Differences in youth and adult headform responses during simulated ice hockey impacts

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Introduction

Ice hockey is a fast-paced sport with a high incidence of both physical contact and injury (Sproule, 1988; Wennberg and Tator, 2003). With over 500,000 youth hockey players enrolled in minor hockey across Canada, it is imperative that safety is a top priority (Hockey Canada, 2014). Unfortunately, significantly high numbers of concussions have been reported in young hockey players (Echlin et al., 2010).

Concussions are of great concern in youth ice hockey players, who are in a critical stage of growth and development (Marchie and Cusimano, 2003). Short-term effects of concussions can include fatigue, inability to concentrate, loss of memory, and headaches, all of which can severely inhibit a youth's academic and athletic performance (Johnson, 2011).

This study will identify the differences in youth and adult headform response to various hockey impacts. It is hypothesized that youth hockey players are at higher risk of minor traumatic brain injury (mTBI) at lower impact velocities, due to their smaller head size and mass.

Methodology

Headforms: A 5th percentile (youth) male Hybrid III headform and a 50th percentile (adult) male Hybrid III headform (both with unbiased necks) were used. Each headform was equipped with nine single-axis accelerometers in a "3-2-2-2" array (Padgaonkar et al., 1975). The accelerometers collected three dimensional impact data at 20 kHz with a TDAS Pro Lab System, using a 300 Hz filter for the purpose of analysis.

Helmets: The youth headform was fit with a small RBK 11K vinyl nitrile (VN) helmet. The adult headform was fit with a medium RBK 11K VN helmet.

Collisions: A pressurized linear impactor (m=13.8 kg) was used to impact headforms with a piston, which was covered with a VN cap (Figure 1). The youth headform was impacted at 3 m/s (Lockwood and Frost, 2007), while the adult headform was impacted at 6 m/s (Marino, 1983). Each helmeted headform was impacted in five centric and non-centric sites (Table 1).

Falls: A monorail drop rig was used to drop the headforms onto an anvil (Figure 2). The youth headform was dropped from a height of 144 cm, and the adult headform was dropped from 173 cm.

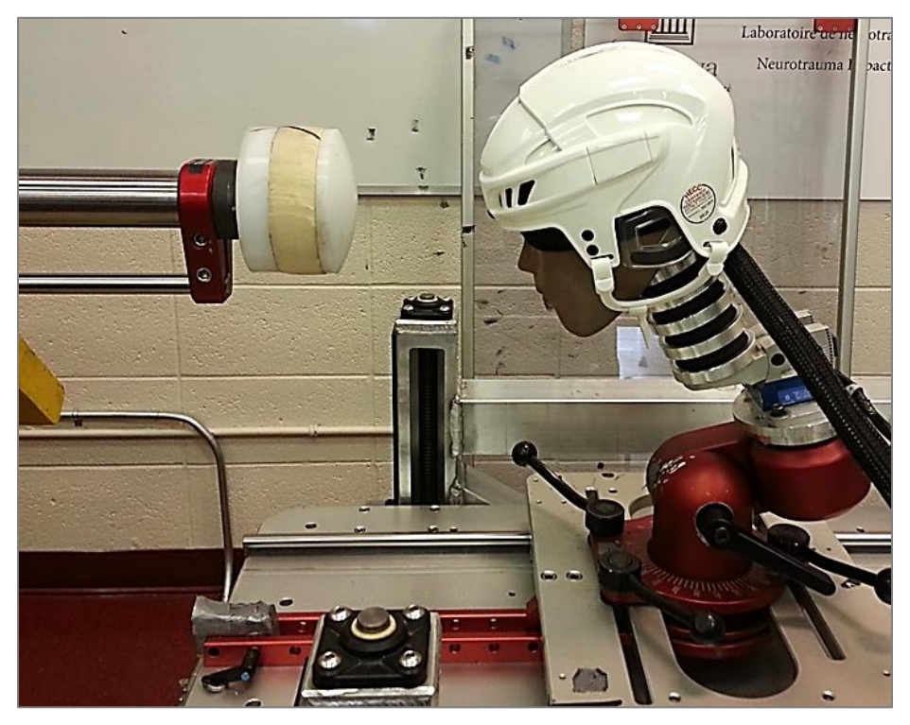

Figure 1. Youth headform, linear impactor

Figure 2. Adult headform, monorail

Table 1. Collision impact sites (Walsh et al., 2010; Post et al., 2011)

