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Alliance OF AUTOMOBILE MANUFACTURERS

October 14, 2004

DOCKETS

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Mr. Stephen R. Kratzke, Esq.
Associate Administrator for Rulemaking
National Highway Traffic Safety Administration
U.S. Department of Transportation
400 Seventh Street, S.W.
Washington, DC 20590

Dear Mr. Kratzke:

RE: Side Impact Protection, Docket No. NHTSA-2004-17694 - 32

The Alliance of Automobile Manufacturers (Alliance) is pleased to provide this response, including preliminary comments and petition, to NHTSA's Notice of Proposed Rulemaking (NPRM), published in the Federal Register on May 17, 2004, on amending the agency's side impact protection requirements. The Alliance is a trade association of nine automobile manufacturers, including BMW Group, DaimlerChrysler, Ford Motor Company, General Motors, Mazda, Mitsubishi Motors, Porsche, Toyota, and Volkswagen.

The Alliance believes NHTSA's proposed side impact protection amendments are premature, for three reasons, which are outlined and discussed below. Because of the complexity of the proposal and insufficient availability of the test dummies proposed by NHTSA, the Alliance petitions NHTSA to re-open the comment period for at least eight additional months. In addition, we request that the agency issue a Supplemental Notice of Proposed Rulemaking to address a number of outstanding issues before proceeding to any final rule.

The first reason why NHTSA's proposal is premature is that the test dummies proposed by the agency are not available in sufficient quantities at this time for the industry to assess NHTSA's proposed revised side-impact test procedures and prepare comments by the October 14, 2004 due date for public comments. To date, NHTSA has proposed to include only one of these two new test dummies, the ES-2re, in Part 572, and this proposed incorporation occurred almost four months after the issuance of the agency's side impact proposal. In contrast, in January 1988, when NHTSA issued its NPRM to establish dynamic side impact protection requirements for passenger cars, the agency issued its proposal to incorporate the side impact test dummy into Part 572 on the same day. In addition, in 1988, the agency allowed a nine-month comment period for both the side impact test procedure and the test device. For the current, far more complex proposal, which applies to light trucks and multipurpose vehicles as well as to passenger cars, NHTSA has only allowed a five-month comment period on the proposed test procedure and only a two-month comment period on only one of the two proposed new test dummies.

The Alliance surveyed auto industry members for their test dummy needs to assess NHTSA's proposal, and compared these needs to the dummies planned to be made available by the dummy manufacturers, First Technology Safety Systems and Denton ATD, Inc. Details of this survey are provided in the attachment to this letter. That assessment concludes that the two test dummies will not be available to auto manufacturers in sufficient quantities until November or December of this year. Subsequent to receiving adequate supplies of test dummies, auto manufacturers then require at least four months to perform assessments of test dummy and vehicle performance under NHTSA's proposed side impact test procedures. Then, it will take one to two additional months to develop comments to NHTSA on these test results. Thus, realistically, the auto industry needs at least until mid-2005 to be able to provide NHTSA with a full assessment of the agency's proposed side impact protection amendments.

Limited testing to date by Transport Canada and USCAR's Occupant Safety Research Partnership (OSRP) indicates that the SID-IIsFRG is not an acceptable test device for assessing occupant injury risk in side impacts. The decreased sensitivity of both upper and lower abdominal rib deflection responses compared to the SID-IIs Build Level C, as well as the uncharacteristic shape and slope changes of the rib-deflection time history caused by the floating rib guide design, render the dummy incapable of accurately assessing thoracic injury risk, one of the most likely sources of injury in a side impact crash. The SID-IIs was specifically designed to measure rib deflection, and the Alliance believes that given the limited initial evaluations of both the SID-IIs Build Level D and FRG, the build level D, not the FRG, is the preferred improvement over the Build Level C dummy. Other than the floating rib guides, the Build Level D version of the SID-IIs includes all of the other enhancements the FRG version provides to the Build Level C version of the SID-IIs. More specific comments on this test device are provided in the test dummy and injury criteria attachment to this letter.

The second reason why NHTSA's proposal is premature is that the agency has not carried out the necessary foundational analysis and evaluation to support this NPRM. First, the Preliminary Economic Assessment (PEA) does not include an analysis of the potential benefits from the newly proposed 5th female dummy MDB test or changing the 50th percentile male dummy currently used in that test. Second, the number of vehicle crash tests on which NHTSA's pole tests benefit estimates were derived is very limited. Third, no thorough evaluation had been performed on the feasibility of the proposed injury assessment value limits (for example, only four tests were carried out per the proposed pole test with the ES-2re dummy, and only one vehicle out of the four passed the proposed rib deflection limit. It is not clear if this result is an experimental artifact or indicates that there is reasonable ground to assume that this is a feasible and practicable procedure). Fourth, the analytical procedures used to estimate the benefits are not rigorous enough to provide a sound basis for rulemaking. The Alliance is conducting a detailed review of the analytical procedures used in the PEA and will submit the results of this analysis as a supplement to these comments shortly. These inadequacies with the underlying analysis raise questions about whether a final rule based on this proposal could be justified under OMB Circular A-4, the Data Quality Act and the Administrative

Procedure Act, as well as the requirements of the Vehicle Safety Act. In addition, the agency typically provides an example of at least one current vehicle that meets all of NHTSA's proposed test requirements. However the agency did not provide such an example in this proposal, raising further questions about its practicability. The Alliance expects that individual member companies will provide NHTSA with test data addressing these concerns in the upcoming months.

The Alliance is disappointed that NHTSA's proposal did not provide further consideration to test procedure and test dummy harmonization. With regard to test procedures, the Alliance urges the agency to work within the International Harmonized Research Activities (IHRA) Side Impact Working Group to achieve consensus on internationally recognized side impact procedures before proceeding to rulemaking that may contradict the outcomes of that working group. In addition, the Alliance believes that NHTSA should lead efforts toward international harmonization of the side impact test dummies. The Alliance will submit data in the coming months to support the most appropriate test device. However, the WorldSID dummy has better biofidelity characteristics than the ES-2re and ES-2, as detailed in the test dummy and injury criteria attachment to this letter. The Alliance would be pleased to work with NHTSA in steps to incorporate WorldSID into Part 572. We note that NHTSA's Vehicle Research and Test Center has two WorldSID test dummies, and thus the agency can make progress in "Federalizing" this device.

Finally, the agency's proposal did not adequately recognize the commitments Alliance members, and other auto manufacturers, made in December 2003, when the Alliance, the Insurance Institute for Highway Safety (IIHS), and the Association of International Automobile Manufacturers announced a voluntary industry agreement to enhance occupant protection in front- and side-impact crashes. As a result of the side-impact commitment, by September 1, 2009, 100 percent of each participating manufacturer's[1] new U.S. fleet of passenger cars and light trucks up to 8,500 pounds Gross Vehicle Weight Rating[2] will be designed in accordance with the IIHS moving deformable barrier (MDB) requirements for driver head protection. In addition, the December 2003 commitment also included a phase whereby, within a year, industry research would focus on assessing the safety benefits of adding performance criteria for other body regions, with particular attention to thorax and abdomen, plus performance criteria for a rear-seat dummy. Nor did the NHTSA safety benefits analysis consider the changes auto manufacturers are likely to make voluntarily to their products, partially in recognition of the fact that IIHS will be performing and publicizing side impact tests with their own MDB. Over the years, the IIHS offset frontal barrier test program has demonstrated the changes auto manufacturers have made voluntarily to their products[3]; we expect the IIHS side impact test program to also demonstrate auto manufacturers'

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[1] The participating manufacturers represent close to 100 percent of the United States' new vehicle market.
[2] With exemptions only for vehicles that a manufacturer determines, due to basic practicability and functionality issues, cannot meet the performance criteria, and would have to be eliminated from the market if compliance were required.
[3] **Insurance Institute for Highway Safety**, "Crashworthiness Keeps Getting Better," Status Report, Vol. 36, Number 3, March 20, 2001.

commitments to voluntarily enhance side impact safety in the future. NHTSA's addition of HIC measurements to its side impact New Car Assessment Program also will help demonstrate auto manufacturers' commitments to further enhance side impact crashworthiness. The industry's voluntary enhanced side impact protection commitment and the existing stringent IIHS side impact test procedure form the appropriate baseline for any estimates of potential safety benefits for amending NHTSA's current side impact protection requirements, not the characteristics of the model year 2003 light vehicle fleet, as assumed by NHTSA. The Alliance believes that the Data Quality Act and OMB Circular A-4 compel a recalculation of these benefits to avoid claiming benefits for the rule from actions that auto manufacturers have already committed to take.

Although the Alliance and its members have not, for the reasons described above, been able to fully assess NHTSA's proposed side impact test procedures and devices, we do have some significant initial concerns regarding the agency's proposal. First, the Alliance believes the agency should not require performing multiple versions of the same side impact crash test procedure with different dummy sizes. NHTSA's analysis of real-world crash data has not demonstrated safety benefits from performing the oblique pole test. NHTSA has not provided data indicating inadequate head protection coverage by some side air bag systems in real-world crashes. Also, the Alliance believes that NHTSA's concerns about the non-deployment of some side air bag systems in the oblique pole crash test are based on test artifacts and do not represent the real-world safety performance of these systems. In addition, NHTSA has not demonstrated that having two FMVSS 214 MDB tests using different size dummies creates real-world safety benefits, particularly in light of the previously mentioned IIHS side impact consumer information program. The agency also has doubled the number of proposed test requirements (from four tests to eight tests) by imposing different arm position requirements for the driver versus the right-front passenger for the same dummy in the same crash configuration.

The Alliance recommends that convertibles be exempt from the pole test requirements because the agency has not demonstrated it is practicable to implement the countermeasures that would be needed to comply for these types of vehicles, while meeting TWG OOP guidelines. Furthermore, we do not agree with the proposal to only exclude these vehicles from the HIC requirements of the pole test, because the lack of roof structure affects the overall response, not just the HIC response, of these types of vehicles in a pole test environment. Similarly, vehicles without doors or easily removable doors should be completely exempted from pole tests (perpendicular or oblique) since the lack of door structure makes meeting these tests impracticable.

The agency also proposes to apply the oblique pole test requirement to vehicles between 8,500 and 10,000 pounds GVWR. However, NHTSA has not demonstrated the practicability of these requirements for these larger/heavier vehicles.

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[4] Vehicles that satisfy the requirements in S4.5.4.1(b) of FMVSS 208

With regard to effective dates, the Alliance opposes differing effective dates for the pole test and the MDB test. Alliance members suggest that occupant safety benefits are optimized and manufacturers' engineering resources are best utilized if the MDB and pole test requirements are addressed in vehicle designs simultaneously. Thus, we recommend phasing in any changes in the MDB test requirements along the same schedule as NHTSA has proposed for the pole test – a three-year phase-in beginning four years after publication of a final rule. Additionally, NHTSA should additionally include a 0/0/100 phase-in for limited line manufacturers with the opportunity to apply credits against the 100% compliance requirement for one year.

In addition, if the agency proceeds to adopt a pole test in a final rule on FMVSS 214, the Alliance believes NHTSA should examine the need for the existing quasi-static door crush resistance requirements in FMVSS 214 for vehicle seating positions subject to the pole test. When NHTSA established the FMVSS 214 dynamic crash test requirements in 1990, the agency indicated it was keeping the existing quasi-static test requirements because, "NHTSA's research has shown that the existing requirements of the standard have been effective in reducing fatalities and injuries in single vehicle impacts. The agency believes that the primary reason for the effectiveness of the current standard is that it reduces intrusion in the vehicle. In particular, the added side door beam helps to keep a pole, tree, guardrail or other fixed object from intruding into the occupant's seating position and from hitting the occupant."[5] Although the preamble to NHTSA's new proposal discusses a 1998 petition for rulemaking from Advocates for Highway and Auto Safety, which the agency granted, that included replacing the quasi-static test with a pole test, NHTSA's new FMVSS 214 proposal maintains the quasi-static test requirement without providing a rationale. If NHTSA adds a dynamic pole test to FMVSS 214, the Alliance believes the agency should determine whether retention of the quasi-static door crush resistance requirements in the standard would add safety benefits, or whether its retention could restrict design flexibility and result in unnecessary and duplicative test costs to the auto industry, and, ultimately, to consumers.

As shown in our attachment, the Alliance is committed to supplement these comments with detailed test data as it becomes available. However, we are unlikely to complete the process of generating and evaluating this data until mid-2005. Assuming the test dummies are supplied to Alliance members and NHTSA publishes calibration procedures for the SID-IIsFRG soon, Alliance members plan to complete much of their planned dummy component level tests within 3-4 months and supply initial results to the agency at that time. The vehicle testing process for individual manufacturers' fleets will require an additional 3-4 months, plus 1-2 months for data analysis, recommendations compilation, and submission to NHTSA. For this reason, we are petitioning the agency to re-open the comment period for at least an additional eight months. Furthermore, due to significant issues surrounding the agency's proposal, the Alliance is requesting that NHTSA's next step in this rulemaking be the issuance of a Supplemental NPRM, rather than a final rule. Enough fundamental questions have been raised about the direction and

[5] 55 FR 45749-45750, October 30, 1990.

content of the agency's proposed amendments to FMVSS 214 that additional analysis by the agency and another opportunity for public comment are essential before issuance of a final rule.

Thank you for this opportunity to provide comments on NHTSA's proposed amendments to its side impact protection requirements.

Sincerely,

Robert Strassburger for
Vice President
Vehicle Safety and Harmonization
Alliance of Automobile Manufacturers

Attachment: Comments on Proposed Test Dummies and Injury Criteria

cc:

R. Saul
L. Summers
S. Backaitis
J. Kanianthra

Alliance Comments on FMVSS 214 Proposed Dummies and Injury Criteria

The following document details concerns with the proposed Anthropomorphic Test Devices (ATDs) and injury criteria included in the FMVSS 214 NPRM. As explained in the cover letter, these comments are provided based on the current state of knowledge regarding the proposed ATDs and will be supplemented with additional conclusions and recommendations pending the completion of an Alliance evaluation of the ATDs, the plan of which is also explained herein. It is noted that the biofidelity rankings ascribed to the subject ATDs in the following discussion were derived using the ISO/TR9790 procedure. While it is acknowledged that an alternate procedure (i.e., Maltese procedure)[1] exists, this procedure was not considered since the Alliance has numerous concerns about it, including the numerical stability of its algorithm.

Appropriate Federalization Procedure for ATDs

The NPRM proposes the use of two new ATDs or dummies: the SID-IIsFRG and the ES-2re. These dummies are currently not included (although inclusion has been proposed for one of the two) in 49 CFR Part 572, which describes ATDs to be used for compliance with Federal Motor Vehicle Safety Standards. As described in Part 572, its purpose is to describe the measuring tools intended for testing to the requirements of the FMVSS. Part 572 is, "...designed to be referenced by, and become a part of, the test procedures specified in motor vehicle safety standards..."[2]. This reference is necessary to facilitate, "repetitive and correlative results under similar test conditions" and to ensure that the device specifications are identical industry wide. While Part 571 standards describe the use of dummies in specific tests, Part 572 includes the critical "design and performance criteria" to define the dummies themselves, including drawings and specifications.

While the Alliance understands that NHTSA is not obligated by law to adopt ATDs into Part 572 before proposing them in a regulation, there are practical reasons that this course of action would be the most productive. As evidenced in this attachment, modern ATDs are complicated, advanced devices. It takes many years and much experience for the vehicle safety community to reach a level of understanding appropriate to warrant widespread use of an ATD, particularly in stringent compliance regimes. The device alone may have inadequacies in its ability to measure elements for which it was ostensibly designed. Coupling these possible difficulties with the complicated environment of a vehicle crash test, one can deduce a host of issues to be resolved before determining that a device is ready for regulatory use.

Unfortunately, by proposing the use of the dummies in a Part 571 regulation before proposing their inclusion in Part 572, NHTSA has denied Alliance member companies the opportunity to evaluate the performance capabilities of the proposed

[1] Maltese, M. R., Eppinger, R. H., Rhule, H. H., and Donnelly, B. R. (2002) Response Corridors of Human Surrogates in Lateral Impact. Stapp Car Crash Journal 46 (Novermber 2002) pp.321-351 Society of Automotive Engineers, Warrendale, PA

[2] 49 CFR 572 October 1, 2003

dummies as measuring devices first before evaluating their use in a crash test. The types of comments to be provided for Part 571 and Part 572 are inherently different; the first addressing the appropriateness and adequacy of a dummy and its injury criteria in a specific test and the latter addressing the capabilities and biofidelity of a dummy as a measuring tool.

Per the Part 572 NPRM for the ES-2re dummy[3], it seems NHTSA understands that there are different evaluations necessary to assess the repeatability and reproducibility of a dummy, including both component tests and sled or vehicle tests. While component tests are, "...better controlled and produce more reliable estimates of the dummy's repeatability and reproducibility than is possible in sled and vehicle tests", the sled tests can, "...offer a method of efficiently evaluating the dummy as a complete system..." to represent a vehicle environment. NHTSA also correctly notes that both types of tests are necessary. The component tests evaluate dummy performance relative to biomechanical corridors whereas sled or vehicle tests establish the, "...consistency of the dummy's kinematics, its impact response as an assembly, and the integrity of the dummy's structure and instrumentation under controlled and representative crash environment and test conditions." However, the Alliance is now forced to perform the evaluation necessary to comment to two different kinds of proposals (Part 571 and Part 572) simultaneously and in short order.

Furthermore, two weeks prior to the Part 572 NPRM for the ES-2 RE dummy was issued, one manufacturer of the ES-2re issued a "quality alert" recall for the rib extensions. This unprecedented move underscores the immaturity of the ES-2re design and exacerbates the difficulty the industry has responding to the NPRM.

Although NHTSA subsequently issued a Part 572 NPRM for the ES-2re dummy on September 15, 2004, its issuance four months subsequent to the proposal of the dummy in an FMVSS provides inadequate opportunity for public comment. Of historical note, when NHTSA proposed to establish the dynamic side impact testing for passenger cars for FMVSS 214 in 1988, the single dummy (DOT SID) was proposed in both Parts 571 and 572 on the same day, allowing industry 9 months to comment. Also, the 1988 NPRM included only 1 dummy, 2 injury criteria, and 1 test. Yet, this NPRM includes 2 new dummies that were not specified in Part 572, 8 tests, and 5 injury criteria for ES-2re and 3 injury criteria for the SID-IIsFRG, and the industry was allotted only 5 months to comment. Further, the new proposal is also applicable to both passenger cars and light trucks whereas the 1988 proposal only applied to passenger cars. As explained in the next section, the 5-month comment period for this NPRM was not useful to the industry as the devices proposed in the NPRM were simply not available to sufficiently supply all Alliance member companies to evaluate the dummies for comment.

Therefore, as described in this document, the Alliance comments are limited by the current state of knowledge of the industry and the short time frame of the current comment due date for the FMVSS 214 NPRM.

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[3] Vol. 69, No. 178 Federal Register. Pgs. 55554 – 55555. September 15, 2004

Lack of Dummy Availability

The industry is familiar with and experienced in the use of the SID-IIs and ES-2 dummies, gaining experience with the SID-IIs in the IIHS MDB test and the ES-2 in the EuroNCAP test. However, NHTSA's proposed dummies include modifications not previously installed on the production devices: the floating rib guide (FRG) for the SID-IIs and the rib extensions (re) for the ES-2. Therefore, NHTSA is essentially proposing two new dummies with which the industry has very limited experience. For example, at the time of NPRM publication, only NHTSA and OSRP[4] member companies had gained experience with the SID-IIsFRG, which requires assessment by all Alliance member companies in order to comment to the NPRM. Therefore, upon publication of the FMVSS 214 NPRM proposing these new dummies, the Alliance member companies proceeded with efforts to obtain the dummies for evaluation. However, this was not possible within the current timeframe allotted for comments.

The Alliance queried current dummy manufacturers[5] to assess their supply capabilities for the modified dummies within the FMVSS 214 NPRM comment period. The Alliance also surveyed automakers, including some non-Alliance members, to estimate the equipment necessary for automakers to gain adequate experience with the dummies for providing comment to this rulemaking. The results of these investigations are included in Table 1 below, which details the difficulty of obtaining both of the dummies and their instrumentation in time to comment completely.

Table 1: Supply and Demand Industry Survey

Equipment	Total OEM Industry* Demand	Cumulative Supply Over Time					Total Available by Comment Due Date
		Jun 2004	July 2004	Aug 2004	Sept 2004	Oct 2004	
SID-IIsFRG							
Spare parts to compile FRG Thx	5	2	4	6	8	10	10
SID-IIsFRG Full Dummies	14	2	4	6	8	10	10
SID-IIsFRG Complete Thx	10	0	4	8	10	12	12
SID-IIs Build Level C Dummies	3	0	1	2	2	2	2
SID-IIsFRG Instrumentation							
SID-IIsFRG Load Cells	12	0	0	10	10	10	10
ES-2re							
ES-2re Full Dummies	10	3	5	7	15	15	15
ES-2re Complete	3	0	0	2	3	4	4

[4] Occupant Safety Research Partnership of USCAR (Members – DaimlerChrysler, GM and Ford)
[5] First Technology Safety Systems and Denton ATD, Inc.

Thorax Kits							
ES-2re Spare parts to compile thx	8	2	6	8	10	10	10
ES-2	2	5	7	7	7	7	7
ES-2re Instrumentation							
ES-2re Load Cells	9	0	0	0	10	10	10
ES-2re Backplate Load Cells	16	10	15	15	15	15	15
ES-2re rib module brackets	4	2	4	4	4	4	4

*Does not include Tier 1 suppliers

First, regarding the SID-IIsFRG, the automakers surveyed anticipate the need for a total of fourteen SID-IIs FRG full dummies. However, the industry supply will only total ten by October 2004. Further, the production of these dummies is gradual, some not being produced until October 2004 (Figure 1).

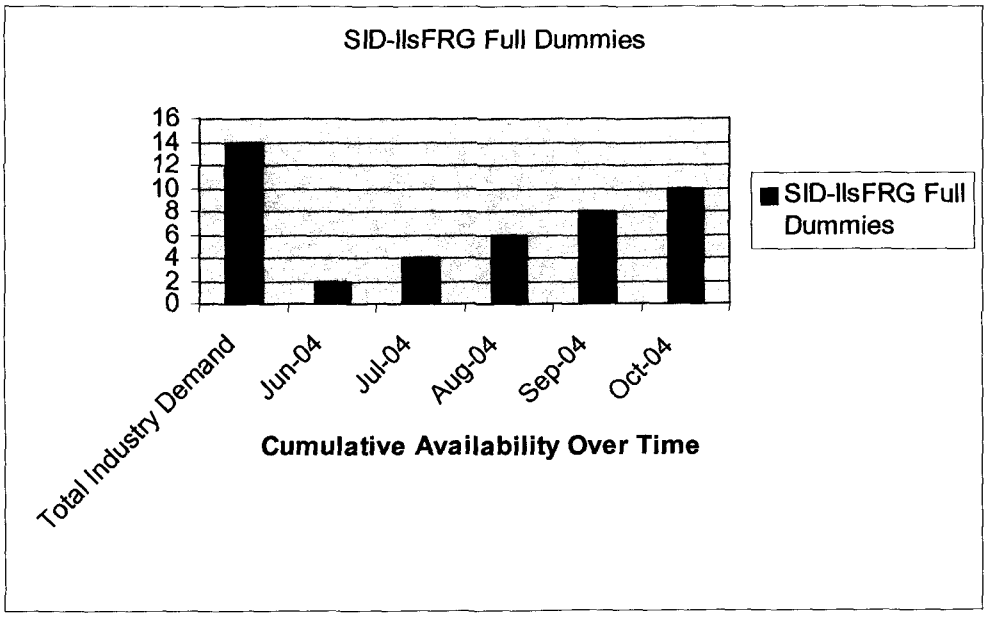

Figure 1: SID-IIsFRG Full Dummy Supply and Demand

The situation is similar for the instrumentation necessary to support the new dummy, including SID-IIsFRG load cells (Figure 2).

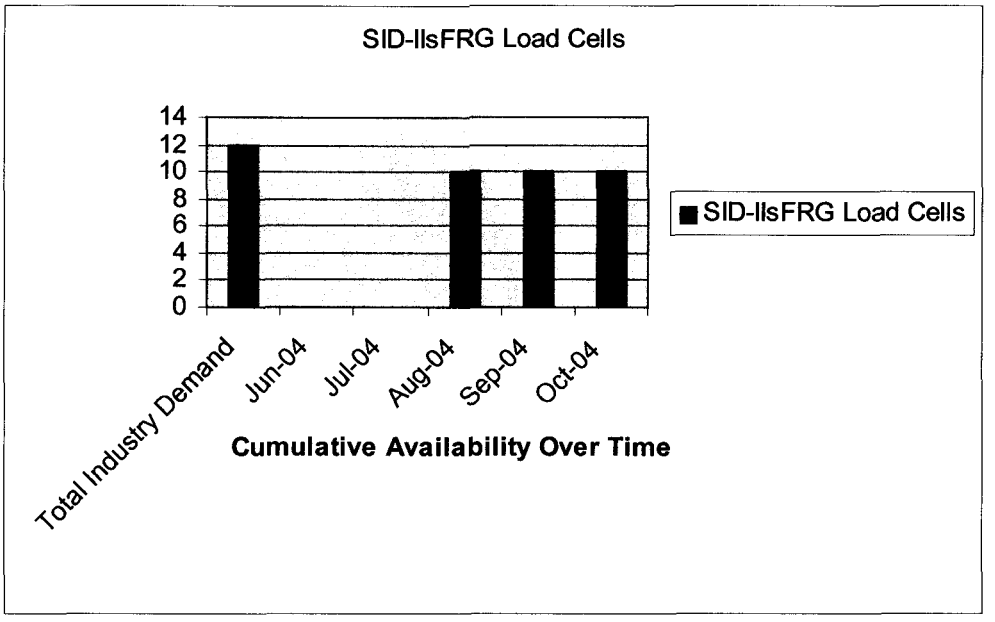

Figure 2: SID-IIsFRG Load Cell Supply and Demand

The situation is similar regarding the instrumentation for the ES-2re dummy (Figure 3).

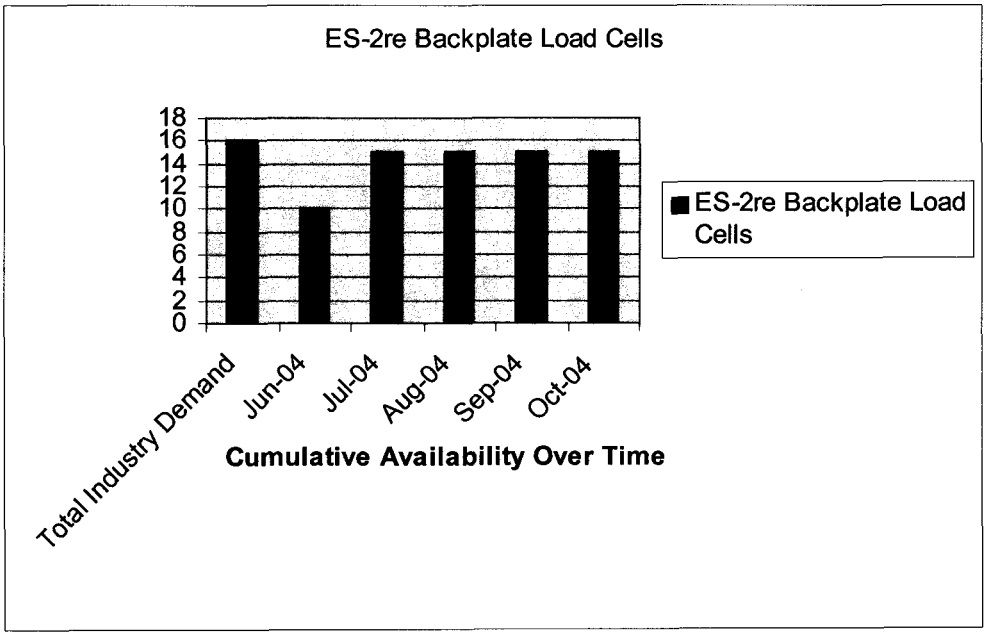

Figure 3: ES-2re Backplate Load Cells Supply and Demand

Automakers anticipate the need for ten ES-2re full dummies from an available supply of fifteen. While the supply situation is not as severe for the complete ES-2re dummy since the industry needs can be met by October 2004, there is an added complication to consider. Two different dummy manufacturers are producing the ES-2re. While this is not typically a concern, it is noted that the drawing package for the ES-2re

was not published by NHTSA until August 13, 2004, three months after the FMVSS 214 NPRM proposal. Consequently, the Alliance cannot be sure that the dummies available from different suppliers are manufactured to identical specifications. Since the dummies included in the above availability survey were designed before the drawing package was published, there exists the possibility manufacturers may be testing with somewhat different ES-2re dummies.

The availability shortage not only leaves industry unsupplied by the comment period due date, but those who can take delivery of the dummies have no time to perform adequate evaluations. In addition, the auto manufacturers are not the only customers in need of the dummies from the aforementioned limited supply. It is understood from some Tier 1 suppliers surveyed[6] that 3 Complete FRG Dummies, 2 FRG Dummy Kits, and 3 ES-2 Dummies have already been purchased. These demands were not included in Table 1 but will also drain the small supply available.

For the reasons described above, a lack of dummy availability is prohibiting the Alliance from providing substantial comment at this time. However, as the dummies become available to all members, the Alliance plans to conduct a rigorous cooperative evaluation among its members as detailed in the following section.

Alliance Dummy Evaluation

The Alliance intends to provide the agency with comments on the SID-IIsFRG and ES-2re following an evaluation by its members as detailed in this section. The Alliance estimates the total time to complete this evaluation and prepare comments is at least 8 months. The characteristics of the evaluation are explained below.

The ability of the Alliance to provide evaluation data on its current plan depends heavily on dummy availability, which the Alliance members cannot control. Supply issues aside, there are other necessary steps to get the dummy transported and prepared for evaluation within the manufacturers. First, for some Alliance members, international shipping can take as much as 2 weeks. Second, following dummy receipt at the manufacturer, instrumentation must be processed, which can typically take as much as 3-4 weeks. For each lab, this process requires time to add cable connectors and instrumentation, manually enter all transducers into the data system, attach all cables, and perform instrumentation calibration.

Following initialization of the instrumentation, each manufacturer must then process the dummy. For each lab, this process requires time to perform dummy calibrations, perform mechanical checks, update the software and databases, install instrumentation, and assemble the dummy. This process can take as much as 3 weeks. Therefore, the dummies are typically not ready for testing until 6-9 weeks from the time the dummy is shipped. However, given the importance of this rulemaking and the

[6] Key, Takata, Delphi, Autoliv, and TRW Automotive

urgency of this evaluation, Alliance members will strive to expedite this process as much as possible.

Following the current timeframe, most members hope to have dummies ready for testing by the end of 2004. From that time, Alliance member companies plan to evaluate the dummies in both component and full scale testing. For some Alliance members who are also members of the OSRP, full scale vehicle testing may be conducted in the near term, since OSRP has already conducted many of the component level tests necessary for these companies. However, other Alliance member companies will need to begin their evaluations with dummy component tests.

Although the Alliance members can share the biofidelity evaluation results from OSRP, it is essential that each laboratory conduct its own component testing. Specifically, since the proposed dummies are new, each laboratory must gain experience with the dummies in these types of tests before the manufacturer reaches a level of confidence and the expertise to correctly use the dummies in full-scale vehicle tests. Each member plans to conduct appropriate calibration tests for each proposed dummy. The ES-2re calibration tests are included in the Part 572 NPRM published on September 15, 2004. Manufacturers plan to conduct calibration tests for the SID-IIsFRG; however, manufacturers await the publication of the SID-IIsFRG Part 572 NPRM in which the NHTSA approved methods and calibration values will become public knowledge. In addition to the calibration tests, manufacturers will also evaluate the capability of the dummy in other loading conditions such as oblique pendulum tests to the thorax and abdomen and oblique sled tests. Furthermore, an extensive series of tests will be necessary to evaluate the repeatability and reproducibility of the dummies with statistical confidence.

Finally, each Alliance member company has begun preparations to conduct fleet evaluations. These evaluations will include the proposed oblique pole and MDB tests. Further, it is likely that manufacturers will evaluate other testing conditions to gain a full understanding of the capabilities of both proposed as well as other side impact dummies. There are considerable efforts necessary to execute vehicle testing. First, the same facilities that are used to develop vehicles for production are used for these evaluations. Therefore, the testing facilities have many other commitments necessary for the conduct of normal business, including certification to existing FMVSS. After successfully scheduling the vehicle test, the dummy and vehicles must be prepared. For example, the data systems for different testing facilities within the same manufacturer may operate on different systems, requiring entry of the necessary data into the vehicle crash facility system. It is noted that most companies already have a heavy compliance testing schedule and can only incorporate a few additional tests each month to contribute to this evaluation.

Provided the dummies are supplied to the Alliance members and the calibration procedures for the SID-IIsFRG are published, the Alliance member companies plan to complete much of the dummy component level testing in 3-4 months and supply the initial results to the agency at that time. Subsequently, to complete the vehicle testing

process for each manufacturer's fleet, the Alliance estimates at least an additional 3-4 months. Allowing time for data analysis and conclusions, the members require 1-2 months to compile all results into recommendations for comment. Therefore, the Alliance requires a minimum of 8 months to complete its evaluation of the proposed dummies and test procedures. Until this evaluation is complete, the Alliance can only discuss the industry's experience to date, which is detailed in the following sections below.

SID-IIs Build Level C Experience and Preliminary Experience with the SID-IIsFRG

The ability of the Alliance to comment on the proposed SID-IIsFRG dummy is limited to the evaluations completed thus far by some of its members as part of the related activity by the OSRP and by researchers from Transport Canada. The OSRP SID-IIs Upgrade Task Group is responsible for coordinating, evaluating and approving any design modifications to the SID-IIs dummy, originally designed in 1994-95.

A technical summary of the Task Group's work, including evaluations of proposed design modifications, is included in Appendix A. The Task Group unanimously agreed to a majority of the proposed enhancements, which are recommended as either a running change to the Build Level C dummy or as major modifications to be incorporated into the Build Level D dummy. However, the Task Group did not agree to the implementation of the FRG. With NHTSA and VRTC as the only Task Group members taking exception, the Task Group agreed in August 2003 to state that there was no durability problem requiring the FRG and that the FRG caused serious changes to the chest deflection responses of the SID-IIs as compared to the original design. Therefore, the Task Group could not recommend a re-design of the thorax at that time.

Since August 2003, the Task Group has continued conducting tests and analyses on the SID-IIsFRG dummy (including lab tests, full vehicle crash tests, and biofidelity tests) as well as generating a SID-IIs Build Level C durability log to characterize and quantify the durability of the existing dummy in the field today. The durability log summarized SID-IIs exposures and the damage sustained, and though 18 dummies sustained damage during 241 reported exposures, the damaged ribs never exited the rib guides, in other words, their damage would not have been remedied by the FRG.

In the full vehicle crash tests, there are significant differences in the shape and magnitude of the chest deflection responses of the SID-IIsFRG and the Build Level C dummies. In addition, OSRP's biofidelity evaluation of the SID-IIsFRG indicates a biofidelity rating, per the ISO 9790 procedure, of "fair" (5.9) compared to the SID-IIs Build Level C rating of "good" (7.0).

Flat Topping and the FRG

In the background section of the NPRM (Pages 28000 and 28001), it was noted that in tests with the EuroSID-1 dummy, "the rib deflections indicated flat topping" and that this meant, "the dummy was not suitable for use in FMVSS 214". The background section devotes considerable discussion to the fact that the ES-2 was modified to reduce the likelihood of flat topping (in addition to reducing back plate loading). Yet, in the discussion on the SID-IIsFRG, the agency does not acknowledge the flat-topping observed by others, most notably by researchers at Transport Canada[7]. Tylko and Dalmotas observed distinct changes in the rib deflection-time histories in the SID-IIsFRG when tested in nominally identical tests to the original SID-IIs.

On Page 28006 of the NPRM, it is noted that the ribs "did not stay in place, which raised concerns regarding the accuracy of the acceleration and deflection measurements". This observation does not follow logically because it is quite normal to have the ribs deform during impact by expanding in the fore-aft dimension of the chest. The fact that they change shape and do not stay in place has nothing to do with the accuracy of the deflection measurements. Also, biofidelity tests show the accuracy of the acceleration and deflection measurements. As noted above, the original SID-IIs biofidelity of 7.0 is in the ISO-defined "good" range. In contrast, the SID-IIsFRG had a lower biofidelity score of 5.9, placing it in the "fair" category. These are objective comparisons. The agency's concerns regarding the ribs moving out of place are a subjective assessment, whereas the biofidelity data show there is no concern regarding the response. Transport Canada's tests show no flat topping in the original SID-IIs, but severe flat topping in the SID-IIsFRG.

Based on the evaluations by OSRP and Transport Canada, significant concerns have been identified regarding the necessity for the FRG, its biofidelity, and the possibility of unintended dummy response artifacts. This leads to the Alliance concern that the SID-IIsFRG has significant issues that were not discovered during NHTSA's testing. Therefore, the Alliance believes it is prudent to conduct a more extensive evaluation of the proposed SID-IIsFRG in order to understand the seriousness of these concerns and whether or not they can be resolved before endorsing the dummy for inclusion in FMVSS 214.

Preliminary Experience with the ES-2re

The OSRP and Transport Canada evaluated the ES-2re dummy to understand the changes made by the addition of the rib extensions. The results of the evaluation are detailed in the Appendix B[8]. The study included biofidelity testing, repeatability evaluation, comparison to ES-2 and WorldSID, and assessment of response to oblique loading.

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[7] "SID-IIs Response in Side Impact Testing", Tylko and Dalmotas, SAE 2004-01-0350

[8] " Technical Summary of OSRP-ES-2 Evaluation Task Group", September 2004.

The biofidelity testing was conducted in accordance with ISO 9790. Each evaluation test was conducted three times. The resulting overall ES-2re biofidelity rating is 4.2, with an ISO classification of "marginal". Repeatability was evaluated using the coefficients of variation (CVs) presented in the results of each biofidelity test (included in Appendices to the report). The neck and thorax regions showed good repeatability with the shoulder having excellent repeatability. However, the abdomen and pelvis had marginal repeatability.

Full-scale vehicle testing with small and mid-sized sedans showed that in the FMVSS 214 MDB test, the ES-2re driver dummy measured higher thoracic deflection than the ES-2 and WorldSID dummies under identical conditions. However the ES-2re rear passenger dummy exhibited lower thoracic deflection than the ES-2 and WorldSID in the FMVSS 214 MDB test. In addition, the ES-2re was also evaluated in oblique impacts with a linear impactor at 0, 15, and 30 degree angles. Publication of the results is pending full analysis of the data from these tests.

Injury Criteria

Thoracic Injury Criteria

The Alliance disagrees with the use of different types of thoracic injury criteria for the ES-2re and SID-IIsFRG dummies as proposed in the NPRM; specifically deflection- versus acceleration-based criteria. It is well accepted in the automotive biomechanics community that the mechanisms of injury do not differ between males and females. While the tolerance values for specific loading conditions may be different, the injury criteria, in general and for the thorax specifically, are not different because the injury criteria are the quantitative descriptors of the injury mechanisms.

In the discussion on the injury criteria for the ES-2re, the agency states, "Chest deflection has been shown to be the best predictor of thoracic injuries in low speed crashes" (Page 28002 of the FMVSS 214 NPRM). It also states, "Data from NASS indicates that the chest is still the predominant seriously injured body region and that serious chest injuries are prevalent in the modern vehicle fleet". Yet, the agency goes on to say that for the SID-IIsFRG, "The agency is not proposing a limit on chest deflection at this time" (Page 28006 of the FMVSS 214 NPRM).

The reason stated in the NPRM for not using deflection as the injury criterion with the SID-IIsFRG dummy is that the agency needs to obtain "more data on the dummy's rib deflection measurement capability under oblique loading conditions". The same could be said for the ES-2re dummy, which has a more unidirectional chest deflection response than the SID-IIs. In fact, other than WorldSID, there are no dummies available today that have addressed the ability of the ribs to accurately measure deflection in oblique loading.

The FMVSS 214 NPRM includes procedures for both a crabbed moving deformable barrier test and an oblique pole test. These tests are performed at angles other than 90 degrees between striking barrier and struck vehicle (or between the vehicle and the pole). Thus, the ES-2re dummy will experience an oblique impact condition like that experienced by the SID-IIsFRG dummy. Yet, the agency has proposed chest deflection criteria for the ES-2re dummy, but not for the SID-IIsFRG.

The Alliance believes that the real reason for this inconsistency in the proposal is because of the objections raised to the Floating Rib Guide addition to the SID-IIs dummy by the OSRP SID-IIs Enhancement Task Group. While these objections were detailed previously in these comments, a short synopsis of that work is relevant here.

The OSRP SID-IIs Task Group investigated possible upgrades to the SID-IIs dummy that its members had developed from 1993 to 1998. The NHTSA/VRTC proposed the addition of floating rib guides to the SID-IIs dummy based on a small series of sled tests, including a single abdominal offset sled test in which the ribs were damaged and exited the original rib guides. The test was performed with an improperly positioned and improperly scaled abdominal plate that simulated a rigid armrest. This setup produced a very severe impact condition for the SID-IIs (AF05) dummy. Instead of being properly scaled for the AF05, the test was performed with an abdominal plate that was offset 100 mm, which are the test conditions for the ES-2 (AM50) dummy. Further, the 100mm offset is at the extreme end of the range of armrest width in typical vehicles. In addition, the abdominal plate is rigid and therefore provided a more severe impact surface than do typically padded and deformable vehicle armrests. This test setup produced an impact condition for the AF05 dummy more severe than that of full-scale vehicle tests, since the dummy's ribs were damaged in the sled test but no rib damage occurred in the vehicle tests using the SID-IIs Version C.

