Experimental study on the effectiveness of a cervical airbag in rear and lateral impacts using BioRID-II and PTW dummies

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I. INTRODUCTION

Upper cervical spine injuries remain a significant concern in cyclist impacts, with the probability of fatality increasing by up to 15 times in such cases [1-3]. Unlike other injuries, advancements in cyclist safety have not led to a comparable reduction in the incidence of cervical spine trauma. Moreover, it remains unclear whether helmets are effective in mitigating neck injuries in addition to protecting the head and brain [3-6]. Cervical airbags have shown promise in reducing neck extension in rear impacts in Hybrid-III dummies without significant compromise in head kinematics [7-8]. The current study aims to investigate the effectiveness of the cervical airbag in reducing neck extension or lateral flexion, while controlling head kinematics, in both rear (neck-extension-inducing) and lateral (neck-lateral-flexion-inducing) impacts, using the BioRID-II and PTW dummies, respectively.

II. METHODS

An ad-hoc testing rig was assembled to conduct both rear and lateral impact test configurations. This rig consisted of a rigid horizontal plate that fell onto a damping material, and the position of the dummy relative to the plate defined the type of impact, depending on whether neck extension or lateral flexion was induced. In the case of the BioRID-II, the dummy lay supine; in the PTW, the dummy was positioned flat in a left lateral decubitus position. In both cases, the head was left free to rotate without the possibility of interaction with the testing rig, and the dummies were restrained to avoid unintended movement during and between tests. Figure 1 shows the two configurations with their local coordinate systems, as well as the prototype airbag used.

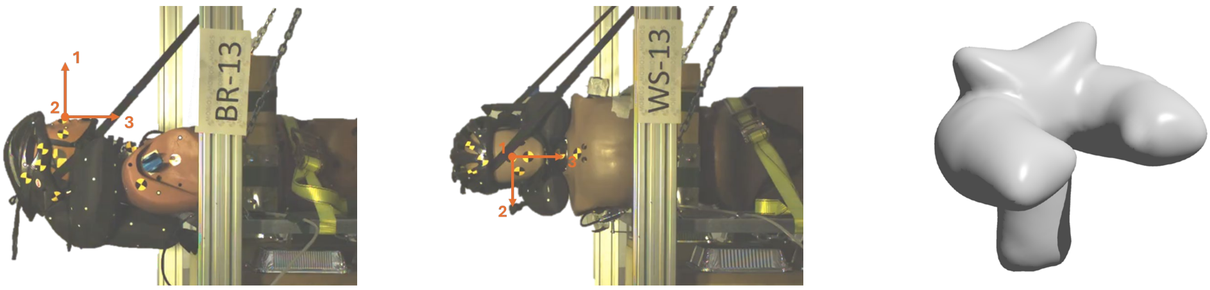

Fig. 1. Rear (BioRID-II dummy) and Lateral (PTW dummy) impact set-ups and local coordinate systems. Airbag prototype.

The system consisted of: (1) the BioRID-II or PTW dummy; (2) a rigid table; (3) a traditional bicycle helmet; and (4) the cervical airbag. The helmet was secured to the head, to avoid any relative displacement. Similarly, the airbag was tied to the helmet, in accordance with the design intentions of its developers. Several landmark measures, alignments and angles were considered to ensure reproducible initial positioning. An electromagnet release mechanism initiated each test, triggering high-speed video recording and data acquisition, thus ensuring proper signal alignment. The sensor outputs implemented included head acceleration and angular velocity, upper neck forces and moments, and table pulse acceleration. Prior to and during the tests, the acceleration pulse of the system was verified and compared with the previous ones, to ensure test repeatability and consistency.

A total of 32 tests were performed, varying the dummy (impact configuration), the impact energy (two drop heights -10 and 20cm-) and the pre-inflated airbag pressure (0.1, 0.15 and 0.2 bar, based on the current prototype airbag capabilities). Baseline tests without airbag (referred to as 0 bar) were also carried out. The maximum impact height was selected so that the induced neck motion for the no-airbag scenarios would not compromise the structural integrity of either dummy. Neck angles were calculated using the integral of the angular velocity of the head, which proved to be a more accurate and efficient method than video tracking in this case.

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III. INITIAL FINDINGS

Figure 2 and Table 2 shows the initial findings regarding head linear acceleration (AC), neck extension (TE) or lateral flexion (TF), and upper neck force (FO) and moment (MO). Only the most relevant axes to each impact type have been included. All airbag pressures (including 0 bar -no airbag-) for both impact heights are shown.

