The potential effects of youth hockey helmet shell add-ons

Andrew Calis[1], Nicole E.-P. Stark[1], Steve Rowson[1]

[1]Department of Biomedical Engineering, Virginia Tech, USA.

Introduction:

Youth ice hockey players are exposed to frequent head impacts, and helmet design plays a critical role in mitigating injury risk. With an estimated rate of 1.20 concussions per 1000 athletic exposures, youth hockey has the second-highest concussion rate among youth sports. In other sports, helmet shell add-ons have shown to decrease concussion risk. However, the biomechanical effects of these shell add-ons on head impact kinematics in youth hockey have not been evaluated.

Objective:

This study's objective was to evaluate whether adding padding to the outside of a youth hockey helmet improves overall performance by reducing linear acceleration, rotational head acceleration, and concussion risk under youth-specific impact conditions.

Methodology:

Six helmets were selected to represent varying levels of impact performance (high, medium, low). Each helmet was tested at four locations (front, back, side, rear-boss) (Figure 1), three speeds (2.3, 3.4, 4.9 m/s), and three shell add-on conditions (control, one-inch VN600 Cap, Guardian Cap). Each test configuration was impacted using a pendulum impact system with a small NOCSAE headform mounted to a 5th percentile female Hybrid III neck on an 8 kg sliding torso mass. A rigid impacting face was chosen to simulate hard surfaces in hockey and to isolate helmet performance. The NOCSAE headform was instrumented with three linear accelerometers and a triaxial angular rate sensor (ARS) at its center of gravity. Data were sampled at 20 kHz and filtered with a 4-pole Butterworth low-pass filter with cutoff frequencies of 1650 Hz for accelerometers and 300 Hz for the ARS. A youth-specific risk function was used to estimate concussion risk from peak linear acceleration (PLA) and peak rotational acceleration (PRA). PLA, PRA, and concussion risk were analyzed in R using linear mixed-effects regression ($\alpha < 0.05$), with separate models for each outcome comparing location, speed, and helmet shell add-on, including helmet type as a random effect.

Results:

Impact speed, impact location, and externally mounted padding each affected PLA, PRA, and concussion risk (all $p<0.001$). Relative to the control helmet, the one-inch VN600 Cap had a 38.2 g reduction in PLA (95% CI 27.7–48.6 g, $p<0.001$) and 18.91 krad/s² reduction in PRA (95% CI 12.38–25.42 krad/s², $p<0.001$), which reduced overall concussion risk by 24.9% (95% CI 17.6–32.2%, $p<0.001$). The Guardian Cap produced a 9.4 g reduction in PLA (95% CI −0.1–18.9 g, $p=0.052$) and a 6.87 krad/s² reduction in PRA (95% CI 9.38–12.81 krad/s², $p=0.026$), corresponding to a 6.6% decrease in concussion risk (95% CI −0.0%–13.3%, $p=0.051$).

Conclusions:

The performance improvement associated with the shell add-ons suggests there is further room to optimize youth hockey helmet design. Currently, most youth hockey helmets are scaled-down versions of varsity models. Differences in protective response between the helmet liner and the shell add-on padding highlight how material thickness and mechanical properties influence energy management across impact severities. Accordingly, helmet manufacturers should prioritize both foam thickness and material composition to ensure effective performance across a range of impact scenarios for youth-specific impact conditions.

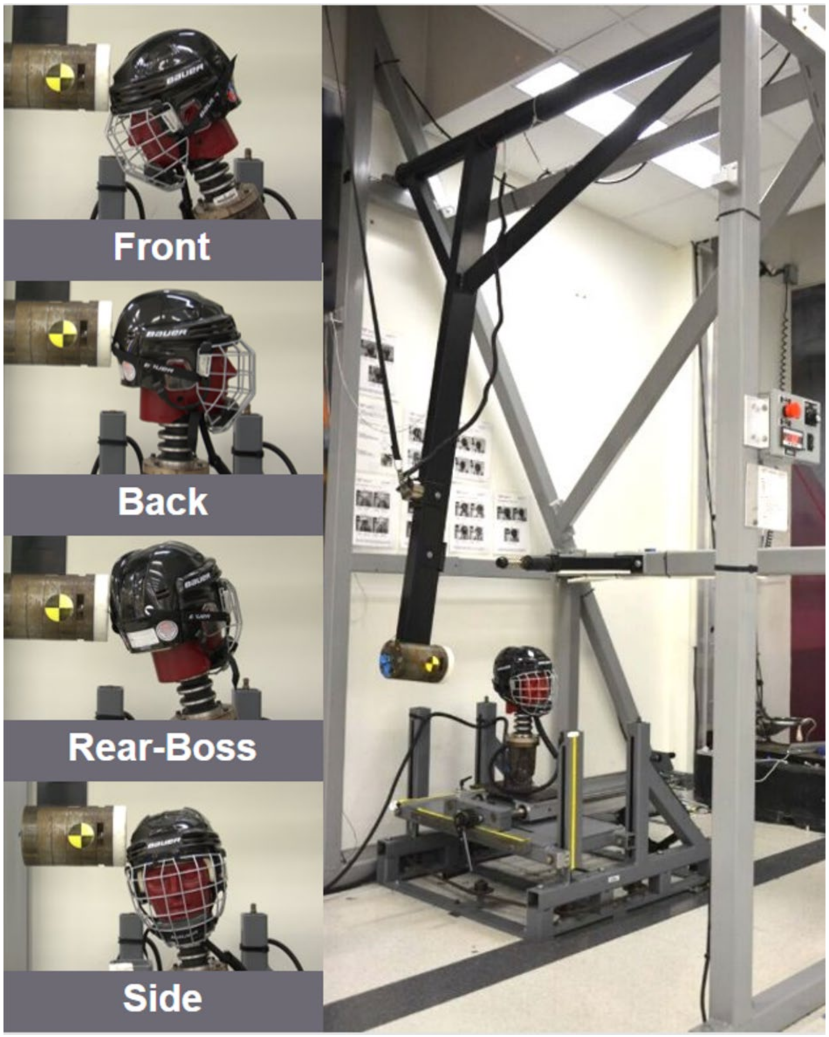

Figure 1. Pendulum impactor and locations tested for youth hockey helmet