

Analysis of Seat Belt Positioning in Recent NCAP Crash Tests

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ABSTRACT

The objective of this study was to analyze the position of the shoulder belt and adjustable upper anchorage (AUA) relative to the occupant in recent (2011-2012) NHTSA NCAP frontal crash tests. Since 2011, certain changes have been made in the NCAP test procedure. These changes include different Hybrid III occupant sizes as well as variations in the methods for calculating injury risk. One of the most significant changes has to do with thoracic injury risk calculation which was previously associated with chest acceleration and is now based on chest deflection as the measurable parameter. Using the NHTSA NCAP database, as well as other crash test data sources, a comparison was made between the designated upper anchorage position prior to a crash test and the actual position of the belt webbing with respect to the chest deflection measurement potentiometer sub-assembly of the Hybrid III. It was found that virtually all of the recent NCAP tests reported a disparity between the position of the shoulder belt webbing and the location of the chest deflection measurement sub-assembly. Furthermore, the effect of this disparity was analyzed using comparable tests with alternative upper anchorage positions. This data comparison reveals a substantial difference in dummy injury measures depending on how the shoulder belt is placed on an occupant prior to a crash test. Finally, comparisons were made using prior research, SAE recommended practices, and United States government engineering reports to determine the biomechanically proper location of the shoulder belt with respect to the occupant.

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INTRODUCTION

The motivation for this study was to examine the changes in recent New Car Assessment Program (NCAP) crash test procedures and how they might affect test results and conclusions. In 2011, the National Highway Traffic Safety Administration (NHTSA) modified the NCAP frontal crash test procedures. NHTSA indicated that they have “decided to include the 5th percentile female Hybrid III dummy in the right front passenger seating position” [1]. Prior to 2011, the right front seating position was occupied by a 50th percentile male Hybrid III dummy. In addition to the change in occupant size, the method for evaluating thoracic injury risk has been modified. Prior to 2011, the measured parameter for assessing thoracic injury risk was chest acceleration. Starting in 2011, the NCAP program “will focus instead on peak chest deflection” [1]. In other words, the only measurable

parameter for assessing thoracic injury risk is chest deflection. Of course, to obtain an accurate probability of injury using this method, an accurate measurement of chest deflection must be recorded. A literature review of the sensitivity of chest deflection measurement has been conducted and summarized.

For the Hybrid III 50th percentile male dummy, in 1991, Horsch et al. stated that by placing the shoulder belt in contact with the neck of a Hybrid III 50th percentile male dummy, versus 50 mm laterally away from the neck, you can decrease the chest deflection by 34% [2]. More recently, in 2012, a study by Pereira and Tank found that the measured chest deflection had decreased up to 33% in dynamic calibrations tests where the load location was moved from rib 3 to rib 6, given rib 3 is the nominal location relative to the chest potentiometer [3]. In other words, the location of the

seat belt can have an effect on the measured chest deflection, and in turn, the injury risk calculation.

In the case of the newly implemented Hybrid III 5th percentile female dummy, it has been documented that chest accelerations are insensitive to seat belt position [4]. However, the same study by Tylko et al. states that: "Subtle belt displacements in the region of the breast were found to influence the recorded chest deflection." These statements are similar to the findings by Horsch et al. and Pereira and Tank for the Hybrid III 50th percentile male dummy.

In addition, a previous study on seatbelt positioning was presented at the 2011 ESV conference in Washington, DC [5]. This study focused on the Japanese NCAP program and their recent changes. One of these changes included a repositioning of the 5th percentile female Hybrid III dummy from the left front (passenger) position to the left rear position. The authors were also interested in how the positioning of the shoulder belts in the real world would affect chest deflection measurements. In this study [5], the authors conducted two tests. In the first test, the shoulder belt was positioned higher on the occupant's chest. In the second test, the shoulder belt path was re-routed to a more realistic position on the occupant's chest. [Figure 1](#) shows the path of the shoulder belt in both tests.

