Comparison of impact response of selected helmets to laboratory impact and penetration testing – a Shinty case study

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Executive Summary
Three helmet models (1x Mycro, 2x Bauer) were subjected to three tests intended to assess suitability for use in Shinty; free-fall impact, projectile impact and stick penetration. Resultant headform acceleration was measured by an accelerometer positioned at the centre of mass and helmets were visually inspected. All helmets were found to be effective in reducing resultant linear acceleration of the headform compared to the baseline, with some producing a greater reduction than others. Visual inspection suggested that all helmets were effective in preventing unwanted contact with the face or head during impacts.

Introduction

Loughborough University Sports Technology Institute were commissioned by the Camanachd Association to test the response of selected Mycro shinty helmets and Bauer ice hockey helmets, as shown in Figure 1, to a range of simulated impact scenarios. Three Bauer IMS 5.0 ice hockey helmets (size M), three Bauer Concept 3 helmet visors, two Mycro shinty helmets (size M), three camans and nine shinty balls were provided by the Camanachd Association for use during testing.

(a) (b) (c)

Figure 1: (a) Mycro, (b) Bauer A and (c) Bauer B helmets

Methods

Three rounds of testing were conducted to assess performance in free-fall impact, projectile impact and stick penetration. For both free-fall and projectile impact testing, a 50th percentile male Hybrid III headform instrumented with a tri-axial linear accelerometer (MEAS 7131A-2000, ± 2000 g, 10 kHz sampling rate; DTS 6DXPRO 2K-18K, ± 2000 g, 10 kHz sampling rate) at its centre of mass was impacted both un-helmeted and helmeted with each type of helmet provided. Where available, a new helmet was used for each round of testing.

For all free-fall impact trials, the linear acceleration was recorded using National Instruments (NI) SignalExpress data acquisition software. For all projectile impact trials, linear acceleration was captured using the DTS Slice Micro Acquisition System. Linear acceleration was not captured during stick penetration testing but stick swing speed processed and analysed using a custom MATLAB script (CFC 1000 filter).

Recordings from a high-speed video camera (Photron Fastcam SA1, 5400 frames per second, 1/5400 s shutter speed, 1024 x 1024 resolution) were used to observe the response of both the helmet and headform during and after the impact for all trials. All trials took place under ambient conditions of 23˚C ± 2˚C and humidity of 37% ± 4%.

1. Free-fall Impact

The headform was dropped from a height of 0.68 m onto a flat, solid steel anvil, resulting in impact energy (30.4 – 30.5 J) approximately equivalent to a collision with a shinty stick at 20 mph or a shinty ball at 60 mph (assuming both objects are their respective heaviest legal mass according to shinty by-laws). These speeds were selected after reviewing literature concerning previous studies of field and ice hockey studies (1,2) and the limitations of the Sports Technology Institute's free-fall drop test rig. Three impact sites (top, side and rear) were impacted three times for each condition.

2. Projectile Impact

The headform was impacted with a shinty ball at 60 mph, fired using a ball cannon, in line with industry standard test protocols (3–5). Three impact sites (forehead, side and eye socket) were impacted three times for each condition.

3. Stick Penetration

Both static and dynamic swing stick penetration tests were conducted. During static stick penetration testing, attempts were made to penetrate the faceguards with the hook of the stick in all possible orientations, following a similar method to that used in ice hockey helmet testing (3). During dynamic swing stick penetration testing, a shinty stick was fixed to a manually rotated arm. One impact site (eye socket) was impacted three times for each condition. A further impact in the same location was carried out at maximum effort. A physical witness coating (Developer spray) was applied to the headform which, together with analysis of the high-speed video recording, was used to determine whether the stick or faceguard had contacted the headform.

Results

The mean peak linear acceleration (PLA) was calculated along with the standard deviation (SD) for each impact condition. Results presented without the baseline data can be found in the Appendix.

