A Comparative Study of Injury Risk in Collapsible and Conventional Bicycle Helmets

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I. INTRODUCTION

Helmets are one of the few protective measures available during cycling collisions, yet their bulk and the practicalities of transporting them remain barriers to consistent use. In response, a growing number of collapsible helmet designs have entered the market, which offer reduced bulk and improved portability. These designs must meet the minimum requirements of current test standards, e.g. EN 1078 [1], though such standards do not employ impact conditions representative of cycling collisions [2]. They only measure linear acceleration with no consideration for rotational induced injuries, and they cannot quantify injury risk beyond a binary pass/fail outcome. We evaluated the reduction in injury risk across a range of commercially available collapsible helmets under conditions representative of real-world cycling collisions and benchmarked their performance against popular conventional designs. The aims of this work are i) to identify where collapsible helmets may succeed or fall short of conventional helmets with regards to safety and ii) to inform how their future designs can better mitigate injury risk.

II. METHODS

Six collapsible helmets were compared against twenty-four popular conventional models. Mean recommended retail price was £100.85 ± £14.78 and £63.85 ± £33.40 respectively (as of November 2025) and mean mass was 449 ± 55 g and 298 ± 55 g respectively. All helmets involved EPS foam, twelve of the conventional designs included patented rotational protection technology (7 MIPS, 4 Kineticore, and 1 WaveCel), as did one of the collapsible helmets (MIPS AirNode).

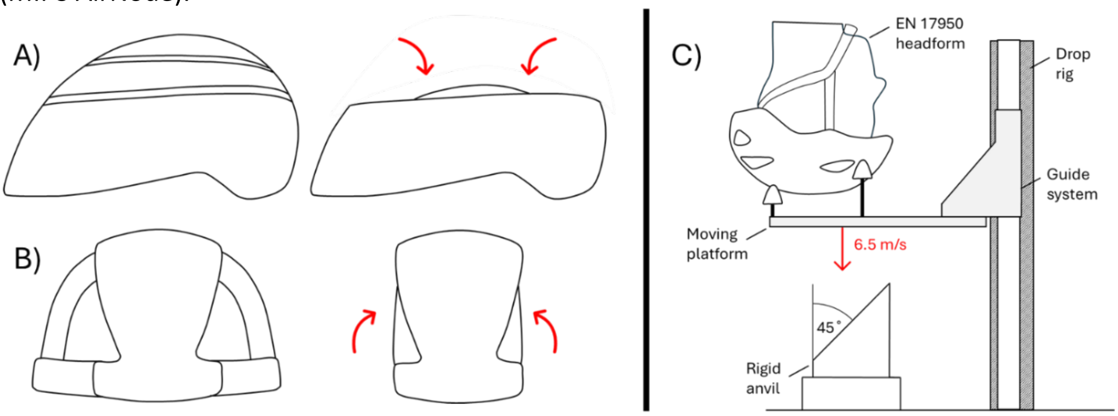

Figure 1, Examples of collapsible bicycle helmet mechanisms including A) telescopic and B) folding solutions. C) Helmets were fitted to an EN 17950 headform and tested at 6.5 m/s onto a 45° anvil.

Helmets were fitted to a 50th percentile male EN 17950 headform [3], which better represents human head shape, mass, moment of inertia and friction than alternatives. Helmets were tested on a drop rig using a rigid 45° angled anvil surfaced with 80-grit abrasive sandpaper (Figure 1). Impacts were conducted at 6.5 m/s at four impact locations on the helmet: front, rear, side, and front-side to represent a range of real-world cyclist incidents [4]. Each model used 6 helmet samples: 2 impact locations per helmet (≥120 mm apart), with three repeats using separate helmet samples. Linear acceleration and rotational velocity were recorded at 20kHz sampling frequency. The results were filtered according to SAE J211/1 [5], with CFC 1000 and 180 for linear acceleration and rotational velocity respectively. Injury risk functions were used to evaluate risk of AIS4+ focal injury from peak linear acceleration (PLA) [6] and AIS2+ diffuse injury from BrIC [4][7]. Injury risks were averaged and weighted by real-world impact location frequency to produce a single helmet-level injury risk score, as shown in Baker et al. (2024)

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[4]. Statistical comparisons between design styles were made using Mann-Whitney U tests (U) and rank biserial correlation (r) for effect size, with significance considered p < 0.05.