The OSRP Task Force with NHTSA participation examined and compared data from tests with the original SID-IIs and the SID-IIsFRG and found that the SID-IIsFRG dummy caused a change in the character of the chest deflection-time histories in full vehicle tests. The FRG dummy chest deflections appeared to change shape and had greatly reduced magnitude when compared with those from a non-FRG dummy in nominally identical tests (Figures 4, 5 & 6)[9].

[9] "SID-IIs Response in Side Impact Testing", Tylko and Dalmotas, SAE 2004-01-0350

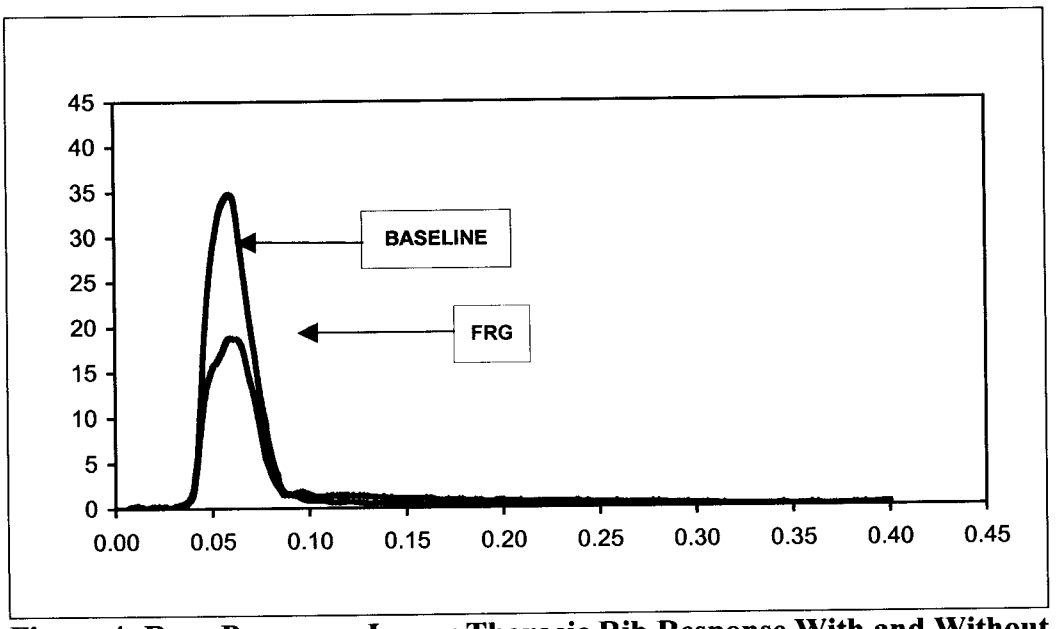

Figure 4: Rear Passenger Lower Thoracic Rib Response With and Without FRG

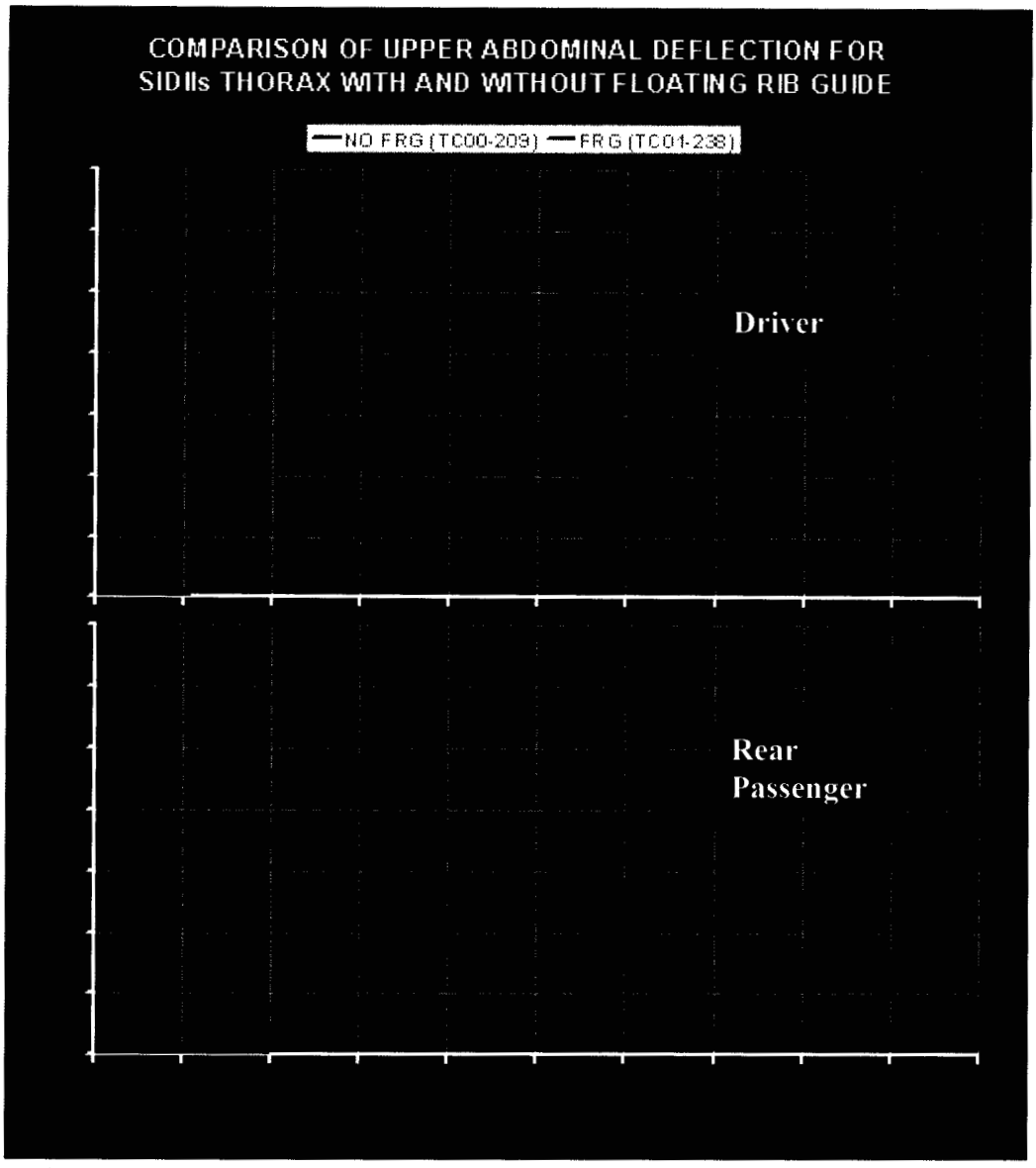

Figure 5: SID-IIs Upper Abdominal Deflection With and Without FRG

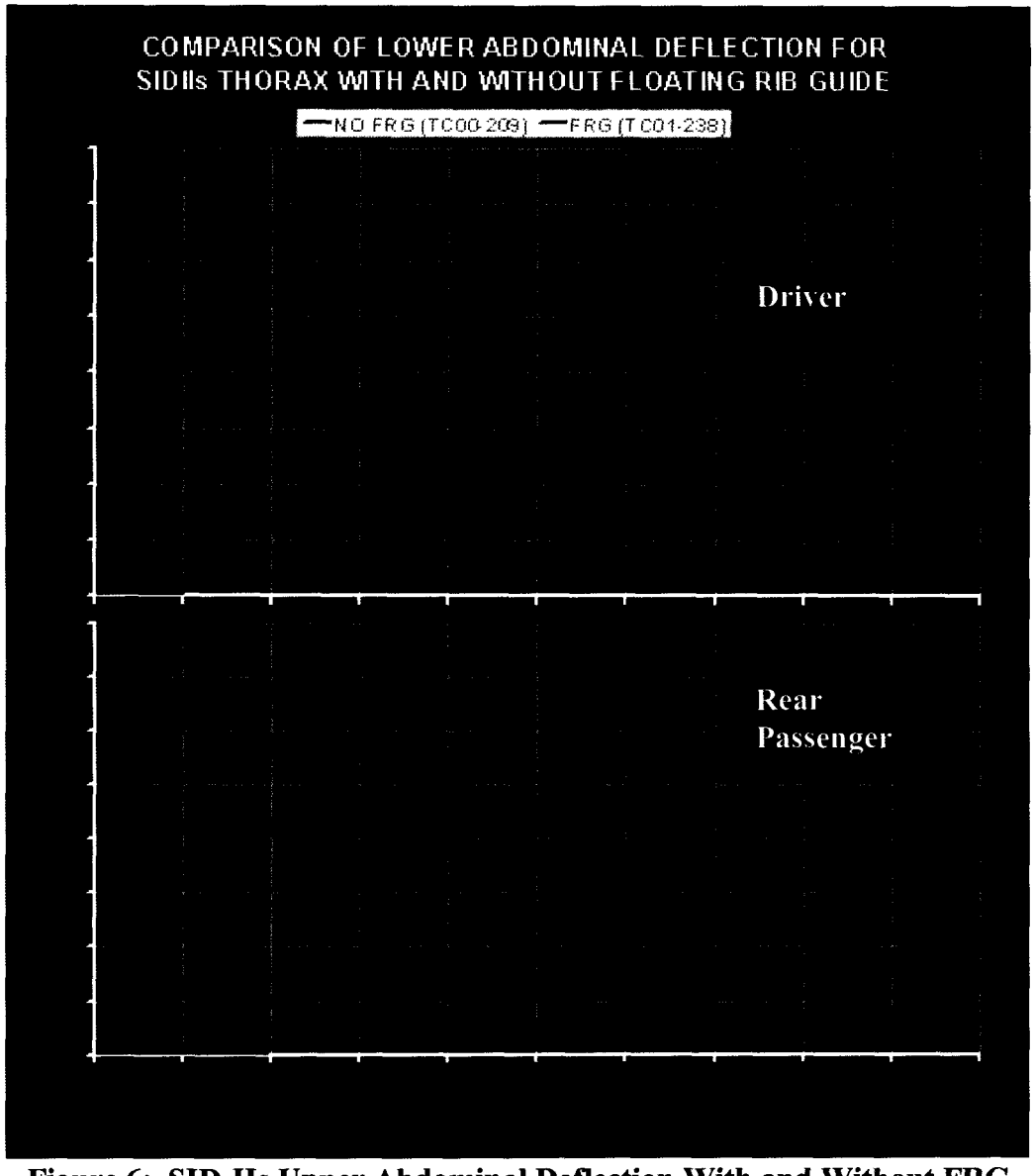

Figure 6: SID-IIs Upper Abdominal Deflection With and Without FRG

Much work has been performed since the 1990 amendment to FMVSS 214 to examine the relative merits of using deflection instead of acceleration for both frontal and side impact thoracic injury prediction[10]. These studies are nearly unanimous in the finding that chest deflection is a far superior predictor of injury than chest acceleration. The Alliance believes that chest acceleration is useful as a measure of the overall loading

[10] Horsch, JD, Melvin, JW, Viano, DC, and Mertz, HJ: "Thoracic Injury Assessment of Belt Restraint Systems Based on Hybrid III Chest Compression", Proceedings of the 35th Stapp Car Crash Conference, 1991.
Lau, IV, Horsch, JD, Viano, DC and Andrzejak, DV: "Mechanism of Injury from Air Bag Deployment Loads", Accident Analysis & Prevention, Vol. 25, No. 1, 1993.
Kent, R, Bolton, J, Crandall, J, Prasad, P, Nusholtz, G, Mertz, H, Kallieris, D.: "Restrained Hybrid III dummy-based criteria for thoracic hard tissue injury prediction", IRCOBI Conference on the Biomechanics of Impact, 2001.

to the body, and supports its use in product development to achieve a balance in the restraint loads between the shoulder, ribs and pelvis. However, the Alliance does not support the use of acceleration as an injury criterion for regulation since it does not assure that thoracic injury will not occur. It is possible to have balanced restraint loads, as indicated by low thoracic spine accelerations, but to have large, injurious rib deflections. Limits must be placed on thoracic and abdominal rib deflections to assure that the risks of thoracic and abdominal injuries are at acceptable levels for the simulated accident condition. The use of lower spine acceleration as an injury criterion is in direct contradiction to the agency's statements in support of deflection criterion for the ES-2re.

The Alliance agrees, in principle, with chest deflection as an injury criterion. However, the proposed limits depend on the severity of the test, the specified injury risk probability, and the ATD used in the test. As noted in other sections of this document, the Alliance does not have enough experience with the NHTSA proposed ATDs nor the test procedures to comment on the proposed injury values. For example, the Alliance does not have enough experience with the ES-2re to be able to comment on the appropriateness of the NHTSA-proposed value for this particular dummy. As detailed earlier, the Alliance members believe in the need for a fleet wide evaluation with the ES-2re before gaining the data necessary to comment on the tolerance limit as measured with this dummy.

The Alliance agrees with NHTSA that chest deflection is the best predictor of injury. However, the Alliance also believes that it is inconsistent to propose chest deflection limits for the 50th percentile male dummy yet neglect to include this relevant criterion for the 5th percentile female dummy. Further, proposing an acceleration-based criterion departs from the commonly accepted finding that deflection correlates better with injury in the field. Though the agency should consider the inclusion of appropriate thoracic deflection limits in possible future iterations of this rulemaking, such as an SNPRM, significant uncertainty exists with regard to the ability of the ES-2re and the SID-IIsFRG to measure loading in oblique conditions such as the proposed oblique barrier and oblique pole tests. Consequently, the agency's selection of dummies will affect whether or not the Alliance can support any proposed criteria limits.

Pelvic Injury Criteria

In 2004, NHTSA published the document ""Injury Criteria for Side Impact Dummies"[11]. On page 40 of this document, the agency states, "Bouquet's (1998)[12] analysis indicated that for subjects with AIS = 2 pelvic injuries, 28.4% of applied force on the cadaver was equal to the pubic force in the EuroSID-1". As detailed below, this statement is incorrect. Scale factors (SF) used are:

[11] "Injury Criteria for Side Impact Dummies", Kuppa, 2004.

[12] Bouquet, R., Ramet, M., Bermond, F., Vyes, C. (1998) Pelvic Human Response to Lateral Impact, 16th International Technical Conference on the Enhanced Safety of Vehicles, Paper No. 98-S7-W-16, National Highway Traffic Administration, Windsor, 1998.

a) The ratio of Post Mortem Human Subjects (PMHS) external load to EuroSID-1 external load for the same energy input (SF1); and

b) The ratio of EuroSID-1 pubic symphysis load to the external load on EuroSID-1 (SF2).

Bouquet et. al. concluded that for subjects with AIS ≥2, SF1 was 1.82 and SF2 was 28.4%. For subjects with AIS ≥3, the scale factors were 2.04 and 26.5%, respectively. This implies that to generate 6000 N at the pubic symphysis of the EuroSID-1, the external load on the dummy would be approximately 21,126 N (6000 N/0.284) and not as shown in the equations or in Figure 31, on page 40 of "Injury Criteria for Side Impact Dummies". According to Bouquet's 1998 paper (Table 11 and Figure 13 on pages 1677 and 1684, respectively), an external force of 21,126 N on a PMHS pelvis would result in 100% probability of AIS ≥3 injury. Therefore, NHTSA's proposal that a 6000 N limit for a pelvic injury criterion reflects a 25% risk of an AIS3+ injury measured at the pubic symphysis on ES-2re is incorrect. The Alliance believes that this issue must be resolved prior to setting a pubic symphysis force criterion.

The agency states in the NPRM, "The proposed 5100 N force level for the SID-IIsFRG corresponds to approximately 25 percent risk of AIS 3+ pelvic fracture." (Page 28007, Column 3, Paragraph 1). This contradicts the statement made in the technical document titled "Injury Criteria for Side Impact Dummies" (Page 55, Paragraph 2) where it is stated that 5200 N reflects 25% risk of an AIS 2+ injury.

The assumption made in the technical document titled "Injury Criteria for Side Impact Dummies" that, "...the normalized applied pelvic force in these cadaver tests was assumed to be equal to the sum of the forces in iliac wing and acetabulum of SID-IIsFRG under similar impact conditions" (Page 55, Paragraph 1) is not based on test data.

The technical document entitled "Injury Criteria for Side Impact Dummies" concludes, "...due to sparseness of pelvic injuries in the 42 side impact sled tests conducted at MCW, it was not possible to develop a robust pelvic injury criterion with this data set" (Page 37, Paragraph 2). Furthermore, the cost/benefit analysis may need to be revised to account for the inconsistencies in the pelvic injury criterion derivation.

For the reasons detailed above, the Alliance feels there is inadequate consensus for determining appropriate pelvic injury criteria for the ES-2re and the SID-IIsFRG.

The Alliance concludes that further research is required to establish valid pelvic injury criterion and will work with the agency to establish practicable IARV levels that will provide a reasonable level of occupant protection. Setting practicable IARV risk limits will also require accounting for practicable test severity levels.

[13] "Injury Criteria for Side Impact Dummies", Kuppa, 2004.

WorldSID

The Alliance is unclear why NHTSA did not choose to gain experience with the WorldSID dummy for consideration in this side impact standard. The WorldSID dummy has been a production dummy since February 12, 2004. A full drawing package, user's manual and calibration tests corridors were available as of March 6, 2004. To ensure that the WorldSID is available to the worldwide vehicle research community, the design details have been documented in ISO/WD 15830, which was recently approved by ISO/TC22/SC12/WG5, and is currently being reviewed and balloted at the Committee Draft level by ISO/TC22/SC12. This documentation, which consists of nearly 500 pages plus 400 fabrication drawings and CAD files, includes all of the design details, material specifications, and performance standards required for the fabrication of the WorldSID. Additionally, Injury Risk curves were made available from ISO in May 2004.

The WorldSID's biofidelity is superior to that of all other side impact dummies. ISO/TR 9790 specifies procedures for evaluating side impact dummy biofidelity performance using a series of 33 laboratory tests. Based on the ISO/TR9790 rating scale, the WorldSID rating is 7.6 ("Good" on a 10 point rating scale See Table 2.).

Table 2: WorldSID Biofidelity Rating

Body Region	Rating
Head	**10.0**
Neck	**5.6**
Shoulder	**7.1**
Thorax	**8.4**
Abdomen	**7.8**
Pelvis	**6.1**
Overall	**7.6**

In comparison, other currently used side impact dummies, US-SID, ES-2re, EuroSID-1, and ES-2, have ratings of 2.3, 4.2, 4.4, and 4.6 respectively. See Table 3.

[14] Bouquet, R., Ramet, M., Bermond, F., Vyes, C. (1998) Pelvic Human Response to Lateral Impact, 16th International Technical Conference on the Enhanced Safety of Vehicles, Paper No. 98-S7-W-16, National Highway Traffic Administration, Windsor, 1998.

[15] Zhu, J., Cavanaugh, J., King, A., "Pelvic Biomechanical Response and Padding Benefits in Side Impact Based on a Cadaveric Test Series," SAE Paper No. 933128, 37th Stapp Car Crash Conference, 1993.

Table 3: Biofidelity Ratings for Current Side Impact Dummies

Body Region	SID	EuroSID-1	ES-2	ES-2re	BioSID	WorldSID
Head	0.0	5	5	5.0	10.0	10.0
Neck	2.5	7.8	4.4	3.8	6.5	5.6
Shoulder	0.0	7.3	5.3	4.5	7.3	7.1
Thorax	3.1	5.4	5.2	4.5	6.8	8.4
Abdomen	4.4	0.9	2.6	3.9	5.6	7.8
Pelvis	2.5	1.5	5.3	3.4	5.0	6.1
Overall	**2.3**	**4.4**	**4.6**	**4.2**	**6.2**	**7.6**

The WorldSID dummy has gone through a more extensive evaluation than either the SID-IIS FRG and ES-2re dummies proposed in this NPRM. In total, testing has included nearly 1000 whole dummy biofidelity, vehicle, and component tests. The WorldSID dummy has undergone 24 full-scale vehicle tests involving either a vehicle-to-pole impact or an MDB-to-vehicle impact. These tests have been conducted in sixteen different test labs and agencies in at least ten different countries including testing by governmental agencies in Canada, Japan, Australia, and various organizations as part of a framework research program of the European Commission. Eleven pre-production level dummies were used for this extensive evaluation. Almost all of the eleven dummies have been upgraded to production-level dummies, making the WorldSID dummy more available at the time of the publication of the NPRM than the ES-2re and SID-IIs FRG, which were owned solely by the NHTSA and OSRP.

The Alliance is pleased that the agency has agreed to evaluate the WorldSID dummy and that testing is planned to begin in November 2004. The Alliance hopes that the agency continues its testing as planned and uses these results to consider the dummy in its present side impact rulemaking effort.

Appendix A

Technical Summary of OSRP
SIDIIs Upgrade Task Group

Technical Summary of OSRP – SIDIIs Upgrade Task Group
September 2004

Table of Contents:

Background:

The Occupant Safety Research Partnership (OSRP) SIDIIs Upgrade Task Group was initiated in 2002 to manage upgrades to the existing (build level C) SIDIIs dummy. The SIDIIs dummy is a second-generation side-impact dummy (SID-IIs) that is sized to represent a small adult female and was originally designed in 1994-95 [1]. The specific objectives of the Upgrade Task Group are to coordinate, evaluate and approve design modifications to the dummy as well as to recommend improvements in verification test procedures.

Participating Organizations:

The following organizations have attended task group meetings and/or have contributed testing to the project:

- Ford Motor Company (OSRP member company)
- General Motors (OSRP member company)
- DaimlerChrysler Corporation (OSRP member company)

- Transport Canada
- National Highway Traffic Safety Administration (NHTSA)
- NHTSA Vehicle Research & Test Center (VRTC)
- First Technology Safety Systems (FTSS)
- Denton ATD, Inc.
- Insurance Institute of Highway Safety (IIHS)

Improvements in Verification Test Procedures:

Improvements to the verification test procedures were proposed to reduce variability and improve efficiency in verification testing. Reduced verification test variability allows tighter performance corridors on the dummy potentially increasing crash test repeatability with the dummy. The task group has unanimously endorsed the following changes to the verification test procedure:

- Removing rib acceleration corridors from verification testing
- Using a bench-type verification test similar to WorldSID
- Adopting changes to some test parameters such as filter classes, dummy clothing, etc.
- Adopting changes to some impact speeds to improve consistency between test types

VRTC drafted a bench test verification procedure [2] encompassing these changes which the task group has endorsed. The development of new performance corridors is pending, as various laboratories are currently conducting tests with the new procedure. Data from tests conducted with the newly developed verification test procedure will be statistically analyzed to establish verification corridors.

Proposed Design Modifications:

Many design modifications have been proposed to the SIDIIs dummy and reviewed by the OSRP SIDIIs Upgrade Task Group. These design modifications are tabulated below and categorized into two dummy "build levels", namely: SIDIIs-FRG and SIDIIs-enhanced (also referred to as build level D). Build level C is the original SIDIIs dummy as currently in use at many laboratories.

Table 1.
SIDIIs Design Modifications

SIDIIs- build level C	**SIDIIs – FRG**	**SIDIIs – enhanced** **(Build level D)**
(design modifications reviewed by task group and approved as running change to build level C)	*(design modifications associated with FRG build combination)*	*(design modifications recommended by task group for future build level of dummy)*
Femur Flange Redesign (eliminates interference with acetabulum load cell.)	**Femur Flange Redesign**	**Femur Flange Redesign**
Femur Holding Shaft Redesign (required to improve fit and reduce mechanical noise.)	**Femur Holding Shaft Redesign**	**Femur Holding Shaft Redesign**
	Shoulder Rib Redesign (with thinner, taller damping material to improve durability)	**Shoulder Rib Redesign**
	Front Rib Guide Redesign (enhancement of static guide to improve rib control.)	**Front Rib Guide Redesign**
	Neck Mounting Bracket Redesign (required to eliminate interference with shoulder redesign)	**Neck Mounting Bracket Redesign**
	Redesigned Rib Stops	**Redesigned Rib Stops**
	Spine Box Redesign (required to enable other design modifications.)	**Spine Box Redesign**
	Thorax Pad Attachment Redesign.(improves repeatability of pad to rib interface.)	**Thorax Pad Attachment Redesign**
	Floating Rib Guide	
		Linear Pot Redesign (increase housing diameter to ½ " to improve durability)
Linear Pot / Accelerometer Mount Redesign. (allows greater vertical R.O.M. of ribs.)		**Linear Pot / Accelerometer Mount Redesign.**

The vast majority of the design improvements reviewed by the task group were unanimously agreed to as positive improvements to the dummy. Thus, they are recommended for rollout to the dummy design either as a running change for build level C, or as a group of major modifications in a future build level D (SIDIIs – enhanced) as indicated in Table 1.

The task group has not agreed to the implementation of the Floating Rib Guide (FRG) in future upgrades to the dummy. The FRG is a redesign of the SIDIIs thorax originally proposed by NHTSA – VRTC and TRC. It was intended to prevent the SIDIIs ribs from exiting the static rib guides in the front and rear of the dummy. NHTSA – VRTC developed the FRG in conjunction with FTSS and provided the OSRP task group with a number of presentations updating the group on the FRG development and FRG test results.

Rhule (NHTSA-VRTC) and Hagedorn (TRC) have published 2 reports summarizing the FRG work; one on the FRG development [3], and one on the FRG repeatability [4].

After much debate and serious consideration of all test data presented, the task group nearly unanimously agreed (with NHTSA and VRTC taking exception) on 8/8/03 to the following statement concerning the implementation of the FRG.

> *"The majority of task group members have not observed a durability problem with the dummy requiring an FRG. Testing has indicated serious reductions in the measured maximum chest deflections and changes in the shape of the chest deflection time-histories in the dummy with the FRG when compared to testing under similar loading conditions without the FRG. Therefore, the task group does not recommend a re-design at this time. The chairman will agree to collect and tabulate durability issues from different laboratories. This summary will include number of crash tests, number of damaged parts, estimate the cause of the damage, categorize damage, maximum rib deflection, etc. If a future review of this durability data reveals a significant problem with durability, then the issue of the FRG will be re-addressed."*

In addition to the testing that VRTC did on the FRG [3, 4], the testing and analysis that the OSRP task group conducted relative to the SIDIIs-FRG can be categorized as follows:

1. A durability log was created which quantified types and frequencies of damage to the SIDIIs (build level C) during full vehicle crash tests at various laboratories.

2. Additional lab tests conducted on the SIDIIs-FRG at OSRP laboratories.

3. Full vehicle crash test data was reviewed comparing the performance of FRG to non-FRG dummies.

4. Biofidelity tests were conducted on a SIDIIs-FRG dummy per ISO9790 [5] to be used in comparison to the biofidelity scores of the original SIDIIs dummy as documented by Scherer, et al [6].

OSRP Data

SIDIIs Durability Logs

The OSRP Upgrade Task Group has tabulated and quantified damage that has occurred to SIDIIs dummies during full vehicle side impact crash testing at GM, DaimlerChrysler, IIHS, and Transport Canada. These laboratories documented any damage to the SIDIIs that occurred during testing and used a combination of proactive and forensic methods to determine whether

the dummy's ribs were exiting the static rib guides during the crash tests. Maximum rib deflections, test types, test dates, etc. were also recorded for each SIDIIs exposure. In all, 241 SIDIIs exposures have been inspected and documented thus far. A brief tabulation of the durability data is listed in Table 2. The damage types reported in Table 2 occurred on ribs that gave no indication of exiting the rib guides, or conversely stated, the small percentage of ribs which exited the guides (0.3%) had no reported damage.

Table 2.
Summary of OSRP SIDIIs Damage Log
(Collected from full vehicle crash tests at GM, DCX, IIHS, and TC)

	SIDIIs Exposures	Rib Exposures
# Reported	241	1446
# with damage	18	27
% with damage	7.5	1.9
# with ribs leaving guides	3	4
% with ribs leaving guides	1.2	0.3
# with damage type:		
damping material damaged		
damping material debonded		6
rib steel bent		6
pot shaft bent		12
pot shaft broken		
pot housing detached from bushing		
pot bushing detached from bearing		
Other		3

Additional Lab Tests Conducted at OSRP Labs

Three lab test series using the SIDIIs-FRG prototype were completed at Ford.

1. Pull tests were conducted to determine the force necessary to move the Floating Rib Guide. *(completed)*

2. A linear impactor series was conducted to evaluate the interactions between the ribs and the FRG in lateral and oblique impacts. *(completed)*

3. A second linear impactor series was performed to compare the SIDIIs (build level C) to the SIDIIs-FRG, and also to provide a more thorough look at the oblique impacts on the SIDIIs-FRG. *(testing completed, analysis in process)*

The pull tests were conducted on both the upper and lower sections of the FRG. With the dummy in its storage seat (a reclined chair), the FRG was pulled perpendicular to its outer surface using a force gage (Figure1.) Wire was wrapped around the FRG so that the force vector was at the center of each section. The minimum force necessary to initiate motion of the FRG was 12 lb (53 N) for the lower portion and 8 lb (36 N) for the upper portion. The maximum displacement of the FRG was 20 mm for the lower portion and 22 mm for the upper portion, requiring 48-lb (213 N) and 42-lb (187 N) forces, respectively.

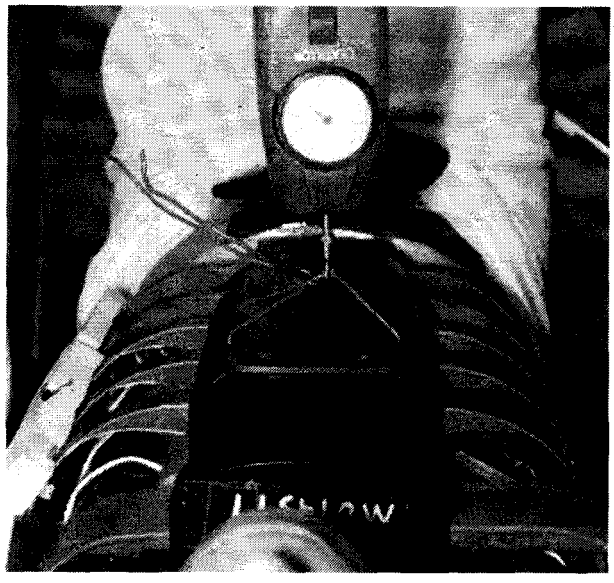

Figure 1.
Laboratory test to measure FRG resistance.

The purposes of the first linear impactor series were to determine the effect of contact between the ribs and the rib stops, and to determine the effect of oblique loading on those contacts. A SIDIIs-FRG was positioned on a flat table with its legs extended and back vertical. The head, neck, and shoulder were removed for high-speed video coverage of the contact points inside the chest cavity. The impactor face was a 6-inch diameter flat plate which simulated the pendulum face used for the small female Hybrid III thorax impact test. The dummy was impacted with a 23 lb (10 kg) impactor at 15 mph (6.7 m/s), with the impact centered at the center of thorax rib 2. One run was completed at each of 4 angles: 0°, 15° rear, 30° rear, and 15° forward. A test at 30° forward was not attempted due to a failure of the FRG parts on the 15° forward run. Two springs and one rod from the rear FRG broke from the spine attachments and fell into the chest cavity during the 15° forward impact, preventing the FRG from returning to its initial position. At 0° and 15° forward the ribs did not contact the rib stop. However, at 15° rear and 30° rear, the ribs contacted the rib stops before full deflection was reached. All runs show a change in the slope of the rib deflection curve that coincides with the contact between the rib and FRG.

Ford's second linear impact series had two purposes: 1) to further evaluate oblique loading using more test runs than the first series, and 2) to compare the lateral response of SIDIIs and SIDIIs-FRG. The setup for this series included a simulated seat that allowed a 10° back angle on the dummy, while keeping the head level. The impactor face was a 3x8 inch rectangular plate that impacted only two ribs. It was angled 10° to match the angle of the dummy's ribs. The dummy was impacted at 9 mph (4.3 m/s) with a weight of 70 lb (32 kg) for lateral and oblique tests.

Additional lateral tests were performed with 50 lb (23 kg) at 9mph (4.3 m/s). Three impact locations were tested: 1) thorax ribs 1 and 2, 2) thorax rib 3 and abdomen rib 1, and 3) abdomen ribs 1 and 2. Three angles were used for the 70-lb (32 kg) tests, 0°, 15° rear, and 15° forward. In total, 38 tests were conducted in this series. Testing is complete and data analysis is currently underway.

Full Vehicle Crash Tests Comparing FRG to non-FRG Dummy Performance

The task group has reviewed data from full vehicle side impact crash tests to compare SIDIIs-FRG dummy performance to a baseline dummy (build level C) with no FRG. One pair of identically run crash tests (IIHS moving deformable barrier) were conducted by Transport Canada, while another pair of identically run crash tests (20 mph, 15 degree oblique pole) are currently in process at Ford.

The first Transport Canada test used two SIDIIs dummies (driver and rear passenger) while the second test used two SIDIIs-FRG dummies in the same seating positions. The two tests were on identically equipped passenger vehicles, with nearly identical impact speeds, dummy positions, vehicle masses, etc. Comparisons of vehicles accelerations and dummy accelerations indicated that the dummies were subjected to nominally identical loading conditions between the two tests. Data review showed the test conditions were identical within the range of test-to-test repeatability.

These tests were documented in detail by Tylko and Dalmotas [7], however two plots are recreated here as Figures 2 and 3 to demonstrate the differences in FRG and non-FRG rib deflection measurements when subjected to nominally identical loading conditions.

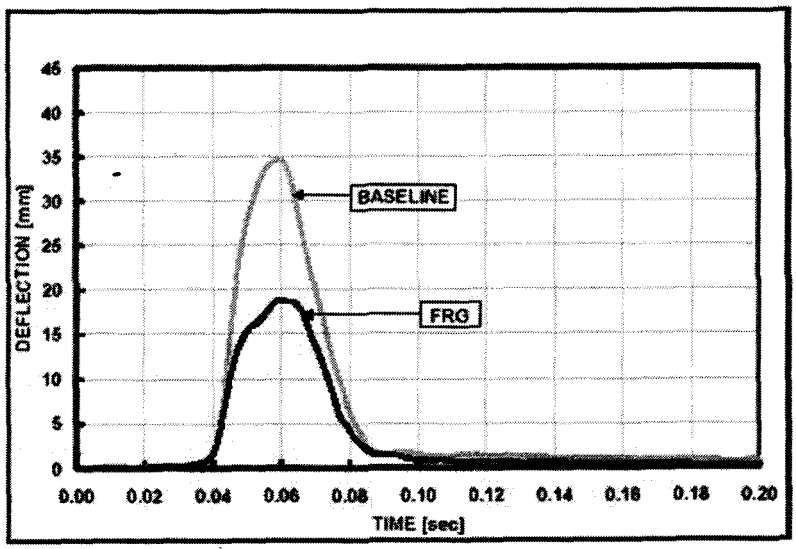

Figure 2.
Lower thoracic rib deflection for rear passenger dummies in two identically conducted MDB side impact tests.

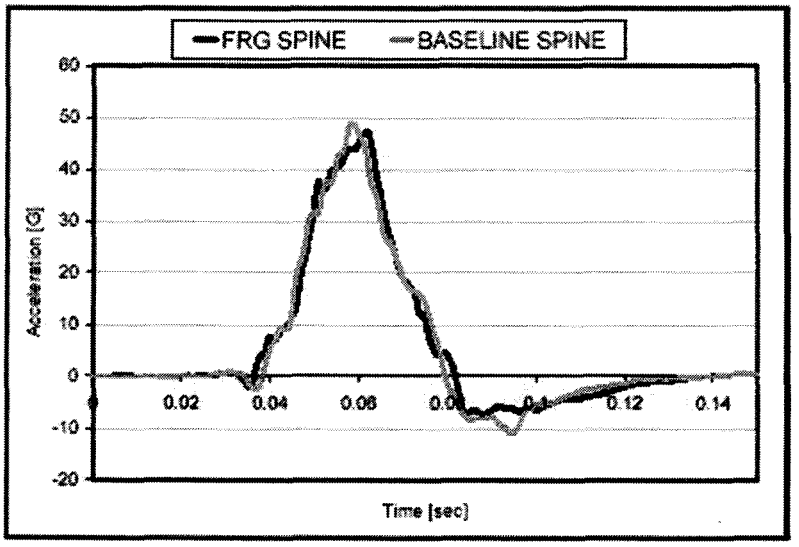

Figure 3.
Spine accelerations for rear passenger dummies in the same two identically conducted MDB side impact tests as in Figure 2.

Biofidelity Testing of SIDIIs –FRG

The OSRP task group conducted biofidelity testing per ISO9790 [5] on a SIDIIs-FRG dummy for comparison to the original SIDIIs dummy's biofidelity score of 7.0 [6]. The testing was conducted at the laboratories of General Motors, Ford, and Transport Canada. Some ISO 9790 tests (such as head drop tests) were not conducted on the SIDIIs-FRG because the design changes associated with the FRG would not affect the performance in those tests. In these cases, the original scores were applied to the SIDIIs-FRG. Other tests were not conducted on either dummy due to lack of specific padding or severity of rigid test condition.

Time history data plots for the SIDIIs-FRG biofidelity tests are included in Appendix 1, while the time history data plots for the original SIDIIs are reported by Scherer, et al [6]. As an example of differences noted in dummy responses, the armrest force (Abdomen Test #1, 1 meter drop) for the FRG and the original SIDIIs dummy are recreated here as Figures 4 and 5, respectively. In both Figures, the solid-line corridors are the pertinent corridors for comparison (representing scaled cadaver responses [5]).

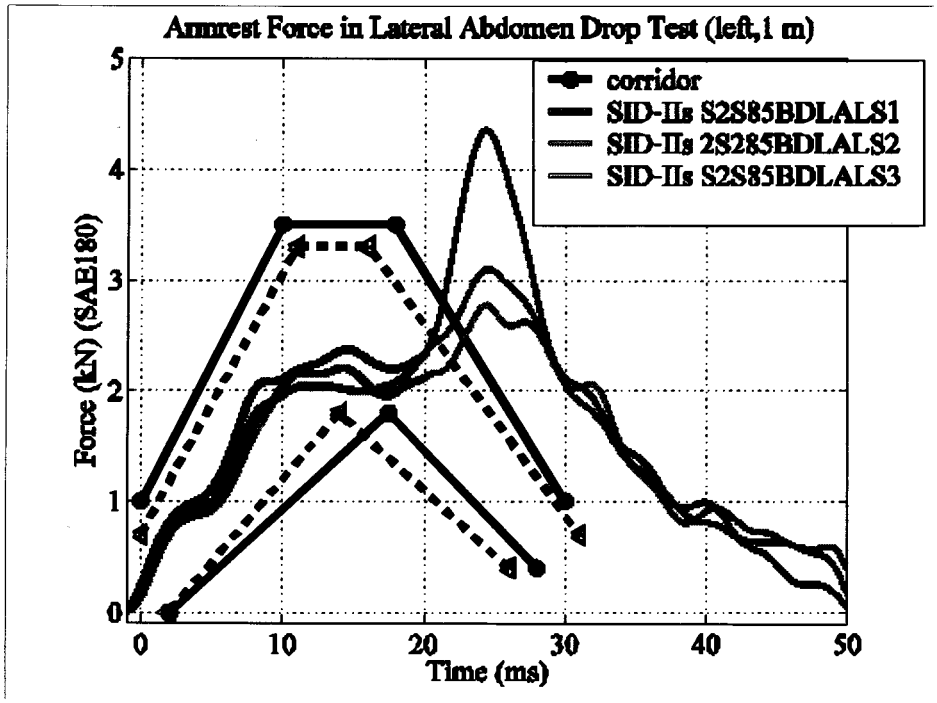

Figure 4
Armrest force for SIDIIs-FRG in ISO 9790 Abdomen Test #1 (1 meter drop test)
Biofidelity ratings for the three repeat tests: 5,5,0

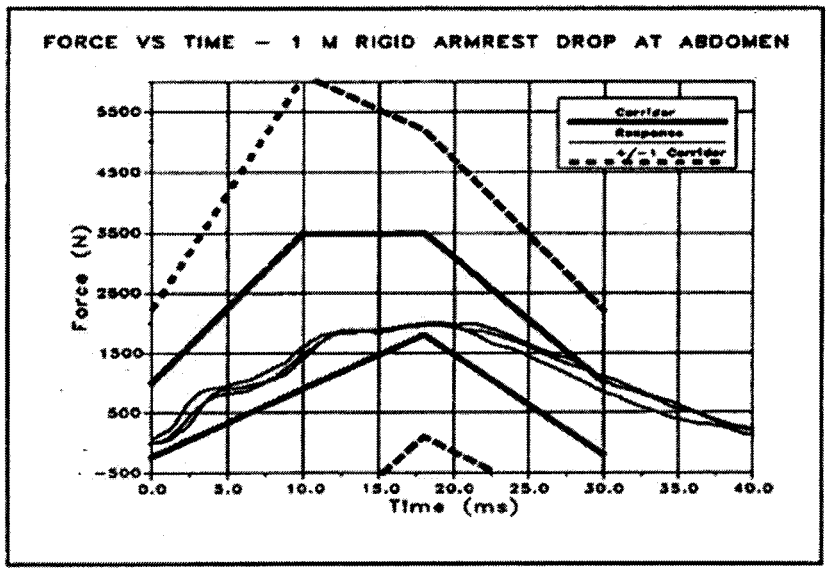

Figure 5 [6]
Armrest force for original SIDIIs in ISO9790 Abdomen Test #1 (1 meter drop test)
Biofidelity ratings for the three repeat tests: 10,10,10

A summary of the biofidelity scores for the SID-IIs and the SIDIIs-FRG as well as a summary of the tests conducted are listed in Table 3. For the original SIDIIs, only the scores from the non-neck shield tests were used (to be consistent with the recent SIDIIs-FRG tests.) The overall biofidelity score for the original SIDIIs is 7.0 (classified as good per ISO 9790); the overall biofidelity score for the SIDIIs-FRG is 5.9 (classified as fair per ISO 9790.) Most of the degradation in the biofidelity score of the SIDIIs-FRG was in the thorax and abdomen scores.

