Assessment of Novel Test Method for Bicycle Helmets.

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I. INTRODUCTION

In Sweden, approximately 2,000 cyclists are seriously injured and about 20 fatalities occur in traffic each year. Head injuries are the most common type of injury in these serious crashes [1]. Fatalities resulting from bicycle-car collisions in urban areas most frequently occur at intersections where the posted speed limit is 30–50 km/h and where the cyclist is struck from the side [2]. According to the Stockholm Declaration from the Third Global Ministerial Conference on Road Safety [3], a maximum road speed of 30 km/h is mandated for areas where pedestrians, cyclists and cars coexist. Currently, there is a lack of bicycle helmet testing that specifically evaluates the protective potential in bicycle-car collisions with impact speeds above 20 km/h. A previous project proposed a new test method for bicycle helmets that represented head impacts against the windscreen during bicycle–car collisions, based on simulations with human body models [4]. This paper analysed the results of a demonstrator testing six helmet models, specifically to evaluate the repeatability of the test method and to calculate the risk of concussion for the tested helmets.

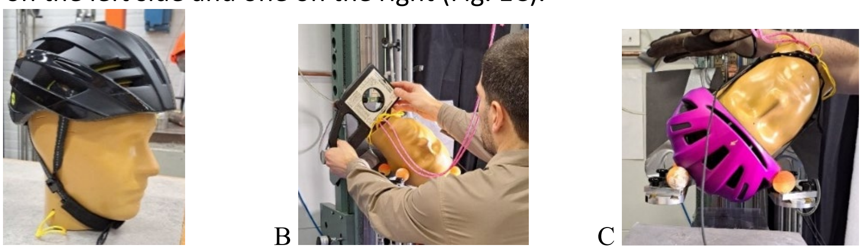
II. METHODS

A proposed novel test method for bicycle helmet testing was evaluated in a demonstrator with six different helmet models, purchased from retail stores. Three helmets of model A were tested, while for the remaining five models (B-F), only one helmet each was tested. The resulting kinematics of the headform were used as input to drive simulations with a brain model.

Demonstrator

A demonstrator was conducted using a helmet drop rig, defined according to EN1078. The new EN17950 headform was used in all drop tests (Fig. 1A). The standard impact surface was replaced with a fixed, deformable plate. Initially, three different deformable impact surfaces were evaluated, from which a fixed polycarbonate plate was selected. The plate was 20 mm thick, 125 mm wide, and clamped 150 mm from the impact point.

The headform was tested without a helmet, and the drop height was increased incrementally to avoid damaging the headform instrumentation, resulting in a maximum impact velocity of 6.07 m/s (22 km/h) for subsequent tests. The final proposal was to orient the headform with a lateral angle of 45° (Fig. 1B) to represent a side collision. Three tests were conducted with only the headform, then each helmet underwent two impacts, with one impact point on the left side and one on the right (Fig. 1C).



A B C

Fig. 1. EN 17950 headform with helmet A (A), placed at 45° angle without (B) and with helmet (C).

Data Processing

The experimental results comprised the headform's translational accelerations and rotational velocities in three dimensions. Data were filtered according to the EN 17950 standard and transformed to the headform's centre of gravity in accordance with the manufacturer's instructions (Humanetics Europe, Heidelberg, Germany). These recorded parameters were subsequently used to calculate the injury criteria HIC15 and BRIC, and as input for simulations with a brain model on the Elemance Virtual Testing Platform [5]. The following parameters were

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analysed; the maximum principal strain at each time step for all elements (MPS100) and for the 95th percentile element (MPS95), the cumulative strain damage measure of the volume of elements exceeding a 15% strain (CSDM15), and AIS2+ injury risk based on the aforementioned strain metrics.

Data Analysis

Test repeatability was evaluated by examining the variance in peak values for headform-only impacts (tests 11–13) and helmet A (tests 14, 22, 24–30). To exclude secondary impacts, the analysis was limited to data recorded within the first 30 ms. Rating of helmets was done by scaling data (HIC, BRIC, MPS100, MPS95, CSDM15) from the helmeted impacts with the corresponding average results from three tests with headform only.

III. INITIAL FINDINGS

Tables 1 - 2 compare the average values (μ) and standard deviations (σ) for headform-only and helmet A impacts, respectively. For headform impacts, the highest standard deviations were observed for Z-axis rotational velocity (41%). For helmet A, the greatest variance was observed for X-axis translational acceleration (21%).

Table 3 presents a comparison for the six helmet models. For models B and F, only one valid test result was available. The risk of concussion was low for all helmeted impacts. MPS100 predicted injury risks of 0.2-3.6%, MPS95 0.4-2.9% and CSDM15 0% risk for all helmets except one test with helmet C, where it was 1.3%.

TABLE 1. IMPACTS WITH HEADFORM ONLY

test	Max. rot-vel. (rad/s)			Max. acc. (g)			BRIC	HIC
	X	Y	Z	X	Y	Z		
11	37.5	3.7	19.1	55	160	118	0.74	316
12	32.7	4.4	9.7	70	161	118	0.80	282
13	31.8	2.9	7.7	58	156	95	0.65	247
μ	34.0	3.6	12.2	61	159	110	0.73	282
σ	2.5	0.6	5.0	7	2	11	0.06	28

TABLE 2. IMPACTS WITH HELMET A.

test	Max. rot-vel. (rad/s)			Max. acc. (g)			BRIC	HIC
	X	Y	Z	X	Y	Z		
14	15.6	3.5	9.8	34	62	55	0.36	187
22	17.4	2.4	11.7	25	57	48	0.39	228
24	14.4	4.3	11.1	20	58	55	0.36	192
25	17.6	2.9	11.3	22	53	48	0.40	253
29	16.7	3.2	10.9	36	61	67	0.37	251
30	17.6	2.9	13.1	30	56	55	0.41	269
μ	16.6	3.2	11.3	28	58	55	0.38	230
σ	1.2	0.6	1.0	6	3	6	0.02	31

TABLE 3. PERCENTAGE REDUCTION COMPARED TO AVERAGE VALUE FROM THE HEADFORM-ONLY IMPACTS.

Helmet	Folksam's rating [6]	BRIC	HIC15	MPS100	MPS95	CSDM15
A	4	43 – 51	4 - 34	28 – 45	29 - 45	84 - 96
B	4	56	17	44	49	97
C	3	32 - 36	32 - 36	20 - 36	19 - 30	62 - 88
D	2	46 - 59	31 - 33	37 - 50	33 - 49	91 - 98
E	1	51 - 54	16 - 18	38 - 41	34 - 42	93 - 97
F	not tested	59	34	61	50	100

IV. DISCUSSION

The demonstrator had repeatability issues, with data variance exceeding a 6% acceptance threshold. This may be attributed to inconsistent headform positioning and unintended headform-rig interaction. Refined positioning protocols are required to improve repeatability. The impact velocity used represented head velocity at windscreen impact in a 30 km/h bicycle-car-collision but failed to replicate the high brain strains (0.7) observed [4]. Consequently, the low predicted concussion risks (<3%) for all helmets limited the comparative relevance of injury risks. Feedback from a stakeholder workshop supported non-standard testing with a deformable impact surface and suggested that headform instrumentation would stand increasing the impact velocity further. We propose that future testing adopt impact velocities of at least 30 km/h and evaluate helmets based on kinematic based injury criteria and simulation-based brain strain measures.

V. REFERENCES

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