Upper Body *In Vivo* Kinematics during Moderate Lateral Accelerations – towards Active Finite Element Human Body Model Validation

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I. INTRODUCTION

Experimental (sled) trials on *in vivo* human subjects are essential to evaluate and further increase the biofidelity of active Human Body Models (HBMs). Nowadays, these models are not only used for high loading conditions, but also for moderate ones, such as crash avoidance manoeuvres prior to crash. Furthermore, volunteer muscular contraction strategies leading to reactive body kinematics also need to be evaluated and implemented in the models.

In previous studies, many volunteer tests were performed focusing on various objectives: awareness, visual perception, level of acceleration or spine morphology [1-4]. However, availability of *in vivo* validation data obtained from moderate lateral accelerations is still insufficient.

The study has two main objectives: Firstly, the understanding of volunteer strategies to stabilise their upper body under imposed variable lateral loadings. Further, the provision of suitable validation data for active HBMs.

II. METHODS

Experimental Testing

Five healthy male subjects whose body size is close to the 50th percentile American Male (175 cm, 77 kg) participated in this study. The subjects were carefully chosen to fit in a deviation of ±4 cm in height, ±4 kg in weight and between 26 and 36 of age. The subjects sat on a flat wooden plate, which was installed onto a linear sled. They were restrained by a thigh belt and lumbar supports for safety reasons (Fig. 1 left).

The sled was controlled by a proportional–integral–derivative (PID) algorithm to realize four lateral accelerations: 2 seconds sine-shaped or 3 seconds of trapezoidal shaped pulses with 0.1g or 0.3g magnitude. The subjects were asked to achieve six different seated configurations: combinations of feet on the footrest or hanging, arms crossed at chest or hands on thighs and spine straight or sagged. Additionally, two muscle conditions, relaxed or braced, were also studied for selected cases. Each condition was randomly performed three times in order to avoid the bias due to a possible habituation of the pulses by the subjects (learning effect).

For the experimental data acquisition a high speed camera (50 fps) moving with the sled and a fixed digital video camera (25 fps) captured the kinematics of the subjects from the back and the side, respectively. Additionally, four 3-DOF inertial measurement units (Xsens, 100 Hz) on head, sternum, T1 and S1 vertebrae and multiple photo targets for further picture analysis were attached to the subjects. Furthermore, sixteen electromyography (EMG) sensors (Delsys, 2 kHz) provided the muscle activities, which relate mainly to upper body kinematics. Moreover, the applied force on the seat surface was recorded by a 6DOF load cell (AMTI, 200 Hz) mounted directly underneath to enable the calculation of the Centre of Pressure (CoP). Prior to the test, initial tension of the thigh belt was measured.

The tests were organised with informed consent to the volunteers and the approval by the French Ethics Committee CPP IDF VII Number 15-018.

Computational Modelling

A reactive FE-HBM developed by Volkswagen [5] was applied to the above-mentioned environment. The model was even used before the tests were carried out in order to design the exact boundary conditions and requirements of the experiments (Figure 1).

The model was developed based on THUMS TUC (Total Human Model for Safety Thums User Community) [6] with modifications regarding material properties and geometry to apply it under moderate loading conditions. Whole body skeletal muscles were added to the model using 1D bar elements, which were regulated by a feedback control algorithm.

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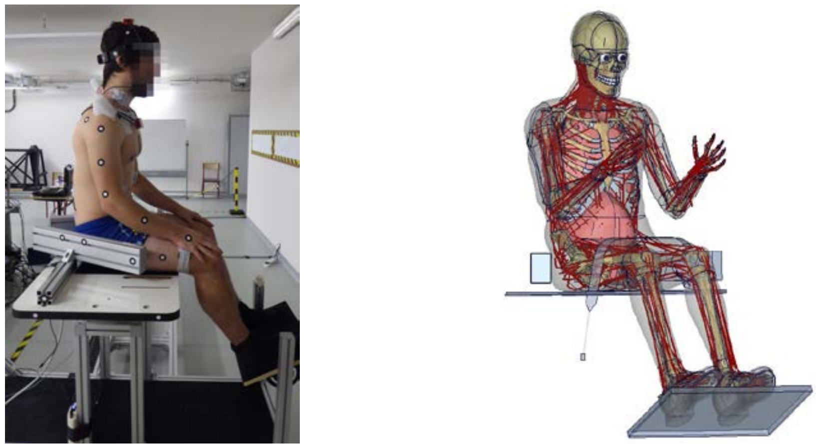

Fig. 1. Left: A volunteer seated on the instrumented lateral sled. Right: Reactive FE-HBM - a functionally extended THUMS TUC by Volkswagen AG.

III. INITIAL FINDINGS

Reproducible experimental data was obtained and analysed statistically for the comparison among the trials. Particularly, head and torso accelerations were highly reproducible regarding amplitude as well as timing delay and relative to the imposed sled pulses. Figure 2 represents the head accelerations in the pulse direction of the five volunteers (top) for the 0.3g trapezoidal shaped pulse (bottom). On the contrary, the muscular activation patterns showed larger variations and only some muscles showed similarities among the subjects. Concerning the CoP, some variations were found among the subjects, and one subject behaved highly different from the others. The virtually reconstructed trials using the reactive Thums VW showed kinematics of the body segments within the corresponding experimental corridors.

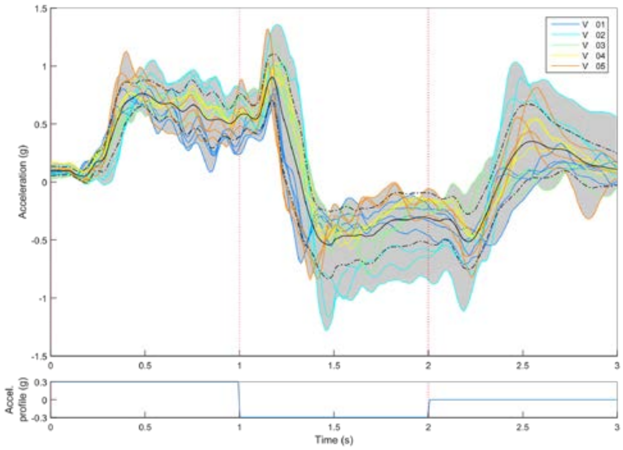

Fig. 2. Head accelerations for trial feet on footrest, hands on thighs, straight spine and relaxed muscles

IV. DISCUSSION

Despite the high variability in the muscular activation patterns, the subjects showed comparable upper body kinematics. However, the muscle recruiting strategy of the subjects and its influence on the experimental results need further investigation. Therefore, future work requires complementary measurements such as pressure distribution on seat or the study of other morphologies. Finally, the variation in posture, muscles active state and sled pulse enables the further enhancement and validation of reactive HBMs.

V. REFERENCES

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