The impact response of four male PMHS to frontal impacts in reclined positions

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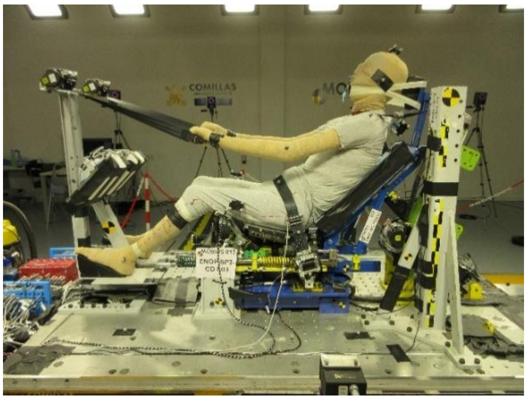
I. INTRODUCTION

There is growing interest to characterize the impact response of humans and crash test dummies adopting reclined positions to frontal impacts, as well as to obtain experimental data that can be used in the development and benchmarking of human body models [1-4]. The ENOP (*Enable New Occupant Seating Positions)* project aims to understand the implications of flexible seating positions, involving several seat pan and seat back angles, on the occupant kinematics and potential new injury patterns. One of these positions corresponds with a seat back angle of 45° and four PMHS have been tested in this condition.

This paper includes preliminary information about these PMHS tests, the performance of the restraint system and considerations about the observed kinematics of the occupants.

II. METHODS

Four PMHS tests were performed in a hydraulic-type sled catapult (ENCOPIM, Barcelona, Spain) using a 35-g peak and 50 km/h delta-v over almost 90 ms generic crash pulse [1]. A semi-rigid seat (seat pan angle: 15° from horizontal; anti-submarining pan angle: 32° from horizontal), designed by Uriot et al., 2015 with increased stiffness to control the rotation of the antisubmarining ramp was used [5]. A rigid backrest at 45° from the horizontal plane retracted right before the onset of the acceleration (t=-20 ms) and was used to ensure a repeatable initial position of the test subjects (Fig. 1). The characteristics of the PMHS are shown in Table I.



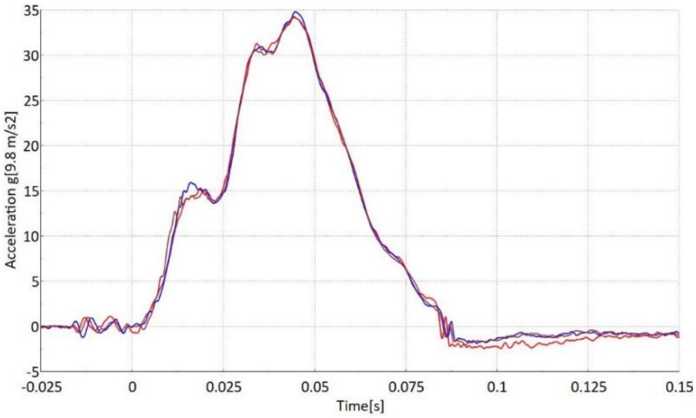


Fig. 1. Initial position of PMHS 3 and test pulse used in the tests.

Test subjects were restrained by an advanced seat-integrated 3-point belt system with a crash locking tongue, consisting of a shoulder belt retractor with 2-kN pretensioner and 4-kN load limiter, 2-kN lap belt pretensioners and approximately 5-kN load limiters at each side of the pelvis [1]. The anchorage points and the angle of the retractors of the seatbelt system were kept constant for all the PMHS, regardless of their anthropometry.

