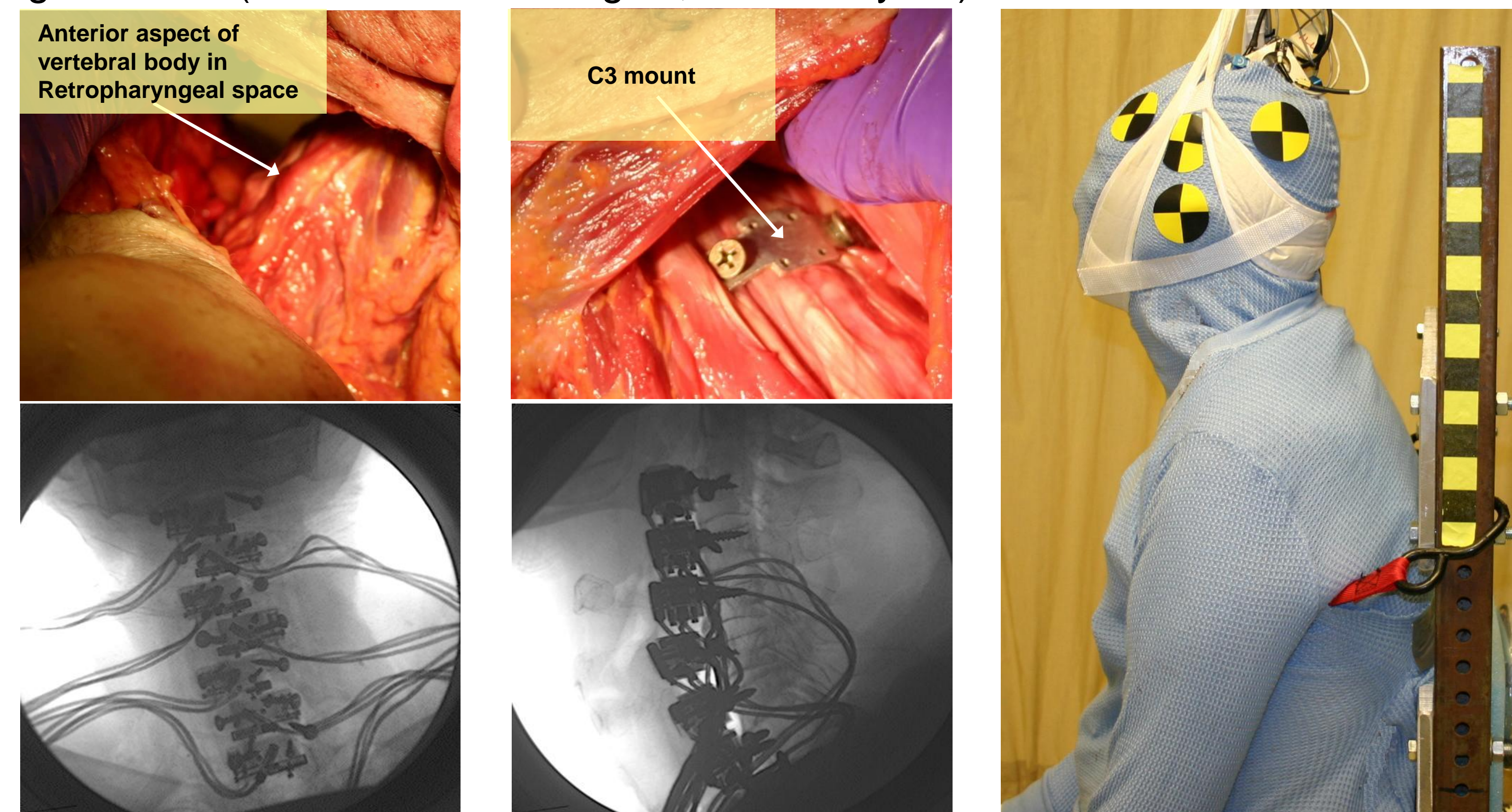


Figure 3. PMHS trial using the proposed instrumentation technique

Results and Discussion

Experimental seat design: Rear impact sled tests (10.5 g and 24 kph) were conducted to evaluate the performance of the designed experimental seat. Steel ballast with mass of 40 kg (similar mass as Hybrid III upper torso) was fixed to the seat back to create an appropriate loading condition during the dynamic event. Figure 4(a) shows that the seat back rotation for the tests was repeatable with a CV value of 3.34 (driver) and 2.69 (passenger) and that the two seats were reproducible with a CV value of 3.02. The instrumentation in the seat was verified by conducting the moderate-to-high speed rear impact test with an unpositioned dummy and it appears adequate to allow for external biofidelity comparisons during the event, as shown in Figure 4(b).

