# A Comparison of Anti-Whiplash Seats During Low/Moderate-Speed Rear-End Collisions

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## I. INTRODUCTION

Whiplash injuries are the most common type of injuries associated with motor vehicle accidents and rear-end collisions pose the greatest risk of whiplash injury [1-2]. The Insurance Institute for Highway Safety (IIHS) utilises a Seat/Head Restraint Evaluation Protocol developed by the Research Council for Automobile Repairs/International Insurance Whiplash Prevention Group (RCAR/IIWPG) to rate the ability of seats and head restraints to protect against neck injury in low/moderate-speed rear-end collisions [3]. Seats and head restraints are evaluated in a two-stage process starting with a static test to measure and rate the geometry of the head restraint, followed by a dynamic test where the seat undergoes a simulated rear-end collision. The seats and head restraints are then rated good, acceptable, marginal or poor depending on both test results.

Current anti-whiplash seats – such as Pontiac Grand AM's *high retention* seat (PGAM-HR), Volvo's Whiplash Prevention Seat (WHIPS) and Saab's Active Head Restraint (SAHR) – attempt to reduce injury risk by reducing occupant kinematics and minimising the relative motion between the head and upper torso. According to the RCAR/IIWPG [4], the PGAM-HR was rated *poor* due to marginal static geometry to protect taller occupants; whereas, both the WHIPS and SAHR were rated *good*. The WHIPS and the SAHR seats are equipped with dynamic anti-whiplash devices that rely on occupant loading of the seatback to activate a recliner mechanism to control seatback translation and rotation in the WHIPS and to raise and move the head restraint forward in the SAHR. Epidemiological studies have indicated potential benefits of both the WHIPS and SAHR in reducing whiplash injury by 20% to 50% following rear-end collisions [5-7]. The goal of this project was to compare the effects of RCAR/IIWPG rated *good* seats (WHIPS and SAHR) to a seat with a *poor* rating (PGAM-HR) on occupant dynamic responses during low/moderate-speed, rear-end collisions.

## II. METHODS

A BioRID II Anthropomorphic Test Device (ATD) was exposed to rear-end collisions using a feedback-controlled linear sled fitted with four different front passenger seats (2004 Pontiac Grand AM PGAM-HR, 2005 Volvo S40 WHIPS, 2004 Volvo S60 WHIPS and 2005 Saab 9.3 SAHR) (Fig. 1-A). The BioRID II ATD was equipped with head and torso accelerometers and an upper neck load cell, and the head restraint was fitted with a contact switch. Three-dimensional kinematic motion capture was used to measure head and torso displacements, i.e. head retraction. The ATD was exposed to a series of six whiplash-like perturbations at increasing speed changes (Δv = 2, 4, 6, 8 and 12 km/h with a collision pulse duration (Δt) of 135 ms, and Δv = 16 km/h with a Δt of 200 ms) (Fig. 1-B and 1-C). Peak forward (x) acceleration of the head and T1, and peak horizontal neck force (in the local ATD frames) were extracted from the sensors. Neck Injury Criteria (NIC) was calculated from the head and T1 accelerations, and retraction was calculated from the motion capture data for the head centre of gravity relative to T1. Time-to-head restraint contact was also extracted.

A. Experimental Set-up B. Sled Velocity Pulse C. Sled Acceleration Pulse

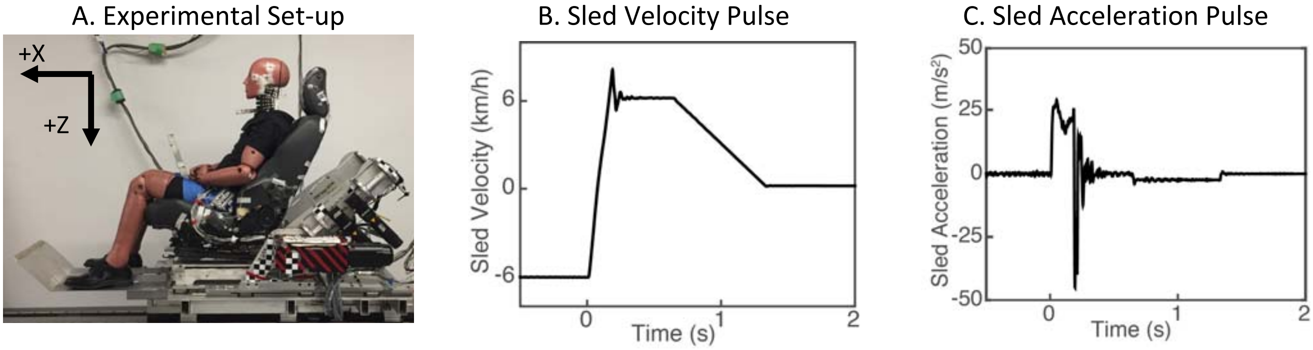


Fig. 1. Exemplar experimental set-up of (A.) the 2004 Volvo S60 WHIPS seat in lab reference frame with (B.) velocity and (C.) acceleration pulses from a Δv = 12km/h whiplash-like perturbation (Δt = 135 ms).