Table 4 summarizes the biofidelity scores considering only those tests conducted on both dummies. That is, it excludes the 2 tests (abdomen test 2 and pelvis test 12) conducted only on the SIDIIs-FRG from the calculations. The overall biofidelity score does not change.

It should be noted that the changes in neck biofidelity score are driven by the fact that the input to the neck during testing is governed by the response of the shoulder and thorax. Therefore, changes to the biofidelity of the shoulder and/or thorax may be reflected in changes to the biofidelity score of the neck.

Table 3
Summary of Biofidelity Scores for SIDIIs and SIDIIs – FRG

		Test Biofidelity				
Body Test No. & Test Description	Test Weighting, Vi,j	Original SIDIIs	SIDIIs / FRG	SIDIIs Enhanced	New tests conducted on SIDIIs-FRG?	Comments
Head Test 1 200 mm Rigid Drop	8	7.5	7.5	TBD	N	No new tests on FRG
Head Test 2 1200 mm Padded Drop	4	N. M.	N. M.	N. M.	N	Not conducted
Head Biofidelity, B1		**7.5**	**7.5**	**TBD**		
Neck Test 1 7.2 G Sled Impact	7	6.8	5.6	TBD	Y	
Neck Test 2 6.7 G Sled Impact	6	3.5	3.5	TBD	Y	
Neck Test 3 12.2 G Sled Impact	3	4.9	5.7	TBD	Y	
Neck Biofidelity, B2		**5.2**	**4.8**	**TBD**		
Shoulder Test 1 4.5 m/s Pendulum	6	5.0	5.2	TBD	Y	
Shoulder Test 2 7.2 G Sled Impact	5	10.0	5.0	TBD	Y	
Shoulder Test 3 12.2 G Sled Impact	3	5.0	5.0	TBD	Y	
Shoulder Test 4 8.9 m/s Padded Sled	7	5.0	5.0	TBD	Y	
Shoulder Biofidelity, B3		**6.2**	**5.1**	**TBD**		
Thorax Test 1 4.3 m/s Pendulum	9	10.0	7.8	TBD	Y	
Thorax Test 2 6.7 m/s Pendulum	9	10.0	6.7	TBD	Y	
Thorax Test 3 1.0 m Rigid Drop	6	9.2	8.3	TBD	Y	
Thorax Test 4 2.0 m Padded Drop	5	N. M.	N. M.	N. M.		Can not conduct tests
Thorax Test 5 6.8 m/s Rigid Sled	7	3.9	4.3	TBD	Y	
Thorax Test 6 8.9 m/s Padded Sled	7	5.0	5.0	TBD	Y	
Thorax Biofidelity, B4		**7.8**	**6.5**	**TBD**		
Abdomen Test 1 1.0 m Rigid Drop*	7	9.2	7.1	TBD	Y	
Abdomen Test 2 2.0 m Rigid Drop*	6	N. M.	6.3	TBD	Y	Only conducted on SIDIIs-FRG
Abdomen Test 3 6.8 m/s Rigid Sled	3	5.0	3.3	TBD	Y	
Abdomen Test 4 8.9 m/s Rigid Sled	3	N.M.	N.M.	N.M.		Can not conduct tests
Abdomen Test 5 8.9 m/s Padded Sled	7	10.0	5.0	TBD	Y	
Abdomen Biofidelity, B5		**8.8**	**5.7**	**TBD**		
Pelvis Test 1 6.0 m/s Pendulum Impact	8	10.0	10.0	TBD	N	No new tests on FRG
Pelvis Test 2 10.0 m/s Pendulum Impact	9	N.M.	N. M.	N. M.		Can not conduct tests
Pelvis Test 3 0.5 m Rigid Drop	4	5.0	5.0	TBD	Y	
Pelvis Test 4 1.0 m Rigid Drop	4	6.7	5.0	TBD	Y	
Pelvis Test 5 2.0 m Padded Drop	3	N. M.	N. M.	N. M.		Can not conduct tests
Pelvis Test 6 3.0 m Padded Drop	5	N. M.	N. M.	N. M.		Can not conduct tests
Pelvis Test 7 6.8 m/s Rigid Sled	8	6.1	4.4	TBD	Y	
Pelvis Test 8 8.9 m/s Rigid Sled	7	N.M.	N. M.	N. M.		Can not conduct tests
Pelvis Test 9 8.9 m/s Padded Sled	8	N. M.	N. M.	N. M.		Can not conduct tests
Pelvis Test 10 6.8 m/s Rigid Sled	3	1.1	2.2	TBD	Y	
Pelvis Test 11 8.9 m/s Rigid Sled	3	N.M.	N.M.	N.M.		Can not conduct tests
Pelvis Test 12 8.9 m/s 15 psi Padded SI	3	N.M.	1.1	TBD	Y	Only conducted on SIDIIs-FRG
Pelvis Test 13 8.9 m/s 23 psi Padded SI	7	2.2	4.2	TBD	Y	
Pelvis Biofidelity, B6		**5.7**	**5.3**	**TBD**		
N.M. = Not Measured						
SIDIIs Original Overall Biofidelity, B		**7.0**	**5.9**	**TBD**		

**: note: rib accelerations excluded from Abdomen Test #1 and #2 ratings for all dummies*

Table 4
Summary of Biofidelity Scores for SIDIIs and SIDIIs-FRG
(Only Common Tests Tabulated)

		Test Biofidelity				
	Test Weighting, Vi,j	Original SIDIIs	SIDIIs / FRG	SIDIIs Enhanced	New tests conducted on SIDIIs-FRG?	Comments
Body Test No. & Test Description						
Head Test 1 200 mm Rigid Drop	8	7.5	7.5	TBD	N	No new tests on FRG
Head Test 2 1200 mm Padded Drop	4	N. M.	N. M.	N. M.	N	Not conducted
Head Biofidelity, B1		**7.5**	**7.5**	**TBD**		
Neck Test 1 7.2 G Sled Impact	7	6.8	5.6	TBD	Y	
Neck Test 2 6.7 G Sled Impact	6	3.5	3.5	TBD	Y	
Neck Test 3 12.2 G Sled Impact	3	4.9	5.7	TBD	Y	
Neck Biofidelity, B2		**5.2**	**4.8**	**TBD**		
Shoulder Test 1 4.5 m/s Pendulum	6	5.0	5.2	TBD	Y	
Shoulder Test 2 7.2 G Sled Impact	5	10.0	5.0	TBD	Y	
Shoulder Test 3 12.2 G Sled Impact	3	5.0	5.0	TBD	Y	
Shoulder Test 4 8.9 m/s Padded Sled	7	5.0	5.0	TBD	Y	
Shoulder Biofidelity, B3		**6.2**	**5.1**	**TBD**		
Thorax Test 1 4.3 m/s Pendulum	9	10.0	7.8	TBD	Y	
Thorax Test 2 6.7 m/s Pendulum	9	10.0	6.7	TBD	Y	
Thorax Test 3 1.0 m Rigid Drop	6	9.2	8.3	TBD	Y	
Thorax Test 4 2.0 m Padded Drop	5	N. M.	N. M.	N. M.		Can not conduct tests
Thorax Test 5 6.8 m/s Rigid Sled	7	3.9	4.3	TBD	Y	
Thorax Test 6 8.9 m/s Padded Sled	7	5.0	5.0	TBD	Y	
Thorax Biofidelity, B4		**7.8**	**6.5**	**TBD**		
Abdomen Test 1 1.0 m Rigid Drop*	7	9.2	7.1	TBD	Y	
Abdomen Test 2 2.0 m Rigid Drop*	6	N. M.	N.C.	TBD	Y	
Abdomen Test 3 6.8 m/s Rigid Sled	3	5.0	3.3	TBD	Y	
Abdomen Test 4 8.9 m/s Rigid Sled	3	N.M.	N.M.	N.M.		Can not conduct tests
Abdomen Test 5 8.9 m/s Padded Sled	7	10.0	5.0	TBD	Y	
Abdomen Biofidelity, B5		**8.8**	**5.6**	**TBD**		
Pelvis Test 1 6.0 m/s Pendulum Impact	8	10.0	10.0	TBD	N	No new tests on FRG
Pelvis Test 2 10.0 m/s Pendulum Impact	9	N.M.	N. M.	N. M.		Can not conduct tests
Pelvis Test 3 0.5 m Rigid Drop	4	5.0	5.0	TBD	Y	
Pelvis Test 4 1.0 m Rigid Drop	4	6.7	5.0	TBD	Y	
Pelvis Test 5 2.0 m Padded Drop	3	N. M.	N. M.	N. M.		Can not conduct tests
Pelvis Test 6 3.0 m Padded Drop	5	N. M.	N. M.	N. M.		Can not conduct tests
Pelvis Test 7 6.8 m/s Rigid Sled	8	6.1	4.4	TBD	Y	
Pelvis Test 8 8.9 m/s Rigid Sled	7	N.M.	N. M.	N. M.		Can not conduct tests
Pelvis Test 9 8.9 m/s Padded Sled	8	N. M.	N. M.	N. M.		Can not conduct tests
Pelvis Test 10 6.8 m/s Rigid Sled	3	1.1	2.2	TBD	Y	
Pelvis Test 11 8.9 m/s Rigid Sled	3	N.M.	N.M.	N.M.		Can not conduct tests
Pelvis Test 12 8.9 m/s 15 psi Padded SI	3	N.M.	N.C.	TBD	Y	
Pelvis Test 13 8.9 m/s 23 psi Padded SI	7	2.2	4.2	TBD	Y	
Pelvis Biofidelity, B6		**5.7**	**5.6**	**TBD**		
N.M. = Not Measured, N.C.=Not Considered						
SIDIIs Original Overall Biofidelity, B		**7.0**	**5.9**	**TBD**		

**: note: rib accelerations excluded from Abdomen Test #1 and #2 ratings for all dummies*

References

1. Daniel, R.P., Irwin, A., Athey, J., Balser, J., Eichbrecht, P., Hultman, R.W., Kirkish, S., Kneisly, A., Mertz, H.J., Nusholtz, G.S., Rouhana, S.W., Scherer, R., Salloum, M., Smrcka, J.: "Technical Specifications of the SID-IIs Dummy", 39th Stapp Car Crash Conference Proceedings, SAE Technical Paper No. 952735, 1995.

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7. Tylko, S., and Dalmotas, D., "SID-IIs Response in Side Impact Testing", Rollover, Side and Rear Impact (SP-1880), SAE Paper 2004-01-0350, 2004.

Appendix 1 – ISO 9790 Biofidelity Test Results of SIDIIs-FRG

(solid line corridors used for all ratings)

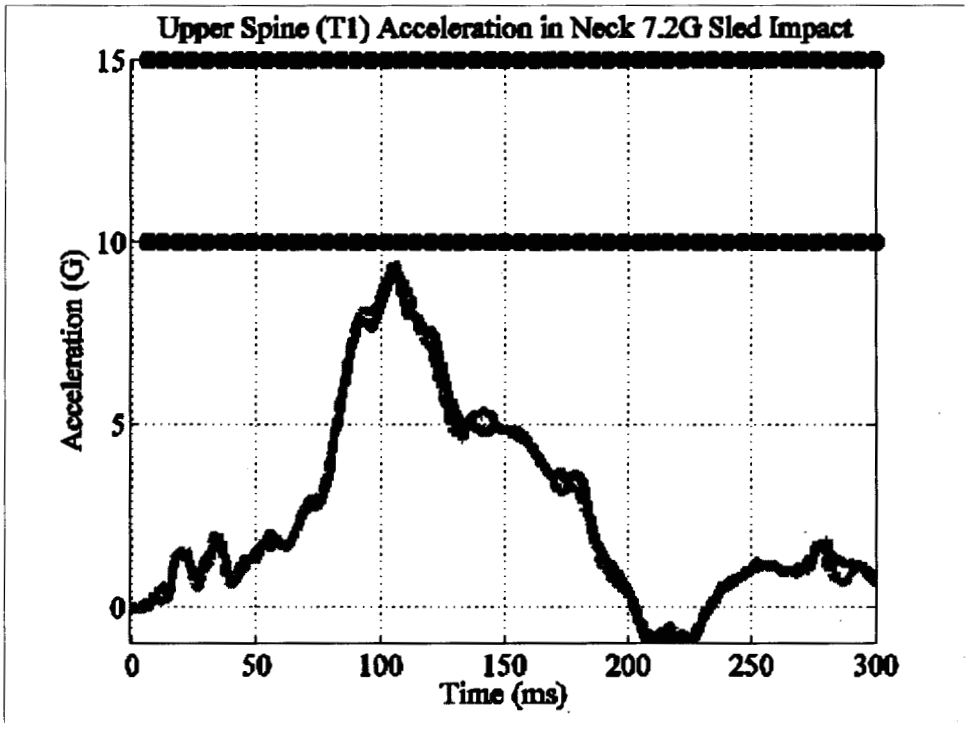


Figure A- 1: Neck Test #1, Shoulder Test #2 (rating 5,5,5)

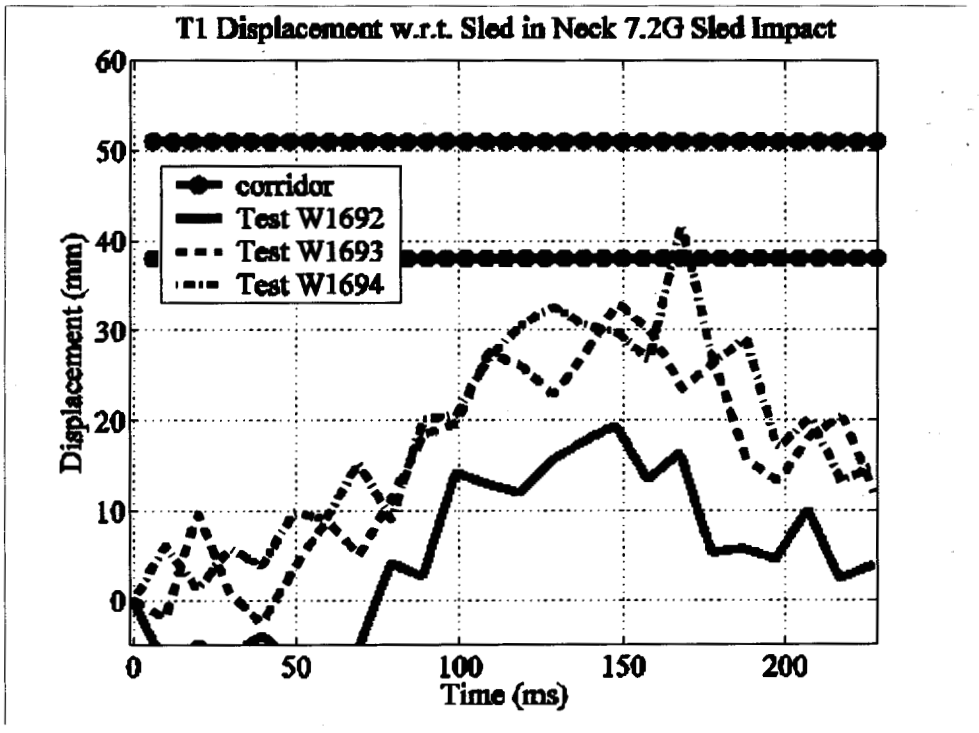


Figure A- 2: Neck Test #1, Shoulder Test #2 (rating 10,5,0)

Appendix 1 – ISO 9790 Biofidelity Test Results of SIDIIs-FRG

(solid line corridors used for all ratings)

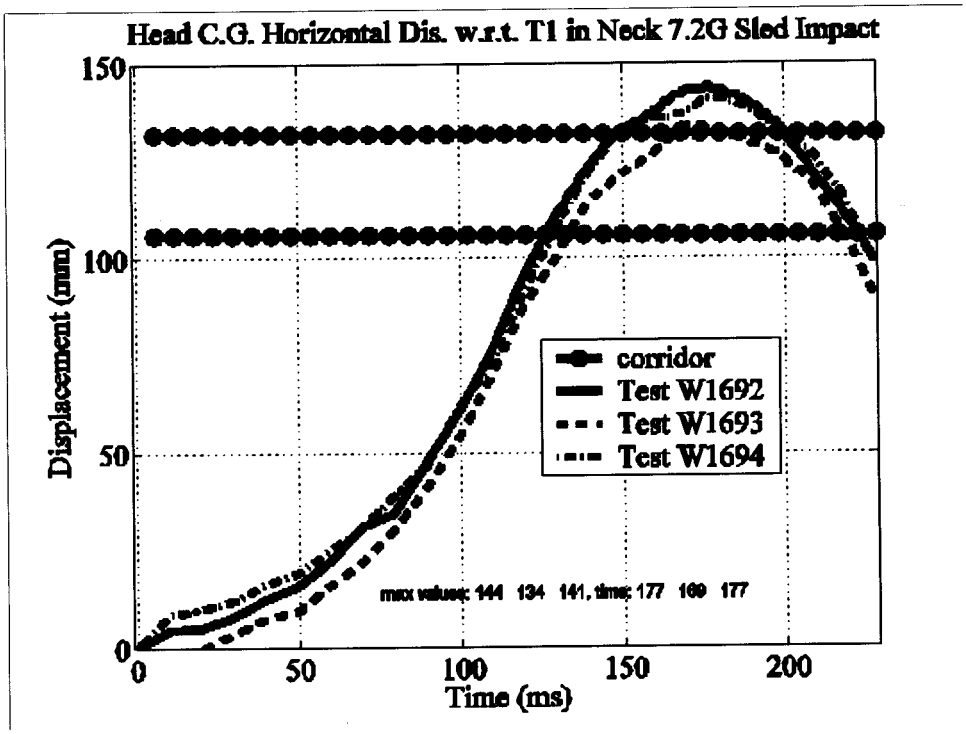


Figure A- 3: Neck Test #1 (rating 5,5,5)
(time of peak excursion rating 5,5,5)

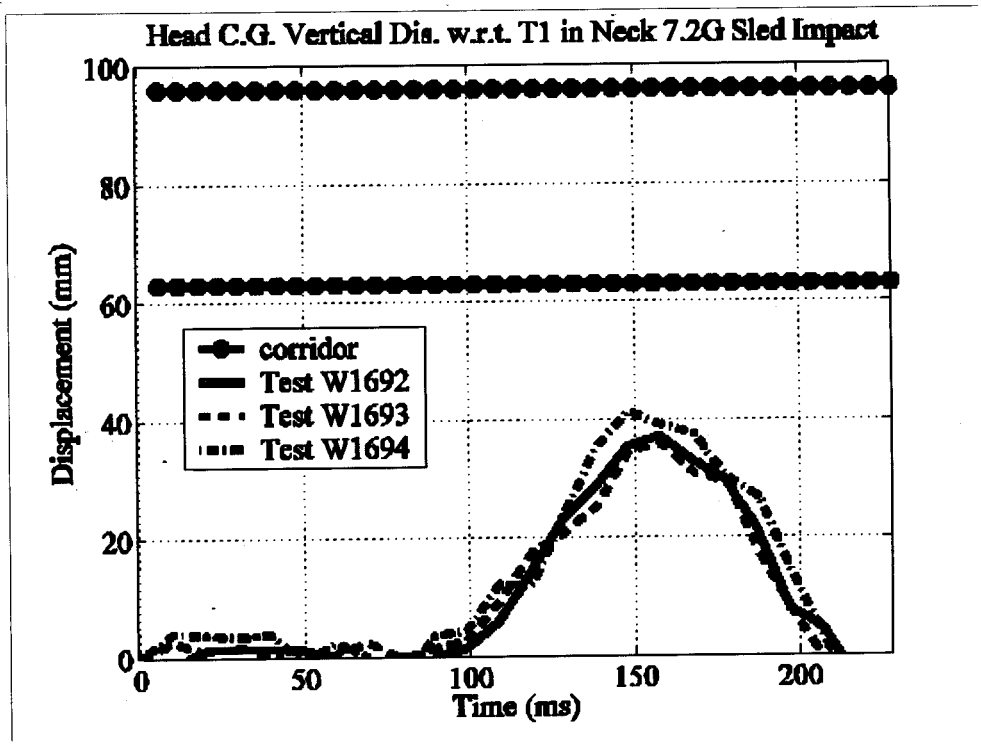


Figure A- 4: Neck Test #1 (rating 5,5,5)

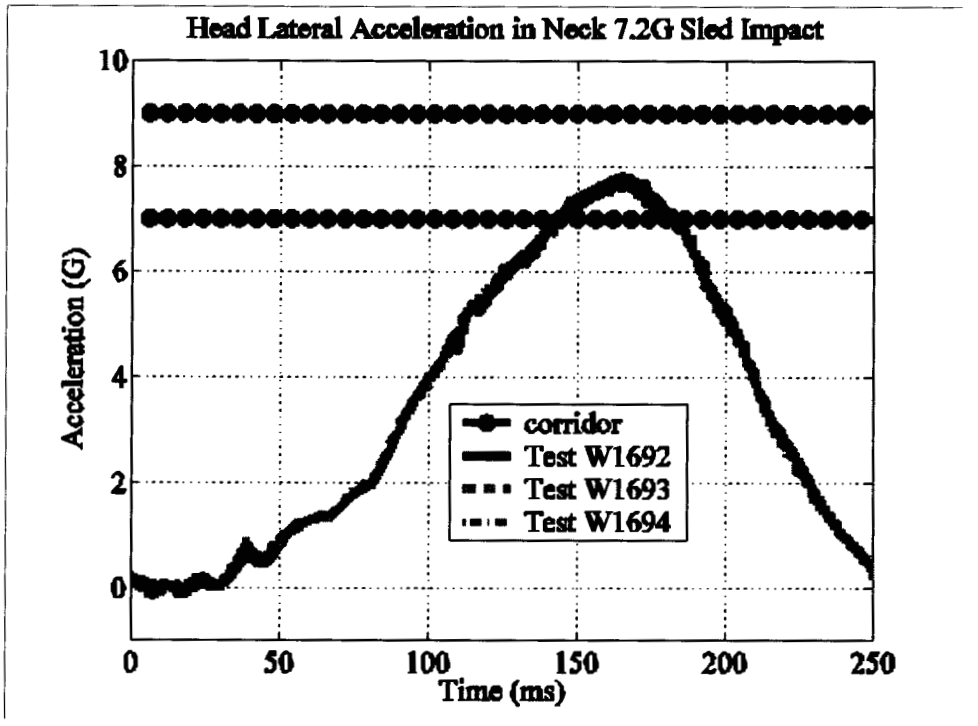


Figure A- 5: Neck Test #1 (rating 10,10,10)

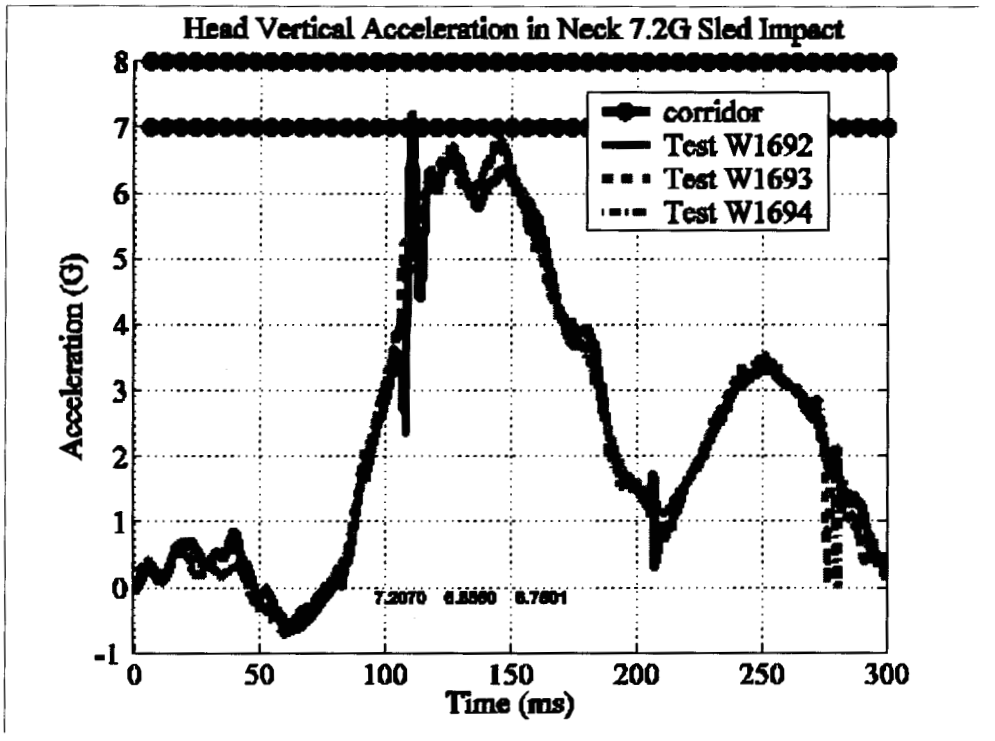


Figure A- 6: Neck Test #1 (rating 5,5,5)

Appendix 1 – ISO 9790 Biofidelity Test Results of SIDIIs-FRG

(solid line corridors used for all ratings)

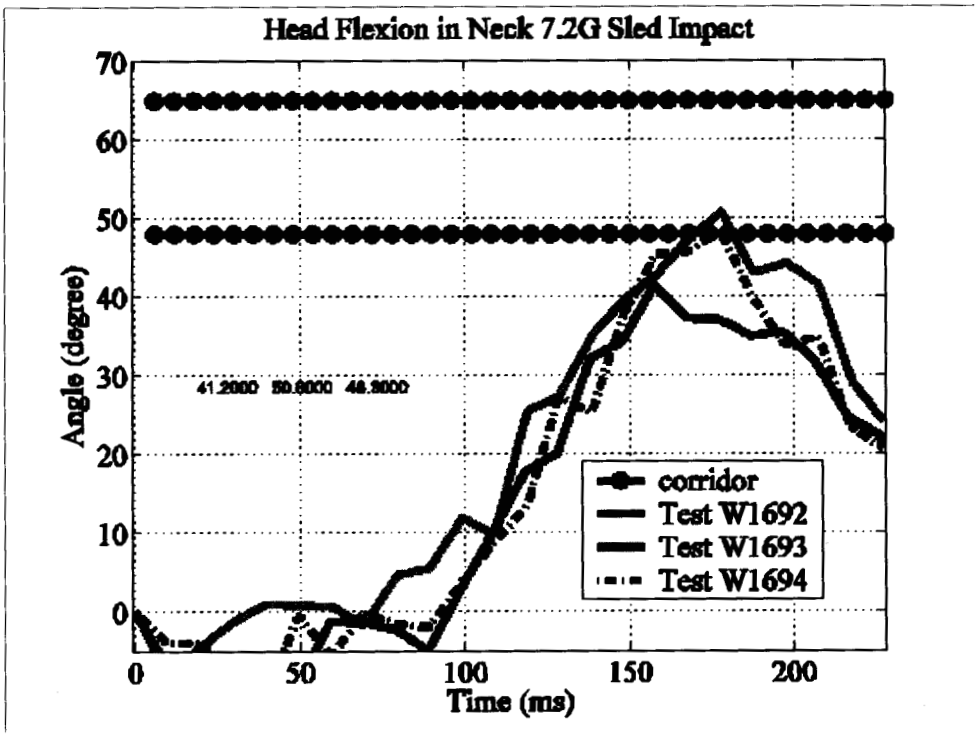


Figure A- 7: Neck Test #1 (rating 10,10,5)

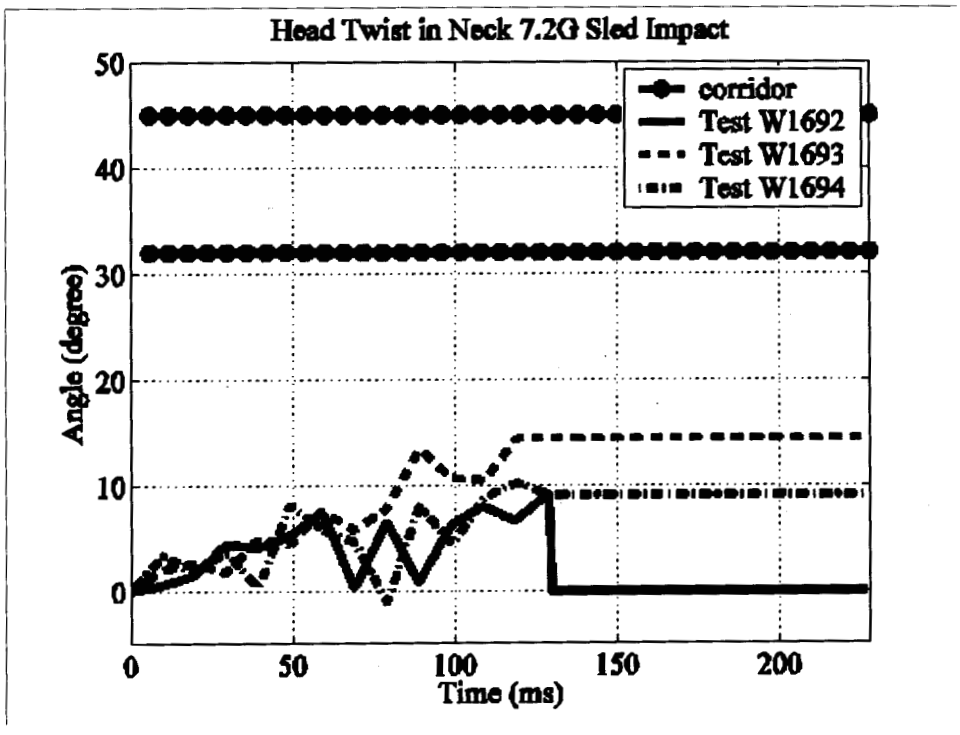


Figure A- 8: Neck Test #1 (rating 0,0,0)

Appendix 1 – ISO 9790 Biofidelity Test Results of SIDIIs-FRG

(solid line corridors used for all ratings)

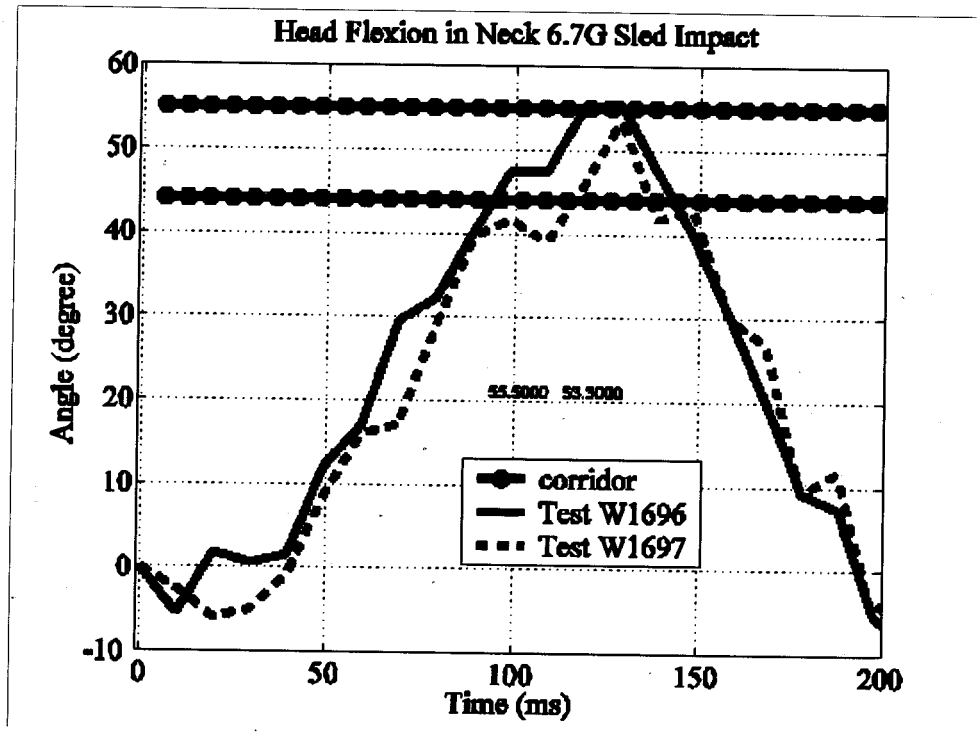


Figure A- 9: Neck Test #2 (rating 10,10)

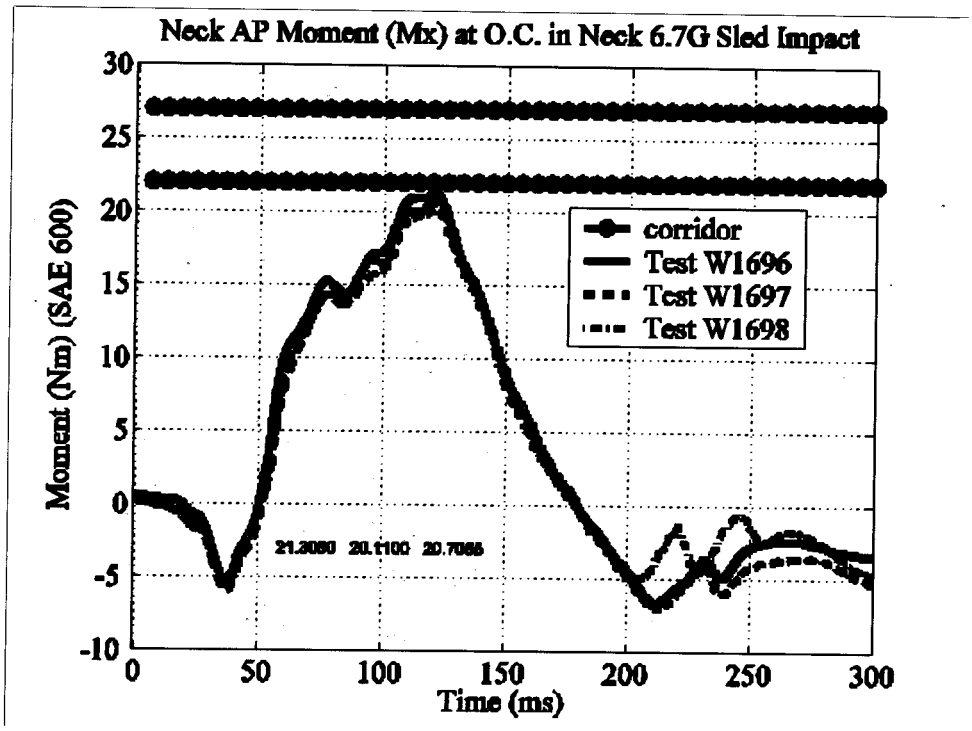


Figure A- 10: Neck Test #2 (rating 5,5,5)

Appendix 1 – ISO 9790 Biofidelity Test Results of SIDIIs-FRG

(solid line corridors used for all ratings)

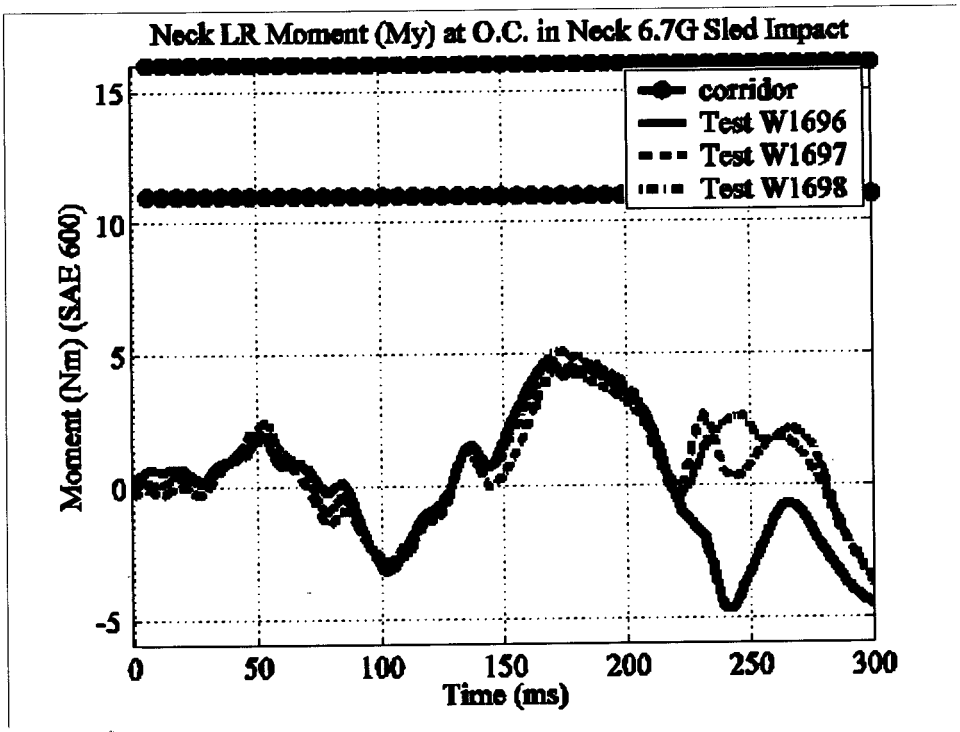


Figure A- 11: Neck Test #2 (rating 0,0,0)

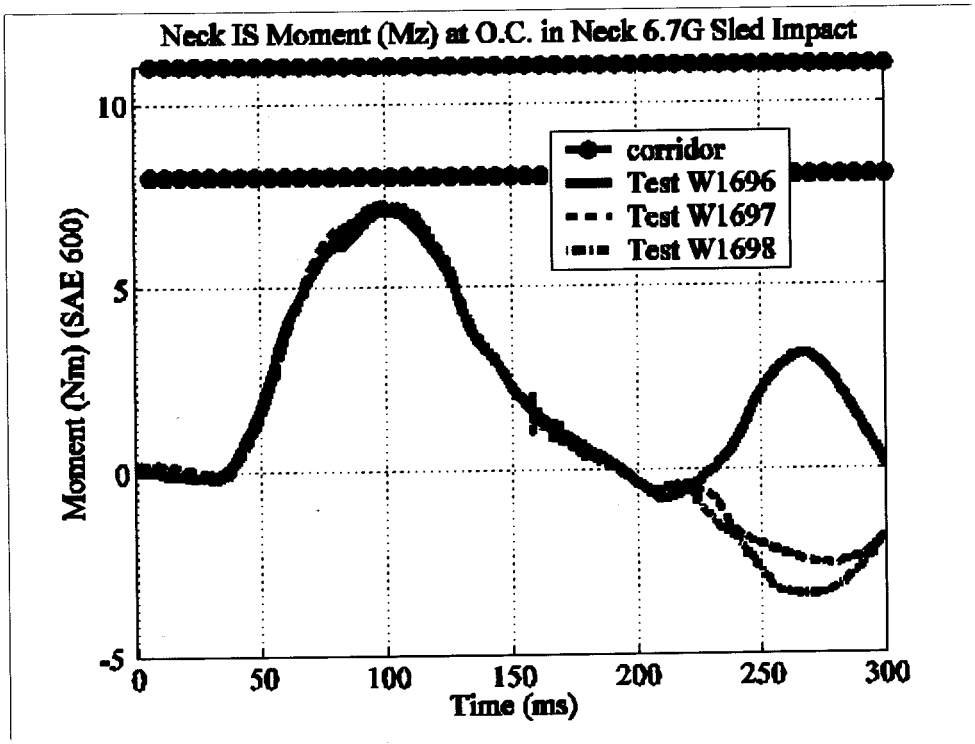


Figure A- 12: Neck Test #2 (rating 5,5,5)

Appendix 1 – ISO 9790 Biofidelity Test Results of SIDIIs-FRG

(solid line corridors used for all ratings)

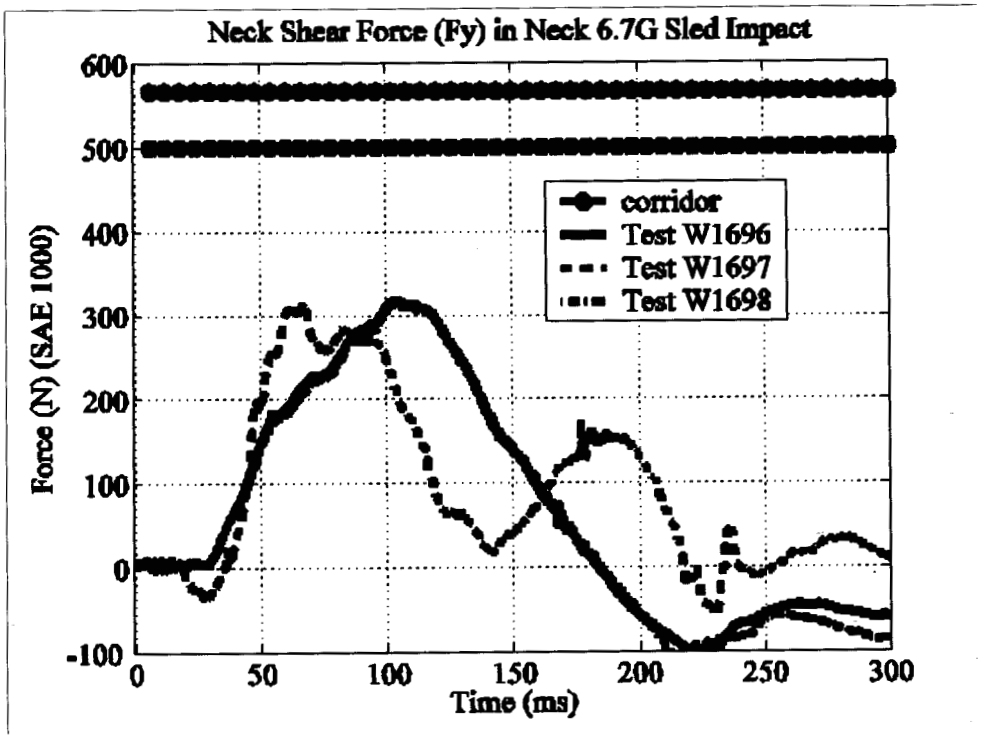


Figure A- 13: Neck Test #2: (rating 0,0,0)