III. INITIAL FINDINGS

Mean (std) PLA across the collective sample was 147.0 ± 27.9 g and mean peak rotational velocity (PRV) was mean: 24.9 ± 5.1 rad/s. There was no clear difference between the two helmet types in deformation mode or failure behaviour post-collision. Collapsible helmets demonstrated higher overall and linear injury risk than conventional designs (Figure 2), with moderate-to-strong effect sizes (r = 0.50 and r = 0.47 respectively), though neither reached statistical significance (p = 0.065 and p = 0.082). Rotational injury risk was effectively equivalent between groups (r = -0.01, p = 0.98). When we removed the one collapsible helmet incorporating MIPS, the overall and linear injury risk were significantly higher in collapsible designs (overall risk: median = 0.28, r = 0.78, p = 0.004; linear risk: median = 0.23, r = 0.67, p = 0.019), yet rotational risk remained similar to the conventional group (median = 0.35, r = 0.17, p = 0.594).

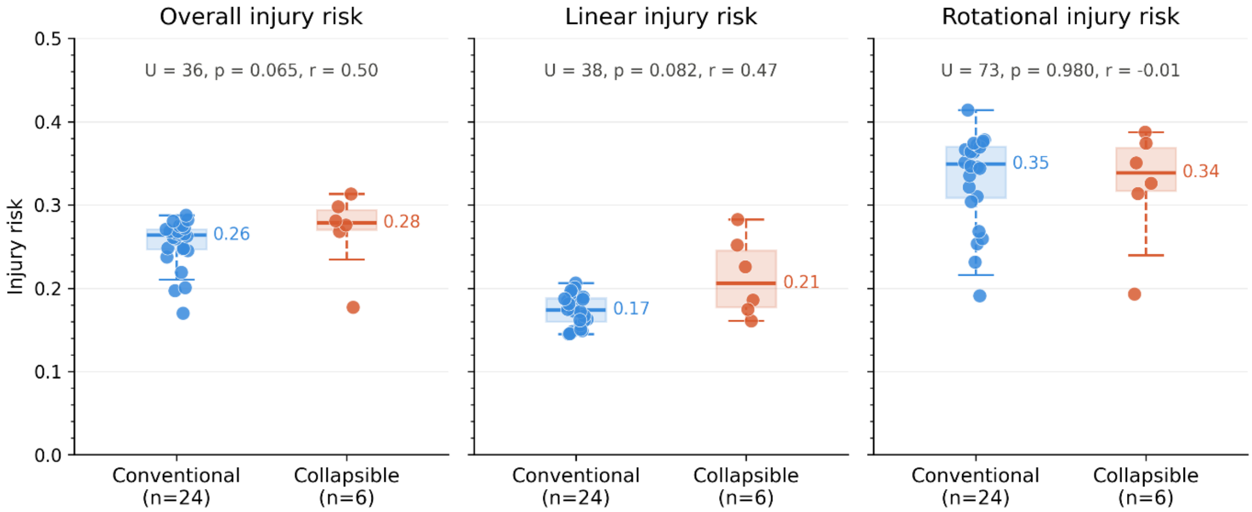

Figure 2, Weighted injury risk comparisons taken from across the four impact locations between conventional and collapsible bicycle helmets designs. Values adjacent to the boxes show the median risk. There were moderate-to-strong effects for higher overall and linear injury risks, though without statistical significance.

IV. DISCUSSION

These findings suggest collapsible designs have a slightly higher risk of overall and linear injury to conventional designs. The absence of significance likely reflects limited statistical power from a small collapsible sample (n = 6) rather than an absence of effect, and the modest differences in median risk suggest the magnitude of this gap is small. Nevertheless, these findings suggest two areas for design improvement that require further investigation. First, excluding the one collapsible helmet with rotational protection technology from the analysis significantly increased the overall risk difference between groups, suggesting the integration of rotational protection into collapsible designs could reduce the gap in risk with conventional helmets. Second, collapsible helmets had a significantly higher mass than conventional designs (+151 g, 51% increase), and higher helmet mass has been associated with increased linear injury risk [4]. Whether this mass penalty is inherent to collapsible architectures or reflects current implementations is unclear, but minimising mass likely reduces linear risk. Further work should statistically model the predictive factors of risk in both designs to quantify their relative effect. Current collapsible helmets address a significant barrier to helmet use by improving portability, and despite a marginal increase in injury risk, these findings suggest equivalent protection is feasible for future designs.

V. REFERENCES

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