Development of Powered Two-Wheeler PMHS Crash Test Methodology

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I. INTRODUCTION

Around the world, there are over 350,000 powered two-wheeler (PTW) fatalities each year [1]. Previous PTW research has focused on analysing crash injury data [1-4] and testing wearable safety equipment [5-6], but very little research has focused on development and validation of current safety tools, such as anthropomorphic test devices (ATDs) and finite element (FE) human body models (HBMs). These safety tools can be improved and validated based on kinematic data, injury timing and injury mechanisms from full-scale post-mortem human subject (PMHS) PTW crash tests. To obtain these data, a repeatable test methodology that mimics a real-world crash scenario is needed. Therefore, the objective of this study was to establish a repeatable method by crashing a PTW with an instrumented PMHS rider into a vehicle to mimic a real-world crash event.

II. METHODS

Analyses of the German In-Depth Accident Study (GIDAS), Motorcycle Accidents In-Depth Study (MAIDS), In-depth Study of road Accidents in FlorencE (InSAFE) and ISO13232 [1-4][7] revealed a common crash scenario across all databases that involved a PTW impacting the side of a car. To mimic this, a common sedan was placed stationary at a 30-degree angle (Fig. 1) and was impacted forward of the b-pillar (on the right front door) by a PMHS-occupied PTW travelling at 50 kmph.

To date, two tests have been completed, each with a 50th percentile male PMHS equipped with a Bell Qualifier helmet and seated on a 2022 KTM 390 Duke (Fig. 2) that was propelled into a 2011 Honda Accord. In consideration of the test speed and the physiological limitations inherent with a PMHS, the PMHS was positioned and maintained in a reasonable urban-riding position from start to impact [7-9], with an approximate 10° forward lean of the thorax to mimic ISO13232 [7]. In Test 1, the thumbs were placed above the handlebar, which was changed in Test 2. Instrumentation on the PMHS included strain gauges on the head, both anterior and posterior ribs, sternum, cervical spine, pubic rami, and both the upper and lower extremities. In addition, six degree-of-freedom (6DOF) motion blocks (6DXPro DTS, Seal Beach CA) were placed on the sternum, posterior nasal bone, C4, C6, T4, T12, S1, as well as the right and left humeri, femora and iliac wings. Data were analysed to determine how the PMHS interacted with the PTW, the vehicle and the ground. Strain and strain rate were used to identify fracture timing, whereas the 6DOF motion blocks were used to analyse occupant kinematics and potential injury mechanisms. Instrumentation on the PTW included rosette strain gauges placed on the right and left aspects of the fuel tank and inferior front forks, and 6DOF blocks at the centre of gravity and posterior left front fork. High-speed cameras were placed surrounding the impact zone and onboard the PTW cart to allow for additional analysis, including aligning the video to strain data to provide context for investigating injury mechanisms. Both the sedan and the PTW were digitised and laser scans taken pre- and post-test to measure impact deformation. After each test, a detailed anatomical dissection identified PMHS injury location and severity, and data were analysed to determine injury mechanisms and overall occupant kinematics. For each test, a pre-test and post-test CT was taken of the PMHS for instrumentation alignment and additional injury assessment.

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Fig. 1. Pre-test photo of sedan from Test 2.

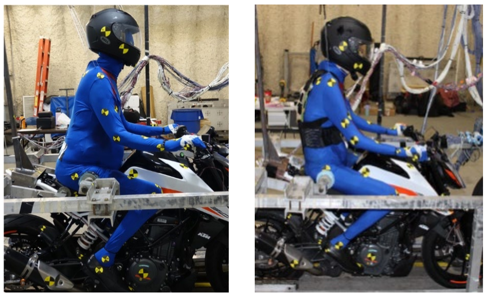

Fig. 2. Pre-test photos from Test 1 (L) & Test 2 (R).

III. INITIAL FINDINGS

Initial analysis has shown similarities between both whole-body kinematics and injuries across the tests, which speaks to the repeatability of the methodology. The PTWs impacted at a speed of 50.0 kmph (Test 1) and 49.8 kmph (Test 2) and had approximate contact timings of 52 ms (Test 1) and 53 ms (Test 2) for the pelvis with the gas tank, and 118 ms (Test 1) and 120 ms (Test 2) for the head with the vehicle. Both tests resulted in severe pelvis injuries and the overall Injury Severity Scores (ISS) between tests were similar, with scores of 36 (Test 1) and 34 (Test 2). The installed instrumentation suite allowed for the timing of skeletal fractures to be identified, thus helping better understand mechanisms of each injury. Strain data helped identify the time of pelvis injury as being early in the event from forward movement of the pelvis into the fuel tank (Fig. 3). The instrumentation suite also revealed slight differences in kinematic response between the PTW tests due to changes in PMHS positioning. Figure 4 reveals slight differences in the acceleration of the left humerus upon impact of the PTW with the sedan door. This difference is attributed to the entire hand being placed on top of the handlebar for Test 1 versus the thumb placed below the handlebar, a more realistic position, for Test 2. The hand position also led to a difference in left upper extremity injuries.

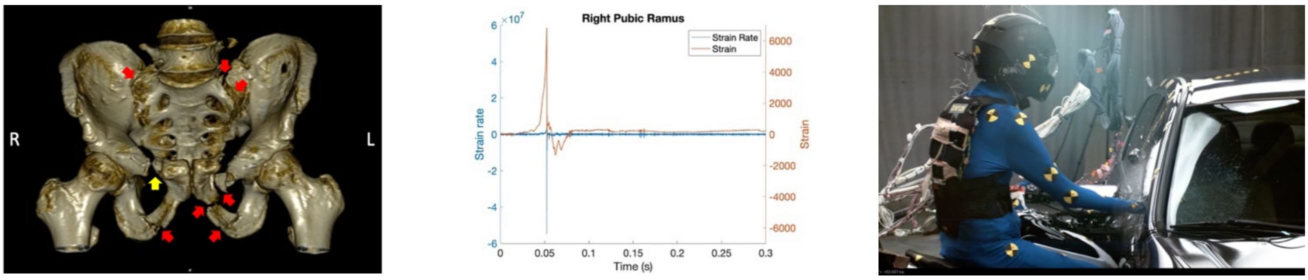

Fig. 3. CT revealing pubic ramus fracture (yellow), strain data, and a high-speed video still at time of fracture (Test 2).

Fig. 4. Resultant left humerus acceleration for Test 1 and Test 2, a still photo from Test 1, and a still photo from Test 2.

IV. DISCUSSION

When comparing the outcomes, it was preliminarily concluded that this testing methodology allows for a repeatable test as both the injuries and the gross kinematics of each PMHS were similar. Literature has revealed the most commonly injured body regions in real-world crashes are lower extremities (including pelvic ring), thorax and spine. Injuries observed in this study were consistent with this, as thoracic, pelvic ring and spinal injuries were documented. Further, previous research theorized that these pelvic injuries were due to the interaction with the gas tank instead of interaction with the ground [10], and the findings from this study confirm this theory. Although injuries from this testing methodology are similar to the main priorities found in the literature, it is important to note that different testing configurations would need to be conducted to consider other injuries and their mechanisms.

Thousands of PTW fatalities occur annually across the world and there is a current gap in knowledge when it comes to how to better protect PTW riders. By creating a repeatable test methodology for PTW and motor vehicle crashes, more research can follow to determine how best to offer protection. Biomechanical data and injuries will be useful in improving current PTW safety tools, which will ultimately help improve the safety of PTW occupants.

V. REFERENCES

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