Response of Seatbelt and Airbag Restrained Post-Mortem Human Subjects to Frontal Impacts

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I. INTRODUCTION

The population of older people, defined as those aged 65 years or more, will increase in Europe rising from 90.5 million in 2019 to reach 129.8 million by 2050 [1]. Elderly people are exposed to a higher risk of injury for a given magnitude of loading and to a higher risk of worse outcome for the same Abbreviated Injury Scale (AIS) level injury, compared to younger people [2]. This increased risk of severe injuries of elderly car occupants is related to their particular characteristics in terms of fragility and frailty. Thus, effective injury criteria must include age effects in their formulation as well as being representative of contemporary restraint configurations. Recognizing these requirements, the European Commission funded the SENIORS (Safety Enhanced Innovations for Older Road Users) consortium aiming to improve the safe mobility of the elderly. Among the activities carried out in SENIORS, six Post-Mortem Human Subjects (PMHS) were exposed to frontal impacts. The objective of this work is to introduce the tests, and the data collected, with a focus on the kinematics of relevant body landmarks.

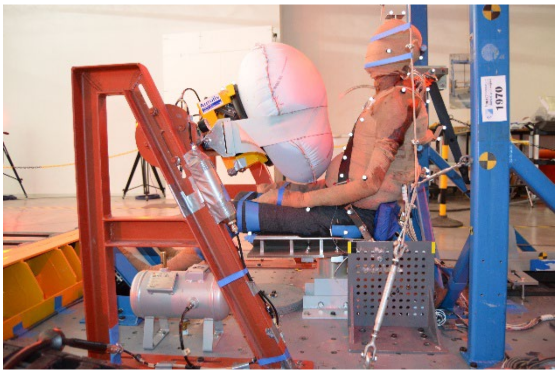
II. METHODS

Test Subjects

Six male subjects with ages ranging between 63 and 94 years were included in this study. With the exception of PMHS three, who was the oldest subject and extremely light and short (34 kg and 156 cm), the other test subjects were within the average male size for the corresponding age group (average values: 172.5 cm height, 69 kg weight and 22.9 kg/m^2 BMI).

Test Bench

All testing conditions, including the restraint systems, were chosen to be as generic as possible to facilitate the development of Finite Element (FE) models of the test setup. The test fixture was designed to approximate the seating position of a front-seat passenger car occupant using a simplified geometry, without considering a knee bolster. It consisted of a rigid inclined seat in the longitudinal axis of the sled, a rigid footrest, and an adjustable backrest made of three segments of metal wire. A non-retractor, force-limited three-point seatbelt (passenger configuration) and a pre-inflated airbag (vented at t=0 ms) were used to restrain the forward motion of the test. The force-limiting feature of the seatbelt was provided by a device that provided a nominal constant force due to the plastic deformation of a set of calibrated metal strips that were pulled through a set of rollers. This device allowed for adjustment of the constant seatbelt force by controlling the thickness of the metal strips, the number of strips, the number of rollers engaged, and the magnitude of the deformation caused by the rollers [3]. Test subjects were exposed to a frontal impact following a trapezoidal deceleration with a plateau at about 14 g, resulting in a 35 km/h delta-v. Figure 1 illustrates the test fixture, the initial position of one PMHS and the crash pulse.



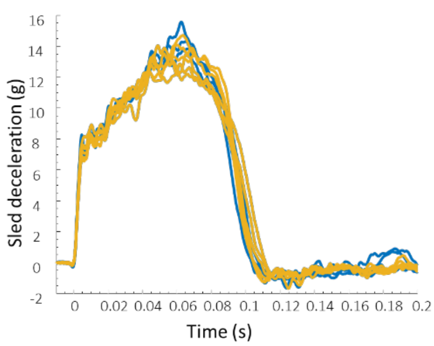


Fig. 1. Initial position of one PMHS (left). Time history of the deceleration pulse used in the tests (right).