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## III. INITIAL FINDINGS

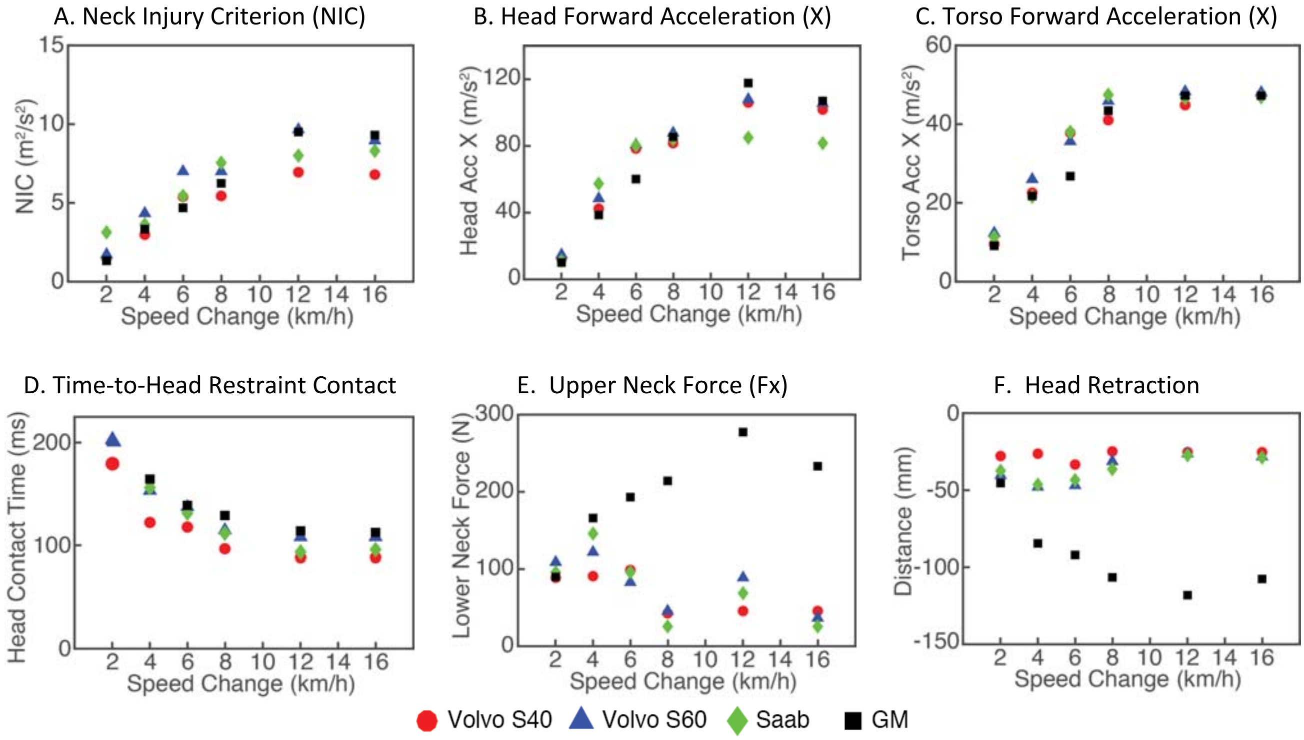


Fig. 2. Experimental results for A) Neck Injury Criterion (NIC), B) head forward acceleration, C) torso forward acceleration, D) time to head restraint contact, E) upper neck anterior-posterior force (Fx) and F) rearward head retraction for the BioRID II ATD in the PGAM-HR, WHIPS, and SAHR seats.

For all three seats, BIORID II ATD responses increased with collision severity for the NIC and forward accelerations of the head and torso (Fig. 2-A, 2-B and 2-C, respectively). The BioRID did not exceed the proposed threshold of NIC>15m$^2$/s$^2$ during any of the tests (Fig. 2-A) [8]. Head-to-head restraint contact times decreased similarly for all four seats with increasing collision severity (Fig. 2-D). Peak upper neck shear force generally decreased with speed change for the WHIPS and SAHR seats, but increased with speed change for the GM seat (Fig. 2-E). Retraction also generally decreased (or remained constant) with increasing speed change for the WHIPS and SAHR seats, but increased for the GM seat (Figure 2-F). Following the tests, there was no residual deformation to the WHIPS deformable element and the deployed SAHR mechanism returned to its original resting position.

## IV. DISCUSSION

The goal of this experiment was to compare four seats (three rated *good* and one rated *poor* by RCAR/IIWPG) over a range of rear-end crash pulses less severe than the RCAR/IIWPG standard test pulse ($\Delta$v= 16km/h, $\Delta$t=88 ms) but in the range of many injury-causing real-world, rear-end collisions [9]. All four seats generated graded ATD responses for NIC, head and torso acceleration, and time-to-head restraint contact. Any differences between the seats were more apparent in the upper neck shear force and head retraction measurements, where the three good seats generated lower or constant values of both parameters whereas the poor seat again exhibited a graded response with speed change. The similarity of the responses between good and poor seats for a number of kinematic parameters potentially related to whiplash injury may explain why even good seats have not achieved reductions of more than 20 to 50% in whiplash injury rates [5-7]. Thus, further research is required to develop anti-whiplash seat devices that reduce occupant responses and injuries across a wider range of collision severities.

## V. REFERENCES

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