LINEAR HEAD ACCELERATIONS RESULTING FROM SHORT FALLS ONTO THE OCCIPUT IN CHILDREN

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INTRODUCTION
Childhood falls are a common occurrence and account for approximately 2.8 million emergency department visits each year. Although short falls most often do not result in serious injury[1], they do have the potential to cause serious head injuries or death[2]. Quantifying the characteristics of falls that lead to injury in children of various ages may lead to a greater understanding of the biomechanical implications of such events and may increase awareness among parents of the potential danger of a short fall. Such awareness could prompt caregivers to seek more timely medical attention should a household fall occur. The purpose of this research was to measure and compare the head response from impacts after falls from various heights and onto various surfaces.

METHODS
To simulate falls of toddlers and young children, two anthropomorphic test devices (ATDs) were used during the testing. A 1-year-old Child Restraint/Air Bag Interaction (CRABI 12-month-old, Denton ATD, Inc., Milan, OH) and a 3-year-old Hybrid III (Denton ATD, Inc., Milan, OH) were used. Instrumentation was placed at the center of gravity (CG) of each of the ATD’s heads to measure the linear head accelerations along the three orthogonal axes. Both the 1-year-old and 3-year-old ATDs were suspended supine from a single point of support with the head angled slightly downward (Figure 1). Using a pneumatic release, the ATDs were dropped such that the back of their head contacted the ground first. The measured drop heights represent the distance from the ATD head to the impact surface. The ATDs were dropped from three heights of 0.8 m, 1.2 m, and 1.5 m (2.5 ft., 4 ft., and 5 ft.) onto two surfaces (concrete, carpet with foam carpet padding). Each age, surface, and height combination was conducted at least three times.

The data were filtered using standard methods for impact data (CFC 1000). Peak linear head accelerations in each of the three directions and the resultant were determined, and the head injury criterion (HIC15) was calculated for each trial. Effects of surface, height, and age on peak head acceleration and HIC were determined utilizing a three-way analysis of variance.

RESULTS AND DISCUSSION
The investigated falls resulted in occiput-to-ground contact velocities ranging from approximately 3.8 to 5.5 meters per second. The averaged peak resultant linear head accelerations and averaged HIC15 for the 1-year-old and 3-year-old ATDs are summarized in Figures 2 and 3.

Consistent with expectation, peak head linear acceleration and HIC15 increased with increased fall height, age, and impact surface stiffness (p<0.001). The linear acceleration and HIC caused by a 1.5 m fall onto carpet in the three year old is less than that caused by a 1.2 m fall onto concrete.
To estimate injury risk associated with these configurations, the HIC$_{15}$ value for each trial was used to calculate the average corresponding risk of AIS$\geq$4 brain injury in the 1- and 3-year-old populations (Figure 4) [3]. As shown in Figure 4, the 0.8 m (2.5 ft) falls on carpet and concrete resulted in minimal risk of brain injury and skull fracture ($\leq$10%). A moderate risk of head injury (30%-55%) was associated with the head accelerations from a 1.2 m (4 ft) fall onto a carpet surface. Falls from 1.5 m (5 ft) onto carpet and concrete and falls from 1.2 m (4 ft) onto concrete produced a high risk of brain injury and skull fracture (>80%). As shown in Figure 3, five conditions (all but 0.8 m carpet) resulted in HIC$_{15}$ values above the Injury Assessment Reference Value (IARV) used in automotive safety testing in both the 1-year-old and 3-year-old ATD[3].

Although falls from relatively short heights do have the potential to cause brain injuries in small children, it is well known that children often fall from similar heights while sustaining only minor injuries. Fall orientation plays a large role in determining the risk of head injury in a short fall. This study focused on a severe scenario where the head was the first point of contact with the ground. Lower accelerations would occur if a child would strike another part of his/her body such as their buttocks, chest, or extremities prior to head contact from the heights investigated [4].

**CONCLUSIONS**

Depending on the circumstances including a child’s age, fall orientation, fall height, and landing surface, even falls from short distances may result in serious injuries in 1- and 3-year-old children.

**REFERENCES**


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