Department of Mechanical Engineering

Testing of a hockey helmet and novel liner material in two rotation-inducing test methods

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Introduction

Impact tests in contemporary helmet standards do not replicate the rotational response of the head in an impact [1]. The rotational response of the head is thought to be closely-linked to the mechanisms of brain injuries such as concussion [2]. Methods for producing more realistic, rotation-inducing, head impacts in the lab have been proposed for various helmet applications [3, 4] but are not yet introduced to standards.

Objective

Compare the headform response of a commercial hockey helmet to design iterations incorporating a novel liner material in two rotation-inducing headgear impact test methods.

Methods

Test helmets

An unmodified, commercially-available, ice hockey helmet and liner design iterations incorporating modular components of a novel auxetic and anisotropic liner material were tested.

Head-first impacts

Performed at 3.6 m/s using a drop tower, a custom neck validated for sagittal plane rotational motion [5], a Hybrid III headform and an angled platen oriented at 30º and 45º from the horizontal (Fig 1).

Pneumatic linear impactor

Impact ram fired at 4.5 m/s at a Hybrid III headform and neck mounted on a translating carriage (Fig 2). Impacts were performed with the ram oriented radially and obliquely to the helmet surface.

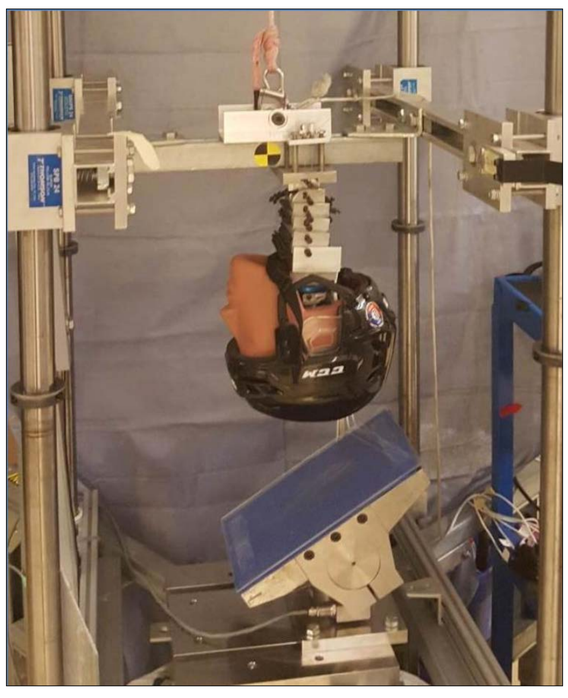

Figure 1 (left)

Head-first impact apparatus oriented for an impact to the rear of the helmet onto an impact platen orientated at 45º from the horizontal. .

Figure 2 (right)

Pneumatic linear impactor test showing the moment of impact to the front of the helmet (top) and subsequent sagittal plane rotation of the head and posteriorly-directed translation of the base of the neck (bottom).

Results

The average peak linear and rotational headform accelerations in the head-first drop tests are shown in Fig 3 and in the linear impactor tests in Fig 4.
Changes in helmet liner design had a varying and inconsistent effect on the peak headform responses across the head impact configurations tested.

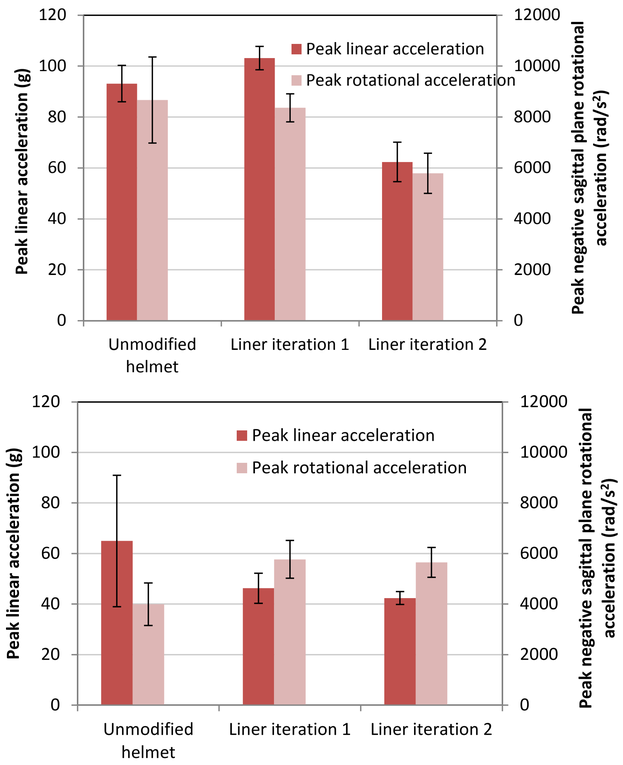

Figure 3 (left)

Mean peak linear and rotational headform accelerations for head-first drops to the front of the helmet onto a 30º (top) and 45º (bottom) impact surface. Error bars show one standard deviation from the mean.

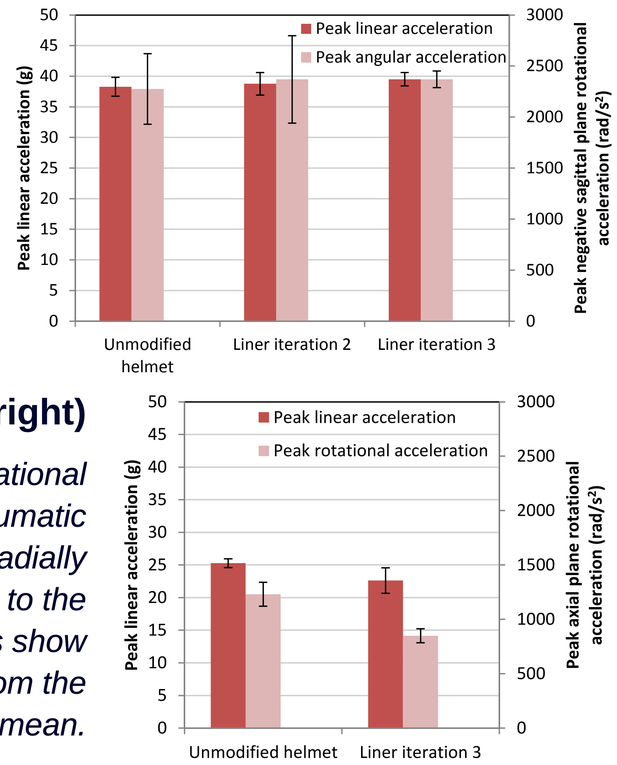

Figure 4 (right)

Mean peak linear and rotational headform accelerations for pneumatic linear impactor tests directed radially (top) and tangentially (bottom) to the front of the helmet. Error bars show one standard deviation from the mean.

Discussion

Design changes to the helmet liner shows some promise in reducing peak rotational accelerations of the headform in certain head impact configurations, particularly head-first impacts onto a 30º surface and obliquely oriented linear impactor events. The impaired or unchanged helmet performance in other configurations highlights the need for a considered approach to headgear design and impact testing. Impact test methods should reflect real-world impact orientations and their frequency as well as the resulting injury types, severities and frequencies.

References

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Acknowledgements

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