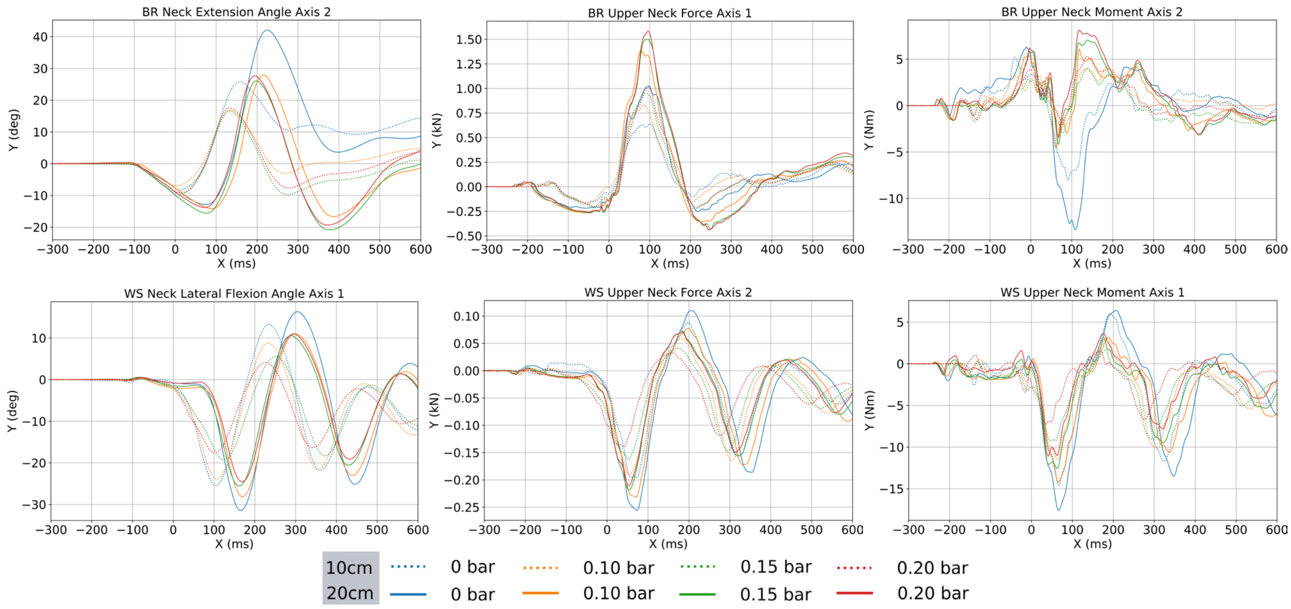

Fig. 2. Neck extension or lateral flexion, and upper neck force and moment for BioRID-II (BR) and PTW (WS).

TABLE I
SUMMARY OF MAIN INITIAL FINDINGS (PEAK VALUES 10CM | 20CM) FOR BIORID-II AND PTW

	BioRID-II (axis 1 & axis 2)				PTW (axis 1 & axis 2)			
	Head AC 1 (g)	Neck TE 2 (deg)	NeckUp FO 1 (kN)	NeckUp MO 2 (Nm)	Head AC 2 (g)	Neck TF 1 (deg)	NeckUp FO 2 (kN)	NeckUp MO 1 (Nm)
0 bar	1.9 | 3.3	25.9 | 42.1	0.6 | 1.0	8.0 | 13.4	4.2 | 5.4	25.5 | 31.5	0.2 | 0.3	14.6 | 17.6
0.1 bar	2.5 | 4.6	17.0 | 27.9	0.8 | 1.4	4.2 | 6.1	4.4 | 5.7	23.9 | 28.2	0.2 | 0.2	11.5 | 14.2
0.15 bar	3.1 | 4.9	16.5 | 26.1	1.0 | 1.5	4.1 | 7.1	3.6 | 5.4	19.4 |25.6	0.2 | 0.2	9.3 | 12.6
0.2 bar	3.2 | 5.3	17.6 | 27.7	1.0 | 1.6	5.3 | 8.1	3.1 | 5.5	17.7 | 24.5	0.1 | 0.2	7.2 | 11.1

IV. DISCUSSION

When including the airbag (and increasing its inflation pressure) in the rear-impact configuration, the peak neck extension angle was improved by 32-38%. Similarly, peak upper neck moment experienced a reduction of 34-55%. However, peak head linear acceleration and upper neck forces suffered an increment of 31-67% and 30-58%, respectively. In the lateral impact scenario, peak neck lateral flexion angle and peak upper neck force and moment experienced improvements of 6-31%, 3-29%, and 19-50%, respectively. On the other hand, peak head linear acceleration experienced mixed results, varying from a -6% (increment) to 27% (reduction). Overall, airbag effectiveness improved when increasing the impact energy. Additionally, optimal airbag performance (within test boundary conditions) was achieved with 0.15 bar for rear impacts and with 0.2 bar for lateral impacts. These results suggest a trade-off between cervical dynamics and range of motion and head kinematics, especially in rear impacts, which could be further researched and addressed through a parametrisation simulation study.

V. ACKNOWLEDGEMENTS

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