TABLE I
CHARACTERISTICS OF THE PMHS

Test #	PMHS	Age	Height (cm)	Weight (kg)	Cause of death
M010	PMHS 1	69	184	69	Cardiac arrest
M011	PMHS 2	81	183	86	Urinary sepsis
M012	PMHS 3	74	174	67	Cardiac arrest

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M013	PMHS 4	64	176	61	Gastric disease

Retroreflective marker clusters were attached to the head, T1, T8, T11 and L2 vertebrae, to the pelvis and to the diaphysis of the femurs. Three-axial acceleration and angular rate were measured at the same locations. Rossette strain-gages were added to the pelvic iliac wings of the subjects. All these magnitudes were collected according to a coordinate system defined according to the standard SAE J211, with origin in the right rotation center of the seat pan. The subjects were positioned so that the initial location of the hip joint and the angle of the pelvis and the head would be comparable between them, allowing some variability to account for the different anthropometries of the PMHS. A rigid body transformation between some external landmarks in the pelvis of the test subjects allowed for a detailed reporting of selected anatomical points prior to impact (ASIS, pubic symphysis, hip joint and pelvic angle). The initial position of the lumbar spine was also acquired via a sagittal view of the subject.

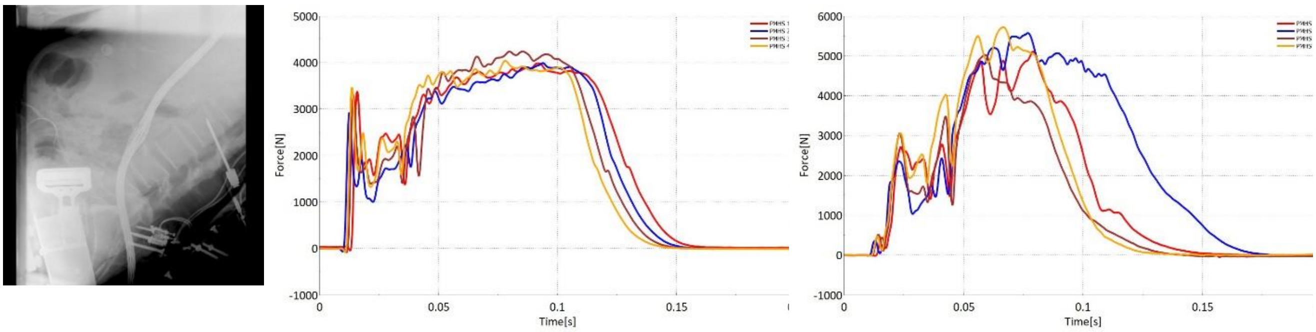

Fig. 2. Left: Sagittal view of the lumbar spine of PMHS 4. Center: Time history of shoulder belt forces measured at B3. Right: Time history of shoulder belt forces measured at B6.

III. INITIAL FINDINGS

After the complete definition of the ENOP test setup via Hybrid III sled tests, this setup was successfully used in the described PMHS tests. Four PMHS tests have been completed to date in a reclined position of the occupant with the backrest oriented at 45° from the horizontal plane. The restraint system used to arrest the forward motion of the PMHS performed according to its design specifications during the tests. The time history seat belt force measured at the D-ring (B3) and at the lap belt (B6, anchor side) are included in Fig. 2, showing that the pelvic region of the subjects are exposed to belt loads of comparable magnitude to those sustained by the thorax of the occupants. In the case of the subject with the largest weight (PMHS 2), the engagement of the shoulder belt with the thorax lasted for approximately the same time as in the other three subjects, but the lap belt demonstrated a much larger interaction time with the pelvic region of the occupant.

IV. DISCUSSION

The four analyzed PMHS tests showed that, under the action of the current restraint system that incorporates load limitation in the lap belt, the pelvis of the subjects undergoes a long forward excursion combined with significant rotation in the Y axis. It should be noted that the feet of the subjects were not restrained to the foot plate and, therefore, the seat assembly and the seat belt are the only restraints acting on the occupant during the test. The obtained kinematics challenged the use of the cluster of VICON markers on the pelvis, which ended up impacting against the seat surface in three of the tests and at different times during the forward motion of the occupant.

These test conditions are similar to those used in previous testing of PMHS in reclined positions, but they incorporate the use of a rigid backrest to facilitate the repeatability of the initial positioning of the test subjects.

V. REFERENCES

[1] Östling et al., IRCOBI 2022

[2] Richardson et al., STAPP 2020.

[3] Grebonval et al., 2021

[4] Wang et al., 2022.

[5] Uriot et al., STAPP, 2015.