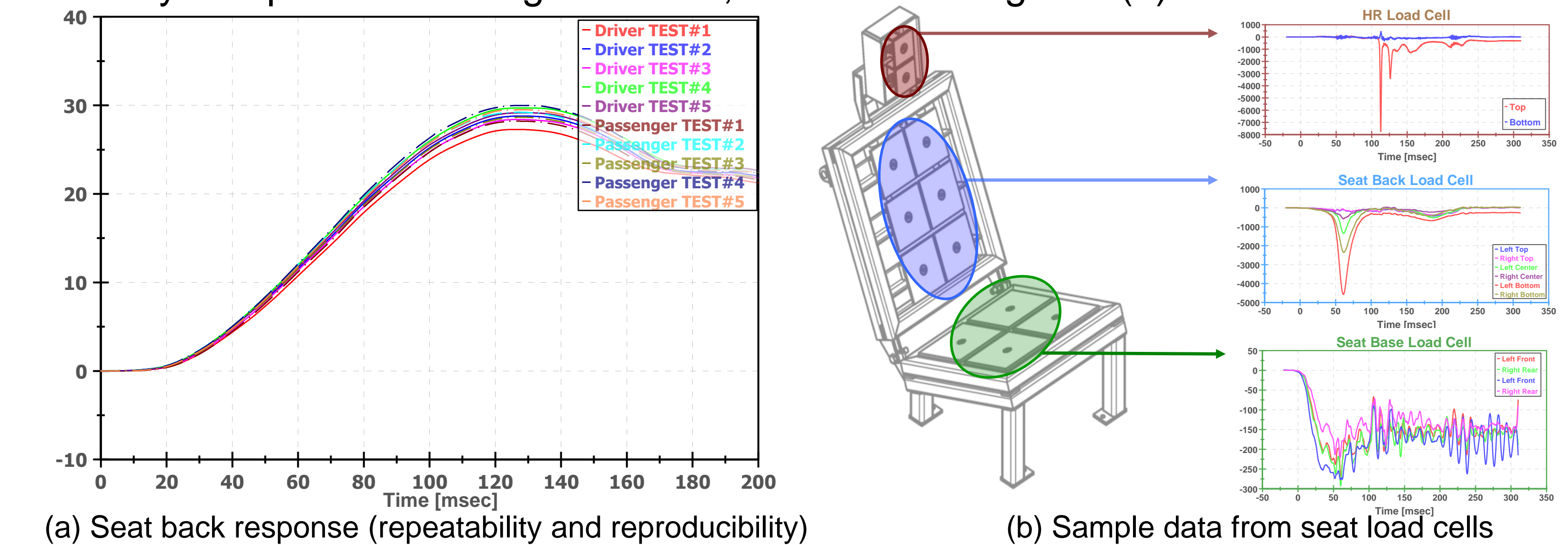


Figure 4. Seat back rotation for the seats in test series (10.5 g, V = 24 km/h)

Instrumentation technique: An 8 kph/100 msec impact trial was performed on an instrumented PMHS seated in a rigid chair on wheels in order to verify the data obtained from the proposed instrumentation technique. Figure 5 (a) shows sequential motion for the cervical vertebrae in the trial. The translational and rotational displacements obtained from the accelerometers and DTS angular sensor installed on the anterior aspects of the cervical vertebral bodies are shown in Figure 5(b), (c), (d).

