

Influence of helmet surface protrusions on youth bicycle helmet impact performance

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Introduction:

Concussions result from impact-induced linear and rotational accelerations, which are influenced by helmet deformation and energy absorption during impact. Increased deformation can extend impact duration (ID) and reduce peak linear acceleration (PLA) and peak rotational acceleration (PRA). Protrusions, such as those that mimic animal faces and mohawks, may increase deformation but also catch during impact, increasing rotational loading. Their net effect on injury risk is unclear.

Objective:

The objective of this study was to compare ID at location-matched impacts between helmets with and without protrusions.

Methodology:

Oblique impact testing was completed using guided drop tests of a helmeted small NOCSAE headform onto a 25-degree anvil with 80-grit sandpaper. This setup simulates falling while traveling forward and contacting pavement. Twelve youth bicycle helmet models with protrusions were selected. Four samples per helmet model were used; two had protrusions intact and two had the protrusions removed. Each helmet sample was tested at 4.2 m/s in three locations, for a total of twelve tests per model, totaling 144 tests. For each helmet model, impact locations were selected so the protrusion would be the first part of the helmet to contact the anvil. The headform was instrumented with a six-degree-of-freedom sensor package mounted at the headform center of gravity that consisted of three accelerometers and a triaxial angular rate sensor. The ID and resultant PLA and PRA were calculated for each test. Linear mixed-effects regression models were conducted separately for PLA, PRA, and ID using a significance level of $\alpha < 0.05$. Protrusion presence was the fixed effect, with helmet model and location (nested within helmet model) treated as random effects. Post hoc comparisons were completed using least squares means to compare pairwise differences for protrusions in the LMER models. Means and 95% confidence intervals (CI) were computed by helmet model and protrusion presence.

Results:

Across the twelve youth bicycle helmet models tested, PLA values ranged from 54.4 to 171.6 g with protrusions and 113.6 to 198.3 g without protrusions, while PRA values ranged from 1883 to 7668 rad/s² with protrusions and 1146 to 8374 rad/s² without protrusions. When looking at each model, adding protrusions to the helmet made it perform equal to or better than it did without protrusions. Presence of protrusions ($p < 0.001$) had strong effects on PLA, PRA, and ID. Protrusions decreased PLA by 40.9 g (CI 36.1 – 45.6 g) and PRA by 745 rad/s² (CI 459 – 1031 rad/s²) and increased ID by 4.4 ms (CI 3.9 – 5.0 ms). The Raskullz MonkeyWrench increased ID the most (6.1 ms) while the Raskullz Block increased ID the least (0.5 ms). Figure 1 shows the temporal progression of an impact on a helmet with and without protrusions. Helmets with protrusions exhibit longer IDs because the deformation of the protrusions extends the time over which the impact energy is transferred and absorbed, lowering the peak acceleration.

Conclusions:

This study indicates that protrusions increase deformation, extend impact duration and reduce peak head accelerations without adversely affecting head rotation in youth bicyclists.

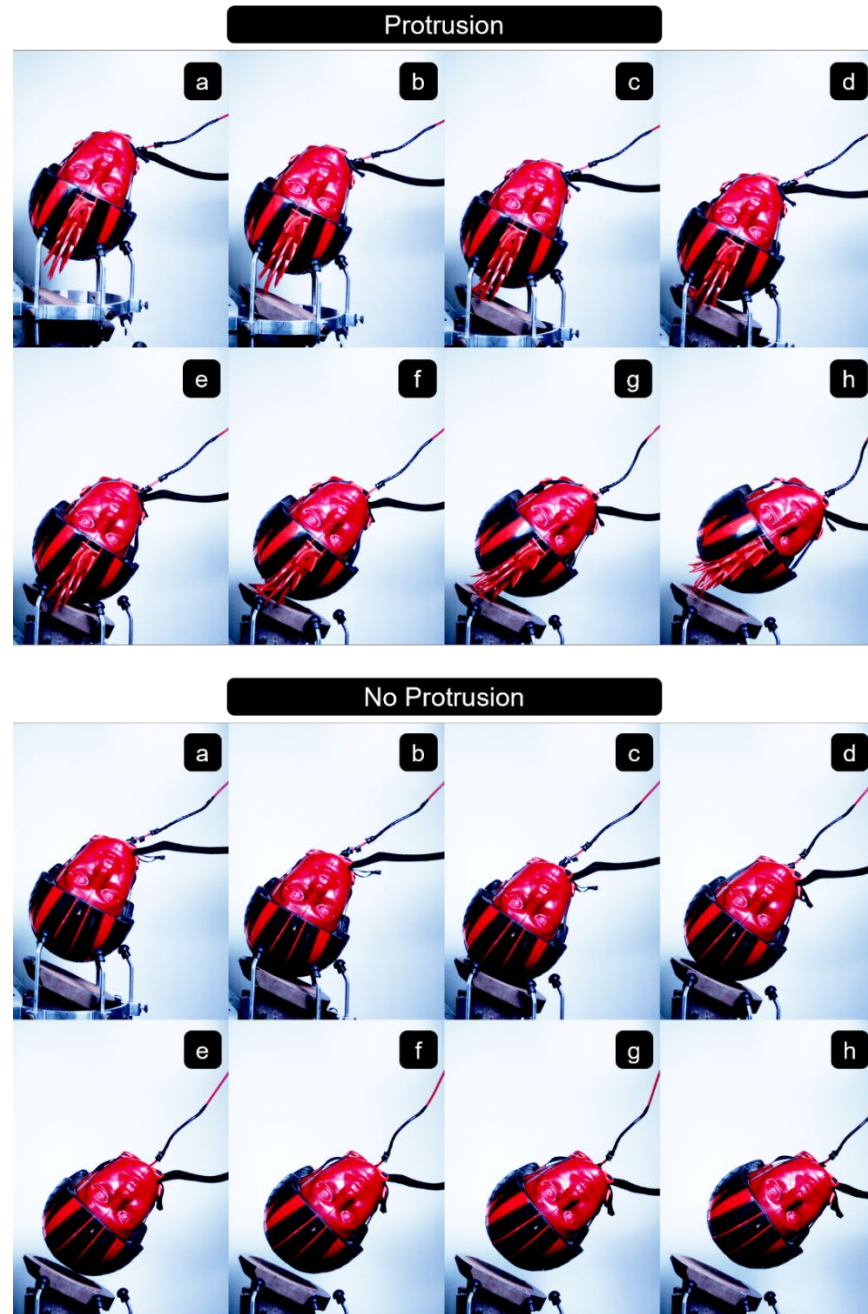


Figure 1. Sequential still images (a to h) obtained from representative high-speed videos. The top two rows illustrate the temporal progression of the impact event for a helmet with protrusions, while the bottom two rows illustrate the progression for a matched helmet without protrusions. Frame (a) corresponds to 10 frames before impact, frame (b) represents the moment of initial contact, and frames (c) through (h) occur at intervals of 10 frames after the preceding frame.