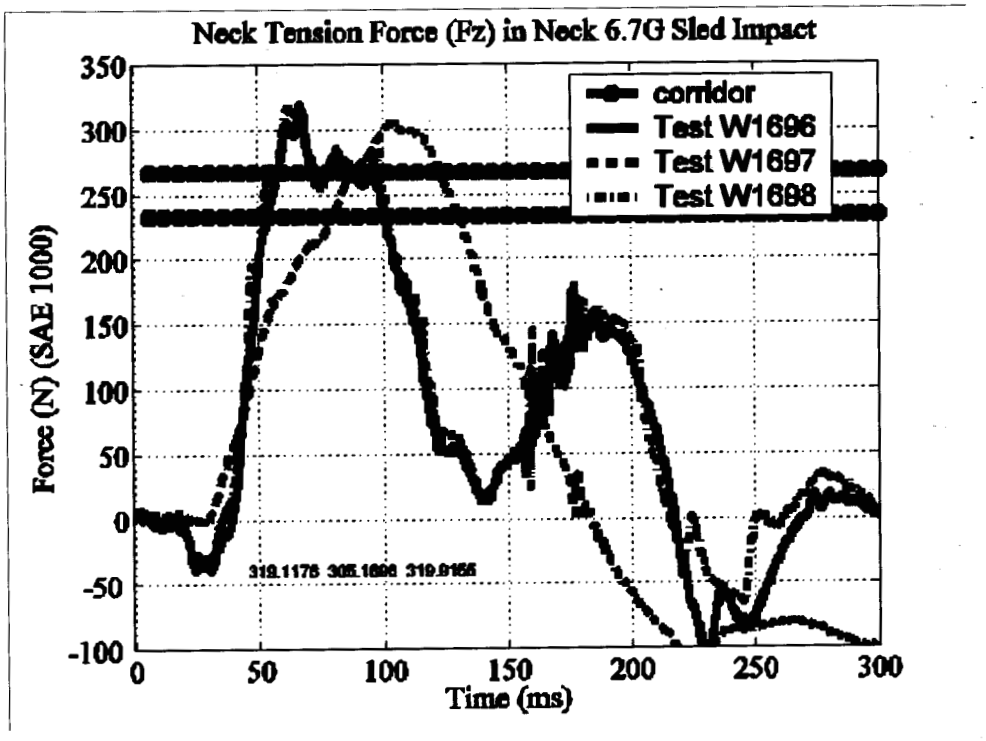


Figure A- 14: Neck Test #2 (rating 0,0,0)

Appendix 1 – ISO 9790 Biofidelity Test Results of SIDIIs-FRG

(solid line corridors used for all ratings)

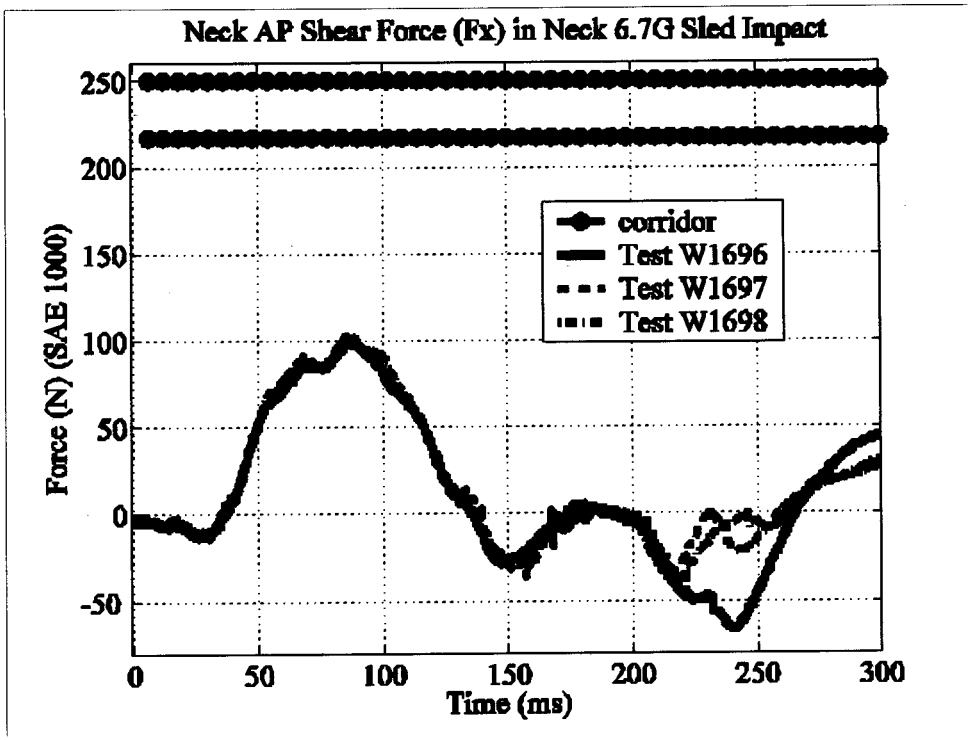


Figure A- 15: Neck Test #2 (rating 0,0,0)

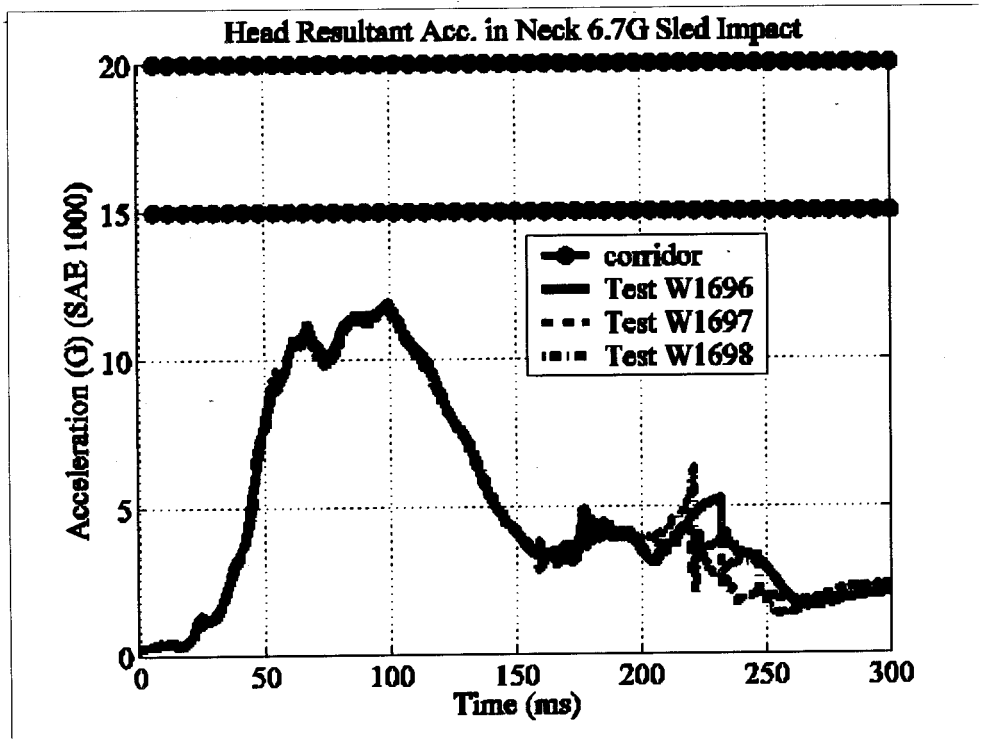


Figure A- 16: Neck Test #2 (rating 5,5,5)

Appendix 1 – ISO 9790 Biofidelity Test Results of SIDIIs-FRG

(solid line corridors used for all ratings)

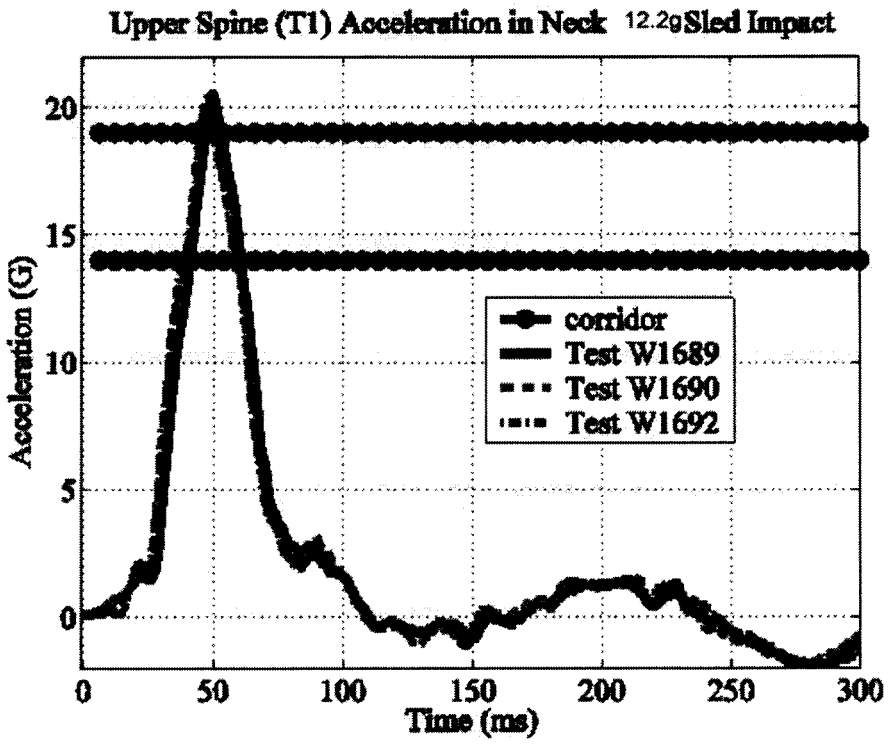


Figure A- 17: Neck Test #3, Shoulder Test #3 (rating 5,5,5)

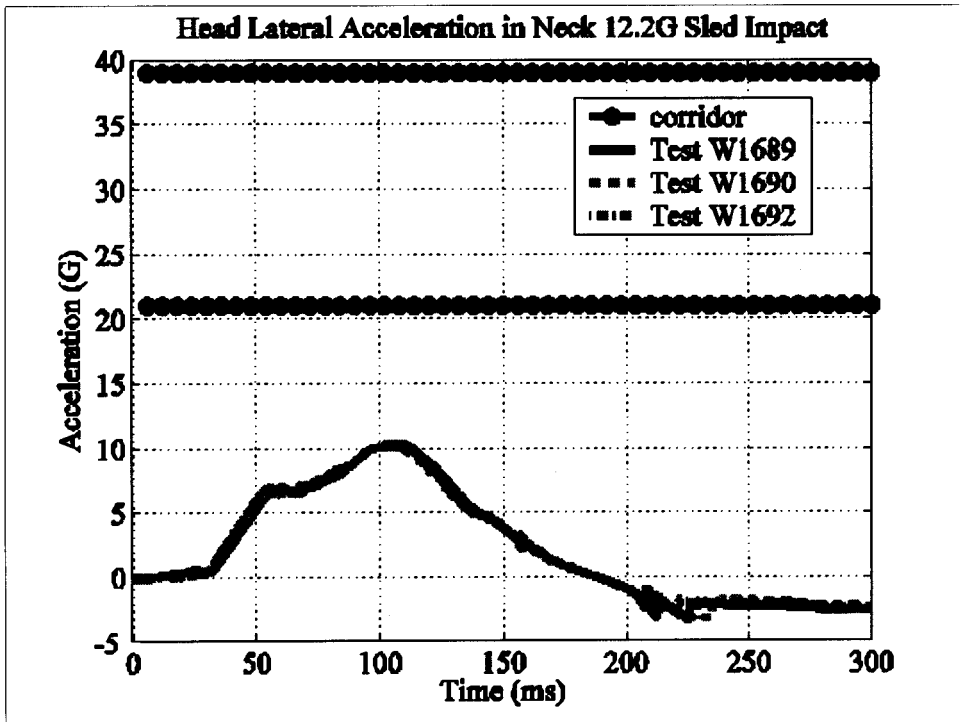


Figure A- 18: Neck Test #3 (rating 5,5,5)

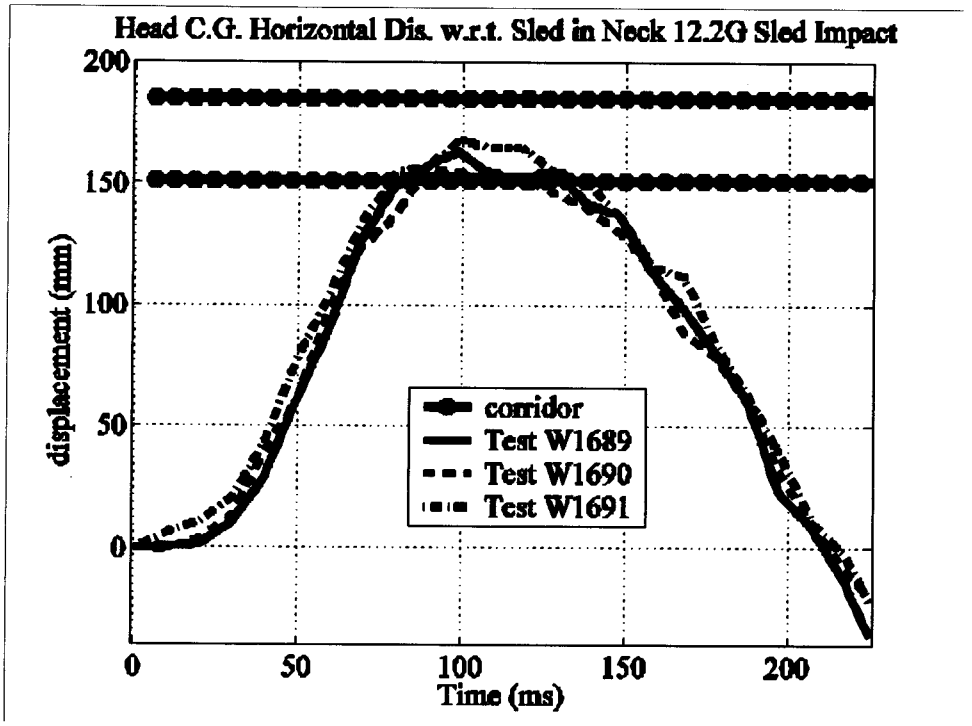


Figure A- 19: Neck Test #3 (rating 10,10,10)

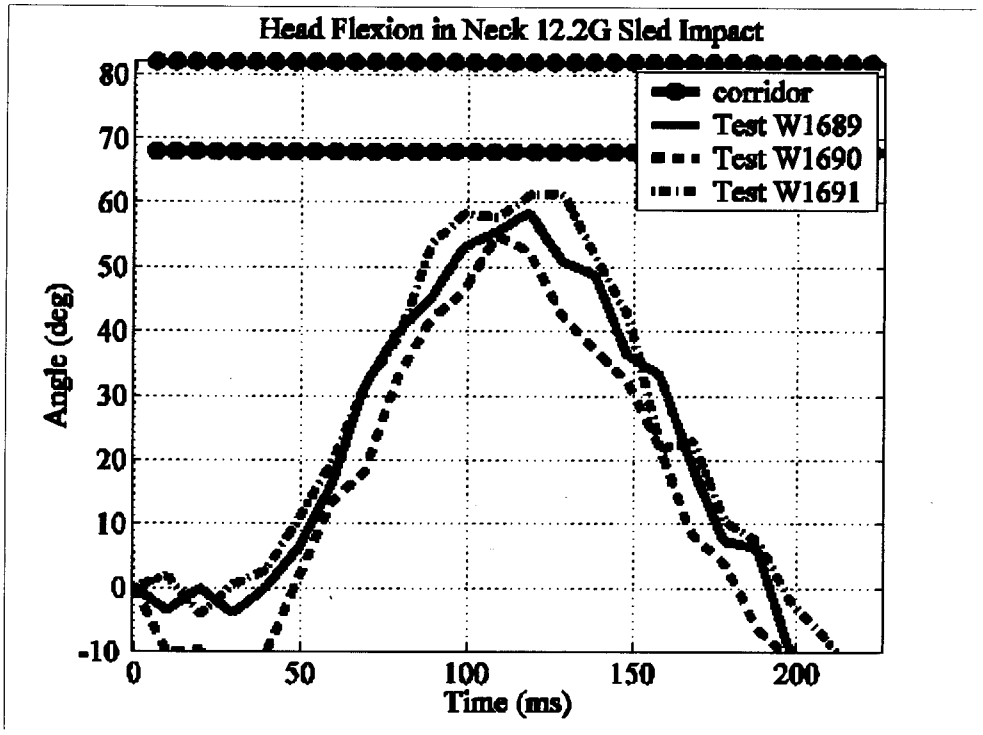


Figure A- 20: Neck Test #3 (rating 5,5,5)

Appendix 1 – ISO 9790 Biofidelity Test Results of SIDIIs-FRG

(solid line corridors used for all ratings)

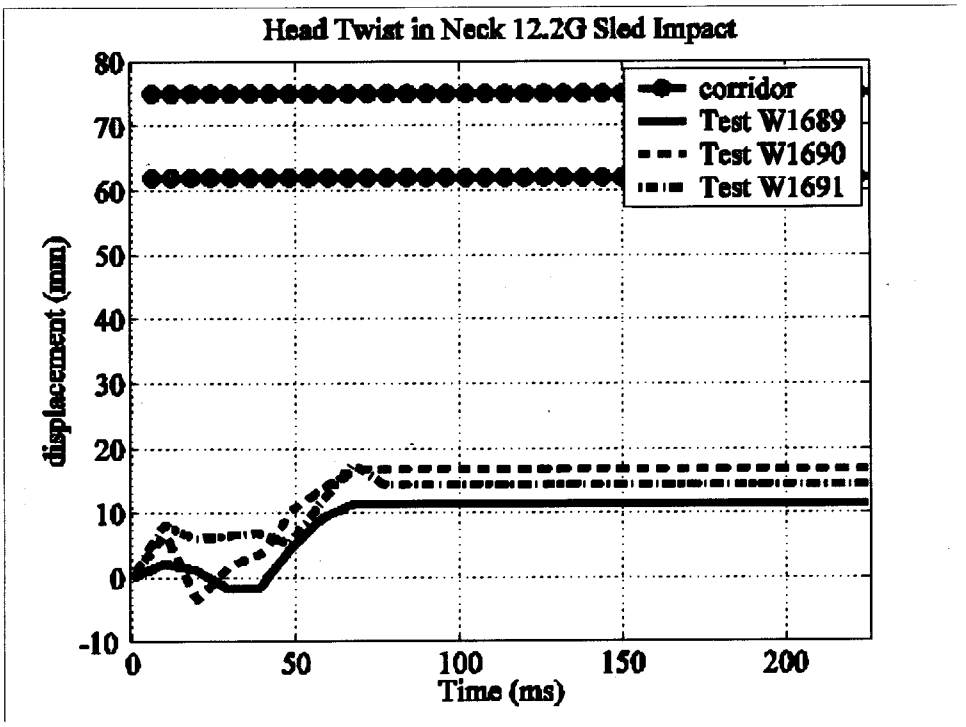


Figure A- 21: Neck Test 3 (rating 0,0,0)

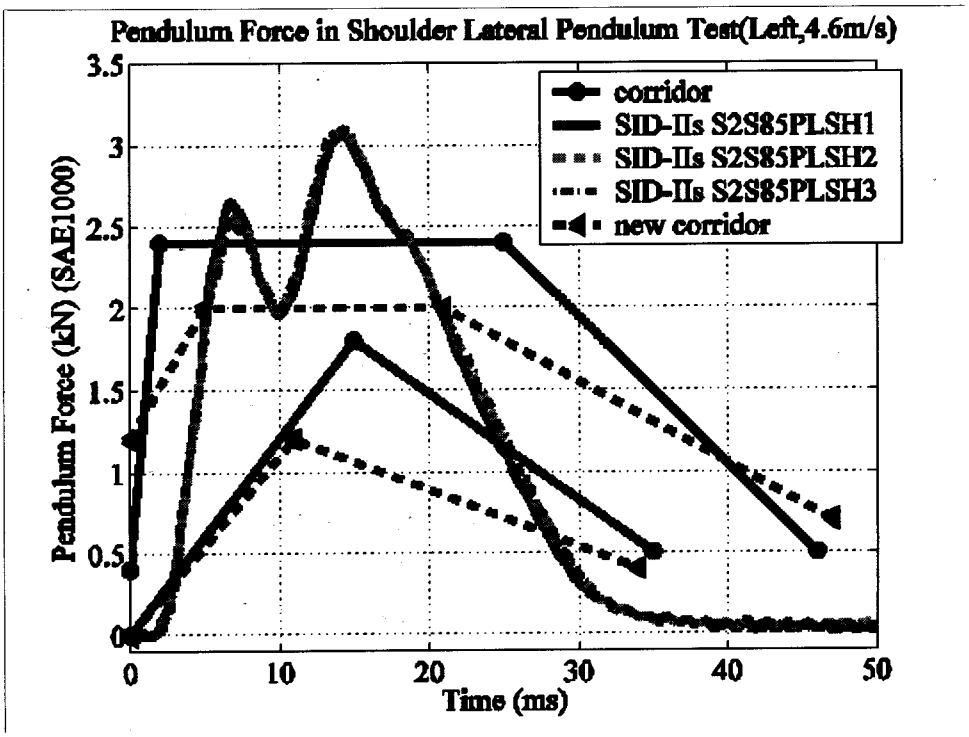


Figure A- 22: Shoulder Test #1 (rating 5,0,0)

Appendix 1 – ISO 9790 Biofidelity Test Results of SIDIIs-FRG

(solid line corridors used for all ratings)

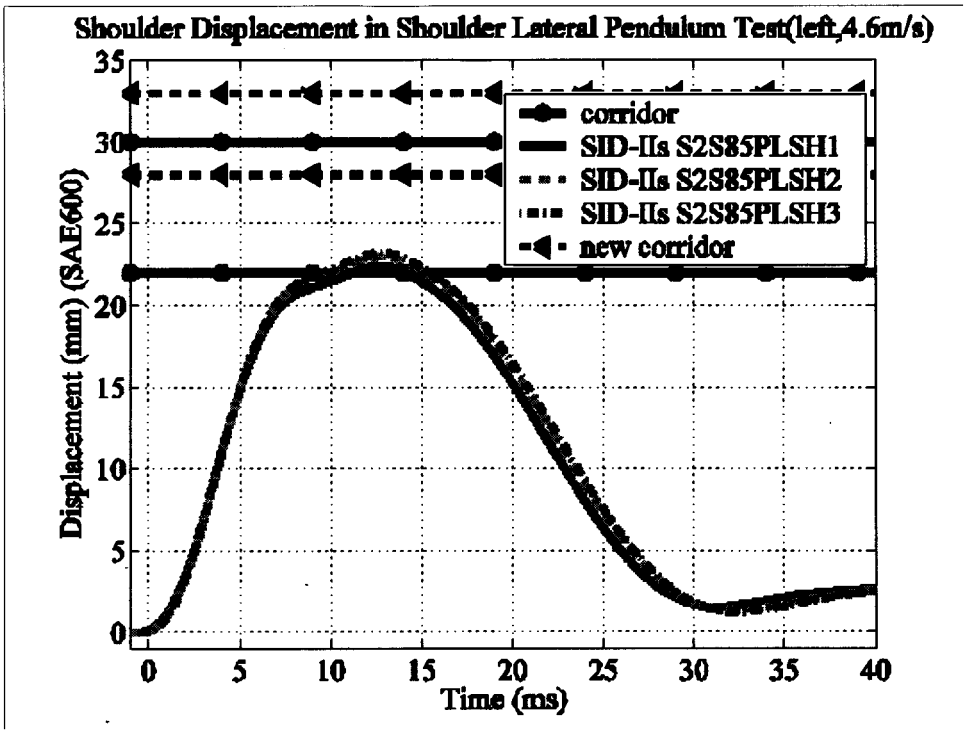


Figure A- 23: Shoulder Test #1 (rating 10,10,10)

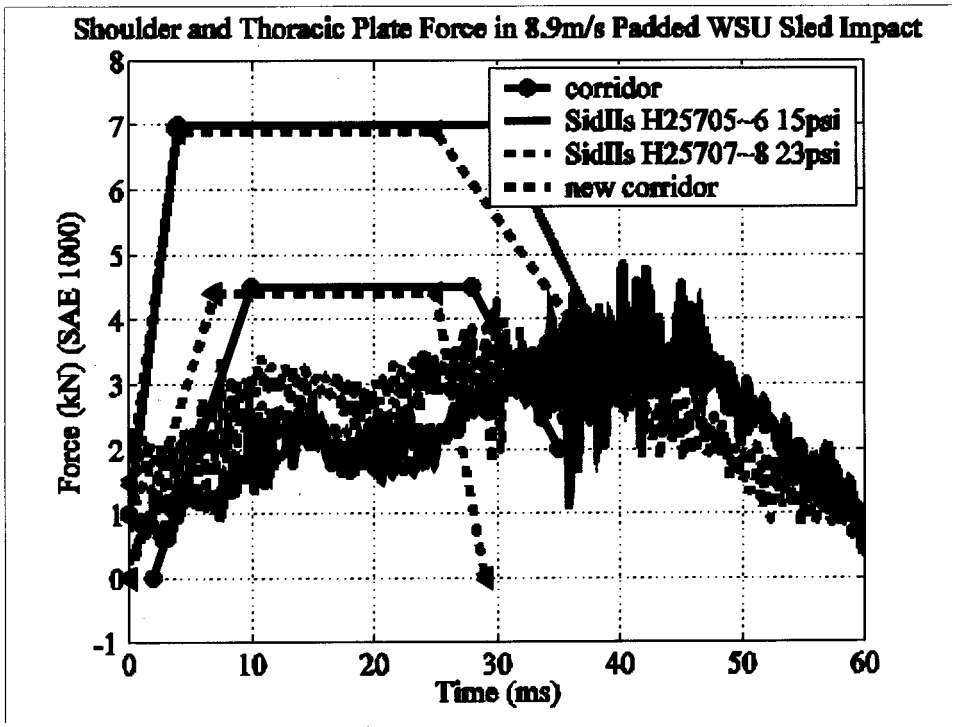


Figure A- 24: Shoulder Test #4, Thorax Test #6 (rating 5,5)

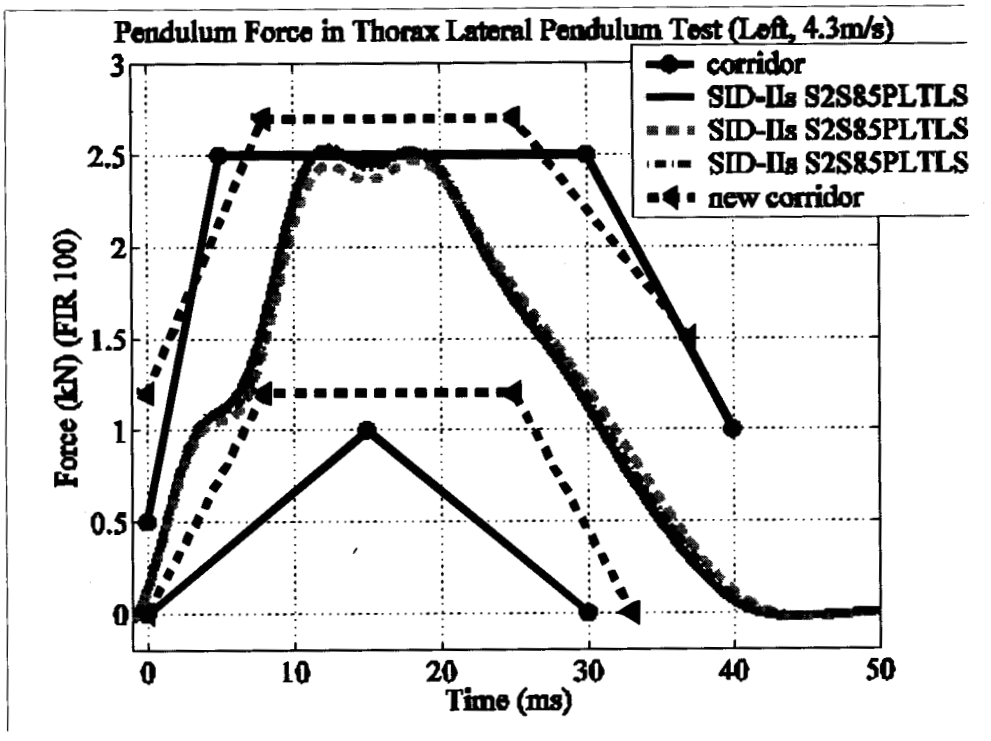


Figure A- 25: Thorax Test #1 (rating 10,10,10)

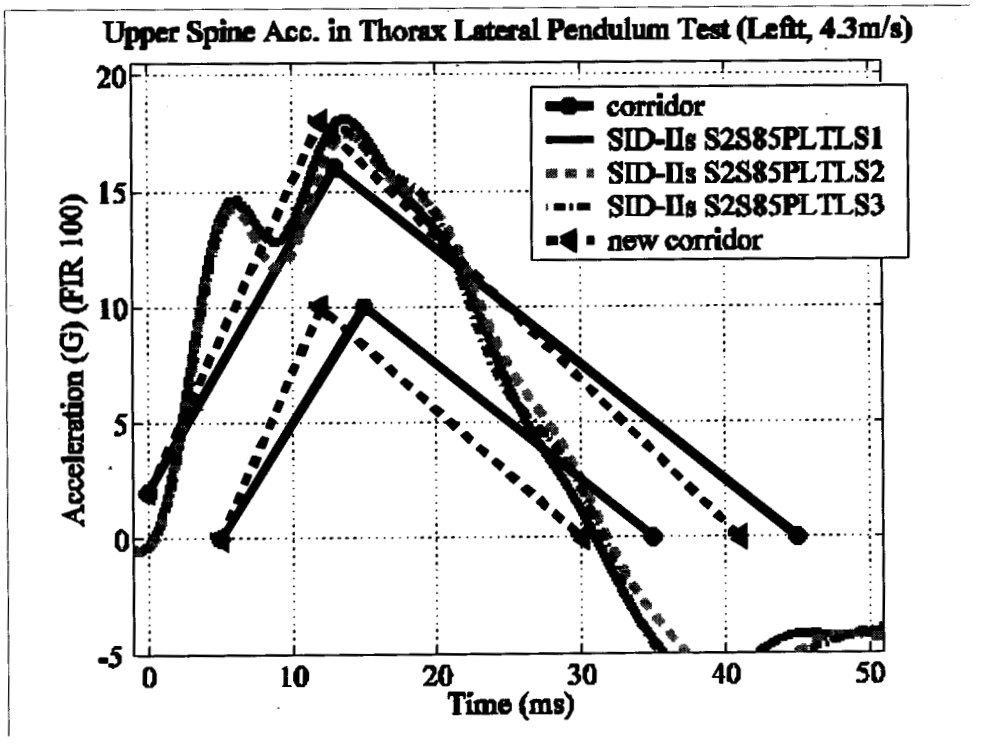


Figure A- 26: Thorax Test #1 (rating 5,5,5)

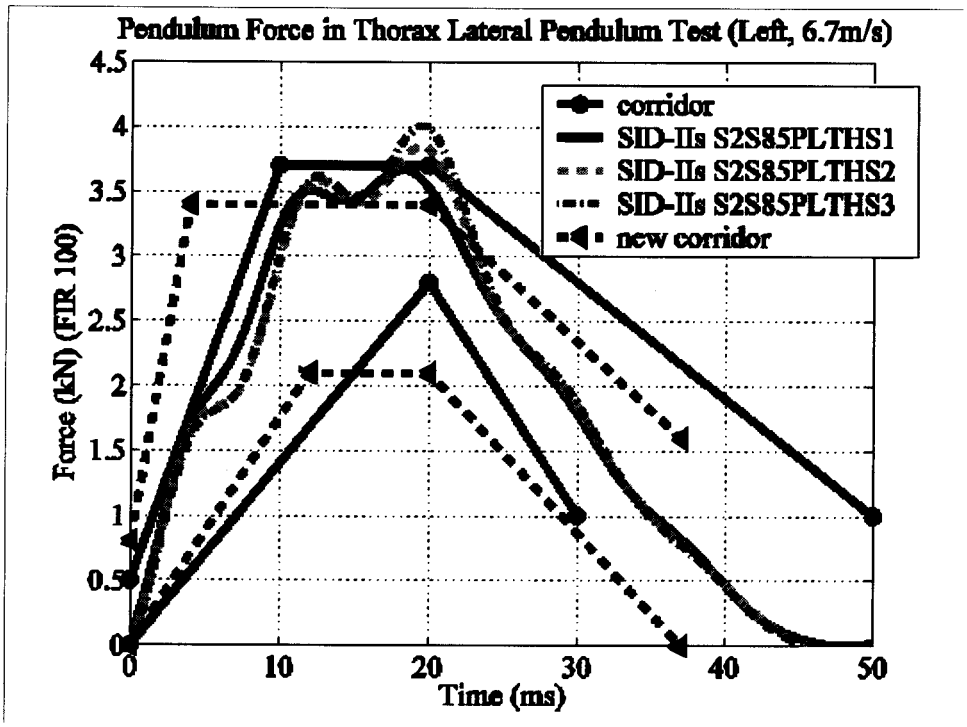


Figure A- 27: Thorax Test #2 (rating 10,5,5)

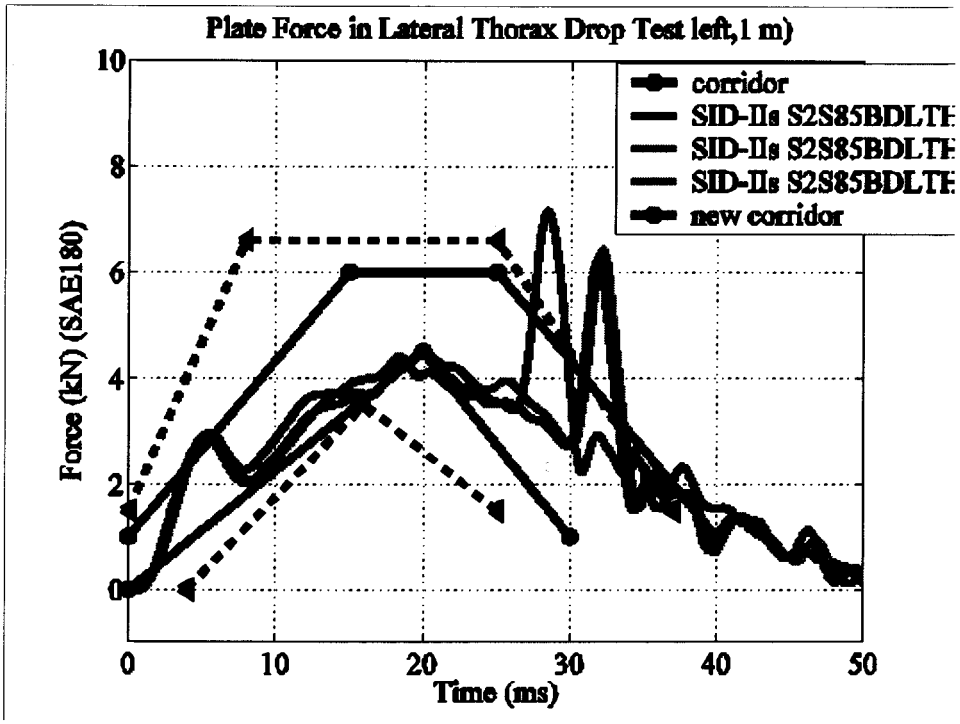


Figure A- 28: Thorax Test #3 (rating 10,5,5)

Appendix 1 – ISO 9790 Biofidelity Test Results of SIDIIs-FRG

(solid line corridors used for all ratings)

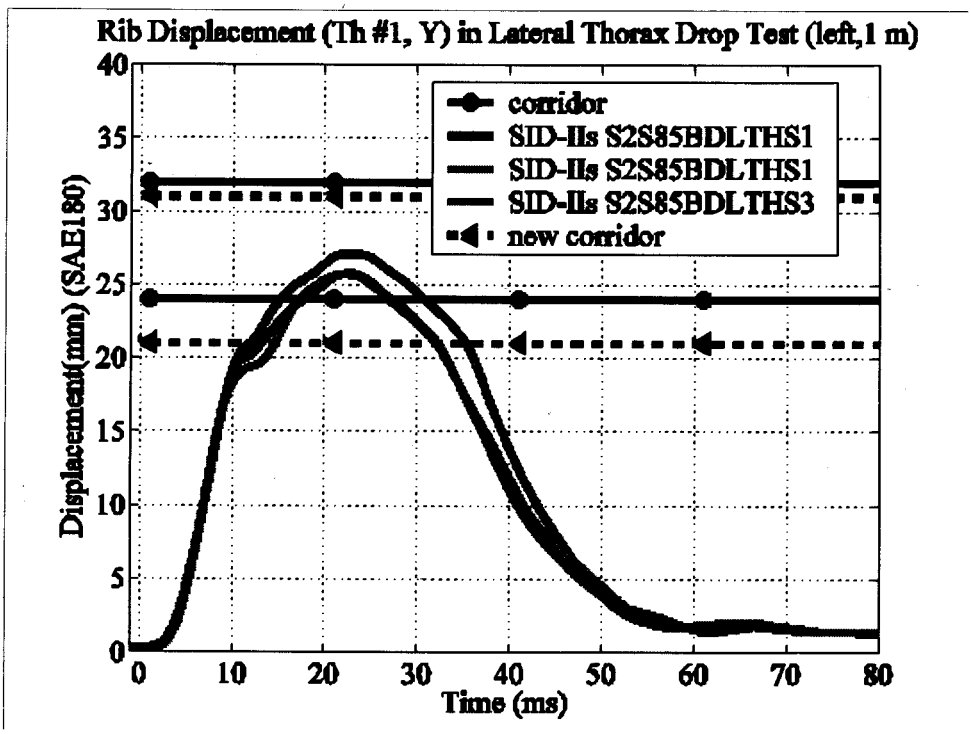


Figure A- 29: Thorax Test #3 (rating 10,10,10)

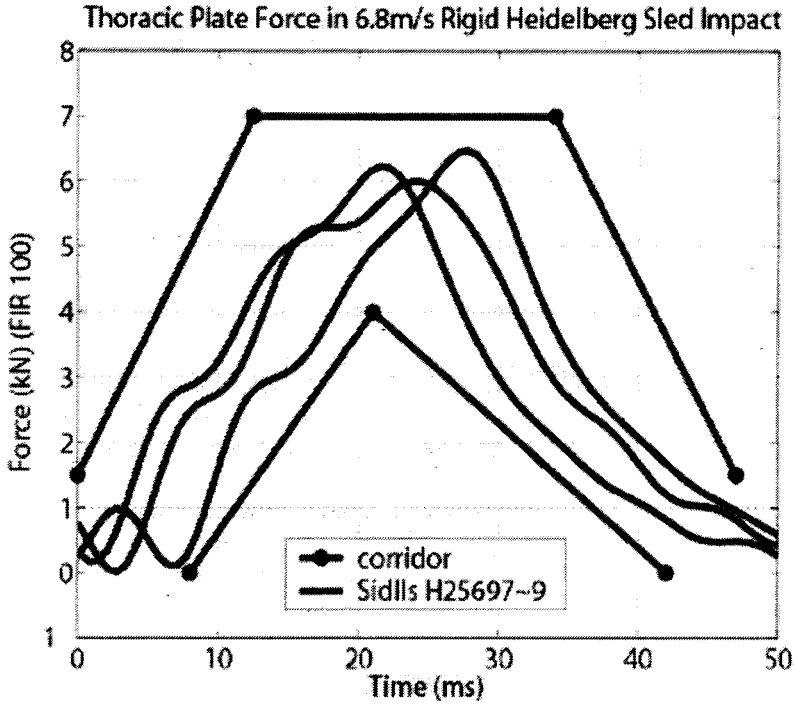


Figure A- 30: Thorax Test #5 (rating 10,10,10)

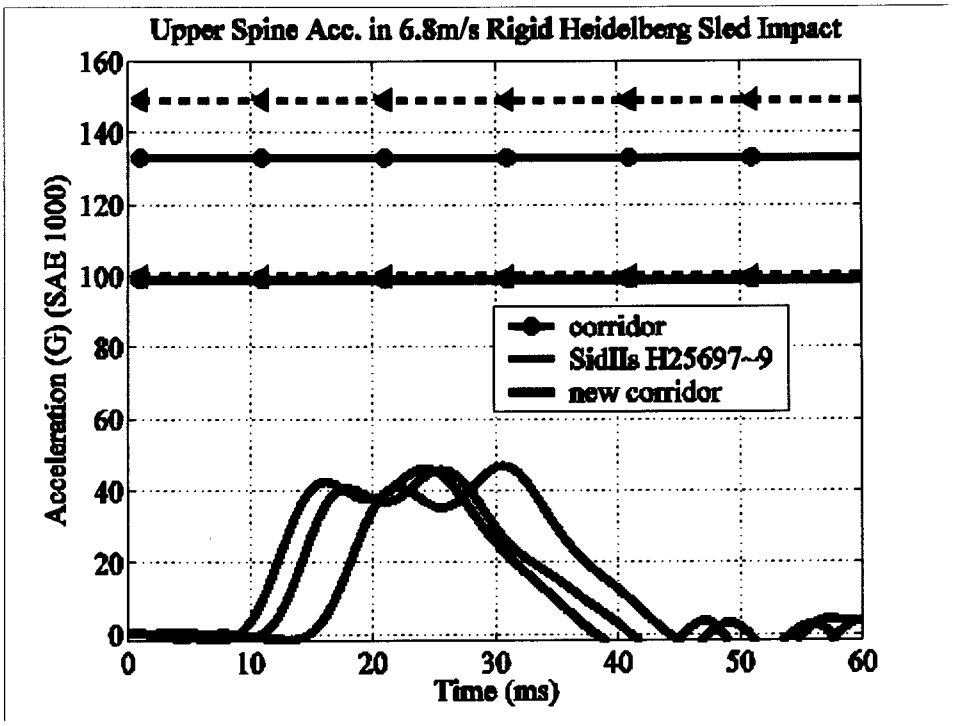


Figure A- 31: Thorax Test #5 (rating 0,0,0)

