Feasibility of a free-fall drop test rig to replicate head impact scenarios in ice hockey

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Abstract. Ice hockey has one of the highest concussion rates of all sports. Methods to evaluate ice hockey helmets in research are variable, while certification standards do not replicate impacts which commonly cause concussion. A free-fall drop test method with interchangeable impact surfaces was used to compare a headform's kinematic response to impacts which commonly cause concussion in ice hockey.

Introduction

Ice hockey has one of the highest concussion rates in sports [1], and ~90% of reported concussions in ice hockey are the result of collisions with other players [2]. Collision type impacts, that can produce high strains in the brain, are characterised by lower accelerations and higher impact durations than falls onto the ice [3], although only falls onto the ice are represented in certification standards [4]. Helmet evaluations in peer-reviewed literature require a variety of laboratory equipment. A simplified test protocol, based on impacts which commonly cause concussion, could facilitate representative helmet testing by more researchers, while increasing the feasibility of modifications to certification standards.

Methods

A 50th percentile male Hybrid III crash-test dummy headform was equipped with a DTS Slice Nano sensor system (Diversified Technical Systems, Inc., 3 linear accelerometers and 3 angular rate sensors (both 100 kHz sampling frequency)) in its centre of mass. The headform was fitted with four different ice hockey helmets, with typical materials and technologies. Linear acceleration and angular velocity were measured during impacts onto different surfaces using a free-fall drop test. During impacts onto a flat anvil, five different surfaces (MEP Pad (1-inch height, CadexInc) and layered EVA (EVAZOTE-50, algeos.com) foam sheets with 24, 48, 72, and 96 mm overall thickness) were applied. During impacts onto a 45° inclined surface, three layered EVA foam thicknesses (24, 48, and 72 mm) were applied. Video footage (Phantom, Miro R311, 2,000 frames per second, 499.6µs exposure, 1024 x 768 pixels, 0.5 mm/pixel) was recorded to explain some impact events and measure impact velocity.

Drops were carried out from a height of 1 m (Fig. 1 (A)), resulting in an impact velocity of 4.5 m/s, similar to standard procedures and common test protocols in literature [5], resulting in an impact energy of 51.3 – 53,8 J (mass of helmet and headform = 5.1 – 5.3 kg, varying with helmet mass). Three centric impact sites (Front (F), Side (S), Rear (R)) were impacted 3 times for each flat impact surface (Fig. 1 (B)) and two centric (Front & Rear) and three non-centric (Side, FrontBoss (FB), RearBoss (RB)) impact sites for each oblique impact surface (Fig. 1 (C)) [4]. A new helmet was used for each surface and all tests were repeated with the unhelmeted headform.

Impact duration and peak linear and angular acceleration were used as measures of helmet performance (Filter: CFC 1000 (linear) & CFC 180 (angular)). Impact duration and velocity were checked against high-speed camera footage.

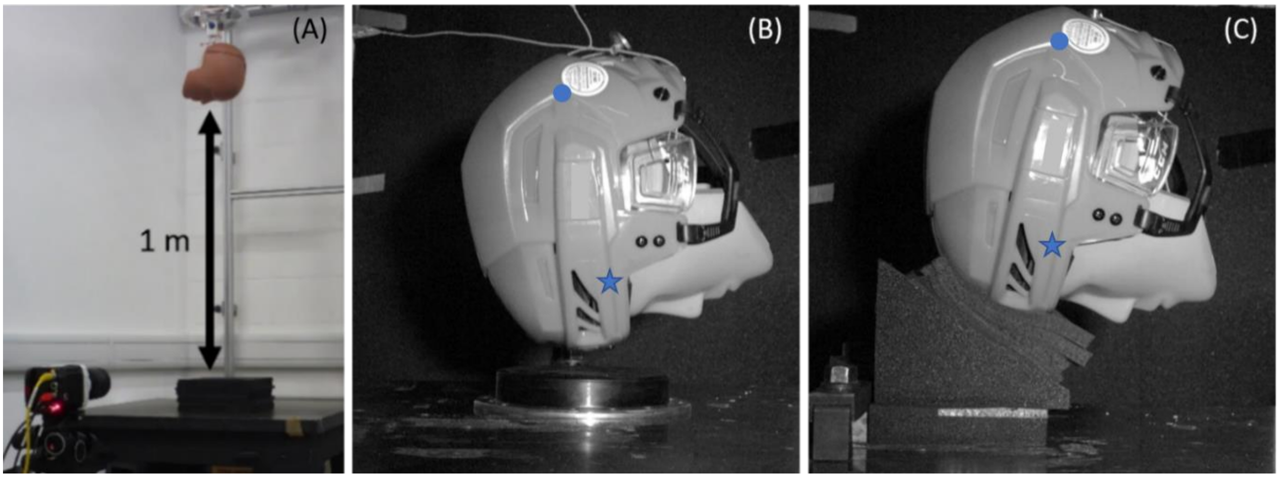

Fig. 1: (A) Free-fall drop test setup, (B) Front site, flat MEP pad surface just before impact (C) Front site, oblique 72 mm foam during impact with FrontBoss (★) and RearBoss (●) impact sites marked.

