# The Influence of the Body on Head Kinematics in Playground Falls for Different Age Groups

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## I. INTRODUCTION

Many children are injured at playgrounds. In Sweden, an EU country of 10 million inhabitants, it is estimated that each year 16,000 children visit the emergency department due to an injury sustained at a playground, with many of the injuries caused by falls [1]. Playground surfaces are evaluated by dropping a missile against the surface, where peak linear acceleration should not exceed 200 g and the head injury criterion (HIC) should be lower than 1,000. There are several limitations with the current testing standard, e.g. a simplified missile representing the head, evaluation of only the linear motion and only the head is included in the test. The question is how these limitations are influencing the head kinematics. The final objective of this study is to bridge the gaps in the current playground surface-testing standard by using multilevel finite element (FE) simulations to evaluate the influence on global head kinematics and head injury prediction for different age groups. This paper focuses on two levels, full body (FB) and head only (HO) tests, for head kinematics.

## II. METHODS

The PIPER scalable human body model (HBM) [2-4] was used in this study. The HBM was scaled to seven ages (1.5, 3, 6, 10, 12, 14 and 18 years old) and then positioned with the PIPER tool (v.1.0.1) prior to impact. More details can be found in a previous study [5]. The head model has been updated since its release version and the performance of the updated model on global head kinematics and brain relative motion is presented in [5]. The impacting surface was modelled with *MAT_SIMPLIFIED_RUBBER in LS-Dyna [6]. The material model was validated against a previous playground surface drop test [7], with details presented in a previous study [5].

Three different impact locations were evaluated (back, front, side) (Fig. 1). The impact velocity was 5.59 m/s perpendicular to the impacting surface, representing a 1.59 m fall. All the simulations were performed in pairs, with (referred to as FB) and without the body (referred to as HO). In the HO simulations, all components below the skull base were removed except the skin and flesh of the cervical spine, which had a continuous mesh with the head. The head kinematics, including resultant linear acceleration, resultant angular acceleration and resultant angular velocity, as well as HIC [8] were analysed. The unlimited HIC was used as this is used in the current test standard.

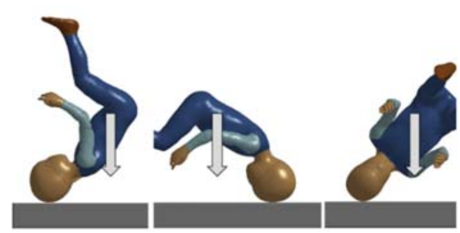

Fig. 1. The three impact locations (back, front, side), illustrated with a 3yo.

## III. INITIAL FINDINGS

The time history curves of the head kinematics of the three impact locations for HO and FB are presented in Fig. 2 illustrated with a 3yo model showing a small difference in linear acceleration between HO and FB. But a larger deviation of the curves is observed after 5–10 ms for angular motion, with higher peak values for the FB simulations.

The difference in HIC and peak angular velocity between HO and FB decreases with age for all three impact locations (Fig. 3). HIC values decrease with age for both HO and FB in all three loading conditions. Whereas for angular velocity, the peak values decrease with age for FB but are relatively constant or slightly increasing with age for HO.

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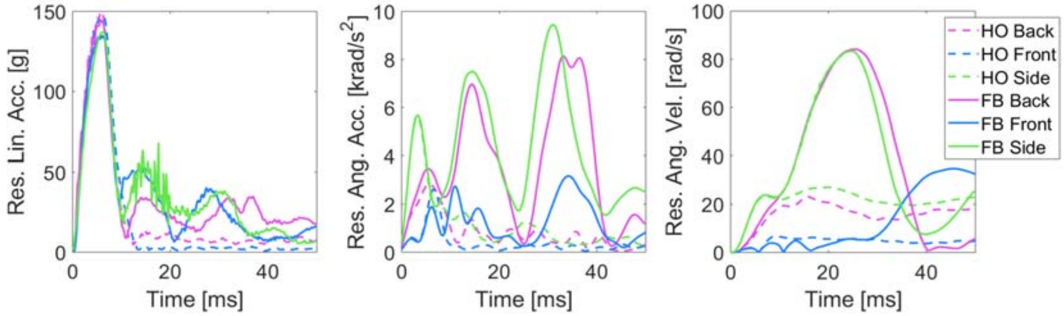


Fig. 2. Head kinematics for all three impact locations for both HO (dashed lines) and FB (solid lines).

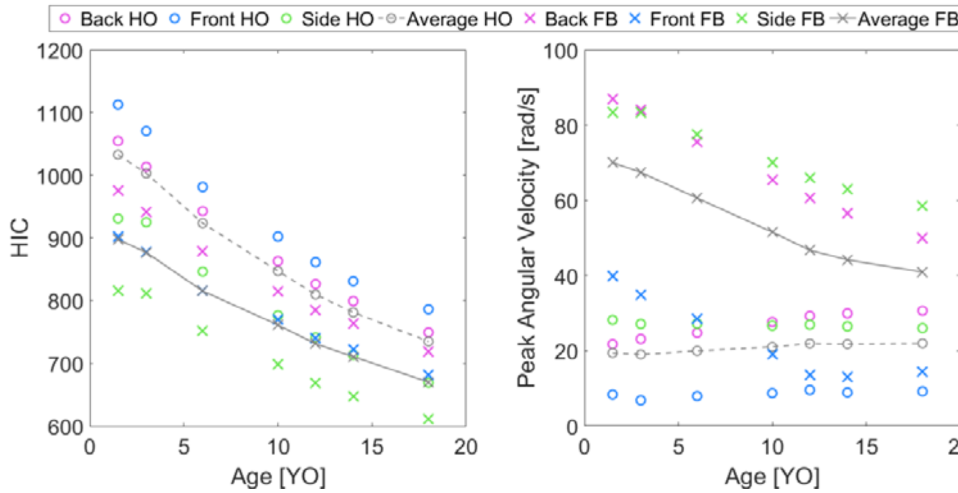


Fig. 3. HIC (left) and peak resultant angular velocity (right) dependent on age, impact location and boundary condition. The lines (dashed line for HO and solid line for FB) show the average of the three impact locations.

## IV. DISCUSSION

The initial results presented in this study show higher HIC values for HO compared to FB for most impact locations and ages, which is in line with previous studies with adult models [9-10]. Previous studies with adult models [9-10] have shown relatively small difference between HO and FB also for peak angular velocity, while this study shows a relatively large difference between HO and FB. This is most probably influenced by the time the impact is analysed and impact location. In the present study, the big difference between HO and FB occurs after 20 ms for linear acceleration and angular velocity (Fig. 2). However, an age-dependent difference is also seen for the ratio between HO and FB, with smaller difference for the older age groups. The ratio also seems to be dependent on impact situations, which was also indicated by a previous study [9].

There are several parameters that could influence the results, e.g. stiffness of the impacting surface, posture of the model, impact location, impact velocity vector and muscle tension. These parameters should be further evaluated. Also, the intermediate step between an anatomically correct model and the metal hemisphere used in the standard, the dummy headform with higher biofidelity, should be further evaluated.

## V. ACKNOWLEDGEMENTS

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## VI. REFERENCES

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