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Occupant kinematics in low-speed frontal sled tests: Human volunteers, Hybrid III ATD, and PMHS

Stephanie M. Beeman[a], Andrew R. Kemper[a,*], Michael L. Madigan[b], Christopher T. Franck[c], Stephen C. Loftus[c]

[a] Virginia Tech – Wake Forest University, School of Biomedical Engineering and Sciences, Center for Injury Biomechanics, 325 Stanger St. (MC 0194), Blacksburg, VA 24061, USA
[b] Virginia Tech, Department of Engineering Science and Mechanics, Kevin P Granata Biomechanics Laboratory, Blacksburg, VA 24061, USA
[c] Virginia Tech, Department of Statistics, Laboratory for Interdisciplinary Statistical Analysis, Blacksburg, VA 24061, USA

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ABSTRACT

A total of 34 dynamic matched frontal sled tests were performed, 17 low (2.5 g, Δv = 4.8 kph) and 17 medium (5.0 g, Δv = 9.7 kph), with five male human volunteers of approximately 50th percentile height and weight, a Hybrid III 50th percentile male ATD, and three male PMHS. Each volunteer was exposed to two impulses at each severity, one relaxed and one braced prior to the impulse. A total of four tests were performed at each severity with the ATD and one trial was performed at each severity with each PMHS. A Vicon motion analysis system, 12 MX-T20 2 megapixel cameras, was used to quantify subject 3D kinematics (±1 mm) (1 kHz). Excursions of select anatomical regions were normalized to their respective initial positions and compared by test condition and between subject types. The forward excursions of the select anatomical regions generally increased with increasing severity. The forward excursions of relaxed human volunteers were significantly larger than those of the ATD for nearly every region at both severities. The forward excursions of the upper body regions of the braced volunteers were generally significantly smaller than those of the ATD at both severities. Forward excursions of the relaxed human volunteers and PMHSs were fairly similar except the head CG response at both severities and the right knee and C7 at the medium severity. The forward excursions of the upper body of the PMHS were generally significantly larger than those of the braced volunteers at both severities. Forward excursions of the PMHSs exceeded those of the ATD for all regions at both severities with significant differences within the upper body regions. Overall human volunteers, ATD, and PMHSs do not have identical biomechanical responses in low-speed frontal sled tests but all contribute valuable data that can be used to refine and validate computational models and ATDs used to assess injury risk in automotive collisions.

1. Introduction

Of the nearly 27,000 total vehicle occupants killed annually in the United States, 25,000 of these fatalities are accounted for in passenger car and light truck occupants (Nhtsa, 2009). Over 50% of passenger car and light truck occupant fatalities are due to frontal collisions. These numbers are dwarfed by the 931,000 occupants sustaining injuries in frontal collisions (Nhtsa, 2009). It has been reported that the total economic cost incurred as a result of motor vehicle collisions 2000 was $230.6 billion (Blincoe et al., 2002). Furthermore, the lifetime economic cost to society for each fatality or each critically injured survivor were both approximated to be around $1 million (Blincoe et al., 2002). These numbers indicate that frontal automobile collisions present an important focus for research given the severity and economic impact.

While it is necessary to analyze automotive collision data and statistics to gain an understanding of the mechanisms leading to mortality and morbidity, it is also critical to perform laboratory tests to improve occupant safety by examining limitations in current automobile safety systems. Knowledge regarding human response and tolerance is essential to improving injury countermeasures. Human occupant responses in motor vehicle collisions are commonly predicted and evaluated in a laboratory setting using surrogates (Begeman et al., 1980; Pintar et al., 1990, 2007; Yoganandan et al., 1991; Hardy et al., 2001a,b; Rouhana et al., 2003; Prasad et al., 2008; Kemper et al., 2009, 2011; Hallman et al., 2010; Crandall et al., 2011; Duma et al., 2011). Several of the surrogates for occupants in motor vehicle collisions include human volunteers, anthropomorphic test devices (ATDs), and post mortem human surrogates (PMHSs). Each of these has inherent strengths and limitations, but the primary goal is to demonstrate a similar response

* Corresponding author at: 325 Stanger St., Room 449 ICTAS (MC 0194), Blacksburg, VA 24061, USA. Tel.: +1 540 231 1617; fax: +1 540 231 2953.
E-mail address: akemper@vt.edu (A.R. Kemper).

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