Results

The acceleration vs. time curves (Fig. 2 (A-C)), produced from the headform's kinematic response, show a single peak, characteristic of collision type head impacts [6]. The highest accelerations and shortest impact durations were produced during impacts onto rigid surfaces. With increasing impact surface compliance, the peak accelerations decreased while impact durations increased (Fig. 2 (D&E)).

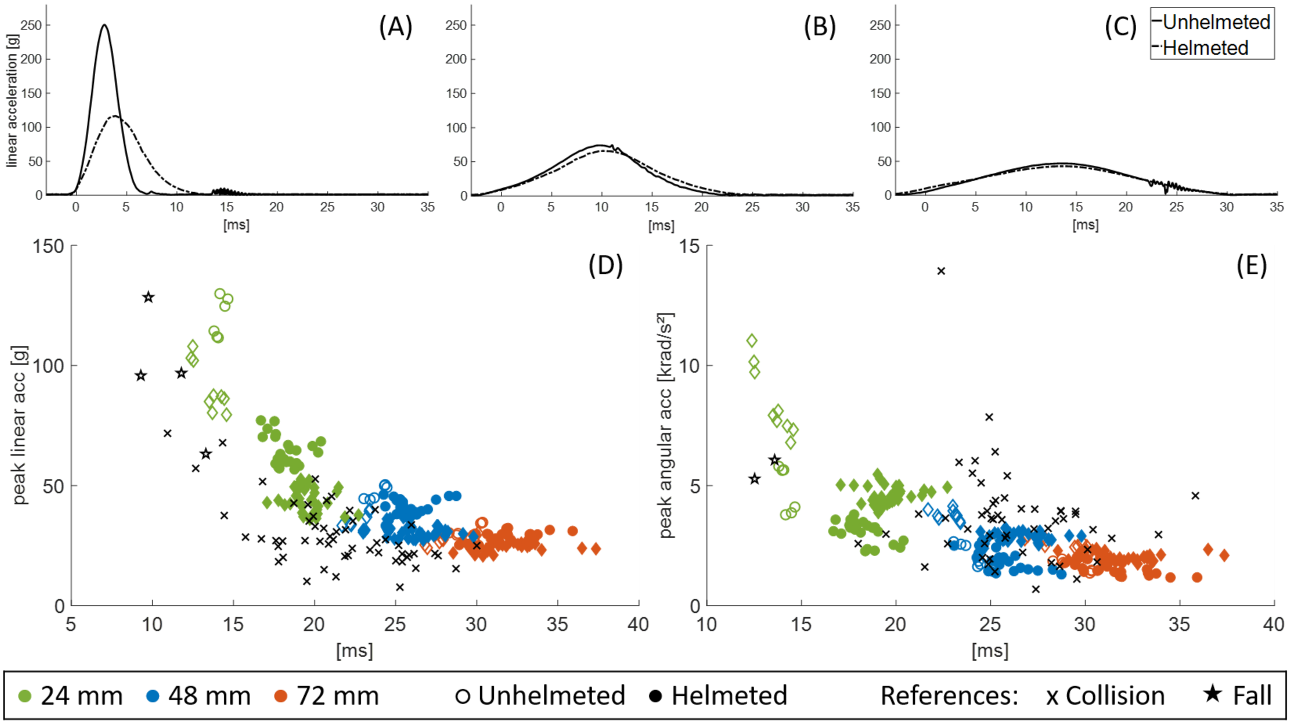

Fig. 2: Linear acceleration vs. time curves for flat surface, unhelmeted and helmeted Front site impacts onto the (A) MEP pad, (B) 48 mm foam layer, and (C) 96 mm foam layer; Peak linear (D) and angular (E) accelerations vs. impact duration for all impact scenarios onto the 45° oblique surface; filled markers represent helmeted impacts and unfilled markers represent unhelmeted impacts, black markers represent reference values of concussive impacts recreated in a laboratory environment [7].

Conclusion

A broad range of headform kinematic responses during impact was obtained, changing with impact surface compliance and surface orientation. The relative difference in kinematic values between helmeted and unhelmeted impacts decreased with increasing impact surface compliance, agreeing with previous work [3]. The linear and angular accelerations were similar to the characteristic kinematic responses of ice hockey head impacts [6]. These findings suggest that the free-fall drop test method can replicate collision type head impacts in ice hockey.

References

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