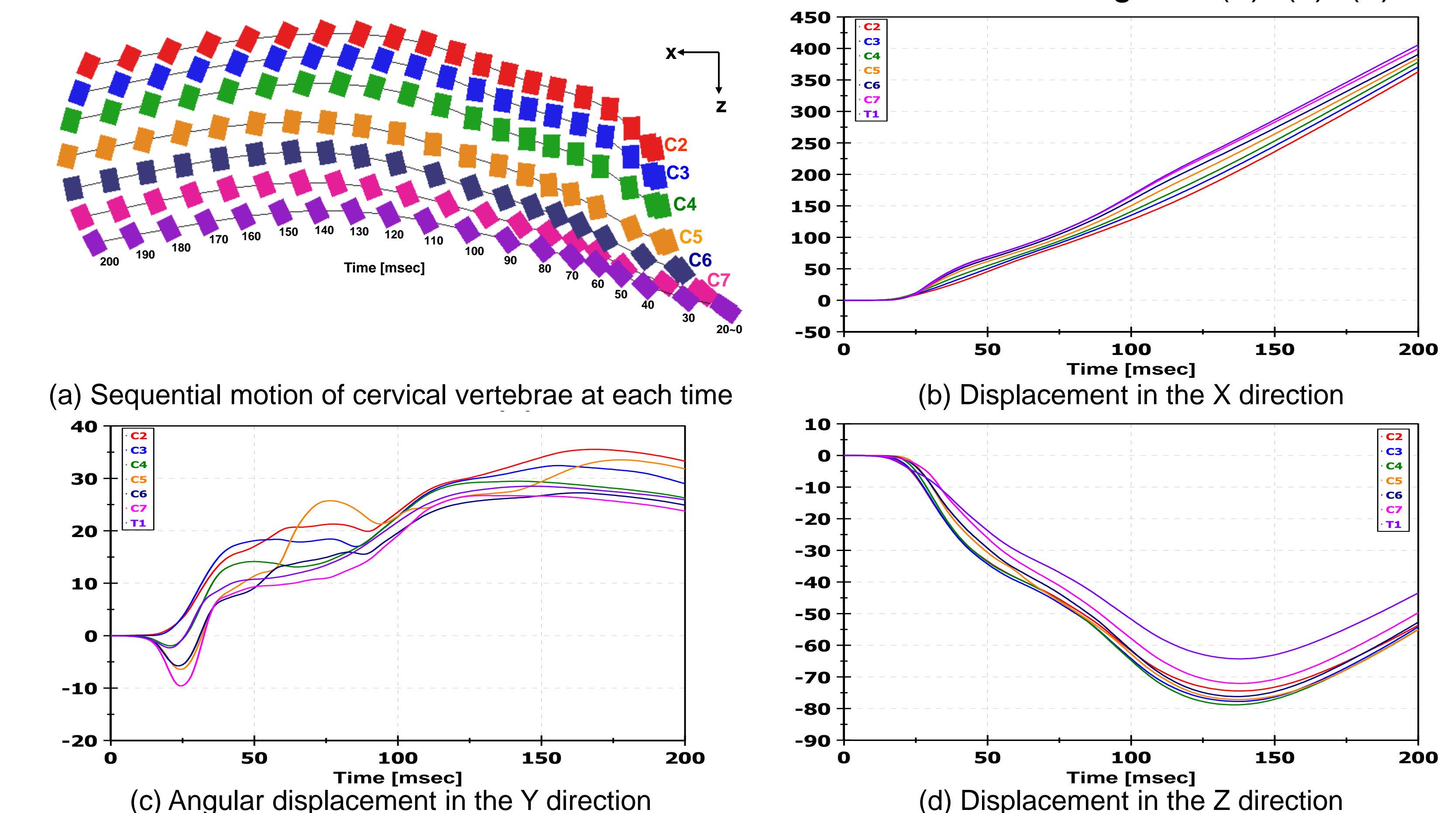


Figure 5. Position analysis from proposed instrumentation

Conclusions

- The experimental seats were able to withstand multiple events with excellent repeatability (CV $<$ 5%) and reproducible (CV $<$ 5%)
- The internal seat instrumentation appears adequate to allow for external biofidelity comparisons between ATDs and PMHS
- The proposed instrumentation technique was capable of measuring detailed neck kinematics without compromising the anatomical structure of the neck

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