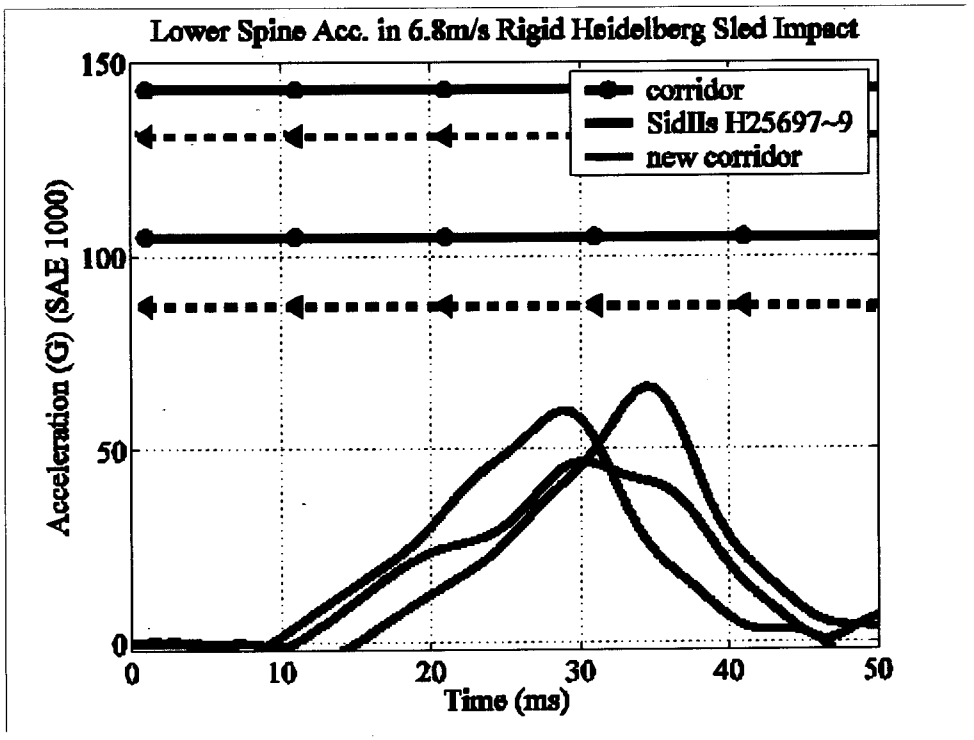


Figure A- 32: Thorax Test #5 (rating 0,0,0)

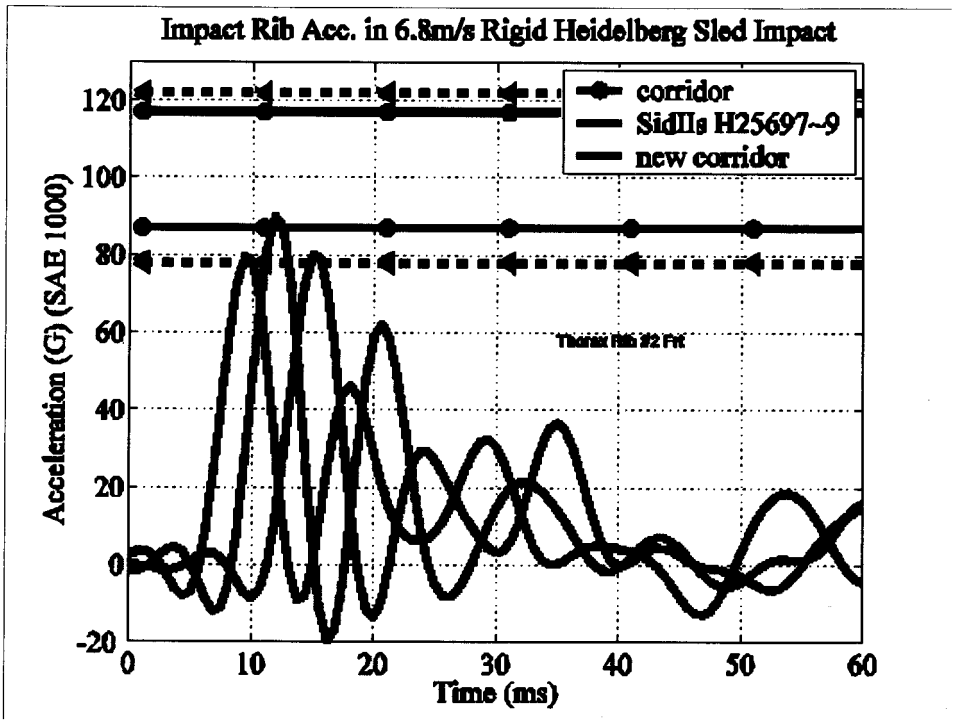


Figure A- 33: Thorax Test #5 (rating 5,10,5)

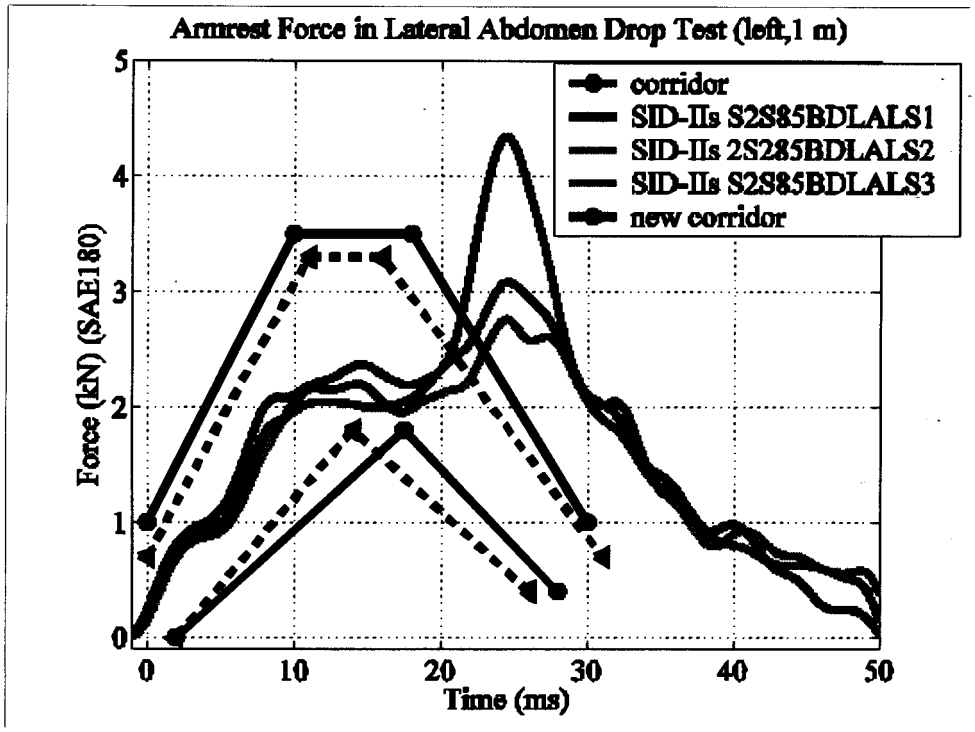


Figure A- 34: Abdomen Test #1 (rating 5,5,0)

Appendix 1 – ISO 9790 Biofidelity Test Results of SIDIIs-FRG

(solid line corridors used for all ratings)

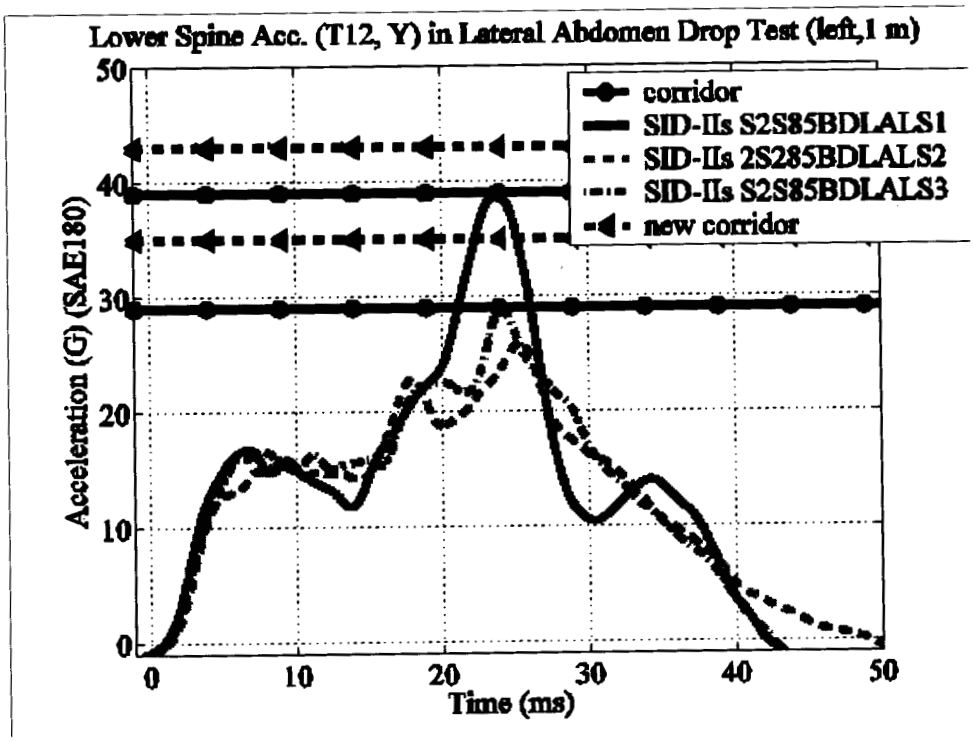


Figure A- 35: Abdomen Test #1 (rating 10,10,5)

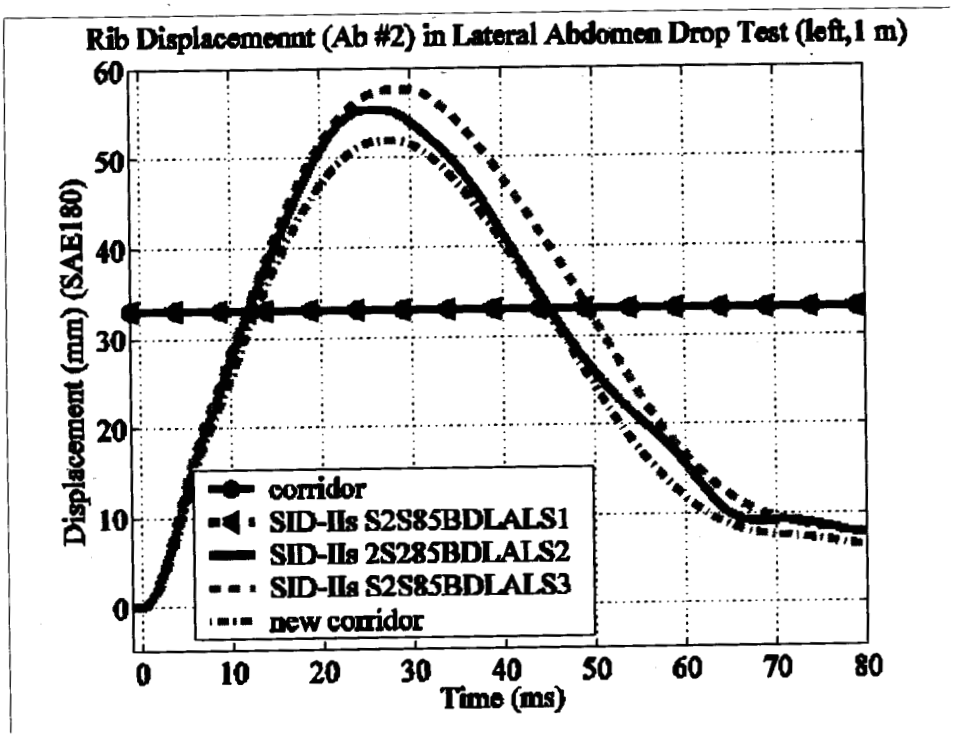


Figure A- 36: Abdomen Test #1 (rating 10,10,10)

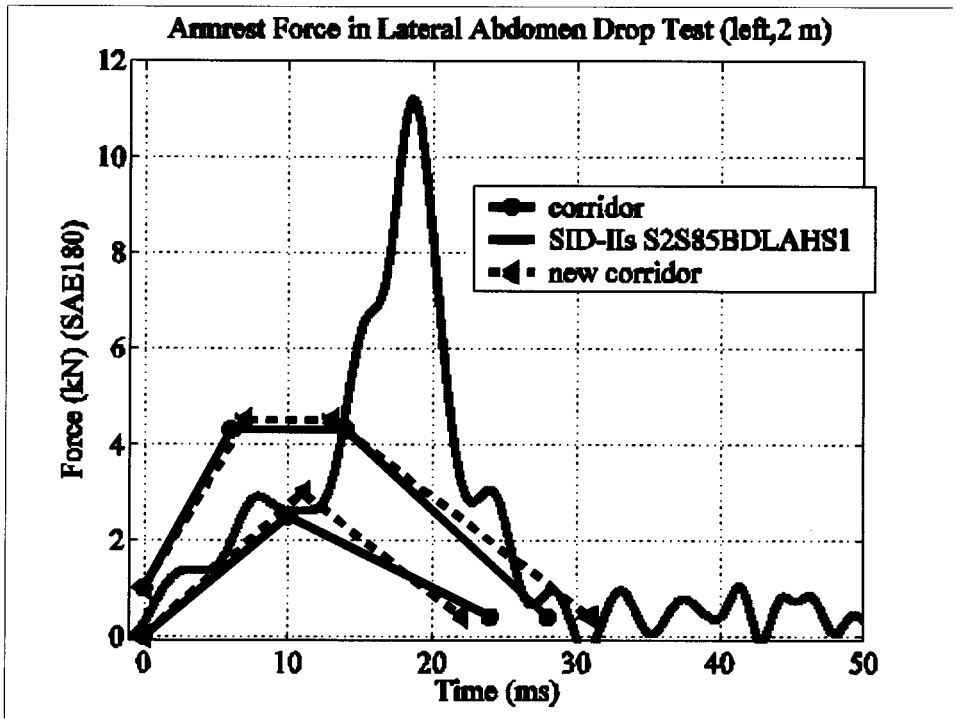


Figure A- 37: Abdomen Test #2 (rating 0)

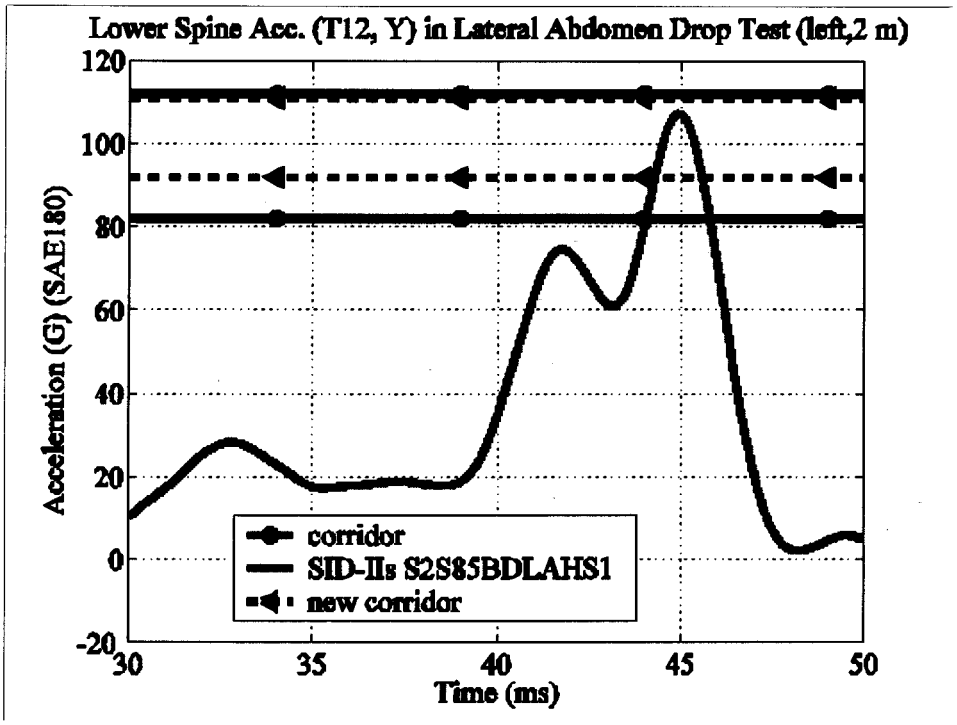


Figure A- 38: Abdomen Test #2 (rating 10)

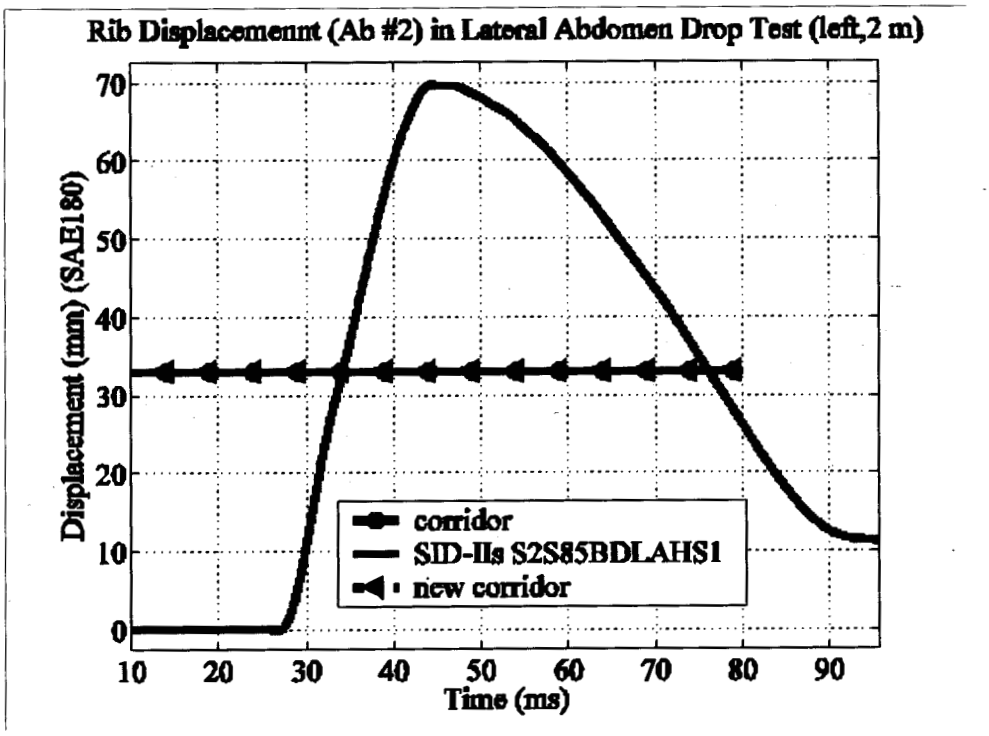


Figure A- 39: Abdomen Test #2 (rating 10)

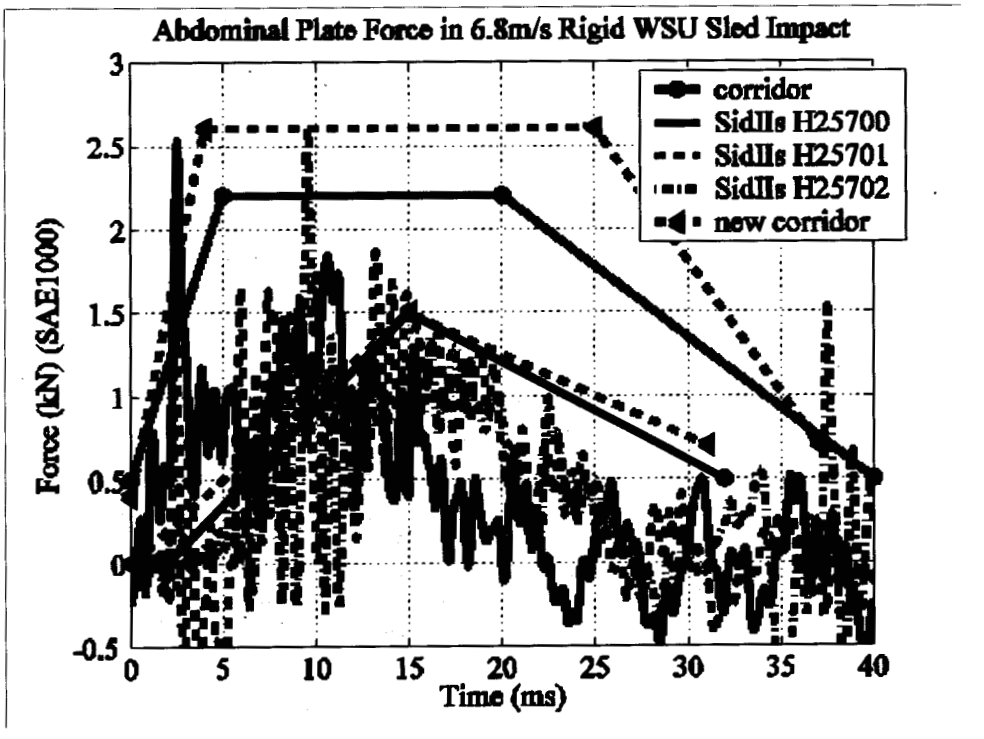


Figure A- 40: Abdomen Test #3 (rating 5,5,0)

Appendix 1 – ISO 9790 Biofidelity Test Results of SIDIIs-FRG

(solid line corridors used for all ratings)

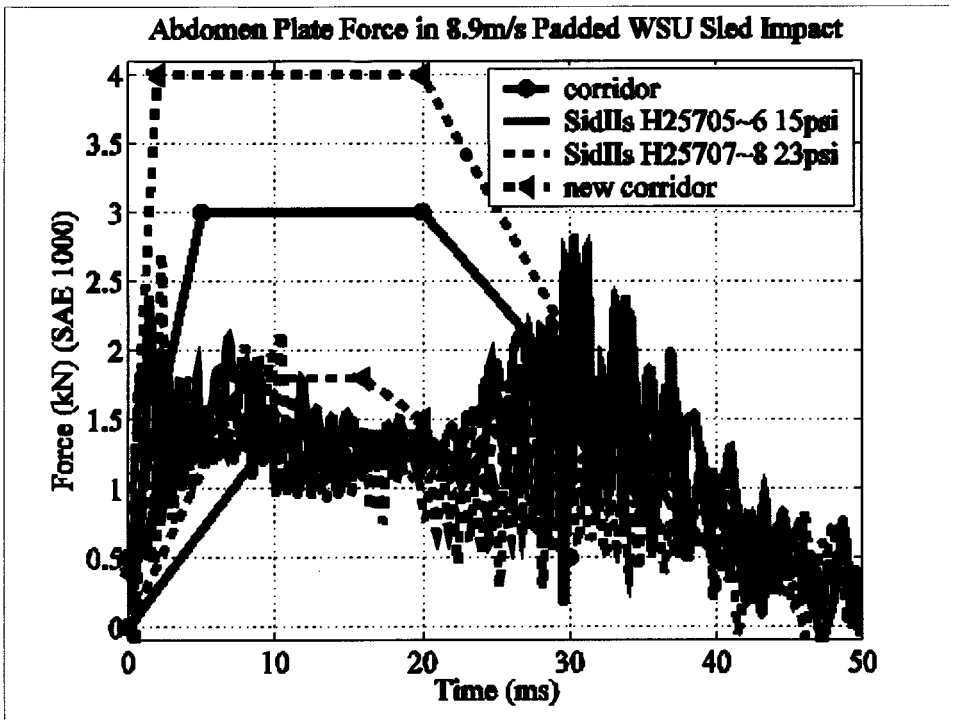


Figure A- 41: Abdomen Test #5 (rating 5,5)

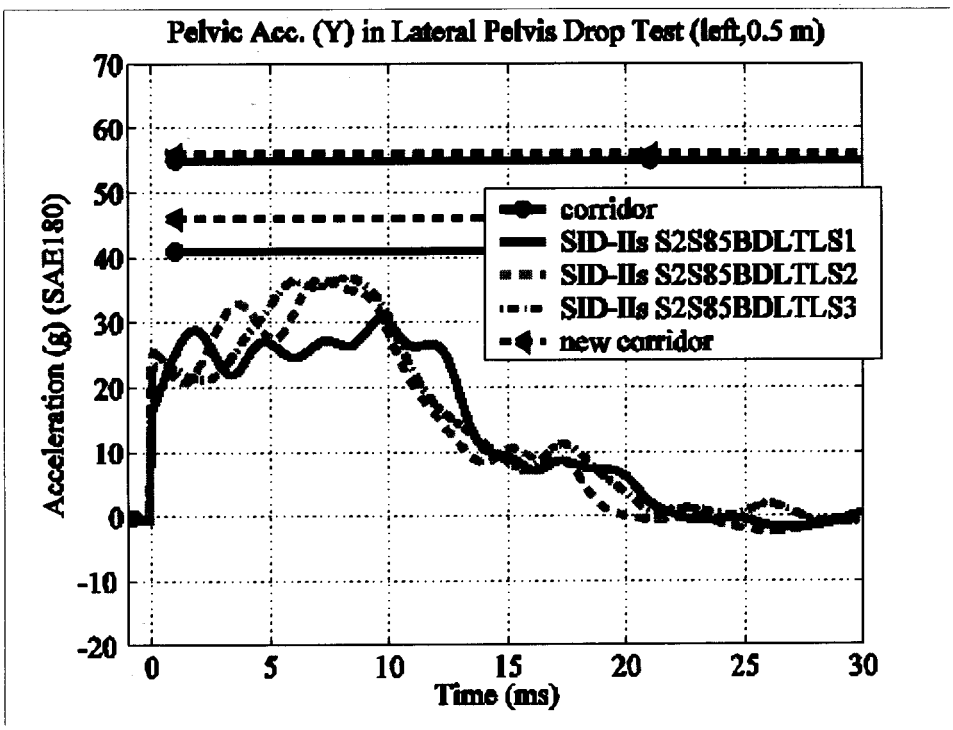


Figure A- 42: Pelvis Test #3 (rating 5,5,5)

Appendix 1 – ISO 9790 Biofidelity Test Results of SIDIIs-FRG

(solid line corridors used for all ratings)

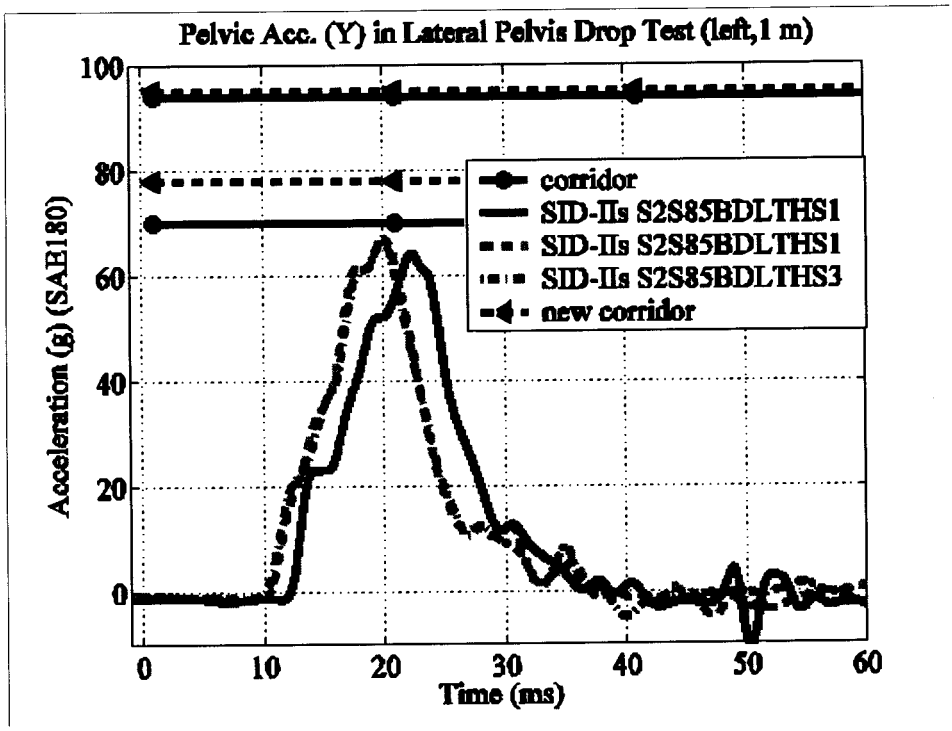


Figure A- 43: Pelvis Test #4 (rating 5,5,5)

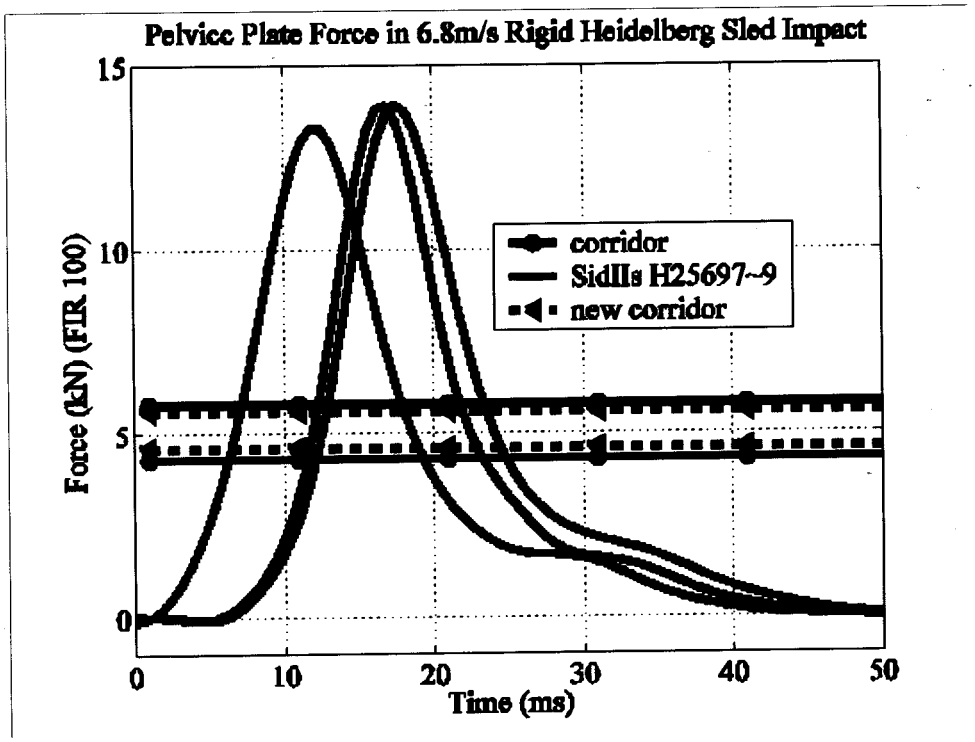


Figure A- 44: Pelvis Test #7 (rating 0,0,0)

Appendix 1 – ISO 9790 Biofidelity Test Results of SIDIIs-FRG

(solid line corridors used for all ratings)

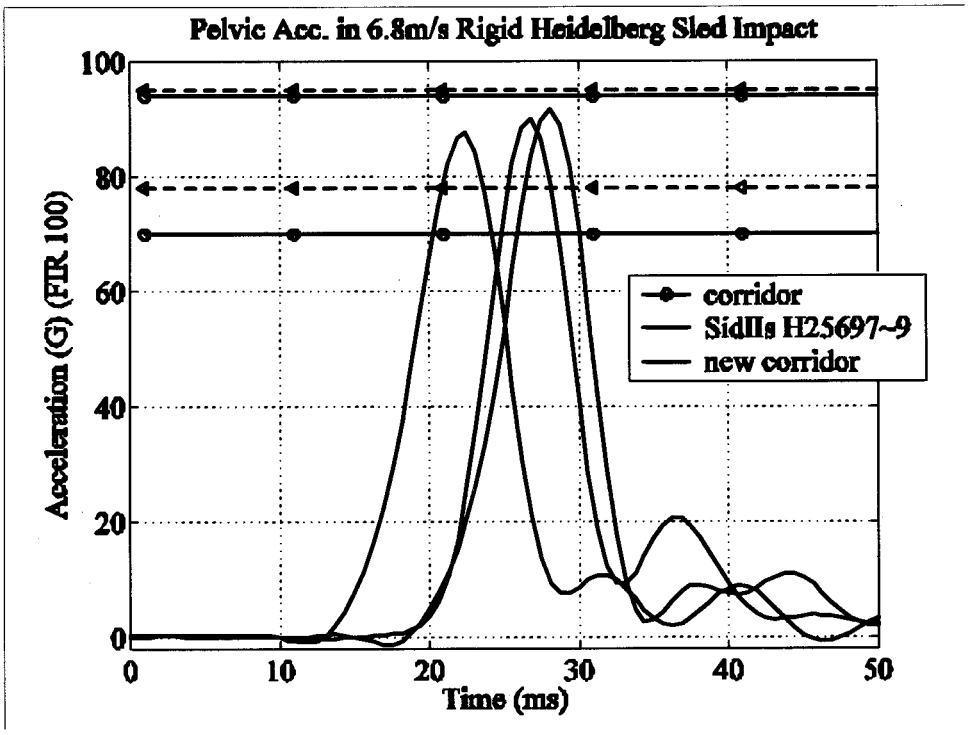


Figure A- 45: Pelvis Test #7 (rating 10,10,10)

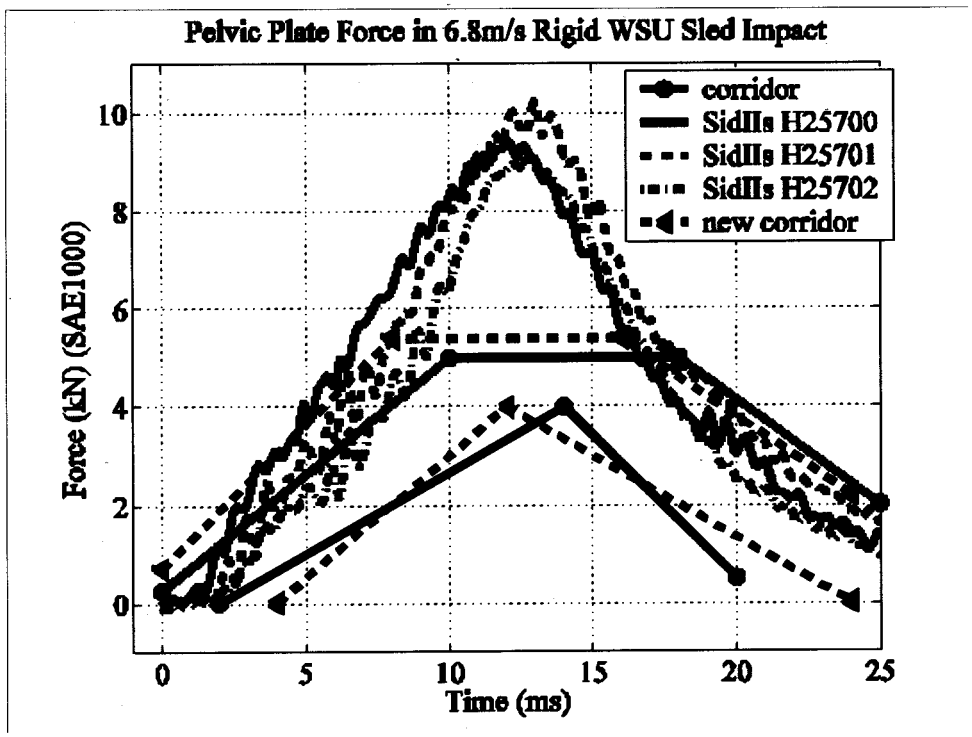


Figure A- 46: Pelvis Test #10 (rating 0,0,0)

Appendix 1 – ISO 9790 Biofidelity Test Results of SIDIIs-FRG

(solid line corridors used for all ratings)

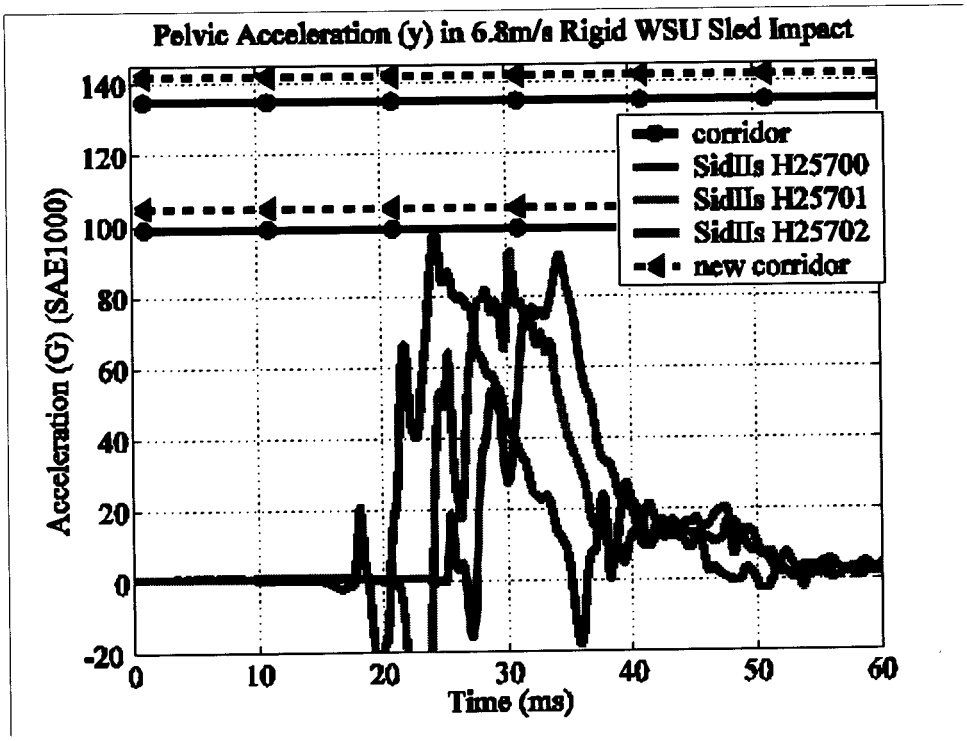


Figure A- 47: Pelvic Test #10 (rating 5,5,5)

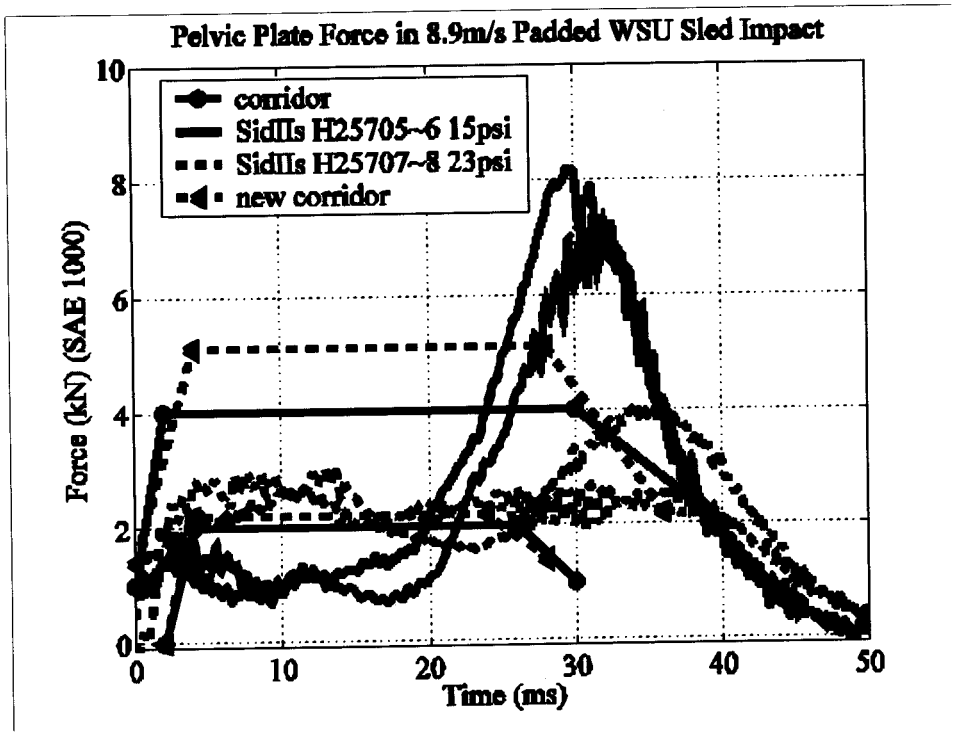


Figure A- 48: Pelvis Test #12 (rating 0,0), Pelvis Test #13 (rating 5,10)

Appendix 1 – ISO 9790 Biofidelity Test Results of SIDIIs-FRG

(solid line corridors used for all ratings)

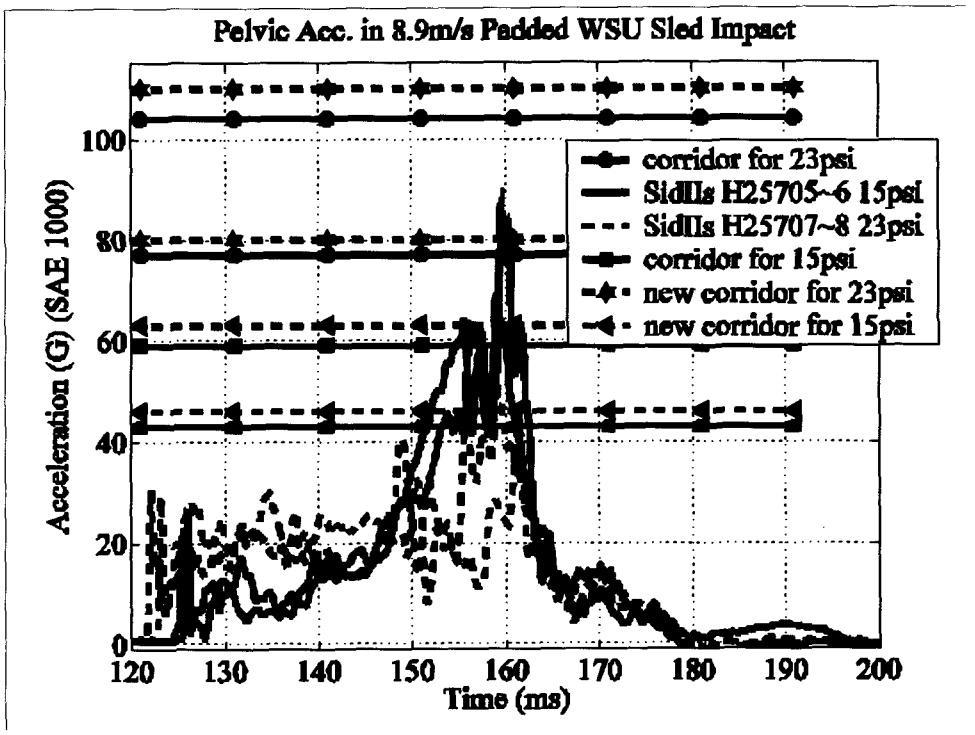


Figure A- 49: Pelvis Test #12 (rating 0,5), Pelvis Test #13 (rating 0,0)

Appendix B

Technical Summary of OSRP
ES-2 Evaluation Task Group

Technical Summary of OSRP – ES-2 Evaluation Task Group
September 2004

Background:

To assess changes made to the ES-2 by the addition of the rib extensions (re), the Occupant Safety Research Partnership (OSRP), and Transport Canada (TC) completed a study of biomechanical testing on the ES-2re dummy. The purpose of this testing was to: 1) establish a biofidelity rating for the ES-2re and compare it with the ratings for other midsize male side impact dummies, 2) evaluate the repeatability of ES-2re, 3) compare the responses of the ES-2re to those of the ES-2 and WorldSID in full scale vehicle tests, and 4) assess the dummy's performance in oblique side impacts.