1. Free-fall Impact

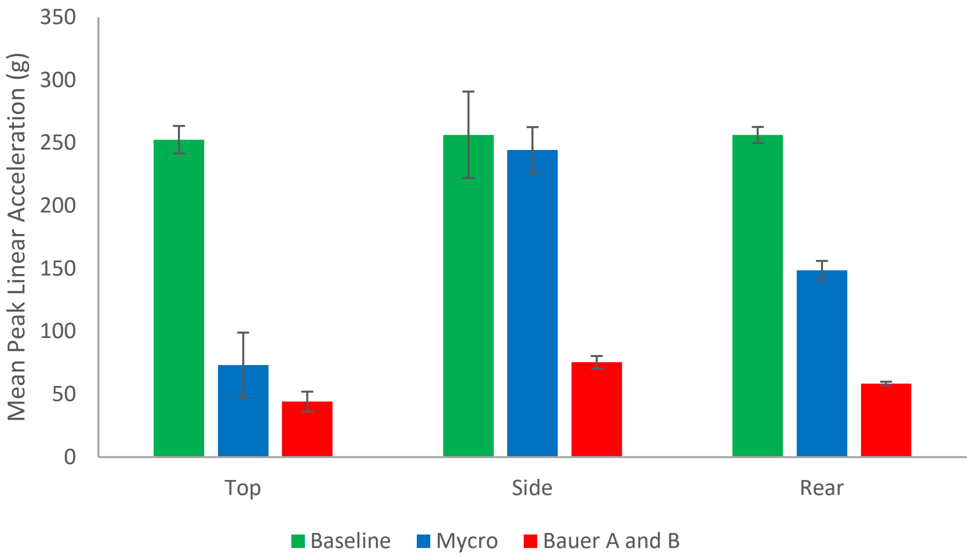

Figure 2: Mean PLA (SD) at drop height 0.68m for Hybrid III un-helmeted and helmeted with Mycro, Bauer A and Bauer B helmets

2. Projectile Impact

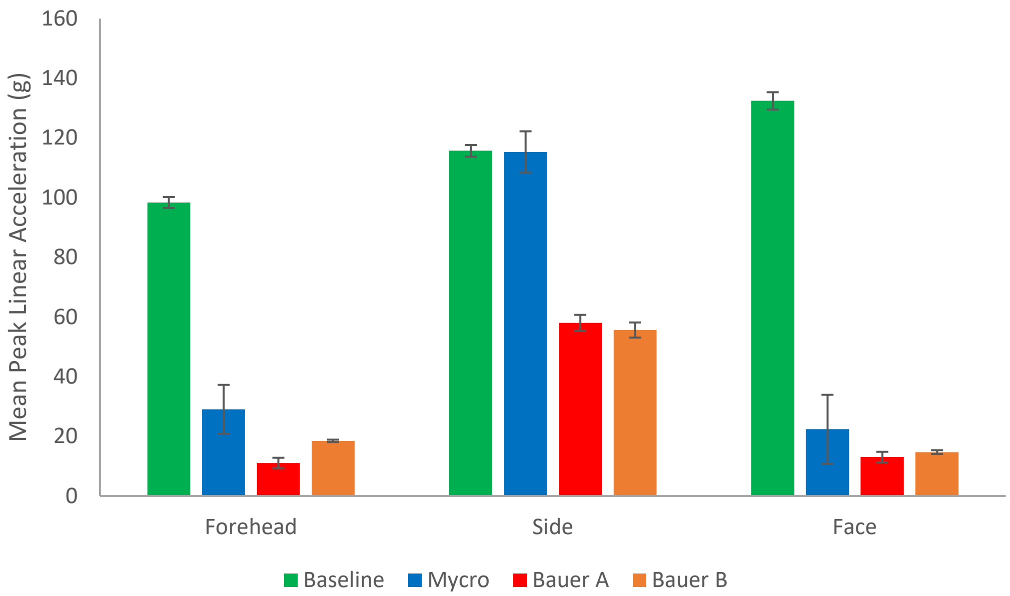

Figure 3: Mean PLA (SD) at 60 mph ball strike for Hybrid III un-helmeted and helmeted with Mycro, Bauer A and Bauer B helmets

3. Stick Penetration

Table 1: Results for dynamic stick swing penetration testing

Helmet	Stick Swing Speed (m/s)	Penetration Observed?
Mycro	9.48 (lowest)	No
	19.97 (highest)	No
Bauer A	8.98 (lowest)	No
	17.97 (highest)	No
Bauer B	8.98 (lowest)	No
	16.97 (highest)	No

Discussion

The response of the Mycro helmets to side impacts in both the free-fall and projectile tests can be explained by the absence of coverage of the ear area, as illustrated in Figure 4. Aside from this, both helmets were found to reduce resultant acceleration to the headform by at least 50% in all other impact locations.

(a)

(b)

Figure 4: Side view of (a) Mycro and (b) Bauer A helmets

Ball strikes at 60mph were found to cause damage to the Mycro and Bauer A faceguards, shown in Figure 5, but the ball did not contact the headform in any trial.