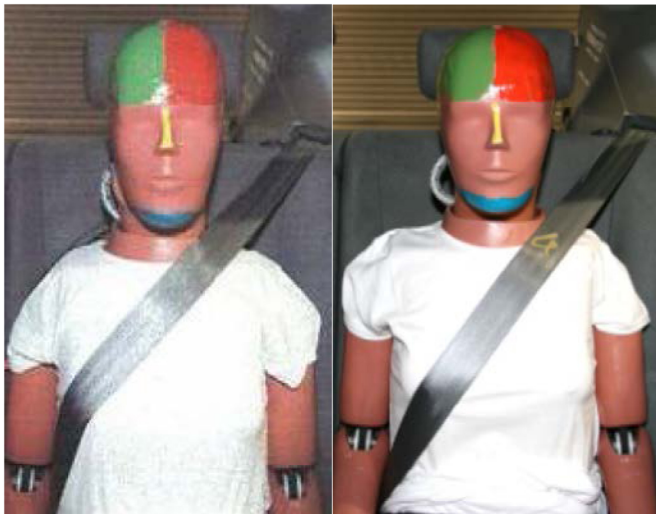


Figure 1. Shoulder belt positioning for the two identical JNCAP tests: Initial test (left) and Re-test (right) [5]

In the initial JNCAP test (high belt routing), the maximum chest deflection was 23.2 mm while the retest (low belt routing) was 42.0 mm. If these chest deflections were used to calculate the US NCAP thoracic injury risk, the results would be 3.9% and 29.0% respectively. Further, the author of the study went on to say: "As predicted, the initial test showed smaller injury values than the retest, thus confirming that the belt path influences the injury value of the chest deflection" [5].

CRASH TEST ANALYSIS

The authors located a pair of frontal crash tests with varying shoulder belt locations for similar vehicles and occupants in the NHTSA Vehicle Crash Test Database. One test was a NCAP frontal crash test and the other was a FMVSS 208 frontal barrier test.

The current NCAP frontal crash test procedures and the Federal Motor Vehicle Safety Standards frontal barrier crash test (FMVSS 208) procedures differ with respect to seat belt placement. The FMVSS 208 test procedure (under data sheet 8) describes the placement of the adjustable seat belt anchorage position prior to the test. For all seating positions, the FMVSS 208 test procedure states to: "Place any adjustable seat belt anchorage in the lowest adjustment position" [6]. In contrast, the NCAP test procedure states that for the 50th percentile male Hybrid III dummy to: "Place adjustable anchorages in the nominal adjustment position in accordance with the manufacturer's data supplied by the COTR" [7]. Additionally, the NCAP test procedure allows for a "nominal adjustment position" with regard to the 5th percentile female Hybrid III dummy [7].

These test procedures are followed for the FMVSS 208 frontal barrier crash test (number 6530) which involved a 2008 Dodge Caliber. The NCAP crash test (number 7189) which will be used to compare to this FMVSS 208 crash test was a 2011 Dodge Caliber. The Insurance Institute for Highway Safety (IIHS) reports that there were no changes in the 2011 Caliber model year relative to the 2008 model "in any way that could affect their performance in crash tests" given the fact there is only one IIHS vehicle rating for the model year range 2007-2012 [8].

In accordance with a typical NCAP test procedure, Test 7189 had an impact speed of 35 mph (56 km/hr). In contrast, FMVSS Test 6530 had an impact speed of 30 mph (48 km/hr). The NCAP crash test had a 50th percentile male Hybrid III dummy in the driver's seat and a 5th percentile female Hybrid III in the front passenger's seat. The FMVSS 208 crash test had 5th percentile female Hybrid III dummies in both the driver and front passenger positions. For the purpose of this study, the results of the crash test and the comparisons of these crash tests will be focused on the right front occupants inasmuch as the right front position had the same sized occupant in both tests. It is important to note that seat was placed in the foremost position for right front 5th percentile female Hybrid III dummy in both NCAP and FMVSS tests.

As per the FMVSS 208 test procedure, the position of the upper seat belt anchorage for the FMVSS 208 Test 6530 was placed in the lowest position [6]. For the NCAP test, the upper anchorage was set at the "nominal adjustment position in accordance with the manufacturer's data supplied by the COTR" [7]. This position was reported as the highest available position. [Figure 2](#) shows pre-test photographs

featuring the right front occupant and the position of the adjustable upper anchor.