Biofidelity:

To establish the biofidelity rating, several types of tests were conducted in accordance with ISO 9790[1], including whole dummy and component drop tests, lateral pendulum impact tests, and sled impact tests. Two different ES-2re dummies were used in the evaluations. The NHTSA ES-2re, which had been used extensively prior to this test series, was used for all test conditions except the shoulder pendulum impact and the Wayne State University (WSU-type) sled tests. The Ford ES-2re, which had not been used prior to this series, was used for the shoulder pendulum impact test and the WSU-type sled tests. Verification tests were conducted on the dummies before and after each biofidelity test. All verification tests confirmed that the dummies' responses were within specified limits throughout the biofidelity test series. Each evaluation test was conducted three times. Only the left side of each dummy was impacted. The data for all biofidelity tests can be found in Appendices A (tables) and B (plots).

According to ISO 9790, measurements falling within the corridor are given a rating of "10." Those that are outside the corridor, but within one corridor width above or below the corridor are rated "5." Measurements that meet neither of these conditions are given a rating of "0." The three ratings for each measurement are averaged and weighted by the measurement weighting factor, where critical measurements have higher weighting factors than less significant measurements. The weighted averages for all measurements of a test condition are summed and normalized. The resulting score for each test condition is then weighted. More relevant test conditions have higher test weighting factors than less relevant test conditions. The weighted test conditions are summed and normalized to obtain the overall biofidelity rating for that body region. The overall biofidelity of each body region of the ES-2re is summarized in Table 1. The overall ES-2re biofidelity rating is 4.2 with an ISO classification of "marginal". A comparison of biofidelity ratings for other mid-sized male dummies is found in Table 2.

Table 1. ES-2re Biofidelity Ratings.

Body Region	Biofidelity Rating	Classification
Head	5	Fair
Neck	3.8	Marginal
Shoulder	4.5	Fair
Thorax	4.5	Fair
Abdomen	3.9	Marginal
Pelvis	3.4	Marginal
Overall Dummy Biofidelity	**4.2**	**Marginal**

Table 2. Mid-Sized Male Dummy Biofidelity Ratings Comparison

Body Region	SID	EuroSID-1	ES-2	ES-2re	BioSID	WorldSID
Head	0.0	5	5	5.0	10.0	10.0
Neck	2.5	7.8	4.4	3.8	6.5	5.6
Shoulder	0.0	7.3	5.3	4.5	7.3	7.1
Thorax	3.1	5.4	5.2	4.5	6.8	8.4
Abdomen	4.4	0.9	2.6	3.9	5.6	7.8
Pelvis	2.5	1.5	5.3	3.4	5.0	6.1
Overall	**2.3**	**4.4**	**4.6**	**4.2**	**6.2**	**7.6**

Repeatability:

Repeatability was evaluated through the CVs presented in the results of each biofidelity test mode and can be found in the tables located in Appendix A. The CV was defined as the standard deviation of the samples divided by the mean of the samples. A CV value of less than 3% is commonly viewed as an indicator of excellent repeatability. A CV of greater than 10% is commonly viewed as an indicator of poor repeatability. The neck and the thorax regions showed good repeatability with the majority of the responses below 10%. The shoulder had good repeatability with all responses below 10%. The abdomen and pelvis had marginal repeatability with all some responses above 10%.

Full Scale Vehicle Tests:

Full-vehicle tests were conducted with the ES-2re for comparison purposes with previous full vehicle data obtained with the ES-2 and WorldSID dummies. See Table 3 for the test matrix. Small sedan testing was conducted in the MDB and oblique pole modes with the ES-2re and WorldSID. The midsize sedan testing was conducted in the MDB test mode with the EuroSID-1, ES-2, ES-2re and WorldSID. Data for the full vehicle tests can be found in Appendix D.

Table 3. Full Vehicle Test Matrix.

	ES-2	ES-2re	WorldSID
Small Sedan FMVSS214 proposed barrier (33.5 mph, 27 deg crabbed cart)		X	X
Small Sedan FMVSS214 proposed oblique pole (20 mph, 15 deg pole impact)		X	X
Mid-sized Sedan FMVSS214 proposed barrier (33.5 mph, 27 deg crabbed cart)	X	X	X

The Head/Neck responses appeared qualitatively similar for the dummies and test modes studied, but there are not enough data to examine quantitatively how similar or dissimilar they are. The ES2re dummy, tested in the front seat during the FMVSS214 test, exhibited higher thoracic deflection than the ES2 dummy under nominally identical test conditions. The ES2re dummy, tested in the rear seat during the FMVSS214 test, exhibited lower thoracic deflection than the ES2 dummy under nominally identical test conditions. It is expected that the loading in the front seat during a FMVSS214 test is primarily in the lateral direction and that in the rear seat is primarily in an oblique direction. The WorldSID dummy, tested in the rear seat during the FMVSS214 test and in the front seat during the oblique pole test, exhibited higher thoracic deflections than the ES2re dummy under nominally identical test conditions. The WorldSID dummy, tested in the rear seat during the FMVSS214 test, exhibited generally higher

thoracic deflections than the ES2 dummy under nominally identical test conditions. The lateral loading on the back plate of the ES2re, in the front seat during the FMVSS 214 test, was one sixth of the ES2, indicating that the back plate of the ES2re did not appear to significantly grab the seat. The longitudinal loading on the back plate of the ES2re, in the front seat during the FMVSS 214 test, was 3 times of the ES2, indicating increased fore/aft interaction with the seat in the ES2re. The ES2re exhibited higher lateral and longitudinal loading, in the rear seat of the FMVSS 214 test, than the ES2. The ES2re and ES2 abdominal responses were below IARV in all loading conditions. Some WorldSID abdominal responses were above the IARV and some were below. WorldSID evaluates abdominal loading differently than the ES2re and ES2, ES2re exhibited higher pubic loading responses than WorldSID.

Oblique Side Impacts:

The ES-2 was also evaluated in oblique side impacts by impacting the thorax region with a linear impactor at 0, 15 and 30-degree angles from pure lateral. The results are not available at this time, but will follow as soon as they are available.

References:

1. ISO/TR9790, Road Vehicles – Anthropomorphic Side Impact Dummy – Lateral Impact Response Requirements to Assess the Biofidelity of the Dummy, International Standards Organization, American National Standards Institute, NY, NY, 1999.
2. Byrnes, K., et al., ES-2 Dummy Biomechanical Responses, Stapp Car Crash Journal, Vol. 46, pp. 353-396, Society of Automotive Engineers, Warrendale, PA, 2002.

APPENDIX A

Table A1. ES-2re Biofidelity Ratings from Neck Test 1 – 7.2 G Sled Test.

Parameter	Units	Corridor	Run 1	Run 2	Run 3	Measurement Ratings	CV (%)
Peak T1 Horiz. Accel, Ay	g	12 – 18	10	11	11	5, 5, 5	4.6
Peak T1 Horiz. Disp. wrt sled, Dy	mm	46 – 63	120	121	131	0, 0, 0	5
Peak Head C.G. Horiz. Displ. wrt T1, Dy	mm	130 – 162	130	132	124	10, 10, 5	3.2
Peak Head C.G. Vert. Displ. wrt T1, Dz	mm	64 – 94	59	64	72	5, 10, 10	9.8
Time of Peak Head Excursion	s	0.159 – 0.175	0.159	0.157	0.157	10, 5, 5	0.6
Peak Head Lateral Accel, Ay	g	8 – 11	13	13	13	5, 5, 5	0.13
Peak Head Vert. (down) Accel, -Az	g	8 – 10	12	13	13	5, 0, 0	2.4
Peak Neck Flexion, θx	deg	44 – 59	65	55	72	5, 10, 5	13
Peak Neck Twist, θz	deg	-45 – -32	-12	-4	-8	0, 0, 0	45

Table A2. ES-2re Biofidelity Ratings from Neck Test 2 – 6.7 G Sled Test.

Parameter	Units	Corridor	Run 1	Run 2	Run 3	Measurement Ratings	CV (%)
Peak Flexion Angle, θx	deg	40 – 50	79	64	87	0, 0, 0	15
Peak Moment about A-P Axis at O.C., Mx	N-m	40 – 50	31	33	31	5, 5, 5	2.7
Peak Moment about R-L Axis at O.C., My	N-m	20 – 30	6	5	6	0, 0, 0	12
Peak Twist Moment, Mz	N-m	15 – 20	7	6.5	7	0,0,0	3.9
Peak Shear Force at O.C., Fy	N	750 – 850	541	546	575	0, 0, 0	3.3
Peak Tension Force at O.C., Fz	N	350 – 400	556	568	541	0, 0, 0	2.5
Peak P-A Shear Force, Fx	N	325 – 375	53	57	92	0, 0, 0	32
Peak Resultant Head Accel	g	18 – 24	17	17	18	5, 5, 10	1.9

Table A3. ES-2re Biofidelity Ratings from Neck Test 3 – 12.2 G Sled Test.

Parameter	Units	Corridor	Run 1	Run 2	Run 3	Measurement Ratings	CV (%)
Peak Lateral Accel, T1, Ay	g	17 – 23	20	20	19	10, 10, 10	4.6
Peak Head C.G. Lateral Accel, Ay	g	25 – 47	15	15	15	5, 5, 5	1.7
Peak Head C.G. Horiz. Displ. wrt Sled, Dy	mm	185 – 226	222	215	213	10, 10, 10	2.2
Peak Head Flexion, θx	deg	62 – 75	64	72	56	10, 10, 5	12
Peak Head Twist, θz	deg	62 – 75	10	6	6	0, 0, 0	33

Table A4. ES-2re Biofidelity Ratings from Shoulder Tests 1, 2, 3, and 4.

Test/Parameter	Units	Corridor	Run 1	Run 2	Run 3	Measurement Ratings	CV (%)
Test 1 – 4.3 m/s Rigid Pendulum Impact							
Peak Shoulder Defl. Relative to T1, Dy	mm	34 – 41	Not instrumented for shoulder deflections			0, 0, 0	
Pendulum Force	kN	Refer to Figure E1.				5, 5, 5	3
Test 2 – 7.2G Sled Test							
Peak T1 Horiz. Accel, Ay.	g	12 – 18	10	11	11	5, 5, 5	4.6
Peak T1 Horiz. Disp. wrt sled, Dy	mm	46 – 63	120	121	131	0, 0, 0	5
Test 3 – 12.2G Sled Test							
Peak Lateral Accel of T1, Ay	g	17 – 23	20	20	19	10, 10, 10	4.6
Test 4 – 8.9 m/s WSU-type Padded Sled (200 mm, 15-psi Paper Honeycomb)							
Shoulder + Thoracic Plate Force	kN	Refer to Figure E2.	556	568	541	5, 5, 5	3

Table A5. ES-2re Biofidelity Ratings from Thorax Tests 1, 2, 3, 5, and 6.

Test/Parameter	Units	Corridor	Run 1	Run 2	Run 3	Measurement Ratings	CV (%)
Test 1 – 4.3 m/s Rigid Pendulum Impact							
Pendulum Force (Left)	kN	Refer to Figure F1.				0, 0, 0	0.9
Upper Spine Acceleration (Left)	g	Refer to Figure F2				0, 0, 0	7.5
Test 2 – 6.7 m/s Rigid Pendulum Impact							
Pendulum Force (Left)	kN	Refer to Figure F5.				5, 5, 5	3.8
Test 3 – 1.0 m Drop onto Rigid Impact Surfaces							
Thoracic Rib Deflection, Dy	mm	26 – 38	25	26	26	5, 10, 10	1.2
Thoracic Plate Force	kN	Refer to Figure F7.				10, 10, 10	3.4
Test 5 – 6.8 m/s Heidelberg-type Rigid Sled							
T1 Acceleration, Ay	g	82 – 122	38	38	43	0, 0, 5	6.8
T12 Acceleration, Ay	g	71 – 107	42	46	28	5, 5, 0	24
Thoracic Rib Acceleration, Ay	g	64 – 100	124	123	123	5, 5, 5	0.5
Thoracic Plate Force	kN	Refer to Figure F8.				10, 10, 10	1.3
Test 6 – 8.9 m/s WSU-type Padded Sled (200 mm Paper Honeycomb)							
Peak Lateral Displ. of T12, Dy	mm	80 – 108 15 psi : 23 psi :	 2 2	 2 2	 2 3	 0, 0, 0 0, 0, 0	 6 20
Shoulder + Thorax Plate Force	kN	Refer to Figure F9.				15 psi : 5, 5, 5 23 psi : 5, 5, 5	10 3

Table A6. ES-2re Biofidelity Ratings from Abdomen Tests 1, 3, 4, and 5.

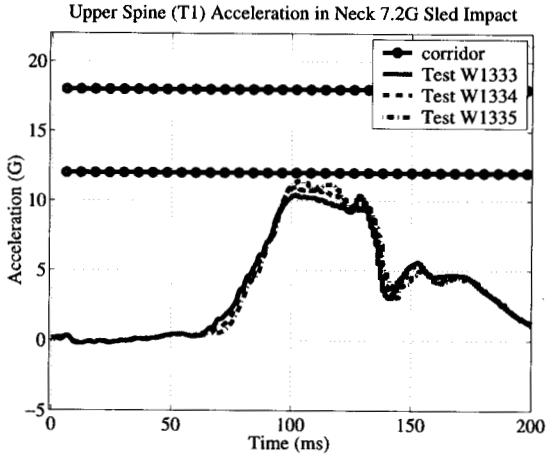
Test/Parameter	Units	Corridor	Run 1	Run 2	Run 3	Measurement Ratings	CV (%)
Test 1 – 1.0 m Drop onto Rigid Armrest							
T12 Acceleration, Ay	g	29 – 35	44	47	43	0,0,0	4.3
Abdominal Rib Acceleration, Ay	g	100 – 125	45	32	29	0,0,0	24
Abdominal Rib Displacement, Dy	mm	>41	9	5	4	0,0,0	40
Armrest Force	kN	Refer to Figure G1.				0,0,0	2.6
Test 3 – 6.8 m/s WSU-type Rigid Sled							
Abdomen Plate Force	kN	Refer to Figure G5.				5, 5, 5	27
Test 4 – 8.9 m/s WSU-type Rigid Sled							
Abdomen Plate Force	kN	Refer to Figure G6.				10,5,5	9
Test 5 – 8.9 m/s WSU-type Padded Sled (200 mm Paper Honeycomb)							
Abdomen Plate Force	kN	Refer to Figure G7.				15 psi: 10, 5, 5 23 psi: 0, 5, 5	31 13

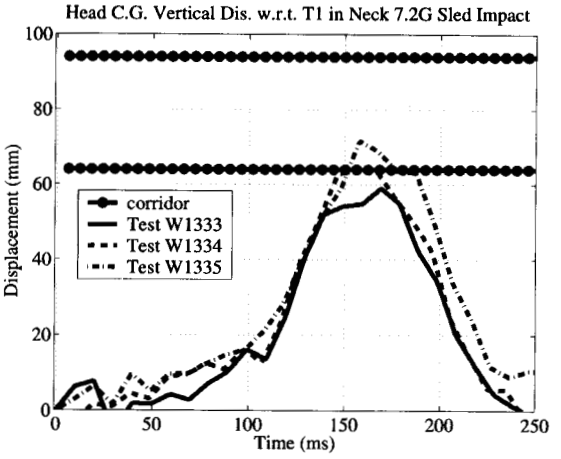
Table A7. ES-2re Biofidelity Ratings from Pelvis Tests 1, 3, 4, 7, 8, 10, 11, 12 and 13.

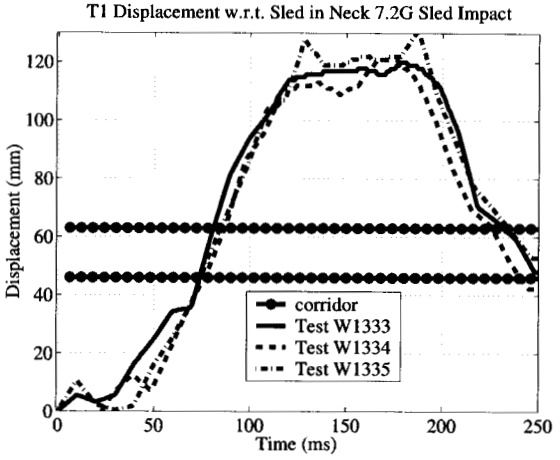
Test/Parameter	Units	Corridor	Run 1	Run 2	Run 3	Measurement Ratings	CV (%)
Test 1 – 6.0 m/s Pendulum Impact							
Pendulum Force	kN	Refer to Figure H1				0, 0, 0	1.9
Test 1 – 10.0 m/s Pendulum Impact							
Pendulum Force	kN	Refer to Figure H1				0, 0, 0	5
Test 3 – 0.5 m Drop onto Rigid Surfaces							
Peak Pelvis Acceleration, Ay	g	37 – 45	32	34	35	5, 5, 5	4.9
Test 4 – 1.0 m Drop onto Rigid Surfaces							
Peak Pelvis Acceleration, Ay	g	63 – 77	60	65	66	5, 10, 10	5.2
Test 7 – 6.8 m/s Heidelberg-type Rigid Sled							
Pelvis Acceleration, Ay	g	63 – 77	83	81	65	5, 5, 10	13.5
Pelvis Plate Force	kN	6.4 – 7.8	15	16	12	0, 0, 0	12
Test 8 – 8.9 m/s Heidelberg-type Rigid Sled							
Pelvis Acceleration, Ay	g	96 – 116	144	145	135	0, 0, 5	4.1
Pelvis Plate Force	kN	22.4 – 26.4	27	27	26	5, 5, 10	2.7
Test 10 – 6.8 m/s WSU-type Rigid Sled							
Pelvis Acceleration, Ay	g	85 – 115	65	71	60	5, 5, 5	8
Pelvis Plate Force	kN	Refer to Figure H2				5, 5, 5	11
Test 11 – 8.9 m/s WSU-type Rigid Sled							
Pelvis Acceleration, Ay	g	111 – 151	131	147	125	10, 10, 10	8
Pelvis Plate Force	kN	Refer to Figure H3				5, 5, 5	3
Test 12 – 8.9 m/s WSU-type Padded Sled (200 mm, 15 psi Paper Honeycomb)							
Pelvis Acceleration, Ay	g	37 – 51	35	36	32	5, 5, 5	7
Test 13 – 8.9 m/s WSU-type Padded Sled (200 mm, 23 psi Paper Honeycomb)							
Pelvis Acceleration, Ay	g	65 – 89	36	30	40	0, 0, 0	14
Pelvis Plate Force	kN	Refer to Figure H4				15 psi : 5,5,5 23psi: 5, 5, 10	33 20

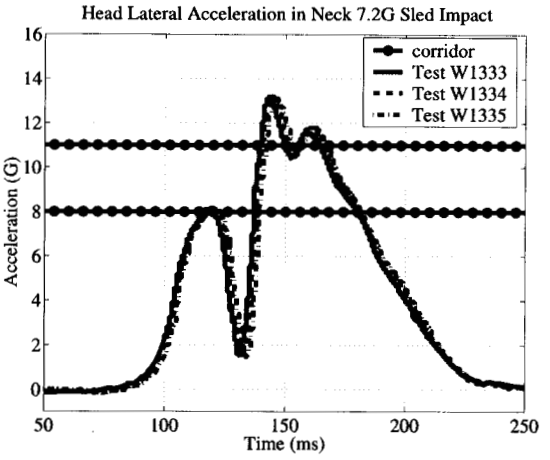
APPENDIX B: Biofidelity Data

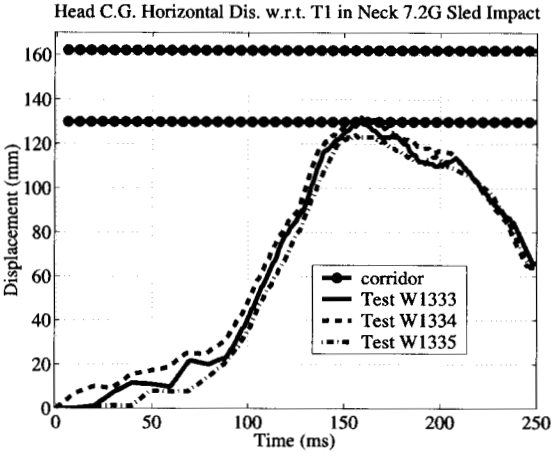
Neck Tests

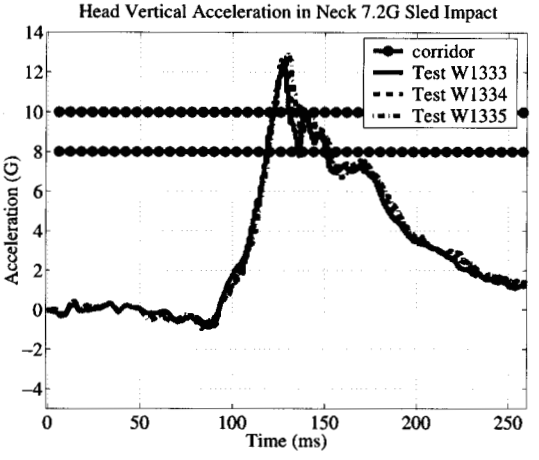


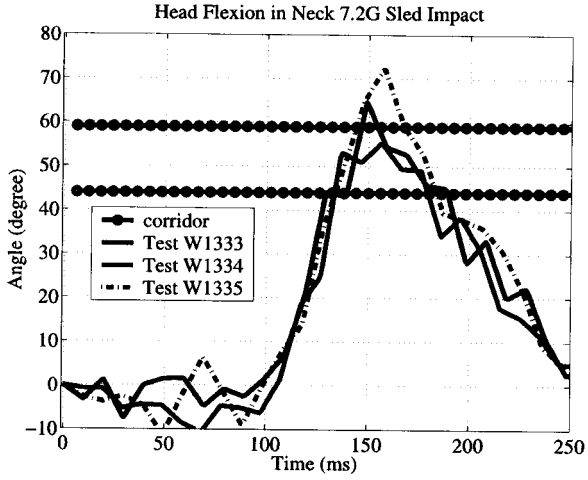


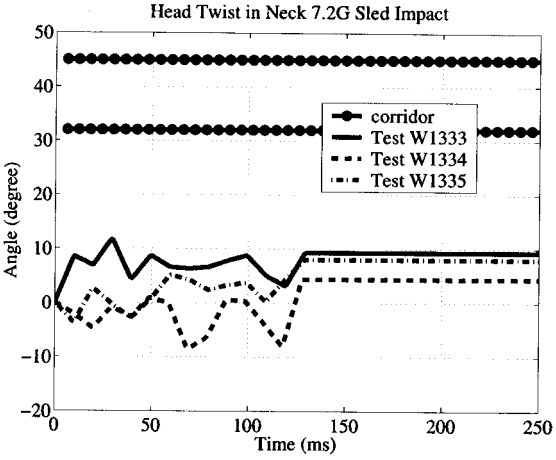


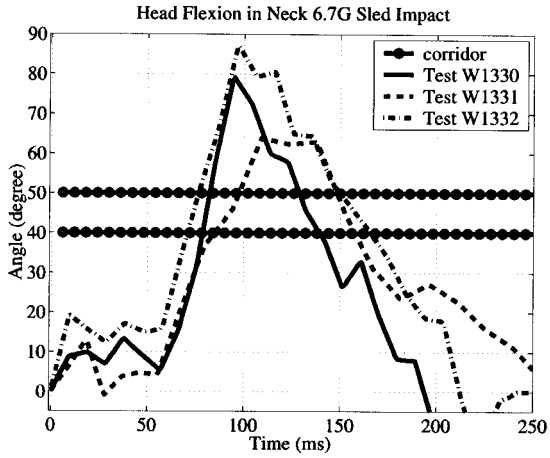


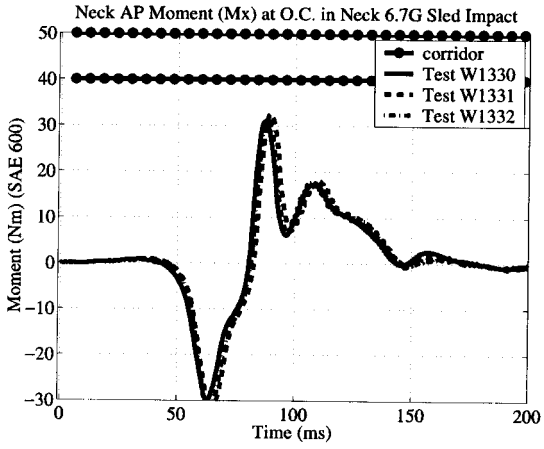


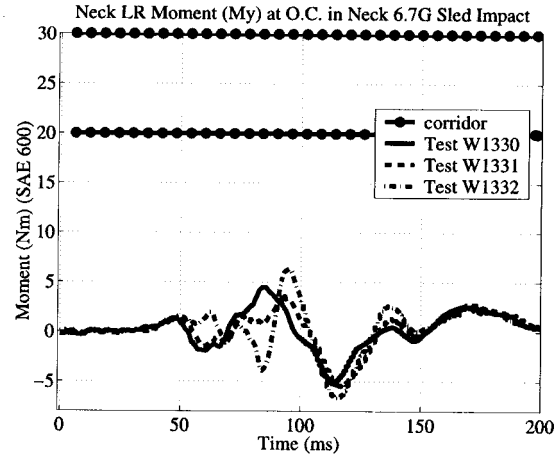


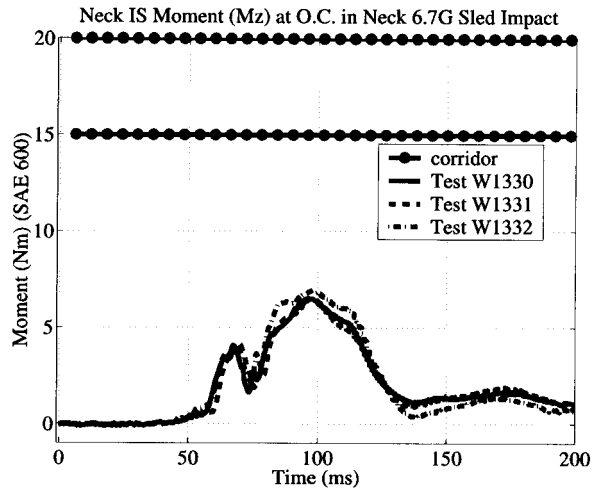

Head Flexion in Neck 7.2G Sled Impact
Angle (degree)
Time (ms)
corridor
Test W1333
Test W1334
Test W1335

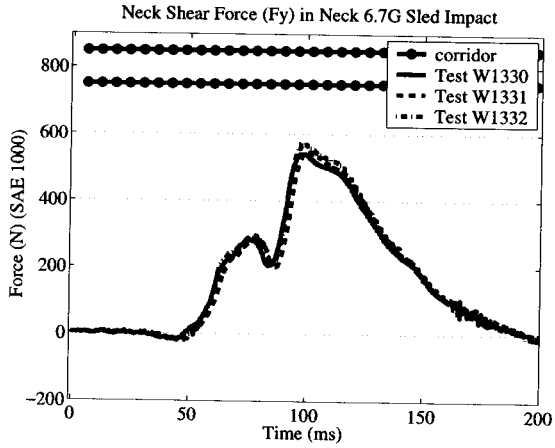

Head Twist in Neck 7.2G Sled Impact
Angle (degree)
Time (ms)
corridor
Test W1333
Test W1334
Test W1335

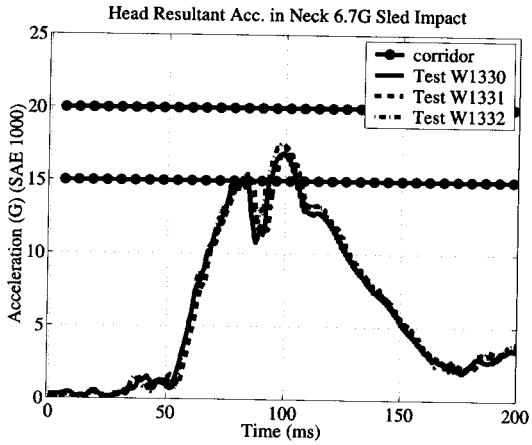

Head Flexion in Neck 6.7G Sled Impact
Angle (degree)
Time (ms)
corridor
Test W1330
Test W1331
Test W1332

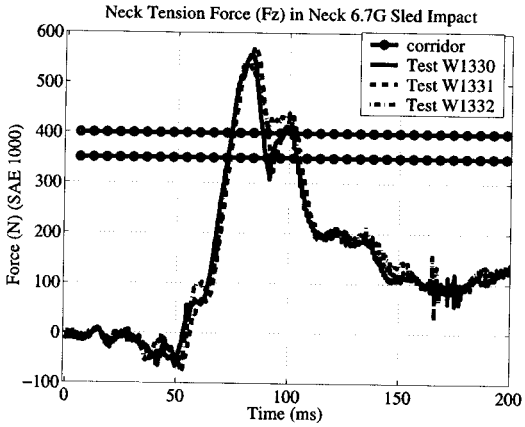

Neck AP Moment (Mx) at O.C. in Neck 6.7G Sled Impact
Moment (Nm) (SAE 600)
Time (ms)
corridor
Test W1330
Test W1331
Test W1332

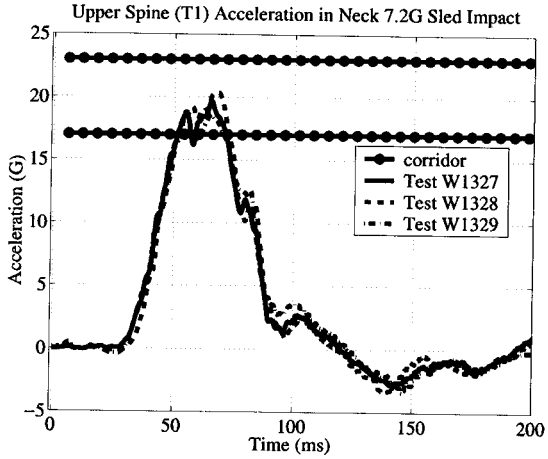

Neck LR Moment (My) at O.C. in Neck 6.7G Sled Impact
Moment (Nm) (SAE 600)
Time (ms)
corridor
Test W1330
Test W1331
Test W1332

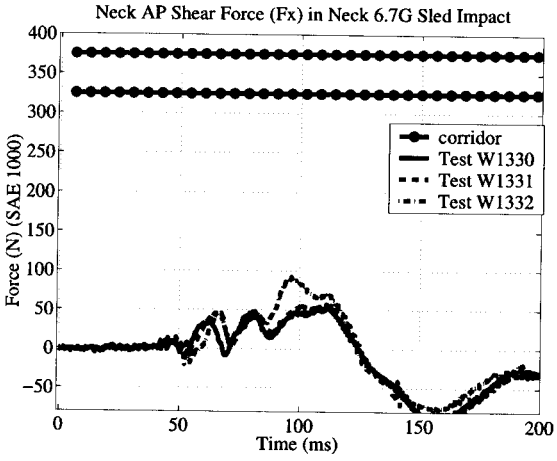

Neck IS Moment (Mz) at O.C. in Neck 6.7G Sled Impact
Moment (Nm) (SAE 600)
Time (ms)
corridor
Test W1330
Test W1331
Test W1332

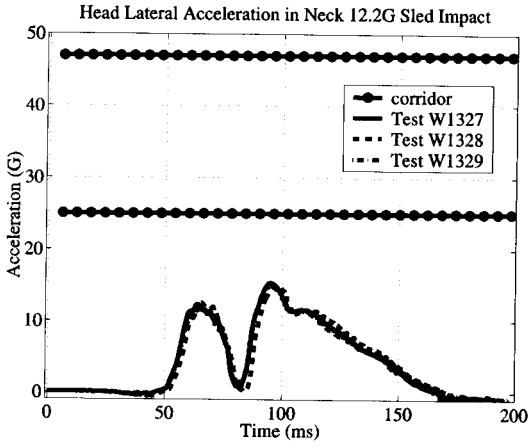

Neck Shear Force (Fy) in Neck 6.7G Sled Impact
corridor
Test W1330
Test W1331
Test W1332
Force (N) (SAE 1000)
Time (ms)

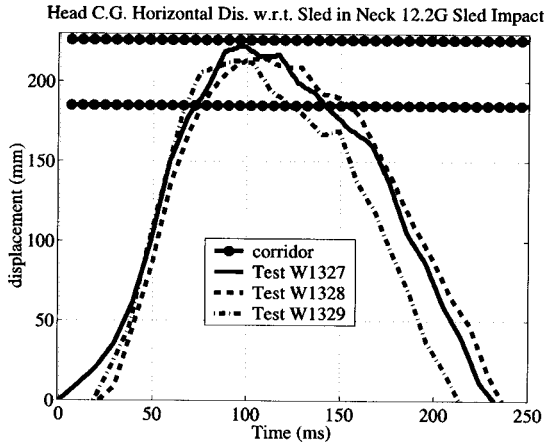

Head Resultant Acc. in Neck 6.7G Sled Impact
corridor
Test W1330
Test W1331
Test W1332
Acceleration (G) (SAE 1000)
Time (ms)

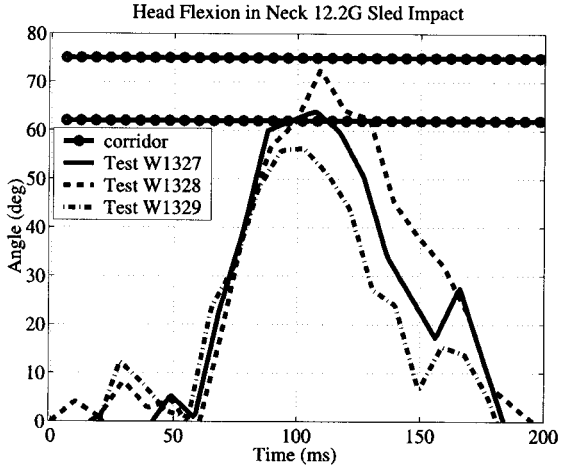

Neck Tension Force (Fz) in Neck 6.7G Sled Impact
corridor
Test W1330
Test W1331
Test W1332
Force (N) (SAE 1000)
Time (ms)

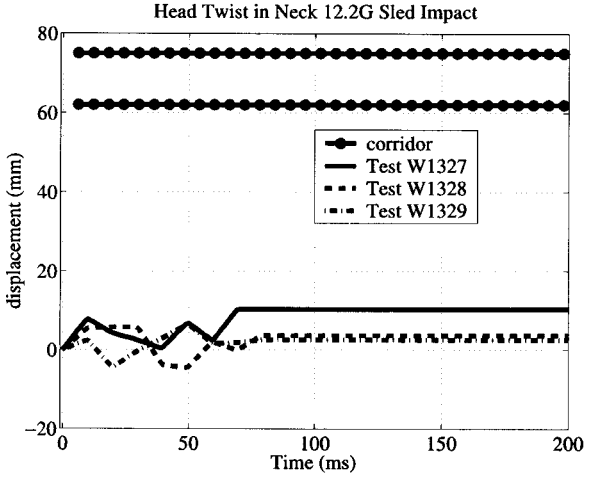

Upper Spine (T1) Acceleration in Neck 7.2G Sled Impact
corridor
Test W1327
Test W1328
Test W1329
Acceleration (G)
Time (ms)


Neck AP Shear Force (Fx) in Neck 6.7G Sled Impact
corridor
Test W1330
Test W1331
Test W1332
Force (N) (SAE 1000)
Time (ms)

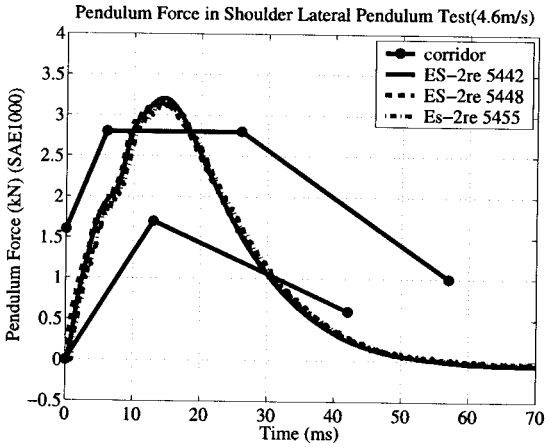

Head Lateral Acceleration in Neck 12.2G Sled Impact
corridor
Test W1327
Test W1328
Test W1329
Acceleration (G)
Time (ms)

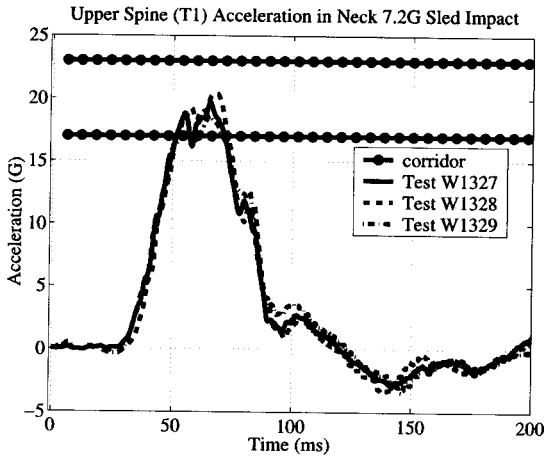

Head C.G. Horizontal Dis. w.r.t. Sled in Neck 12.2G Sled Impact
displacement (mm)
Time (ms)
corridor
Test W1327
Test W1328
Test W1329

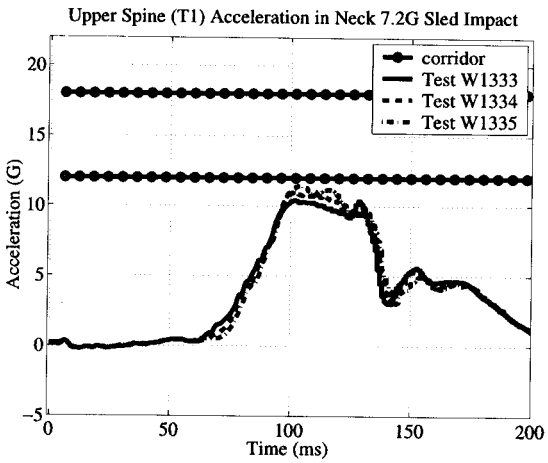

Head Flexion in Neck 12.2G Sled Impact
Angle (deg)
Time (ms)
corridor
Test W1327
Test W1328
Test W1329

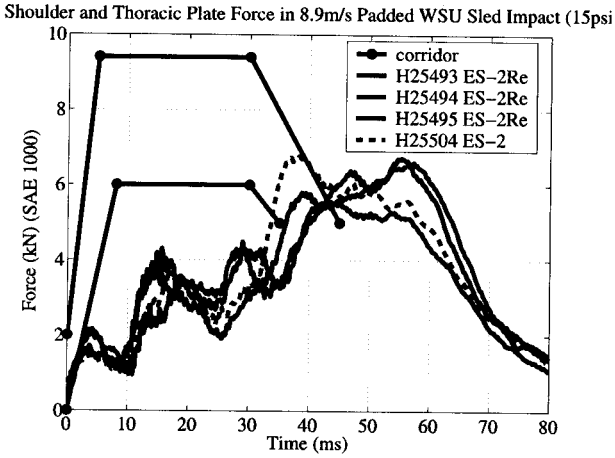

Head Twist in Neck 12.2G Sled Impact
displacement (mm)
Time (ms)
corridor
Test W1327
Test W1328
Test W1329

