Comparison of PIPER child human body model and Q6 Dummy analysing sensors of the HBM

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I. INTRODUCTION

The PIPER child model was introduced in 2017, and in 2018 the standing derivative was released [1]. The interpretation of simulation results from such models with lack of injury criteria is challenging. But with well-known test devices, a comparison with new modelling approaches can support the development of the devices. Regarding the PIPER child model, which is in the baseline model a 6-year-old child, the comparison with the Q6 dummy should be performed analog to the comparison of P6 and Q6 dummy in [2]. As the comparison of PIPER child model and Q6 dummy is a comparison between a singular numerical model and a test subject with its numerical derivative, the aim of this investigation is to assess Q6 measurements and the possibility of transferring them to the PIPER child model.

II. METHODS

This study analysed only numerical models. The PIPER child model Version 1.0.0 and the Q6 FE-Model Version 1.0 were calculated with LS-DYNA 7.1.3. In a first step, the reference axes and sensor locations of the Euro NCAP Bulletin 024 [3] were added to the PIPER model extended by all vertebras. All points were connected to receive a simplified skeleton in order to visualise basic kinematics and compare seating positions. Secondly, the Q6 dummy was seated in a posture as close as possible to the initial PIPER child model posture and afterwards a simplified skeleton was added to the Q6 dummy, similar to the simplified skeleton of the PIPER model. The simplified skeleton meant a comparable posture of both models on the ECE-R129 bench could be achieved. The models were seated directly on the bench, following the ECE-R129 posture, without using a child restraint system. The environment of the presented simulations, including bench, belt and retractor, was validated using Q6 frontal impact experiments with different sled acceleration, resulting in a CORA rating of 0.83 for all direction-relevant sensors. An extensive simulation matrix was performed using pulse scaling to address a wide range of injury risk criteria for the Q6. The pulse was derived from an ECE-R44 frontal pulse and scaled in duration and maximum acceleration. The duration of the pulse was scaled between 50 ms and 120 ms, with increments of 10 ms. The maximum acceleration was scaled between 10 g and 30 g, with increments of 10 g. Higher accelerations of 40 g, 50 g and 60 g led to numerical instabilities in the dummy simulation and were excluded for this short communication.

The results of the simulation were analysed with respect to established dummy readings and their corresponding injury risk criteria, such as a_{3ms} value for head, chest and pelvis acceleration, HIC_{15} and HIC_{36} values, max. chest deflection, max. neck force and max. neck moment. Additionally, the loadcells of the lumbar spine were included. Maximum X value of the trajectories of the Euro NCAP points were analysed: centre of gravity of the head (HC), centre of C1, centre of C7, centre of T8, centre of T12, centre of right (ACR) and left (ACL) acetabulum and their midpoint (AC), shoulder right (SCR) and left (SCL) analog to the definition of SC in Euro NCAP TB24 [3]. For the analysis of the PIPER child model the local accelerometers were deactivated and only the global accelerometers were considered to avoid additional stiffness due to the rigid body connections. Alongside the added trajectories, the standard sensors of the HBM were used. The three chest deflection sensors in the sternum were all compared with the single IR-TRACC of the Q6 dummy.

III. INITIAL FINDINGS

The results were compared between PIPER child model and Q6 dummy with a scatter plot. The dummy values correspond to the x-axis and the PIPER values to the y-axis. A linear trend line was added and the determination

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coefficient was calculated, per the example in Fig. 1 for the a_{3ms} value of the head acceleration. For all other datasets the slope, y intercept and determination coefficient are listed in Table I.

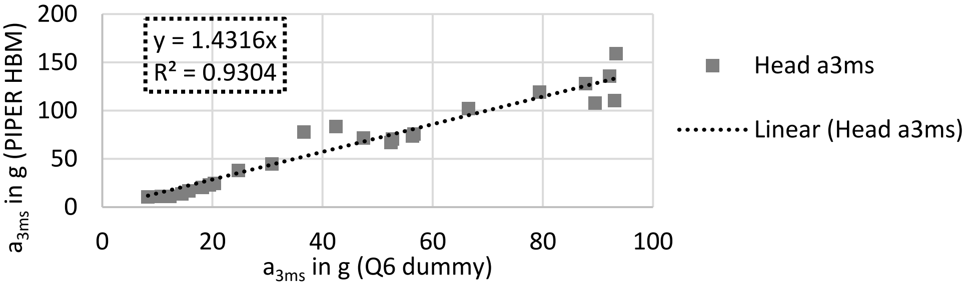

Fig. 1. Comparison of a_{3ms} values of the head acceleration between PIPER child model and Q6 dummy.

TABLE I
RESULTS OF THE COMPARED SIMULATION RESULTS OF THE PIPER CHILD MODEL AND Q6 DUMMY

	HIC_{15}	HIC_{36}	a_{3ms} head	a_{3ms} chest	a_{3ms} pelvis	Max. x-traj. Head	Max. x-traj. C1	Max. x-traj. C7	Max. x-traj. T8	Max. x-traj. T12	Max. x-traj. Pelvis	Max. x-traj. SCL	Max. x-traj. SCR
slope	1.92	1.90	1.43	1.06	1.25	1.12	1.07	1.03	1.02	0.89	0.75	1.16	0.93
R^2 in %	93.1	97.2	93.0	89.0	93.6	99.3	99.2	99.4	98.3	93.2	90.0	98.5	91.0

	Max. up. neck F_X	Max. low neck F_X	Max. up. neck F_Z	Max. low neck F_Z	Max. up. neck M_Y	Max. low neck M_Y	Lumbar Spine F_X	Lumbar Spine F_Z	Lumbar Spine M_Y	Chest def. low	Chest def. mid	Chest def. up
slope	2.91	1.33	0.32	0.82	0.18	0.04	0.24	0.20	0.38	1.18	1.21	0.99
y intercept	-0.76	0.09	0.31	0.18	4.89	6.69	0.05	0.04	3.07	7.59	15.9	19.3
R^2 in %	67.8	93.1	95.4	91.5	66.9	72.3	83.8	70.6	92.8	96.3	89.2	81.5

The results show that despite upper neck force X, moment Y, lower neck moment Y and lumbar spine forces, the determination coefficient is higher than 89% and y intercepts are needed only for the loadcells and the chest deflection. This shows that a prediction of the PIPER results by using the Q6 output is possible with respect to the calculated determination coefficients. Using this approach with a simulation of the matrix with 25 g max. acceleration and 80 ms pulse height resulted in a mean difference of all channels between predicted value and simulated value of -0.5%, with a standard deviation of 22.0%. The singular analysis of the max. x-trajectories showed a mean difference of 0.1%, with a standard deviation of 1.3%.

IV. DISCUSSION

The results of the comparison between the PIPER child model and the Q6 dummy show that the prediction of PIPER output based on dummy results is possible for the presented load cases. Nevertheless it should be mentioned that this current study consists of frontal impacts only and the complex kinematics of such HBMs was insufficient considered by only max. x excursion of the desired sensors. Additionally, the analysis was performed on a standard bench, neglecting the vehicle interior and child restraint systems. Further work will be performed in this study with additional booster cushion and booster seat with backrest. Lateral and oblique pulses will be analysed and a simplified vehicle interior will be used to analyse accident reconstruction. To address the complex modelling and kinematics of HBMs, several approaches to measure the spine loading and ribcage deformation will be analysed.

V. REFERENCES

[1] Peres, J., IRCOBI, 2018.
[2] EEVC Report, Advanced Child Dummies and Injury Criteria for Frontal Impact, Document No. 514, 2008.
[3] Euro NCAP Technical Bulletin 024, 2017.