	Location	Impact Angle
Site 1	Anterior intersection of the mid-sagittal and absolute transverse planes	15º elevation in the mid-sagittal plane towards the impactor
Site 2	Midpoint between the anterior mid-sagittal and right coronal planes in absolute transverse plane	45º rotation in the transverse plane
Site 3	Right intersection of the coronal and absolute transverse planes	No vertical or horizontal rotation was applied to the vector
Site 4	Midpoint between the posterior mid-sagittal and right coronal planes in absolute transverse plane	-45º rotation in the transverse plane
Site 5	Posterior intersection of the mid-sagittal and absolute transverse planes	-45º rotation in the transverse plane

Results

Collisions

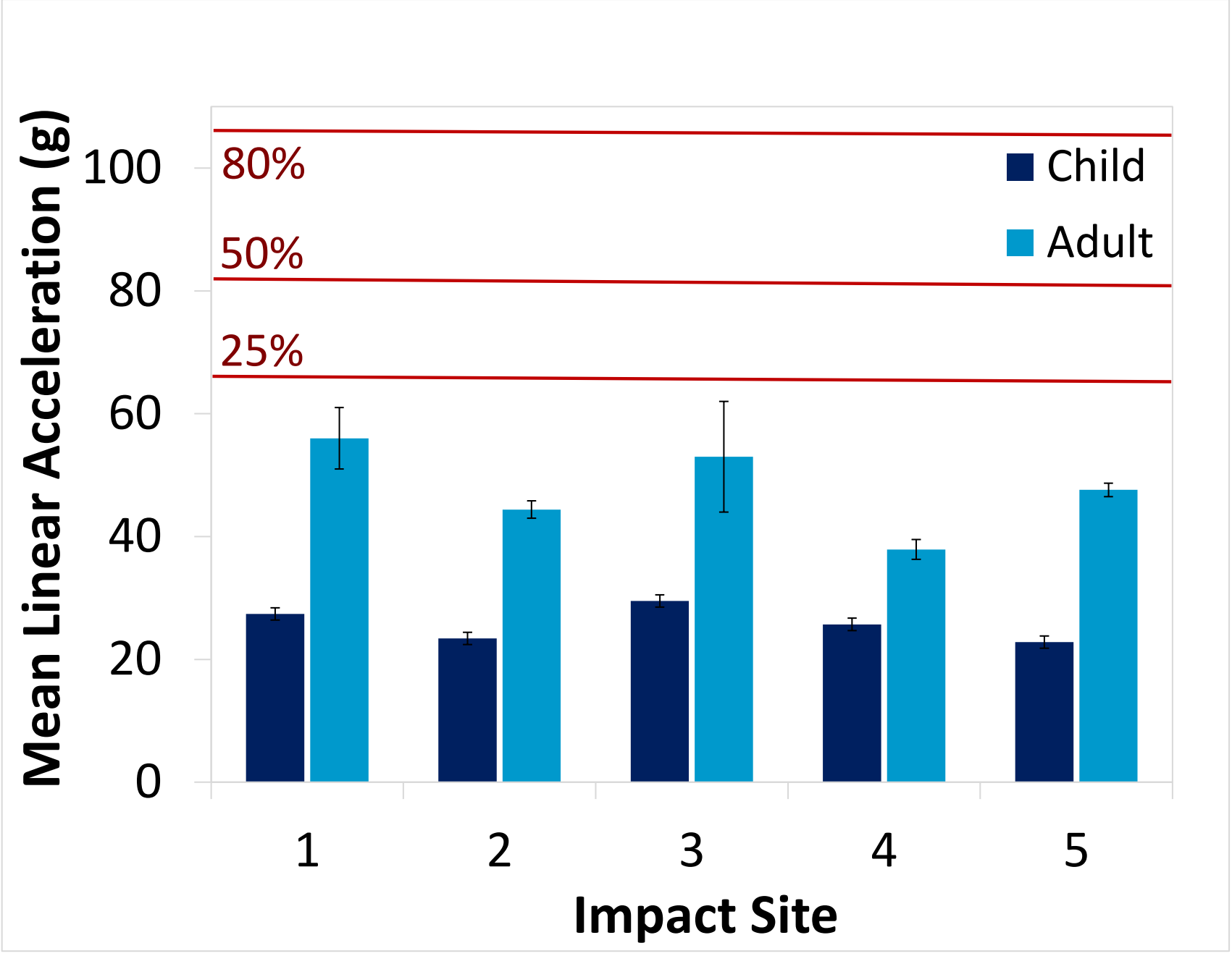

Figure 3. *Mean linear acceleration across collision impact sites.*
Horizontal lines represent 25%, 50%, and 80% probability of incurring an mTBI (Zhang et al., 2004)