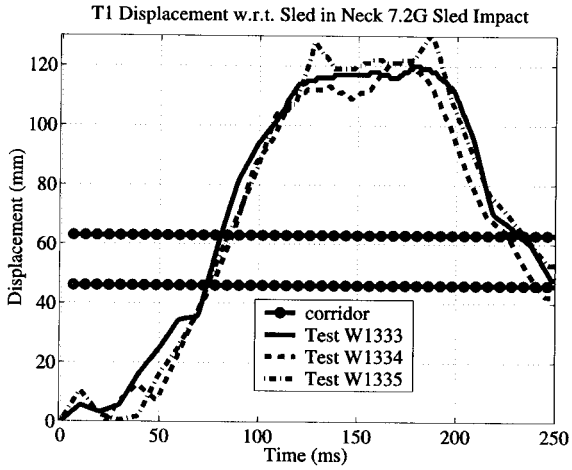
Shoulder Tests



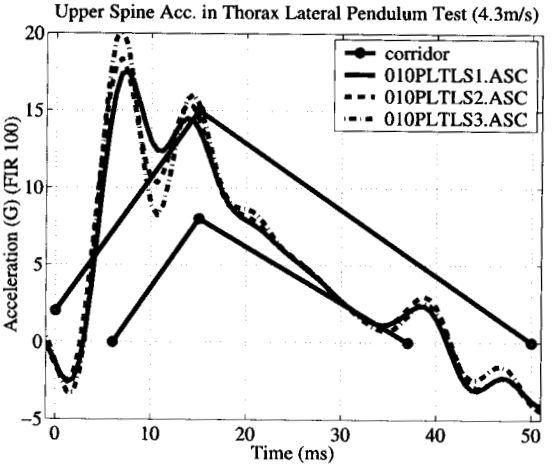


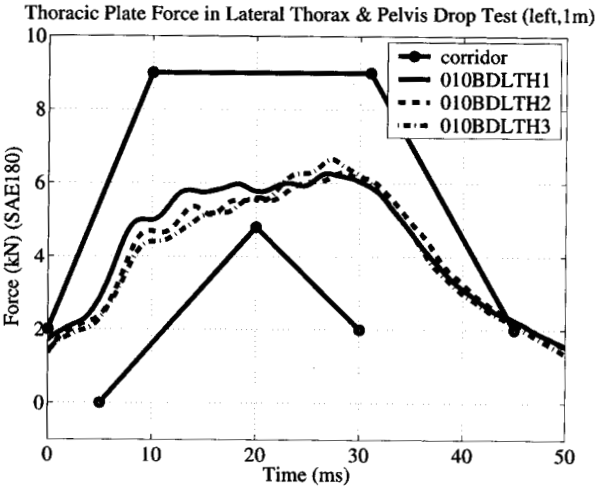


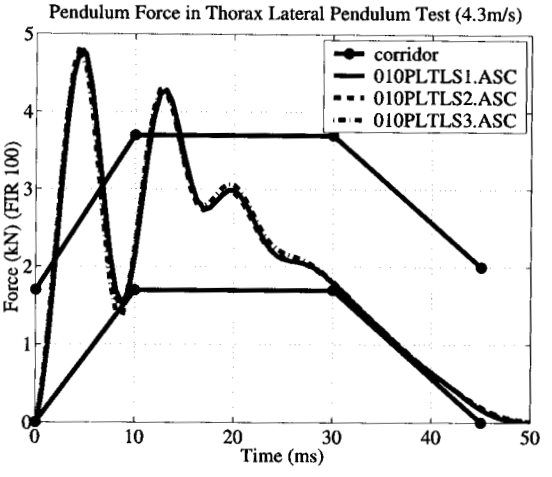


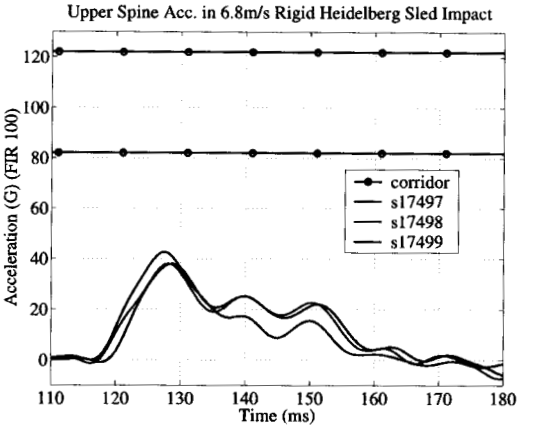


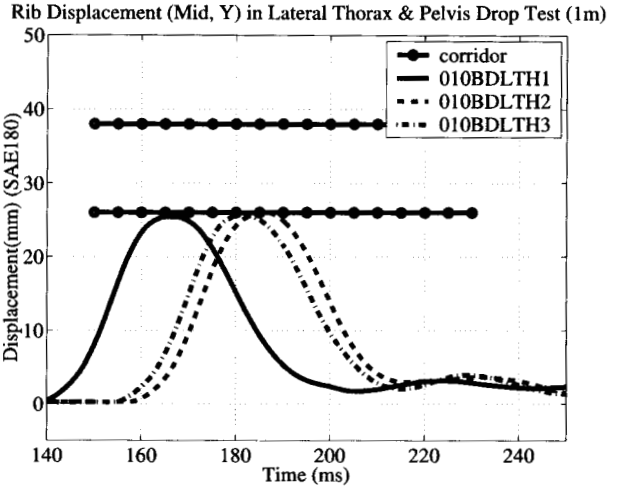
Thorax Tests

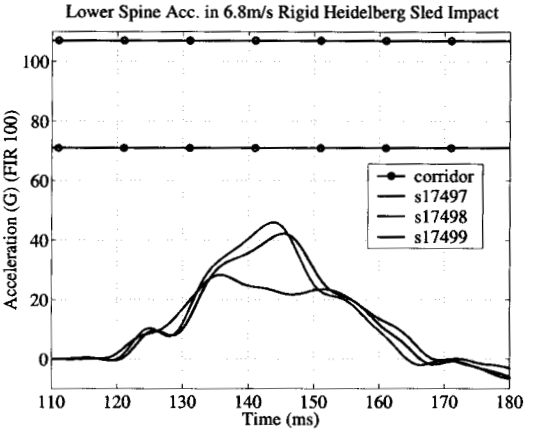


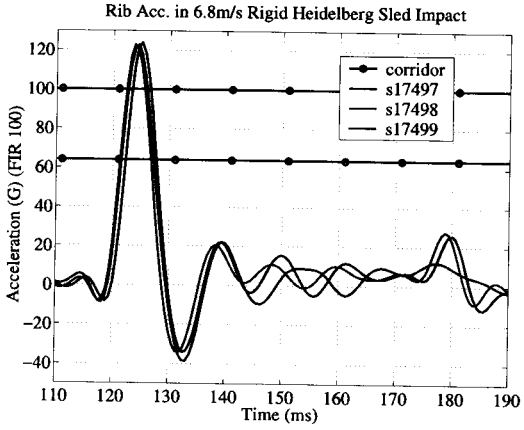


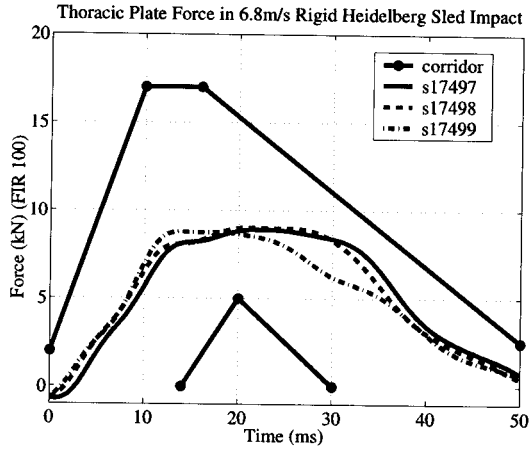


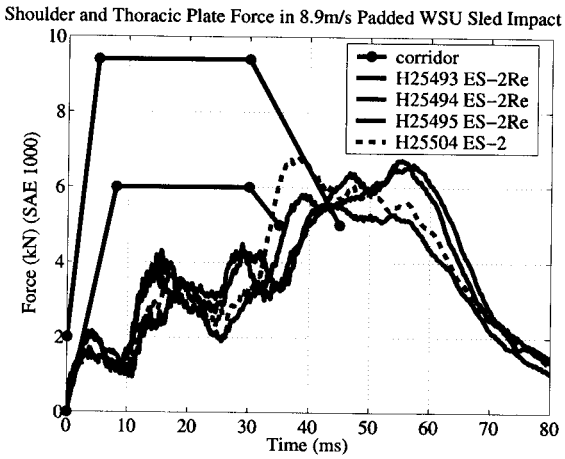




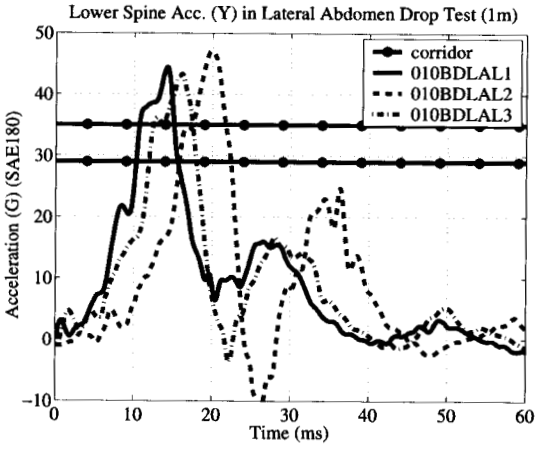


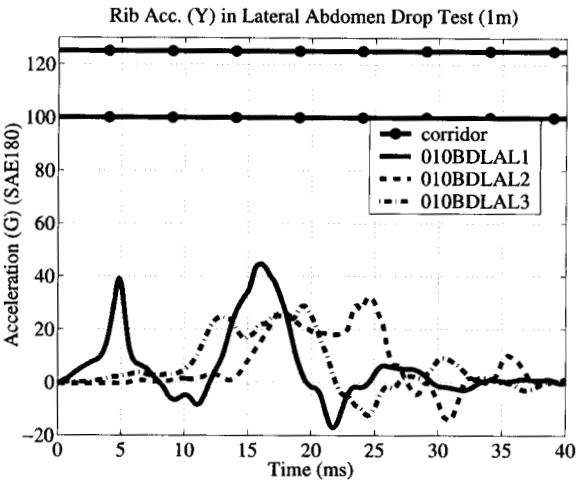

Rib Acc. in 6.8m/s Rigid Heidelberg Sled Impact
corridor
s17497
s17498
s17499
Acceleration (G) (FIR 100)
Time (ms)

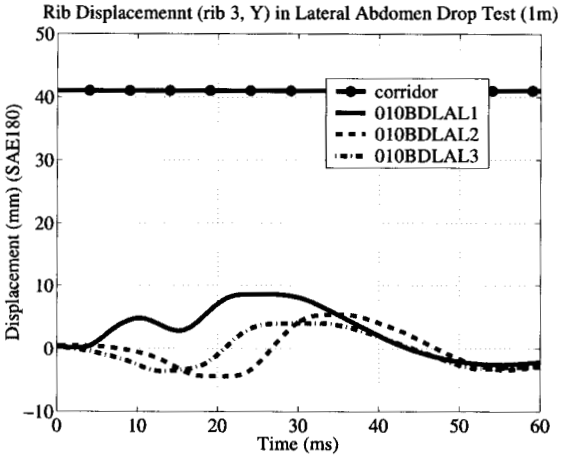

Thoracic Plate Force in 6.8m/s Rigid Heidelberg Sled Impact
corridor
s17497
s17498
s17499
Force (kN) (FIR 100)
Time (ms)

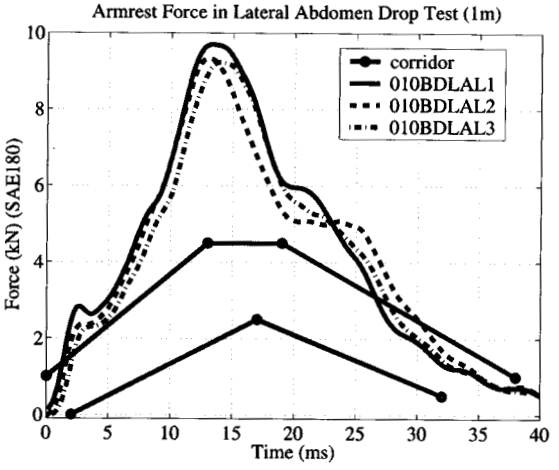

Shoulder and Thoracic Plate Force in 8.9m/s Padded WSU Sled Impact (15psi
corridor
H25493 ES-2Re
H25494 ES-2Re
H25495 ES-2Re
H25504 ES-2
Force (kN) (SAE 1000)
Time (ms)

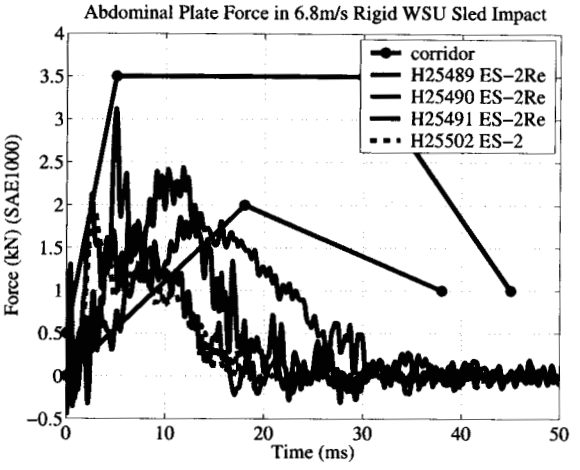
Abdomen Tests

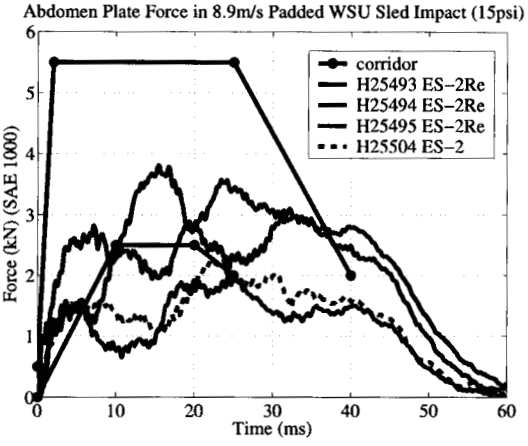




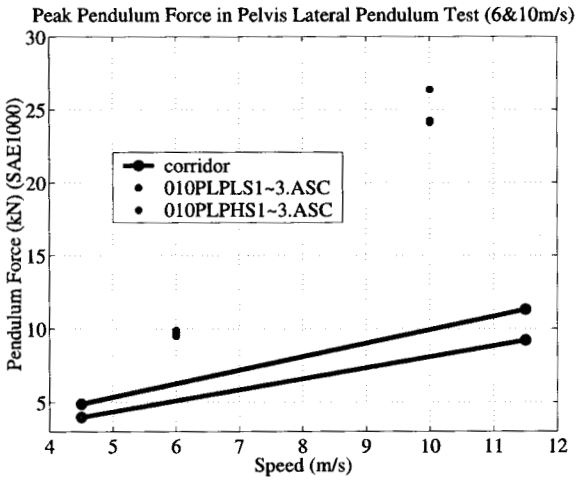


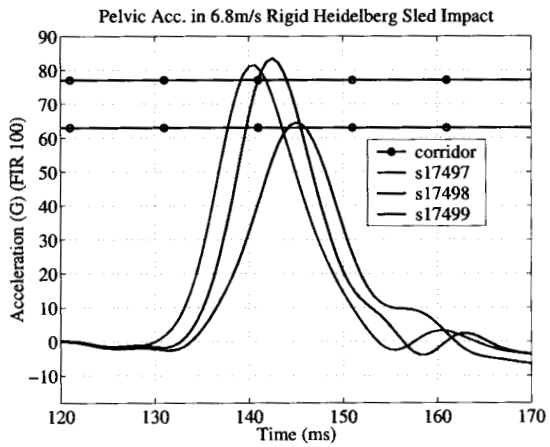


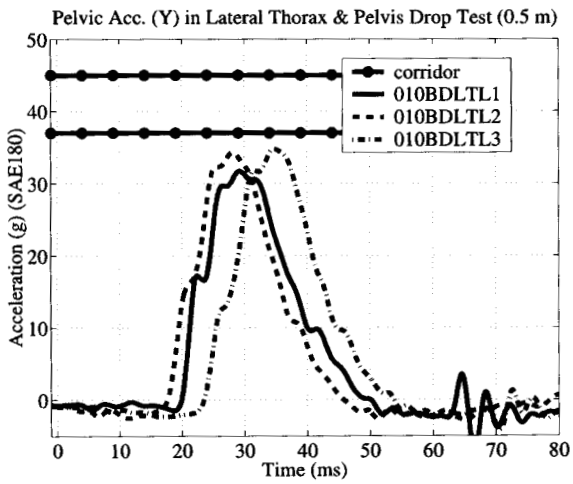


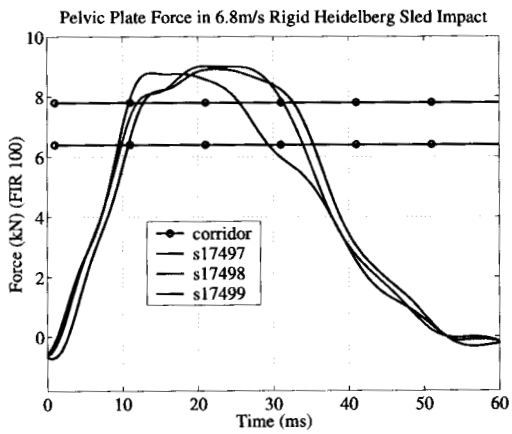


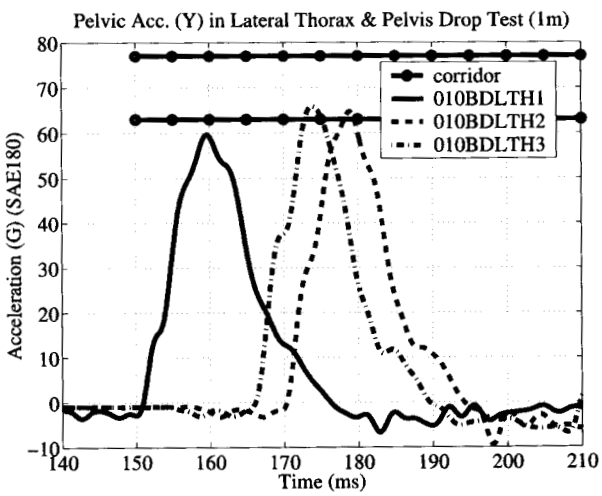
Pelvis Tests

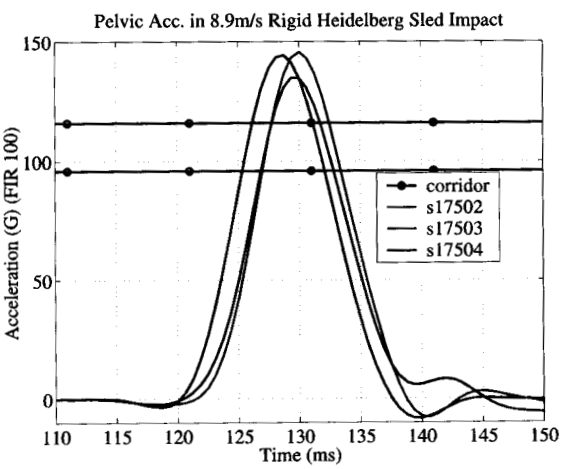


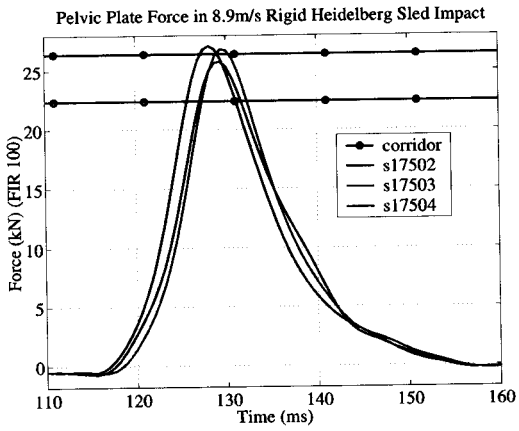


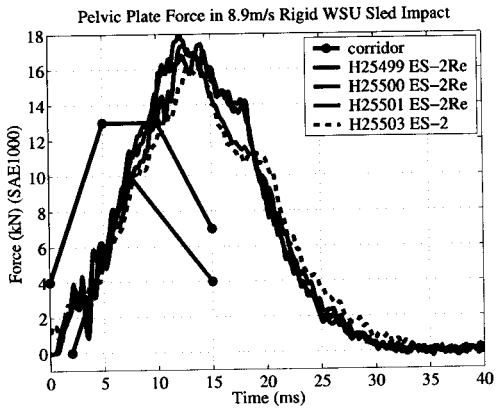


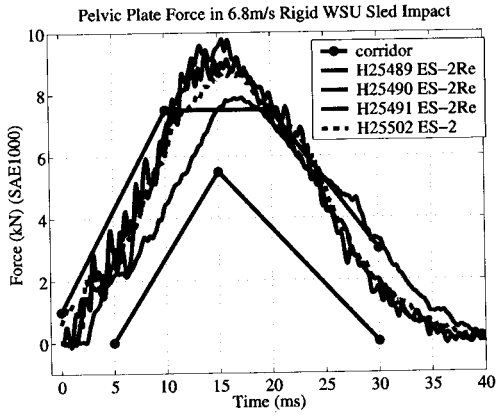


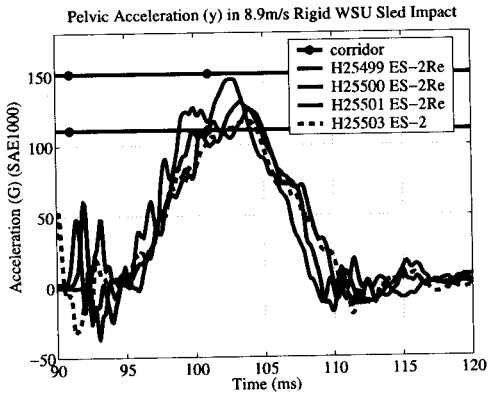


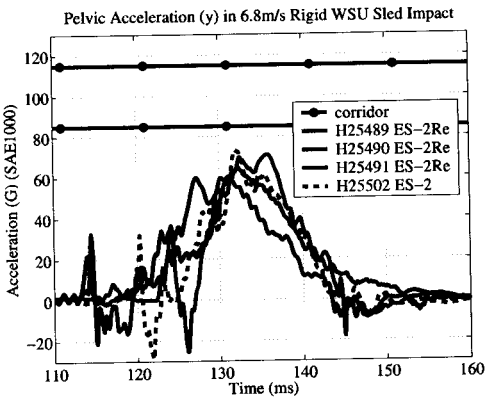


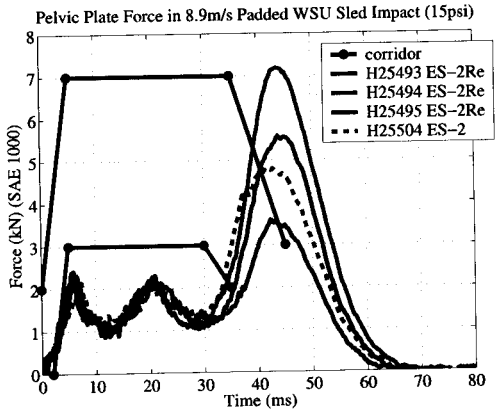

Pelvic Plate Force in 8.9m/s Rigid Heidelberg Sled Impact
Force (kN) (FIR 100)
Time (ms)
corridor
s17502
s17503
s17504

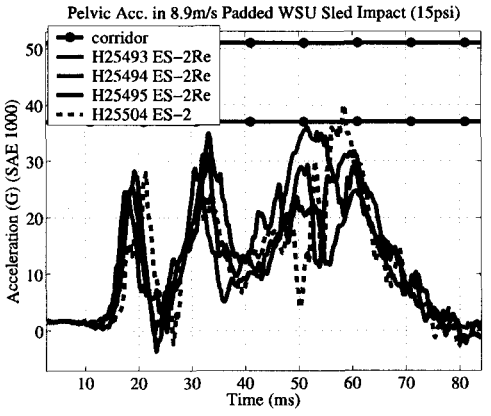

Pelvic Plate Force in 8.9m/s Rigid WSU Sled Impact
Force (kN) (SAE1000)
Time (ms)
corridor
H25499 ES-2Re
H25500 ES-2Re
H25501 ES-2Re
H25503 ES-2

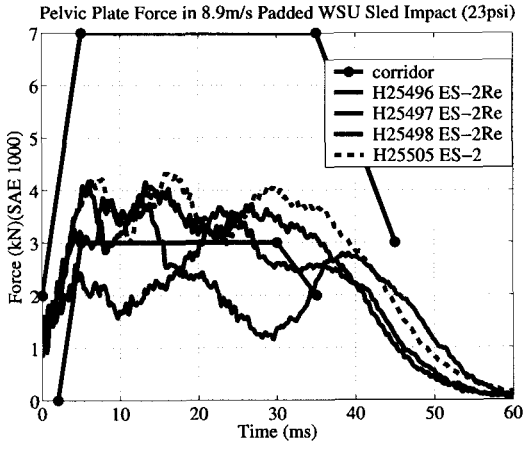

Pelvic Plate Force in 6.8m/s Rigid WSU Sled Impact
Force (kN) (SAE1000)
Time (ms)
corridor
H25489 ES-2Re
H25490 ES-2Re
H25491 ES-2Re
H25502 ES-2

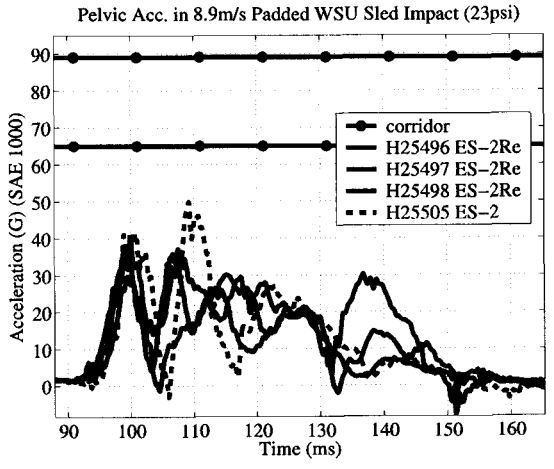

Pelvic Acceleration (y) in 8.9m/s Rigid WSU Sled Impact
Acceleration (G) (SAE1000)
Time (ms)
corridor
H25499 ES-2Re
H25500 ES-2Re
H25501 ES-2Re
H25503 ES-2


Pelvic Acceleration (y) in 6.8m/s Rigid WSU Sled Impact
Acceleration (G) (SAE1000)
Time (ms)
corridor
H25489 ES-2Re
H25490 ES-2Re
H25491 ES-2Re
H25502 ES-2


Pelvic Plate Force in 8.9m/s Padded WSU Sled Impact (15psi)
Force (kN) (SAE 1000)
Time (ms)
corridor
H25493 ES-2Re
H25494 ES-2Re
H25495 ES-2Re
H25504 ES-2


Pelvic Acc. in 8.9m/s Padded WSU Sled Impact (15psi)
corridor
H25493 ES-2Re
H25494 ES-2Re
H25495 ES-2Re
H25504 ES-2
Acceleration (G) (SAE 1000)
Time (ms)

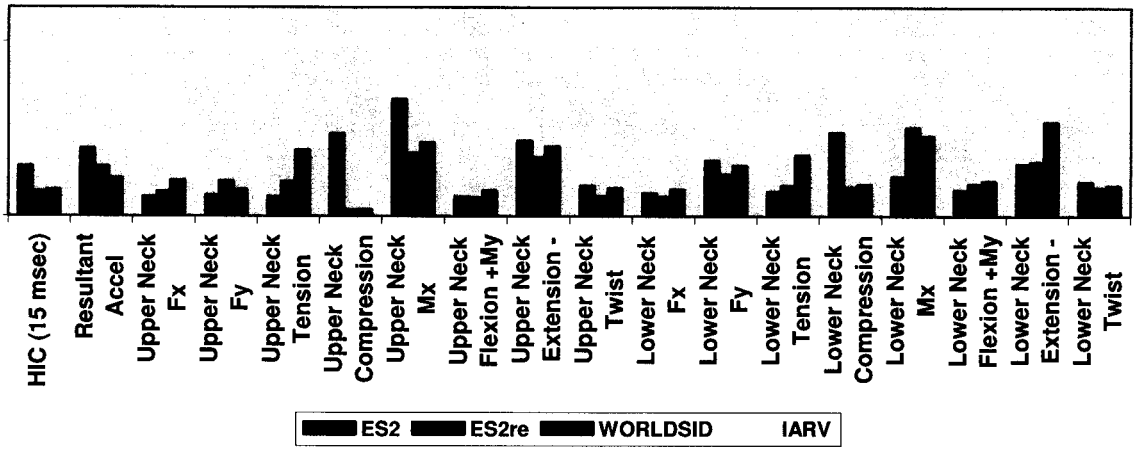

Pelvic Plate Force in 8.9m/s Padded WSU Sled Impact (23psi)
corridor
H25496 ES-2Re
H25497 ES-2Re
H25498 ES-2Re
H25505 ES-2
Force (kN)(SAE 1000)
Time (ms)

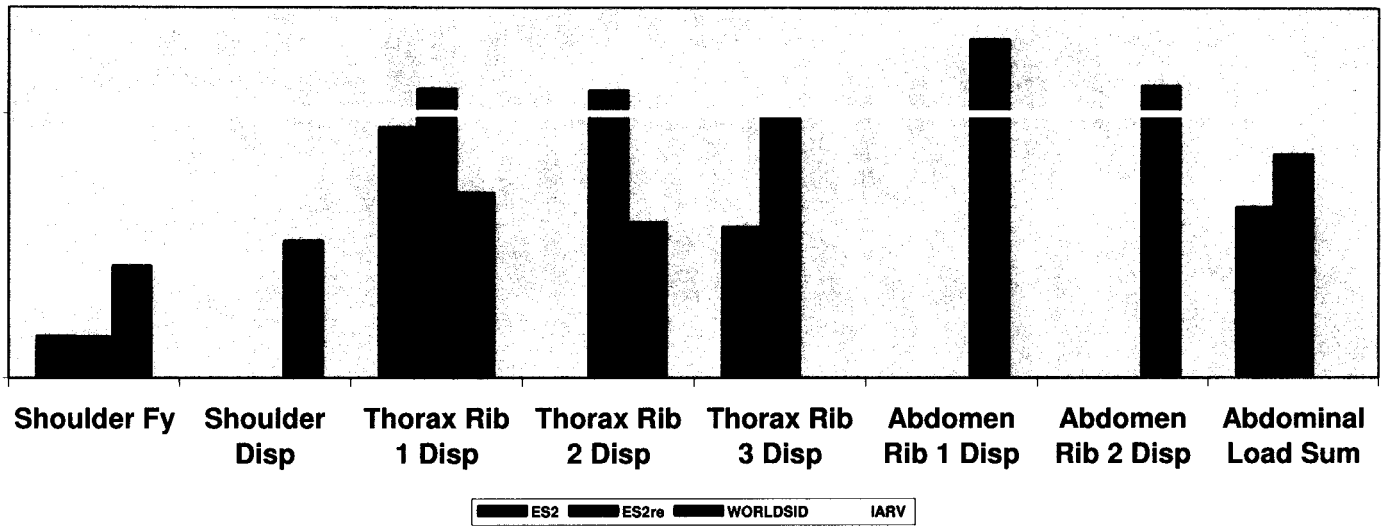

Pelvic Acc. in 8.9m/s Padded WSU Sled Impact (23psi)
corridor
H25496 ES-2Re
H25497 ES-2Re
H25498 ES-2Re
H25505 ES-2
Acceleration (G) (SAE 1000)
Time (ms)

