Headform response and testing of a hockey helmet and novel liner material in two rotation inducing headgear test methods.

T. Whyte[1,2], C.A. Stuart[1,2], P.A. Cripton[1,2]

[1]Orthopaedic and Injury Biomechanics Group, Department of Mechanical Engineering, The University of British Columbia

[2]International Collaboration on Repair Discoveries (ICORD), Blusson Spinal Cord Centre

Outline of the problem: Impact tests specified by headgear standards typically involve a linearly-guided headform drop. The guided drop test cannot replicate or measure the rotational response of the head in an impact which research has shown to be more closely linked to the mechanism of brain injuries such as concussion and diffuse axonal injury. The guided drop test, therefore, cannot evaluate if headgear or headgear design changes provide the wearer with a reduced risk of these brain injuries. Recognising this limitation, many methods for producing more realistic, rotation inducing, head impacts in the lab have been proposed. Two such methods are drop tests onto an angled surface and using a pneumatic linear impactor.

Study objectives: To compare the kinematic response in two headform rotation inducing impact methods and a standards-specified guided headform drop test.

Methodology: A commercially available ice hockey helmet and design iterations incorporating modular components of a novel auxetic and anisotropic liner material were tested in a guided headform drop test at an impact speed of 4.5 m/s (as per Canadian Standard CSA Z262.1-09) and in two test methods that generate headform rotation. The first rotational test was conducted with an impact speed of 3.6 m/s using a drop tower, custom neck validated for sagittal plane rotation, a Hybrid III headform and an adjustable angled platen (Figure 1a). The second rotational test was carried out using a pneumatic linear impactor fired at 4.5 m/s at a Hybrid III headform and neck mounted on a translating carriage (Figure 1b).

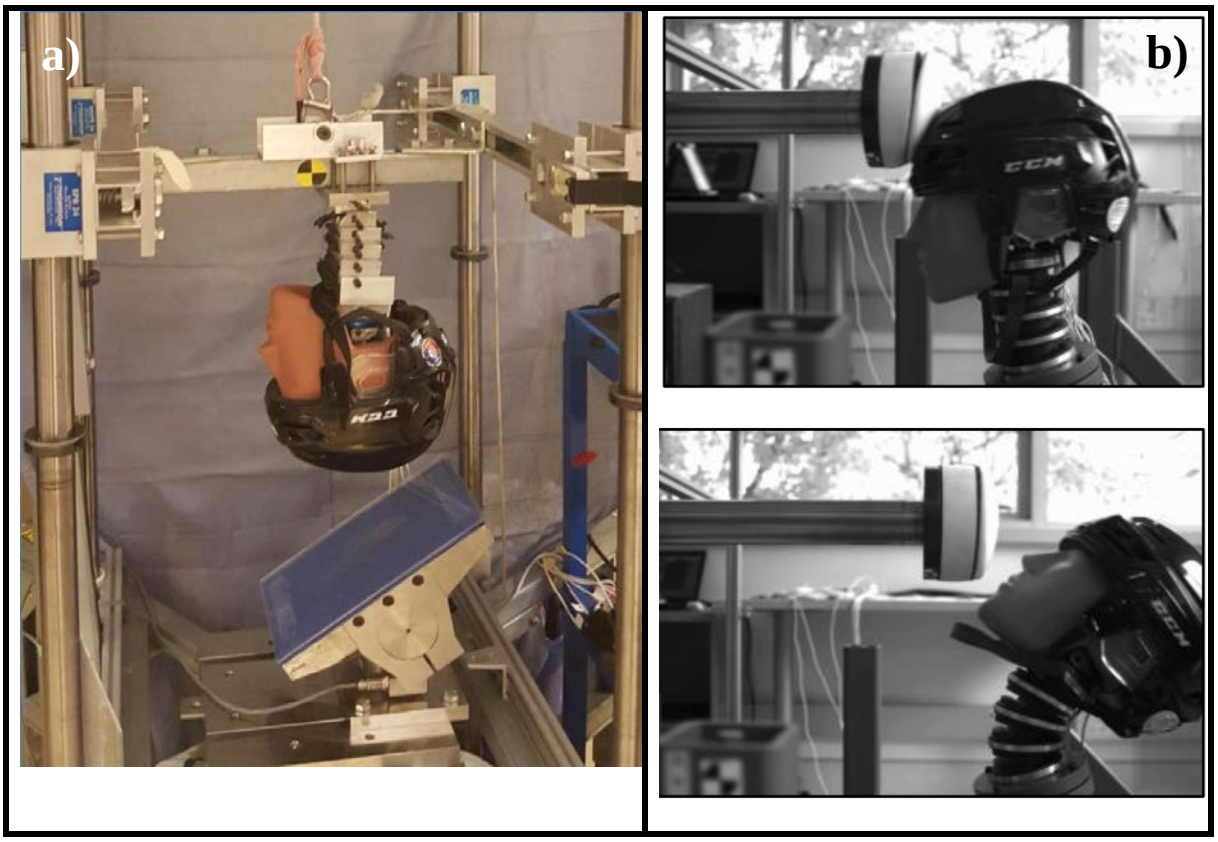

Figure 1 a) Headform and surrogate neck drop test onto an angled surface (left) and b) pneumatic linear impactor test method (right).

Data to be included: The peak linear and rotational headform responses in the described impact tests.

Summary of results and current conclusions of the study: Frontal impacts to the unmodified helmet achieved an average peak headform linear acceleration (PLA) of 157g in the guided drop test that permitted no headform rotation while the PLA and peak rotational acceleration (PRA) of the headform were 93g and 8667 rad/s^2 in 30º angled surface tests, 65g and 3992 rad/ s^2 in 45º angled surface tests and 38g and 2275 rad/s^2 in the linear impactor tests.

Compared to the unmodified helmet, prototypes utilising a novel liner material showed little difference in standards tests to the frontal region (up to 3.2%), while in 30º angled surface impacts both the PLA and PRA were reduced by up to 33%. In frontal impacts onto a 45º surface, the same helmet prototypes reduced the PLA by up to 35% while the PRA increased by 45%. Linear impactor events directed toward the headform centre of gravity resulted in less than 5% variation of the PLA and PRA for a novel prototype liner compared to the unmodified helmet. In impact conditions inducing a more severe oblique impact, achieved by aligning the impactor surface eccentric to the headform centre of gravity, the prototype helmet reduced the PRA by 31% compared to the unmodified helmet.

A novel material with auxetic and anisotropic behaviour shows promising results as a helmet liner in many impact orientations representative of real world impacts. Differences in headform response arise due to the choice of test method highlighting the need for considered test method selection such that the chosen test method reflects realistic loads experienced in the specific headgear application.