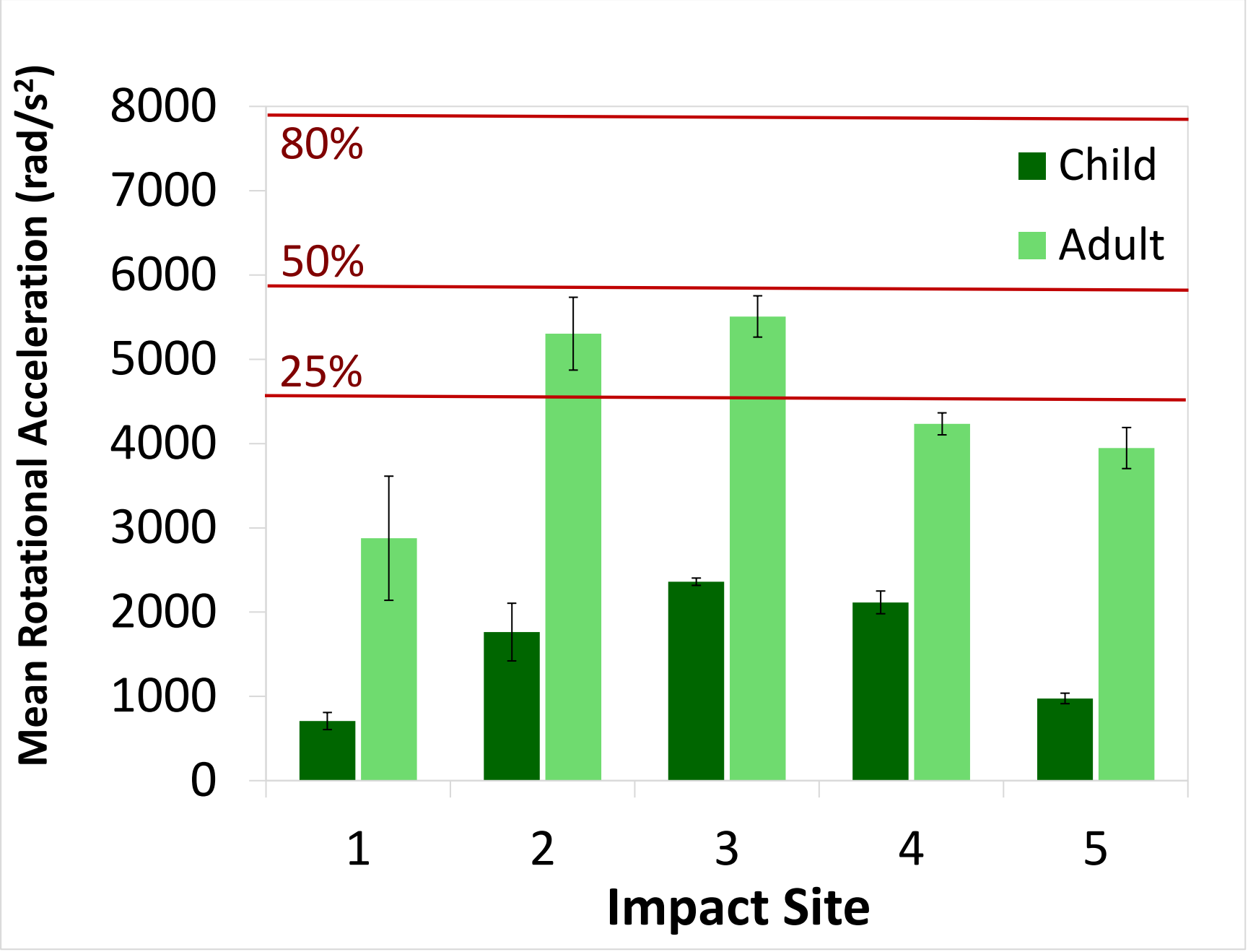

Figure 4. *Mean rotational acceleration across collision impact sites.*
Horizontal lines represent 25%, 50%, and 80% probability of incurring an mTBI (Zhang et al., 2004)