Figure 2. Pre-test photographs of the right front occupant in FMVSS test 6530 (left) and NCAP test 7189 (right)

As shown in [Figure 2](#), the position of the shoulder belt differs between the two presented crash tests. The NCAP test report states that the midpoint of the shoulder belt (along the centerline of the dummy) is 328 mm from the “top-of-the-legs” measurement plane (shown in [Figure 4](#)). The FMVSS 208 test report provides a value of 240 mm for the same measurement. For these two tests, the chest deflection was measured for the right front occupant (see [Figure 3](#)).

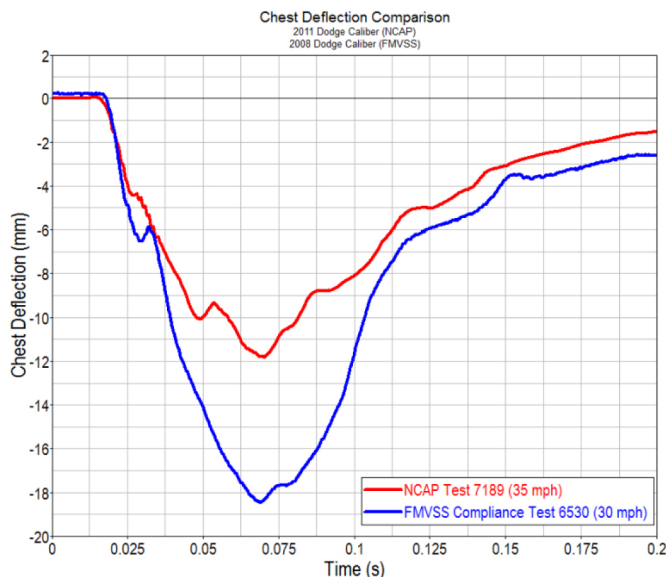


Figure 3. Chest Deflection results from NCAP and FMVSS 208 crash tests

As shown in [Figure 3](#), the FMVSS test occupant had a larger chest deflection despite the lower impact speed (by 5 mph) and larger crash energy. The maximum chest deflection for the right front occupant for the FMVSS 208 crash test was 18.5 mm. The maximum chest deflection for the right front occupant of the NCAP crash test was 11.8 mm. The thoracic

injury risk from these two tests was calculated to be 1.9% and 0.57% respectively [1]. [Table 1](#) shows the summary of the test conditions and results from this comparison.

Table 1. Summary of crash test results

	<i>NCAP Test</i>	<i>FMVSS 208 Test</i>
<i>Vehicle</i>	2011 Dodge Caliber	2008 Dodge Caliber
<i>Impact Speed</i>	35 mph (56 km/hr)	30 mph (48 km/hr)
<i>Right Front Occupant</i>	III 5 th Female	III 5 th Female
<i>Anchorage Position</i>	Top (of 4)	Bottom (of 4)
<i>PBU / PBL from Fig 4</i>	364 mm / 292 mm	280 mm / 200 mm
<i>Shoulder Belt Position</i>	328 mm	240 mm
<i>Chest Deflection</i>	11.8 mm	18.5 mm
<i>Thoracic Injury Risk</i>	0.57 %	1.91 %

CRASH TEST DATABASE ANALYSIS

Given that the NCAP test procedures presently allow for the manufacturer to decide the location of the shoulder belt prior to the crash test, recent test reports have been reviewed to determine if any trends have been developed for shoulder belt positioning. The NHTSA Vehicle Crash Test Database was queried for NCAP crash tests conducted for MY 2011 and 2012 vehicles. At the time of this study, 98 crash tests were obtained from the database and in each of these crash tests a pre-test measurement of the shoulder belt position relative to the occupant was included. The location of this measurement is shown in [Figure 4](#).

As seen in [Figure 4](#), the upper and lower edge of the shoulder belt is measured with respect to a flat plane resting on the top of the occupant's legs. This measurement was taken along the centerline of the occupant. These two distances were then averaged to create a “midpoint” position of the shoulder belt. The midpoints were then tabulated for all of the 98 NCAP frontal crash tests. In addition to the shoulder belt location, the maximum chest deflection data was also extracted and tabulated.