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Two Restraint Conditions

Two restraint conditions were used. Condition A consisted of a force-limited at 2.5 kN three-point seatbelt, a pre-inflated airbag at 12 kPa (nominally), a more forward position of the D-ring and a low-friction seat surface. Condition B corresponded to a lower force limit of the seatbelt (2 kN), a lower airbag initial pressure (10 kPa), a rearward position of the D-ring (100 mm with respect to Condition A) and a high-friction seat surface.

Data

PMHS subjects were instrumented with three-axes linear accelerometers and angular rate sensors at several vertebral levels, the head and the pelvis. Data was collected at 10,000 kHz. A motion-capture system (VICON) was used to track the trajectories of clusters of markers attached to the head, T1, T8, L2 and the pelvis at 1,000 Hz. The trajectories of external markers were processed to provide the actual trajectories of local coordinate systems attached to the corresponding bones.

III. INITIAL FINDINGS

As illustration of the trajectories of the anatomical landmarks, the sagittal motion of the center of gravity of the head is shown in Figure 2. The two restraint conditions resulted in substantial differences in the shape and magnitude of the head trajectory. Restraint condition B allowed for almost twice forward excursion of the head as shown in the plots. The forward displacement of all the analyzed landmarks of the PMHS restrained in Condition A were always smaller than those of the PMHS in Condition B. Other differences in the transverse plane trajectories were also observed between the two restraint conditions.

PMHS three (test 1765) exhibited a distinct fracture pattern compared to the other five PMHS, showing 13 rib fractures in the costovertebral joint but only two fractures in the anterior aspect of the rib cage. No posterior rib fractures were identified for the other five PMHS [4]. Focusing on these five subjects, Condition A (12 rib fractures on average) resulted into a more severe condition for the thorax compared to Condition B (1.67 rib fractures on average). Peak lap belt forces (2.9 ± 0.8 kN) were higher compared to upper shoulder belt forces (2.1 ± 0.4 kN), regardless of the restraint condition.

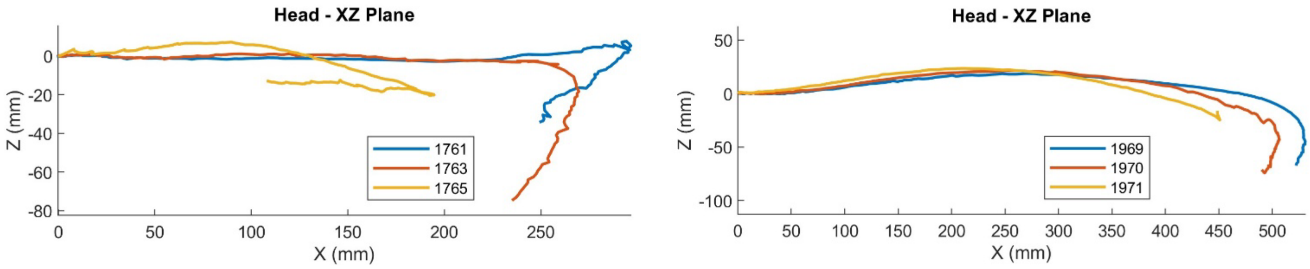

Fig. 2. Sagittal (XZ plane) trajectories of the centre of gravity of the head for Condition A (left) and Condition B (right).

IV. DISCUSSION

This manuscript describes briefly the test conditions and some of the information obtained from six PMHS tests exposed to a 35 km/h frontal impact. The PMHS tests performed within the SENIORS project are a unique set of data reporting tests from frontal impacts performed in controlled test conditions and using a generic test fixture to facilitate the development of FE models that could be used to validate Human Body Models (HBM). To date, only a small fraction of the experimental data has been published [3]. Detailed sensor data, anatomical landmark coordinates obtained from VICON and a detailed description of the procedures will be made available to researchers in the field through the THUMS Users Community (TUC) repository [4].

V. REFERENCE

[1] European Union. Ageing Europe- Statistics on population development. 2020.

[2] Kent *et al*. *Annu. Proc. Assoc. Adv. Automot. Med*., 2009.

[3] Lopez-Valdes *et al*. *Traffic Injury Prevention, 2018.*

[4] https://tuc-project.org