Falls

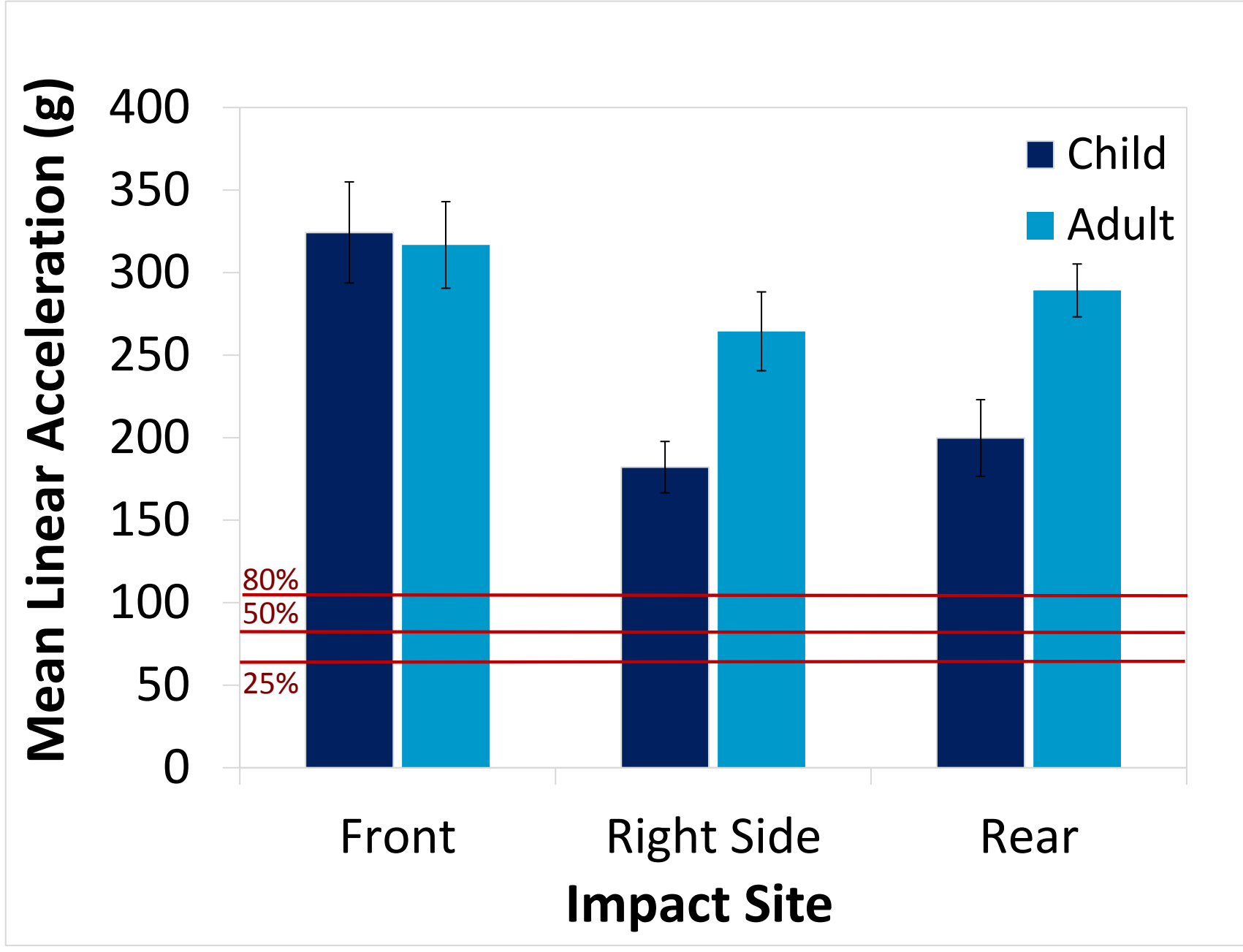

Figure 5. *Mean linear acceleration across falling impact sites.*
Horizontal lines represent 25%, 50%, and 80% probability of incurring an mTBI (Zhang et al., 2004)

