Objective Measures for Determining Submarining and Abdominal Injury in Hybrid III Crash Test Dummies

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I. INTRODUCTION

The abdomen is the second most commonly injured body region in children in motor vehicle accidents [1]-[3] and abdominal injuries have been attributed to 'submarining' [2]. Submarining is defined by pelvic rotation resulting in the lap belt sliding up and over the iliac crests of the pelvis, and the lap component of the seat belt penetrating the abdomen. However, the ability to assess submarining and abdominal injuries in the Hybrid III family of crash test dummies is limited to visual assessments of abdominal penetration by the seat belt. Abdominal inserts have been developed in an attempt to quantify the level of abdominal injury [4], but have not been validated to an extent in which they could be implemented universally in crash test dummies. This study aims to explore methods of assessing abdominal injury through analyzing measures that are associated with submarining. These measures include femur displacement, pelvic rotation and characteristics of the lap belt force trace.

II. METHODS

14 simulated frontal impacts (Phase 1) were conducted at 16g and 29 km/h with the Hybrid III 6 year-old dummy, 38 simulated frontal impacts (Phase 2) were conducted at 16g and 28 km/h with the Hybrid III 5th%tile adult female and 23 simulated frontal impacts (Phase 3) were conducted at 27g and 46 km/h with the Hybrid III 5th%tile adult female. Both dummies were equipped with triaxial rate-sensitive gyroscopes to measure pelvic rotation and belt forces were recorded for each test. Dummy and restraint motion were captured using a high-speed digital camera. This high-speed footage was used to assess whether or not the lap belt moved up into the abdomen during testing, and also to measure femur excursion.

III. RESULTS

The results of Phase 1 testing demonstrated that while pelvic rotation is related to submarining (average 5.7° for 'no submarining' and 7.2° for 'submarining'), femur displacement was a better discriminant (average 75mm for 'no submarining' and 129mm for 'submarining'). In Phase 2 testing, pelvic rotation correlated with femur displacement (R^2=0.616), and both objective measures were shown to be good determinants of submarining (area under ROC curve was 0.875 for pelvic rotation and 0.847 for femur displacement). Using binary logistic regression, the dummy was shown to have a 90% chance of submarining when the pelvis rotates 30° or more and when the femur displaces 48mm or more from its pre-impact position. With the dummy in an upright seated posture, lap belt force traces during submarining exhibited a large initial peak followed by one or two smaller peaks. Cases of submarining with the dummy in a slouched seated posture were characterized by one or two small peaks followed by a large peak in the lap belt force. Cases without submarining showed a single peak.

IV. Discussion and Conclusions

Due to the absence of an accepted sensor for measuring abdominal injury in the Hybrid III family of dummies, the feasibility of using other measures to detect submarining were assessed. Femur displacement and pelvic rotation were both shown to be promising determinants of submarining, and criteria for each were suggested. In addition, it may be possible to identify submarining from characteristics of the lap belt force curve. A combination of these metrics may provide the basis for a useful predictor of submarining. While this work shows potential for creating an objective measure of submarining, further work is required to validate this method in other test series, with other crash test dummies and at other test speeds.

V. References

[1] Bergqvist et al, Injury, 1985
[2] Durbin et al, Ped Emergency Care, 2001
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[4] Rouhana et al, Stapp, 2001

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