Analysis of head and neck kinematics of the VIVA+ and THUMS V5 HBM in a generic rear-impact simulation

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I. INTRODUCTION

In recent years, virtual testing with finite element human body models (FE HBMs) has opened a spectrum of new possibilities in road safety testing. On the way to establishing virtual methods in consumer and regulatory testing, it is crucial to understand how differences between available HBMs (e.g. anthropometry, posture, material properties) influence the kinematics and the resulting injury risk assessment. This holds particularly true for the rear-end impact load case, as the head and neck kinematics (and, consequently, the neck injury risk) in this scenario are particularly sensitive to minor changes in the loading conditions [1].

Hence, the aim of this work was to analyse the head and neck kinematics of the 50th percentile male version of the VIVA+ and THUMS V5 HBMs in a generic rear-impact simulation. Furthermore, the sitting postures of the two HBMs resulting from the same positioning procedure were compared.

II. METHODS

Both the VIVA+ and THUMS V5 HBMs were placed in an open access Toyota seat model [2] using a method by Poulard *et al*. [3]. A total of 26 constant force beam elements of the same length and direction as the distance between the mid-hip point and the H-point of seat model were attached to head, shoulders, ribs, hip and knees. Then the HBMs were pulled towards the respective beam element endpoints. At a point in time where the length of the beams amounted to roughly zero (i.e. the target position was reached), the forces of the beams were cancelled, followed by 100 ms of gravity settling. The whole seating procedure lasted for 300 ms. The final sitting position was compared to target positions according to a statistical model of driving postures by Park *et al*. [4].

The rear-impact test was run immediately after the pre-simulation. A medium severity crash pulse (delta-v of 16 km/h) according to the Euro NCAP protocol [4] was applied by specifying an acceleration loading of the entire model. Muscle activity was deactivated in both HBMs. The pre- and main simulations were performed using a double precision message passing parallel (MPP) version of the LS-DYNA 11.2.1 solver. All acceleration signals were filtered using CFC180.

III. INITIAL FINDINGS

For the VIVA+ model, the maximum deviation from the target position occurred at the L1 vertebra, with -15 mm in x-direction and -18 mm in z-direction with an overall RSME of 9.5 mm and 11.7 mm, respectively. The THUMS model showed the maximum deviation at the tragion (9 mm in x-direction, -50 mm in z-direction), with an overall RSME of 8.1 mm and 39.3 mm, respectively (Figure 1). Target points below the hip joint were not considered as their position is less relevant in a rear-impact scenario. The head restraint distance was 87.6 mm for the VIVA+ model and 76.2 mm for the THUMS model. Contact with the head restraint (head restraint contact time) occurred 63 ms after the onset of the crash pulse for the VIVA+ (56 ms for the THUMS model).

Figure 2 and Figure 3 show the head and T1 vertebra accelerations as a function of time. The maximum head accelerations were 18 g and 19 g for the VIVA+ and the THUMS model, respectively. The NIC curves are shown in Figure 4, with maximum NIC values of 25.6 m^2/s^2 (VIVA+) and 18.1 m^2/s^2 (THUMS). Reducing the head-to-head restraint distance of the VIVA+ model to 77.7 mm lowered the NIC value substantially (19.7 m^2/s^2).

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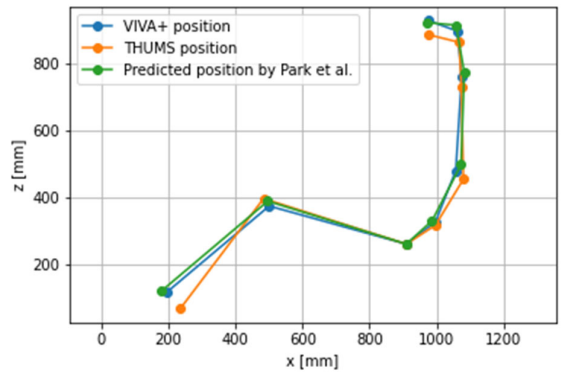

Figure 1. Comparison of final sitting positions with the predicted position from Park *et al*. [4].

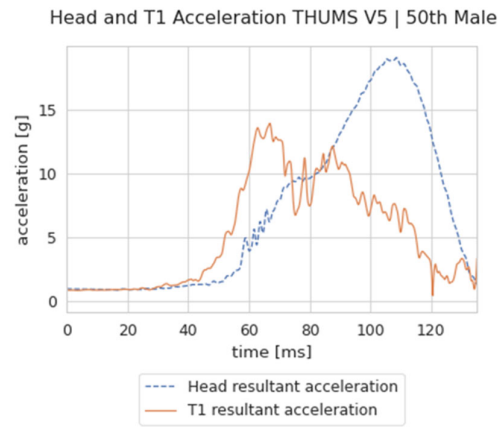

Figure 2. Head and T1 acceleration of the THUMS V5 50th percentile male model.

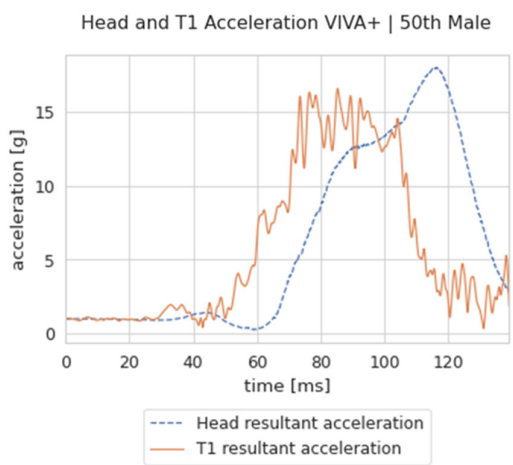

Figure 3. Head and T1 acceleration of the VIVA+ 50th percentile male model.

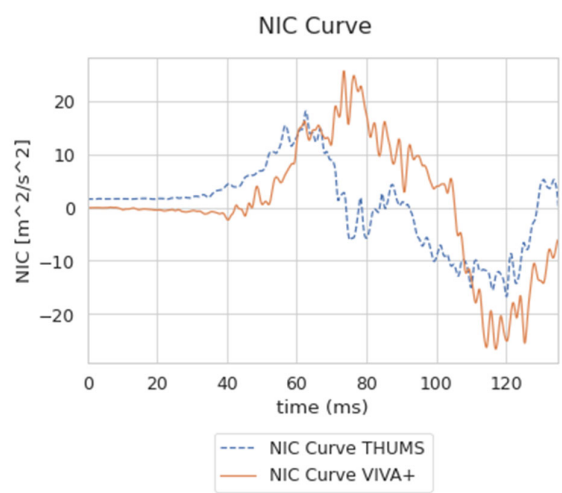

Figure 4. NIC curves of the VIVA+ and THUMS model.

IV. DISCUSSION

As expected, the resulting head-to-head restraint distance and overall body posture differ, although both models were positioned with the same method. Reasons for this include different initial spinal curvatures and a larger head circumference of the THUMS model compared to VIVA+. Consequently, different head and neck kinematics result. Especially, the NIC value is highly sensitive to head-to-head restraint distances. A major effort is required to align the postures of both HBMs. However, if at least the head-to-head restraint distance is almost equal, the difference in NIC value strongly diminishes. In view of current attempts to establish virtual testing protocols, this demonstrates the necessity to develop standardized procedures to cope with the different behaviour of different available HBMs under similar loading conditions.

V. REFERENCES

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