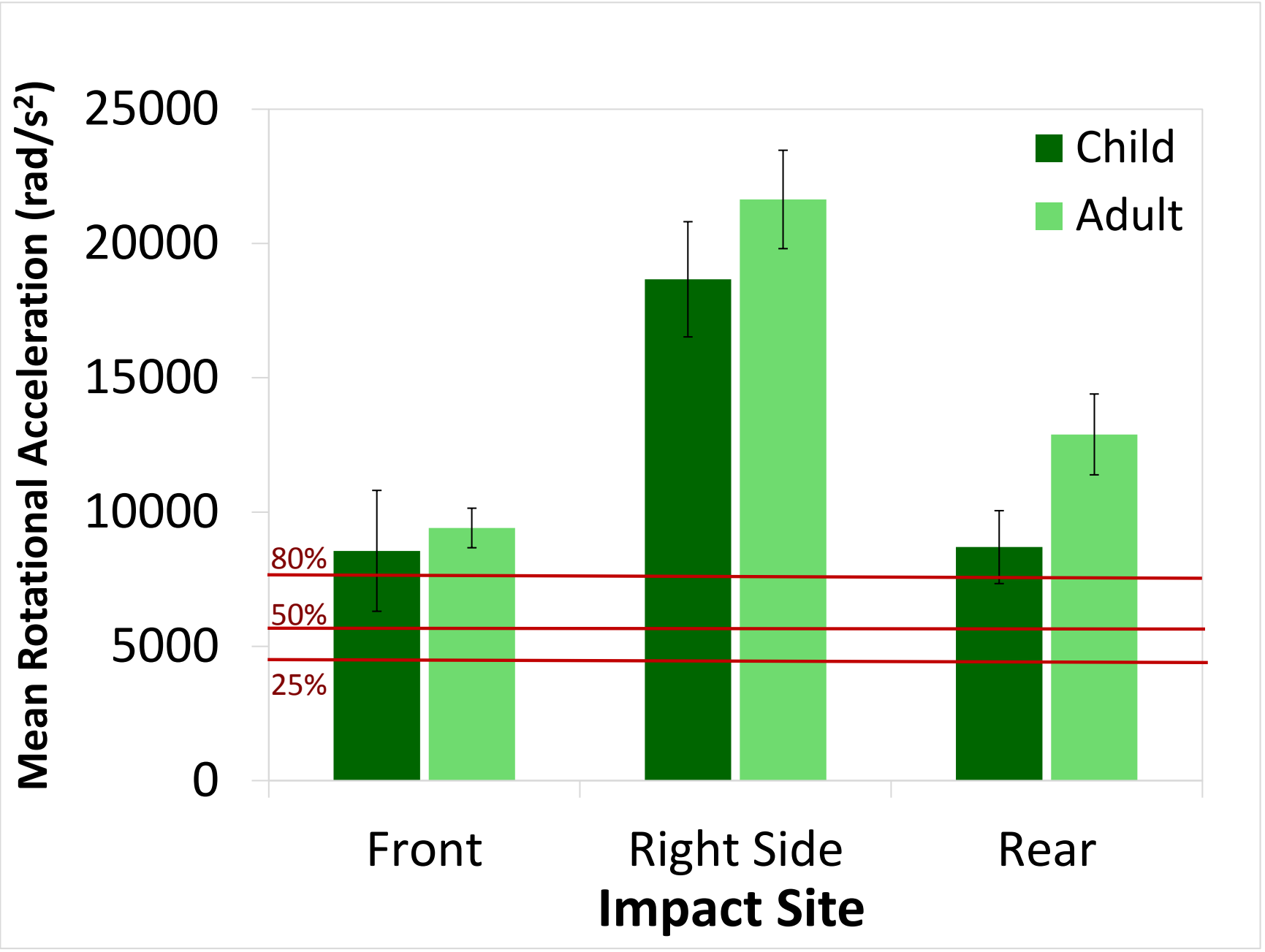

Figure 6. *Mean rotational acceleration across falling impact sites.*
Horizontal lines represent 25%, 50%, and 80% probability of incurring an mTBI (Zhang et al., 2004)

For all collision impacts, accelerations incurred were statistically different between youth and adults ($p<0.001$). Impacting the youth headform in site 3 elicited the largest mean linear and angular accelerations (29.5 g and 2361 rad/s^2, respectively). However, all youth headform collision impacts remained below the threshold for mTBI. Impacting the adult headform in sites 1 and 3 produced the largest mean linear and angular accelerations (56 g and 5507 rad/s^2, respectively). Impacts to sites 2 and 3 produced rotational accelerations that indicated 25-50% probability of incurring mTBI. (Figures 3 and 4).

For falls, impacts to the front of the head produced similar accelerations between youth and adults ($p>0.05$), while impacts to the rear of the head produced statistically different accelerations ($p<0.05$). Dropping the youth headform on the front and right side produced the largest linear and angular accelerations (323.2 g and 18668 rad/s^2, respectively). The adult headform also experienced the largest linear and angular accelerations when dropped on the front and right side (316.8 g and 21639 rad/s^2). In both youth and adults, falls on all three impact sites resulted in accelerations well above the threshold for 80% risk of injury. (Figures 5 and 6).

Discussion

Impacts were simulated by recreating a reasonable representation of how the game is played at youth and adult levels. While the acceleration values incurred by the youth headform collisions did not exceed the injury thresholds proposed by Zhang et al. (2004), it is still possible that youth hockey players may be injured at lower inputs of linear and rotational acceleration. Additionally, the consequences of mTBI are much more severe in youth hockey players.

This can be explained by youths' constantly developing brain structures. Total cerebral volume, quantity of cortical and subcortical gray matter, and quantity of white matter are constantly changing throughout a youth's growth and development (Rhoshel et al., 2006). For example, a youth's brain experiences a gradual loss of gray matter from age 5 to 20, corresponding with increased cognitive abilities (Figure 7). There are also differences in brain composition and development between genders (Giedd et al., 1996).

Considering the long-term effects, youth who sustain repeated mTBIs can suffer from cumulative cognitive deficits and motor system dysfunction later in life (Collins et al., 2002; Beaumont et al., 2007). In addition, repeated head injuries put youth hockey players at risk of chronic traumatic encephalopathy (CTE), a progressive deterioration of brain tissue (McKee et al., 2009). A youth's brain is an extremely valuable asset that should be protected at all costs.