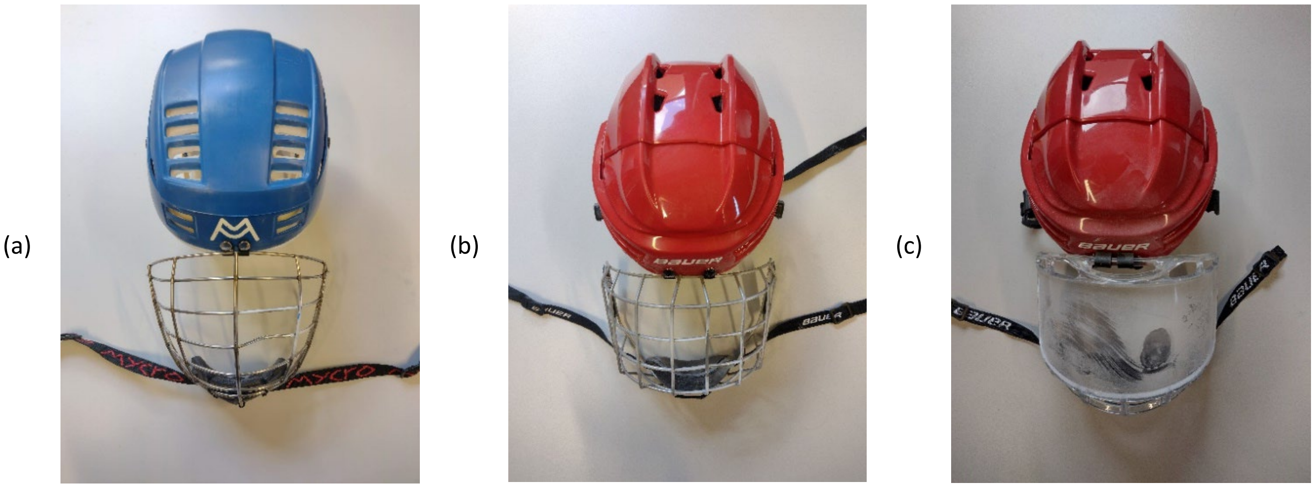

Figure 5: Damage caused to (a) Mycro, (b) Bauer A and (c) Bauer B helmets during projectile impact testing

The manual nature of the stick swing test procedure meant impact speeds at the helmet varied between 9 and 20 m/s. Across the 12 trials, no penetration of the faceguard was observed.

Conclusion

It can be concluded that all helmets tested reduced resultant headform acceleration from a 0.68 m (~30 J) drop.

The Bauer helmet was shown to reduce resultant acceleration by more than the Mycro helmet.

References

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Appendix

Figure 2 without baseline data

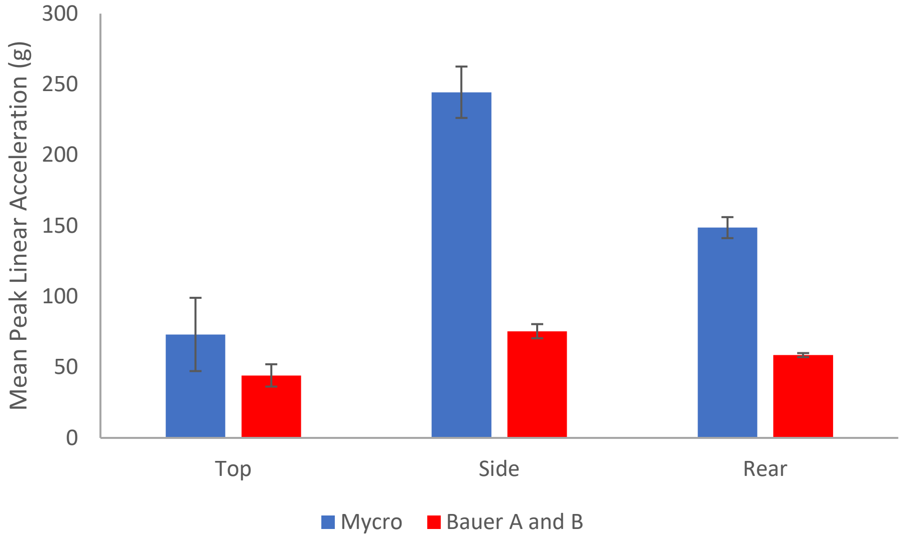

Figure 3 without baseline data