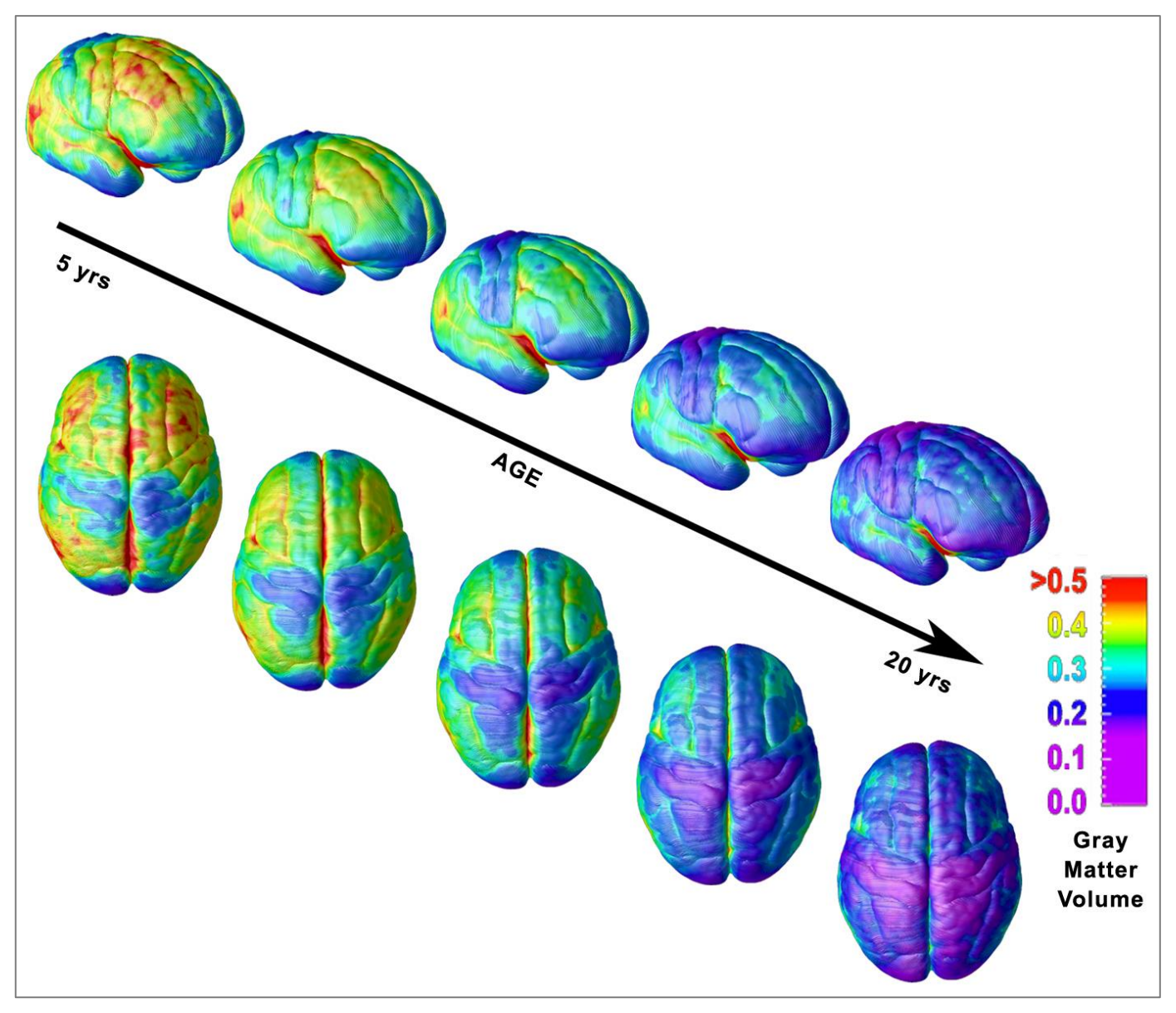

Figure 7. Between ages five and 20, the youth brain undergoes many compositional changes. This includes the gradual loss of gray matter, linked to an increase in cognitive abilities (Gogtay et al., 2004).

Conclusion

The results of this study demonstrated that youth hockey players experience very low risk of mTBI from collisions, but are at a very high risk from falls to the ice. In contrast, adult hockey players are at risk of incurring mTBI from collisions, and are also at a very high risk from falls to the ice. Due to their state of growth and development, the consequences of mTBI are much more severe in the youth population.

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