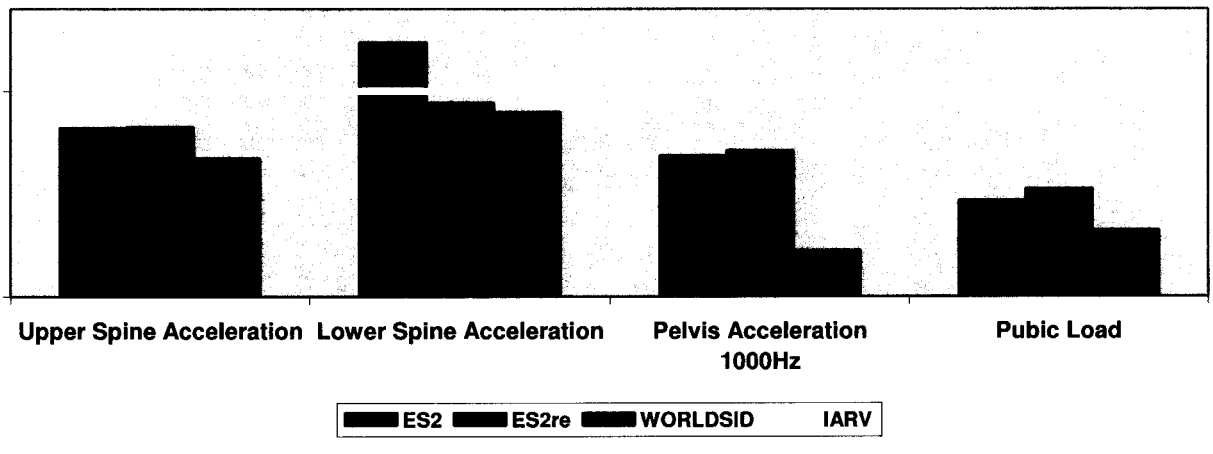
APPENDIX C. Full Vehicle Data

Bar Chart Comparisons

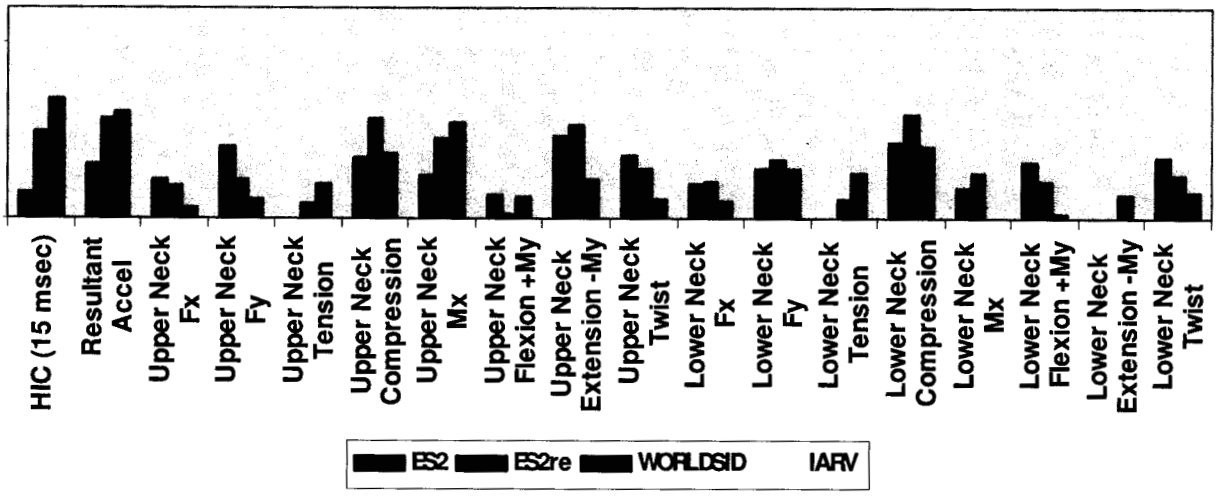
Mid-sized Car, Front Dummy

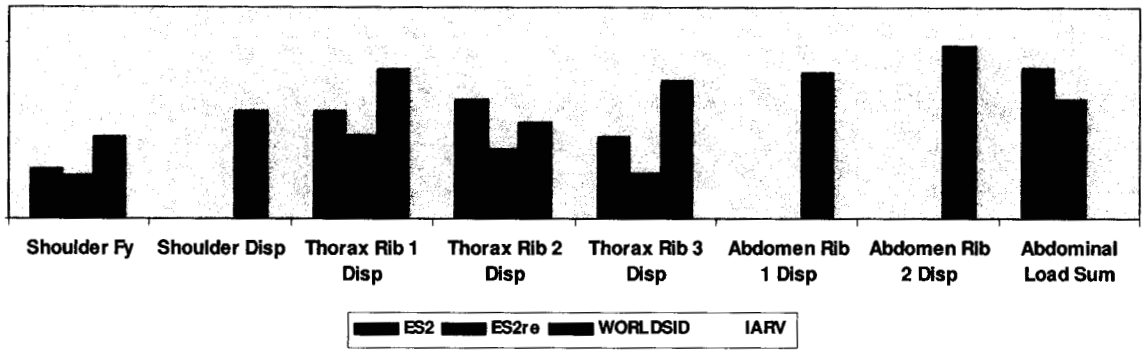


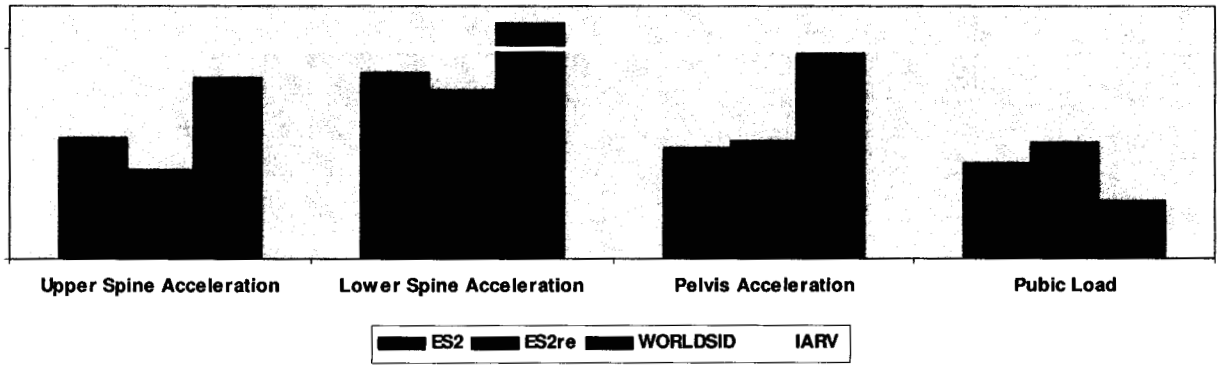




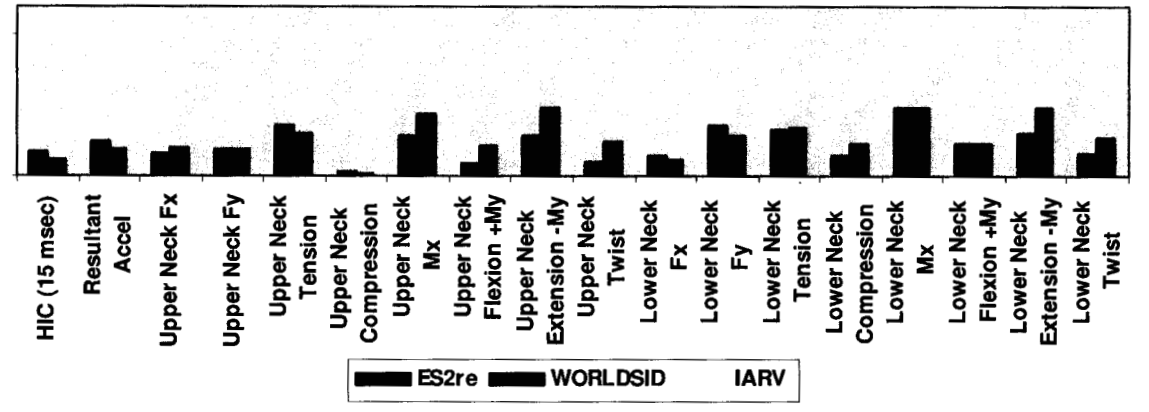
Mid-Sized Car, Rear Dummy

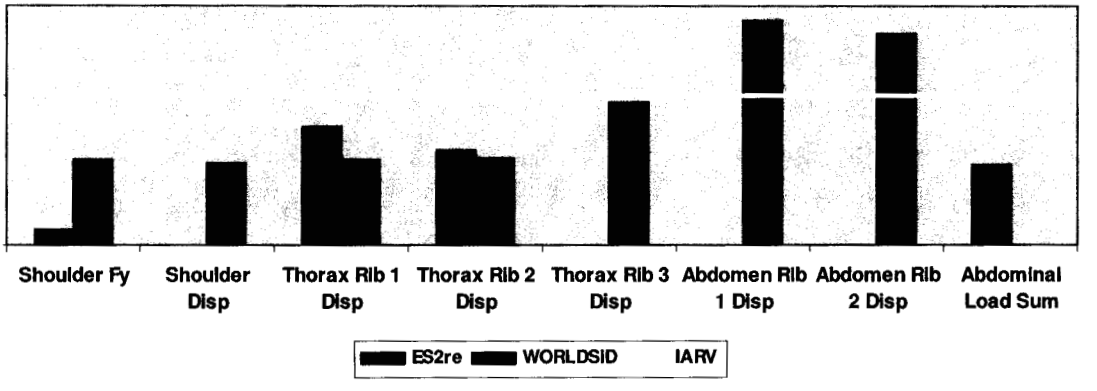


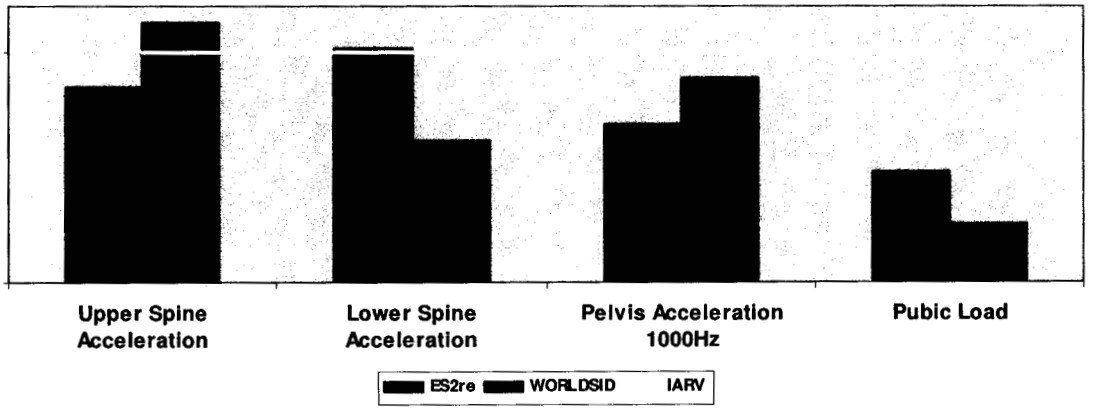




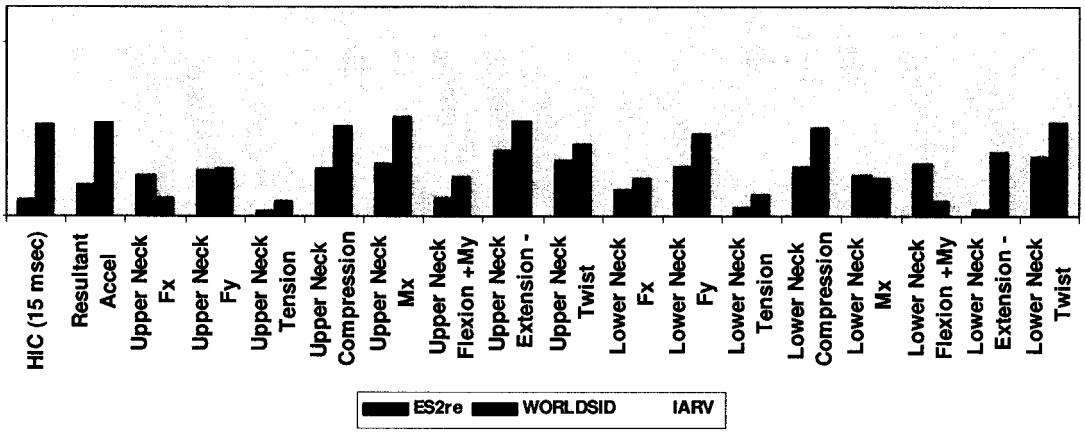
Small Car, Front Dummy

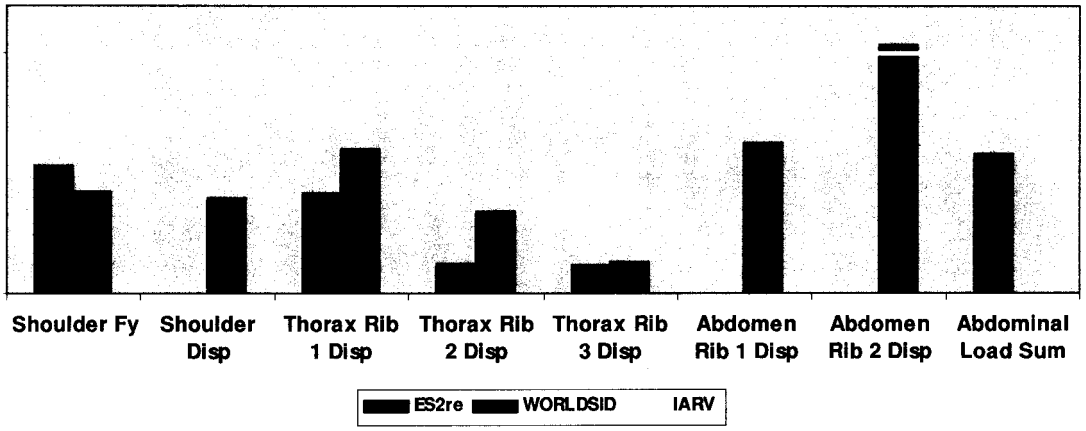


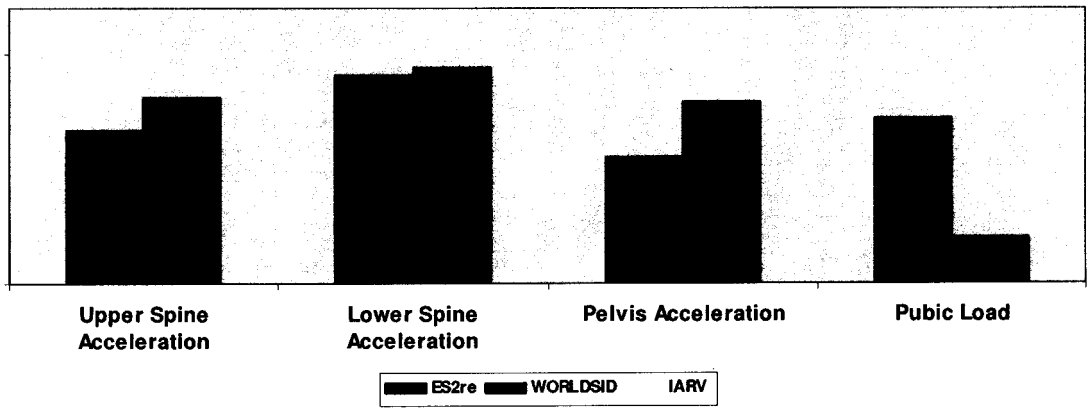




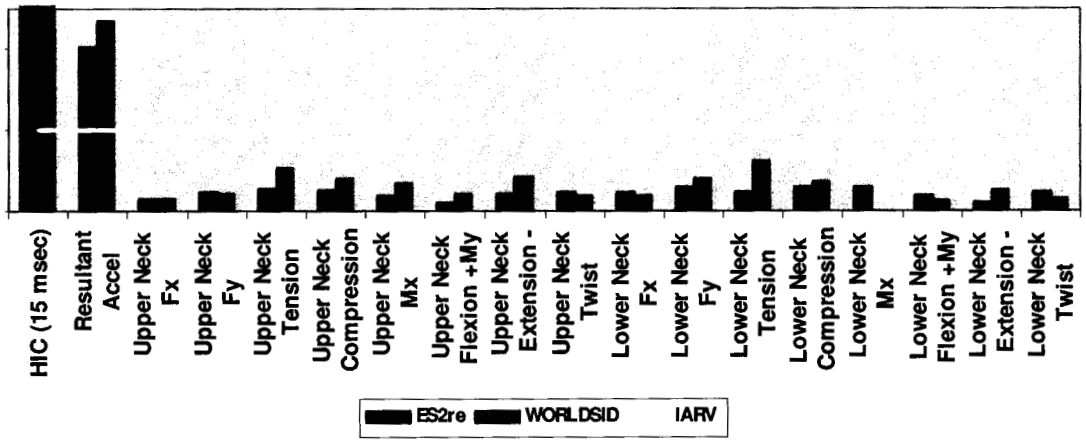
Small Car, Rear Dummy

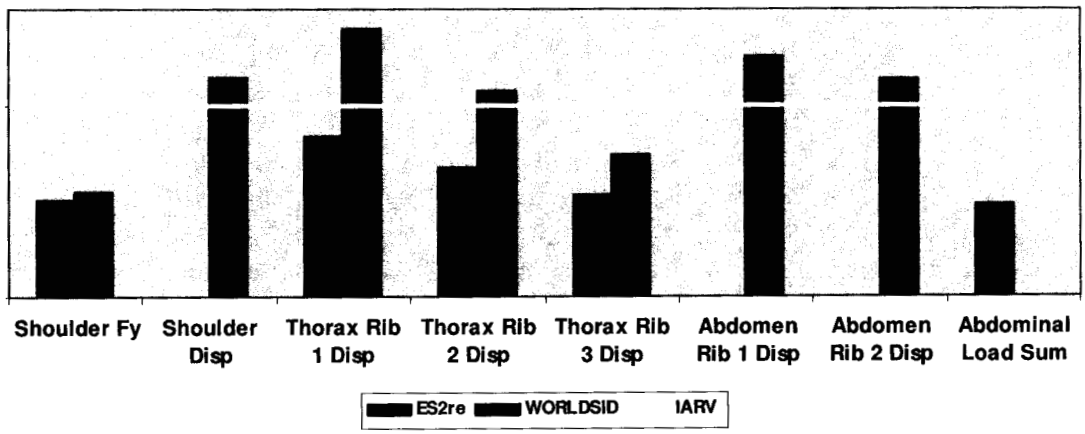


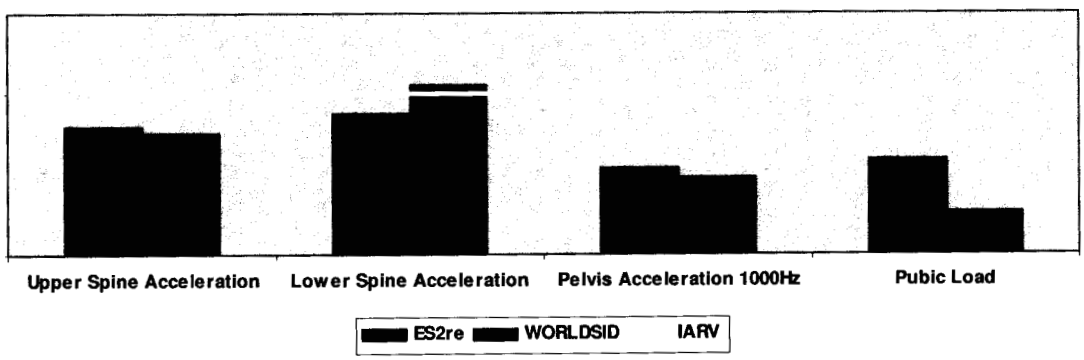




Small Car, Oblique Pole Testing, Front Dummy

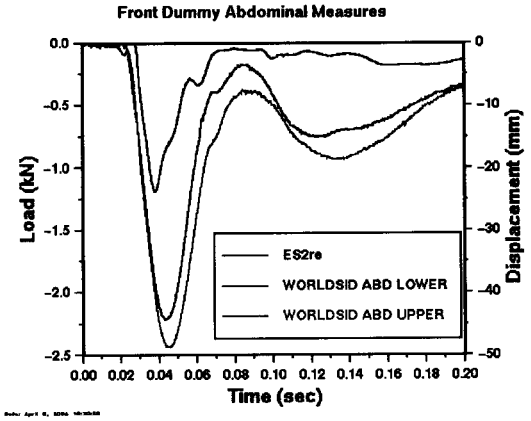


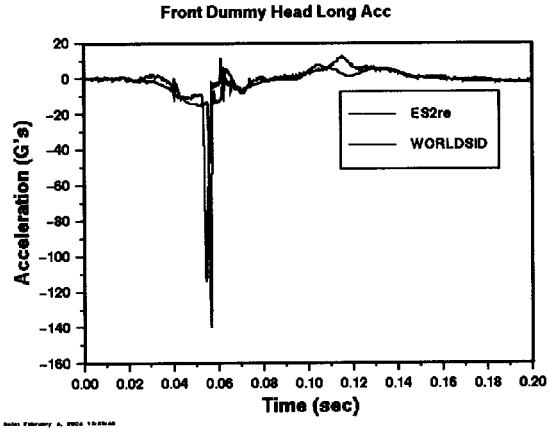


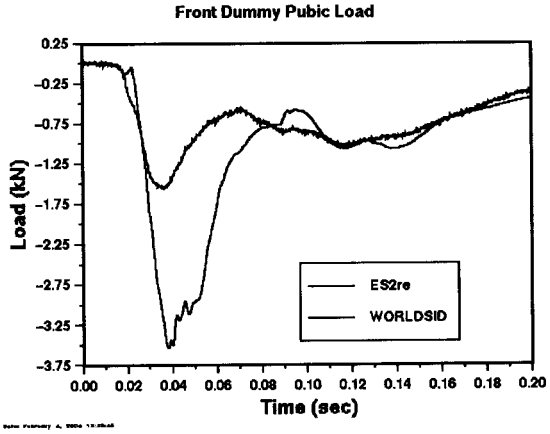


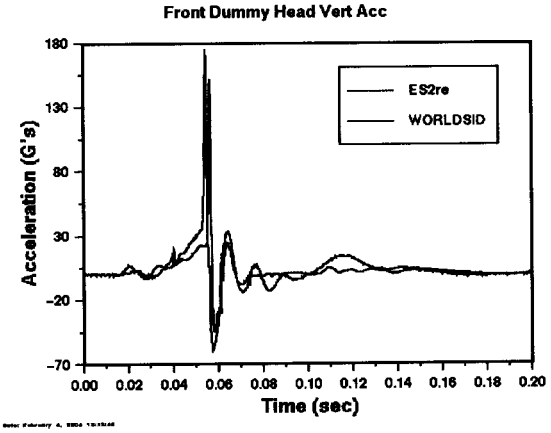
Full Vehicle Data Plots

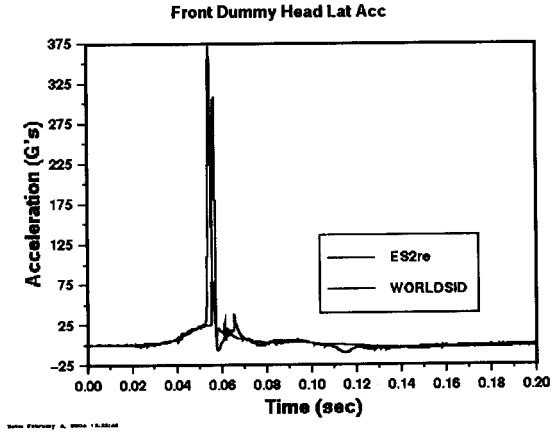
Small-Sized Sedan Oblique Pole Data

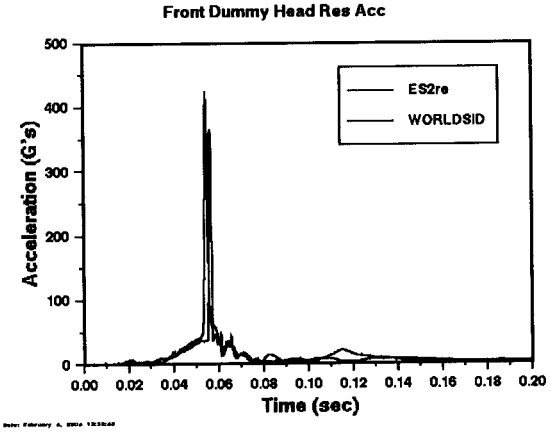




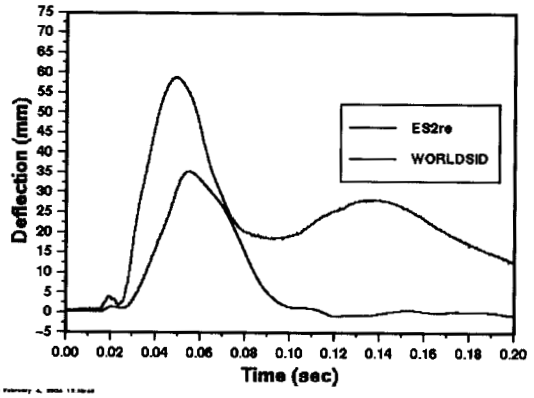




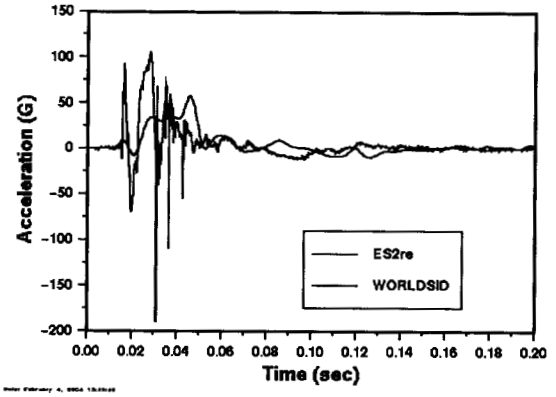




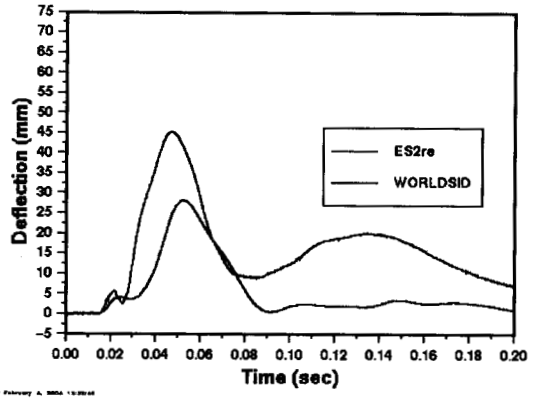
Front Dummy Upper Rib Deflection (600 Hz)



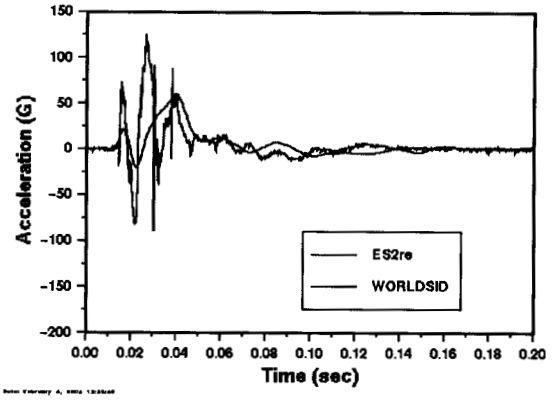
Front Dummy Upper Rib Acceleration



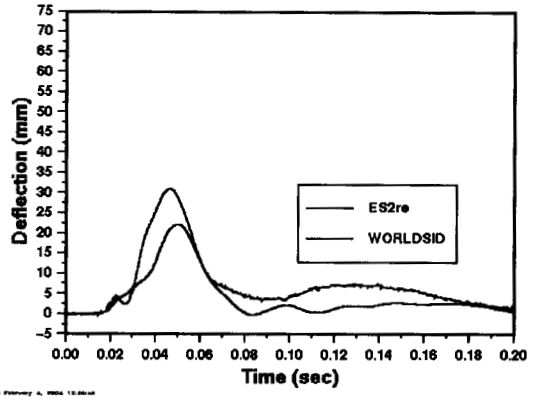
Front Dummy Center Rib Deflection (600 Hz)



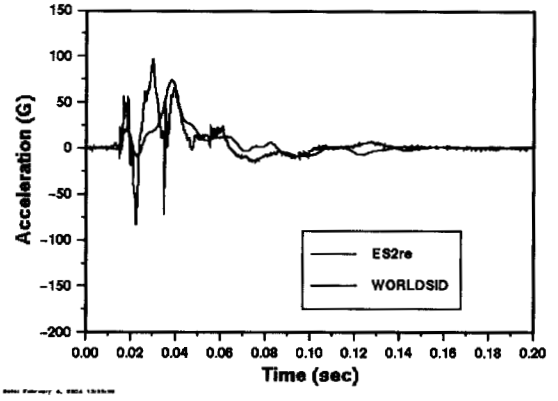
Front Dummy Center Rib Acceleration



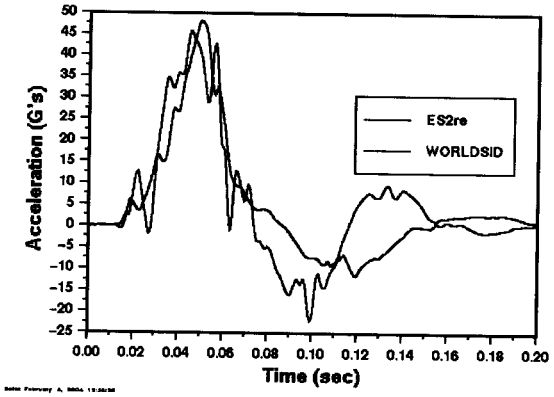
Front Dummy Lower Rib Deflection (600 Hz)



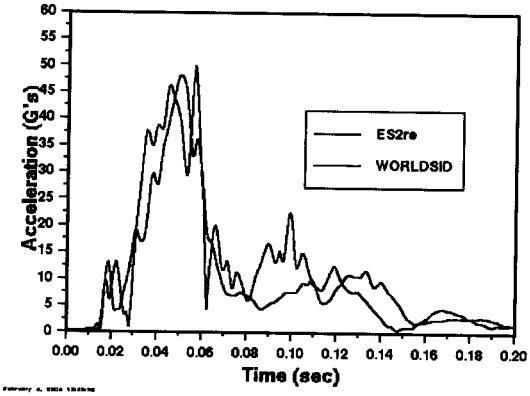
Front Dummy Lower Rib Acceleration



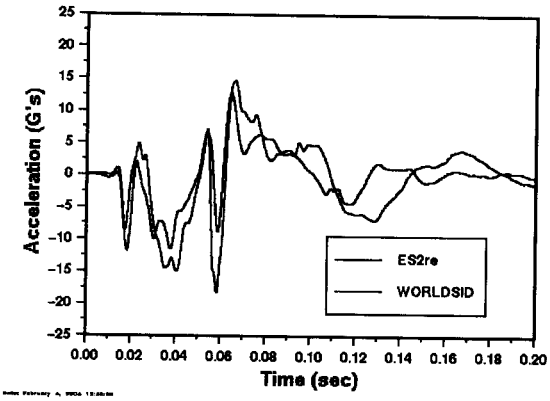
Front Dummy Upper Spine Lateral Acceleration



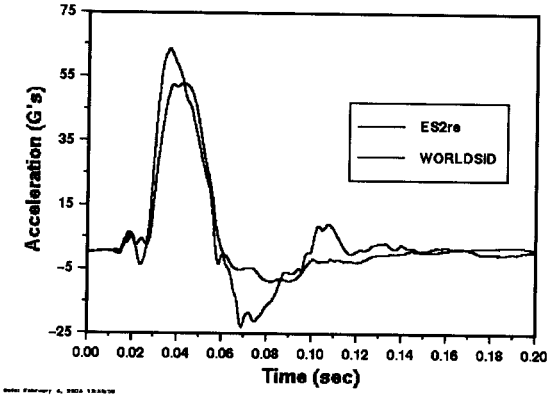
Front Dummy Upper Spine Resultant Acceleration



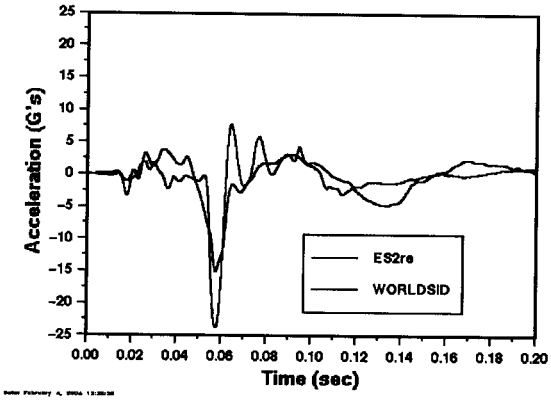
Front Dummy Upper Spine Longitudinal Acceleration



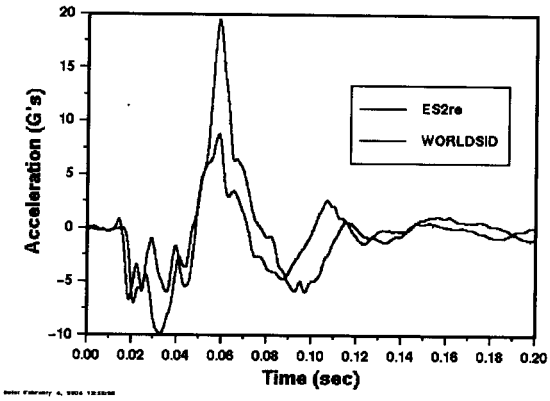
Front Dummy Lower Spine Lateral Acceleration



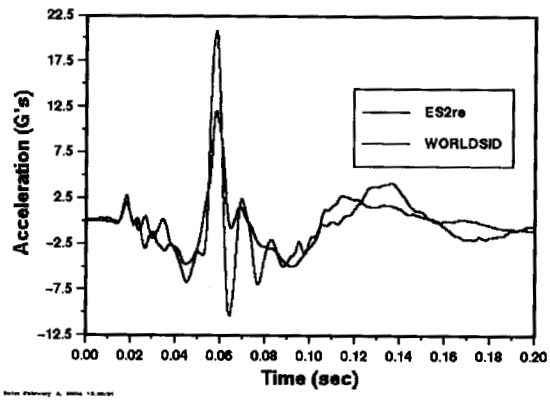
Front Dummy Upper Spine Vertical Acceleration



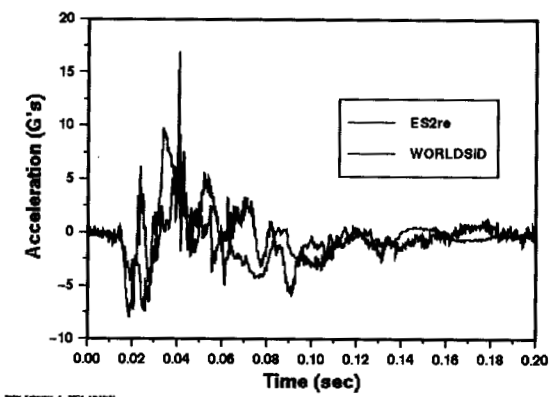
Front Dummy Lower Spine Longitudinal Acceleration



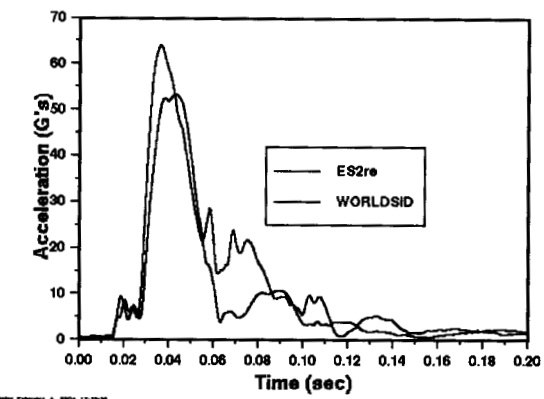
Front Dummy Lower Spine Vertical Acceleration



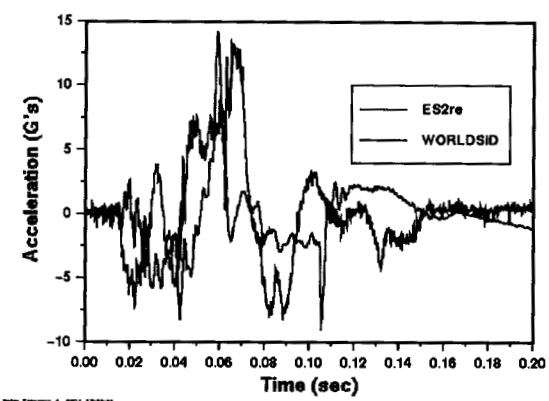
Front Dummy Pelvis Longitudinal Acceleration



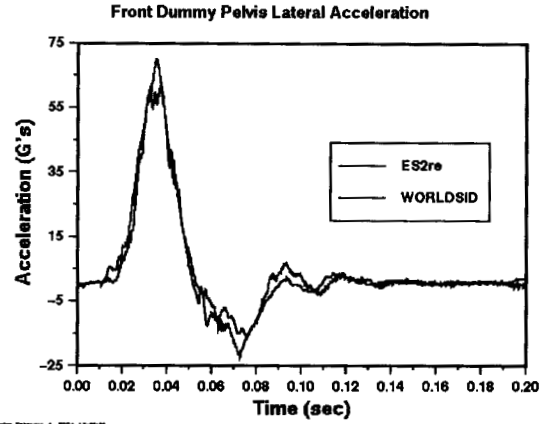
Front Dummy Lower Spine Resultant Acceleration



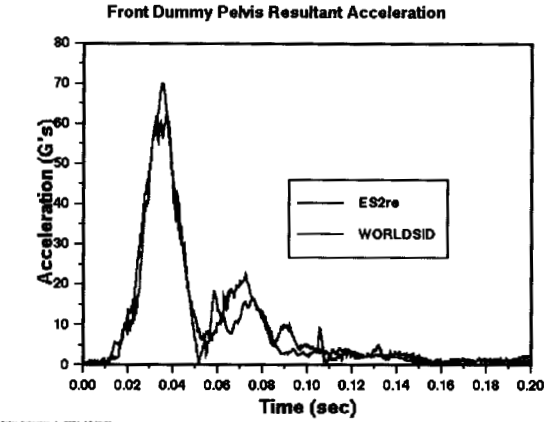
Front Dummy Pelvis Vertical Acceleration

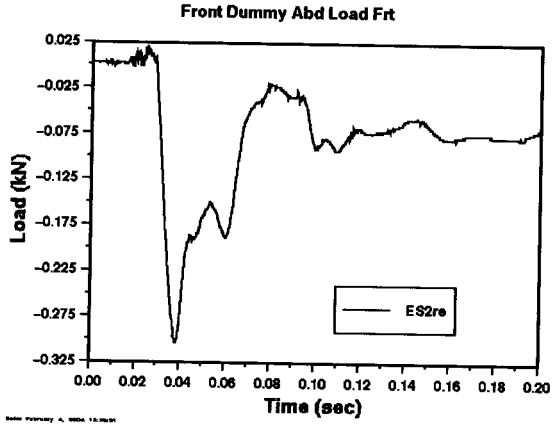


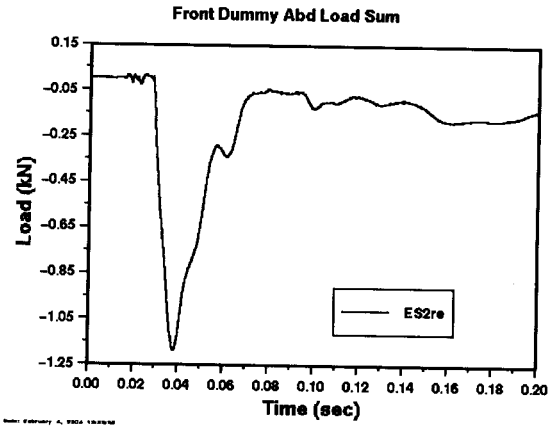
Front Dummy Pelvis Lateral Acceleration

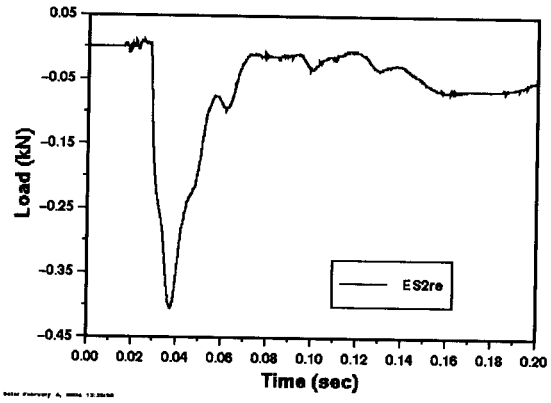


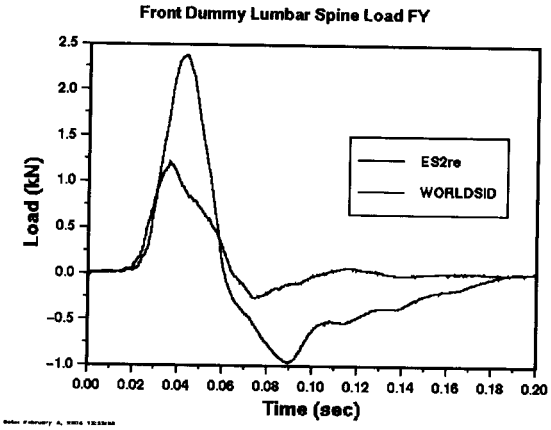
Front Dummy Pelvis Resultant Acceleration

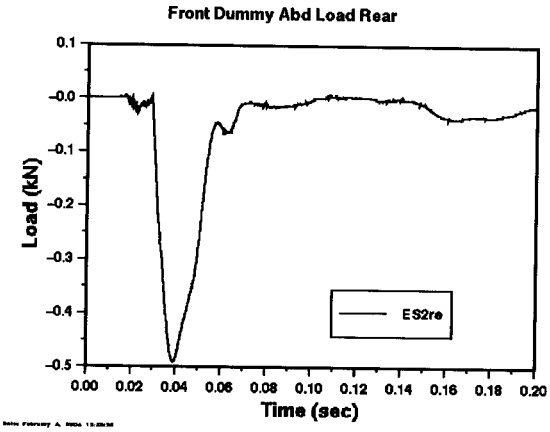


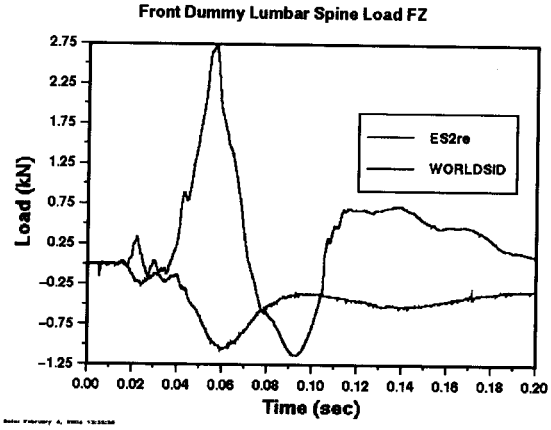

Front Dummy Abd Load Frt
Load (kN)
Time (sec)
ES2re


Front Dummy Abd Load Sum
Load (kN)
Time (sec)
ES2re

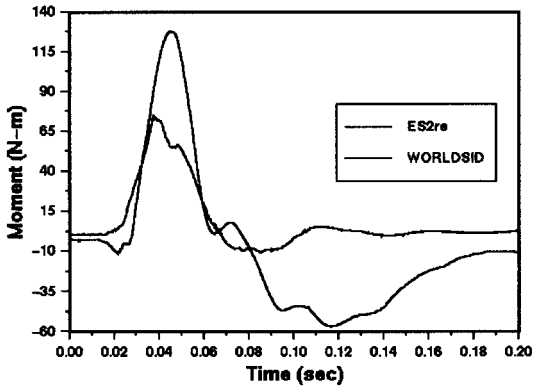

Front Dummy Abd Load Mid
Load (kN)
Time (sec)
ES2re


Front Dummy Lumbar Spine Load FY
Load (kN)
Time (sec)
ES2re
WORLDSID

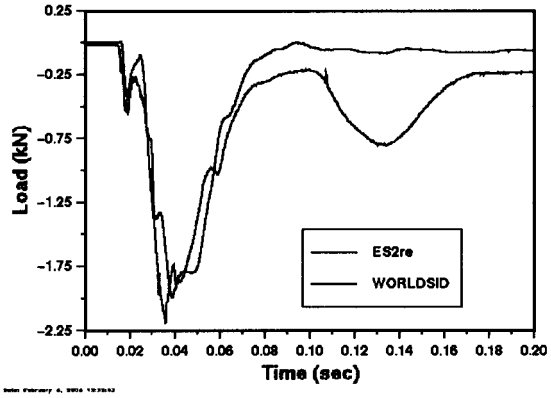

Front Dummy Abd Load Rear
Load (kN)
Time (sec)
ES2re


Front Dummy Lumbar Spine Load FZ
Load (kN)
Time (sec)
ES2re
WORLDSID

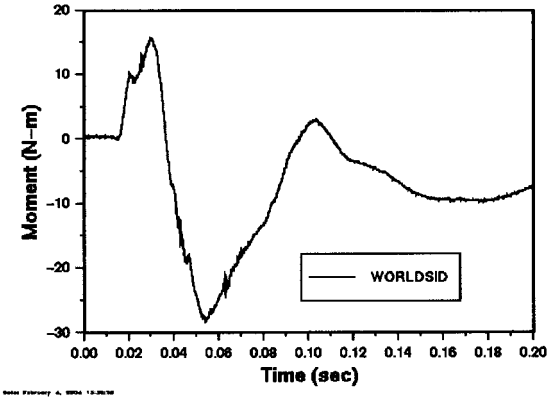
Front Dummy Lumbar Spine Load MX



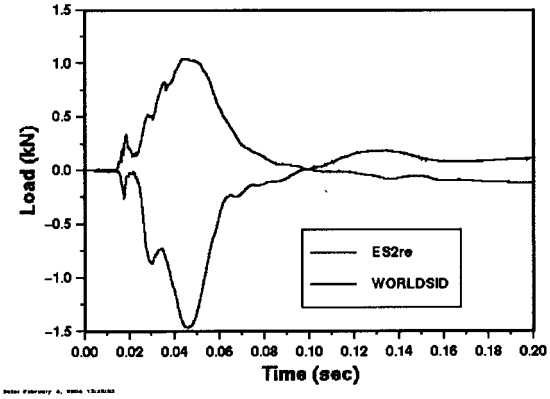
Front Dummy Shoulder Load FY



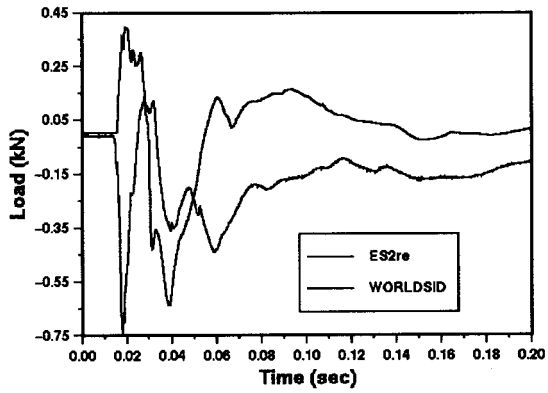
Front Dummy Lumbar Spine Load MY



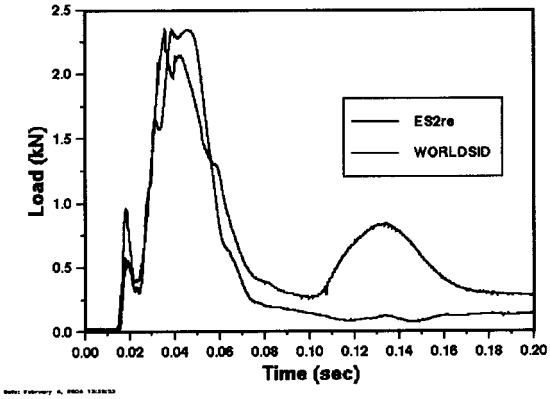
Front Dummy Shoulder Load FZ

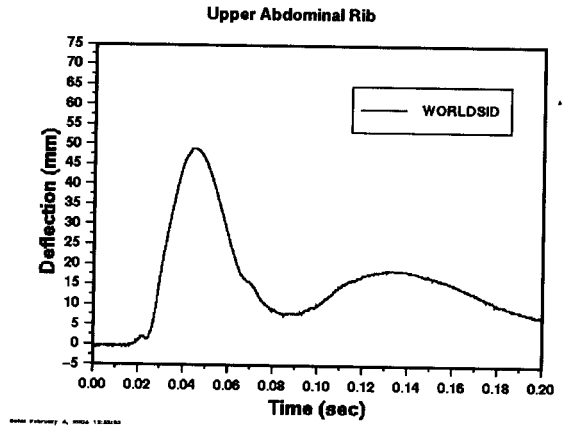


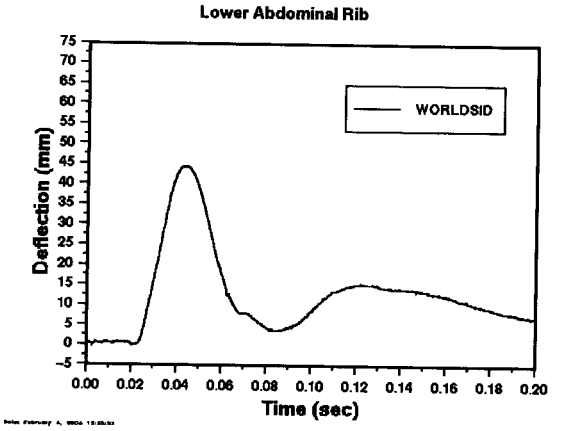
Front Dummy Shoulder Load FX



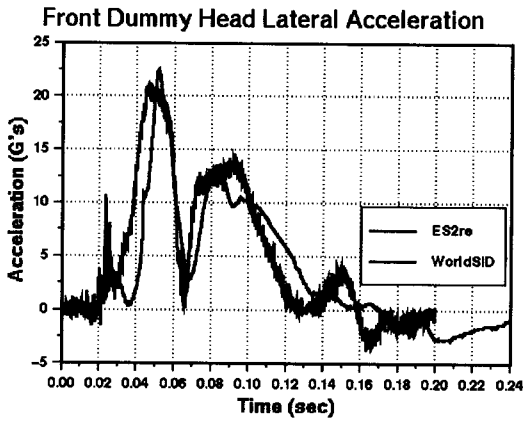
Front Dummy Shoulder Resultant Load

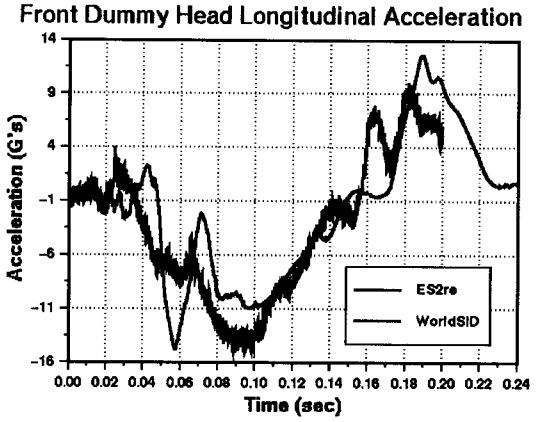


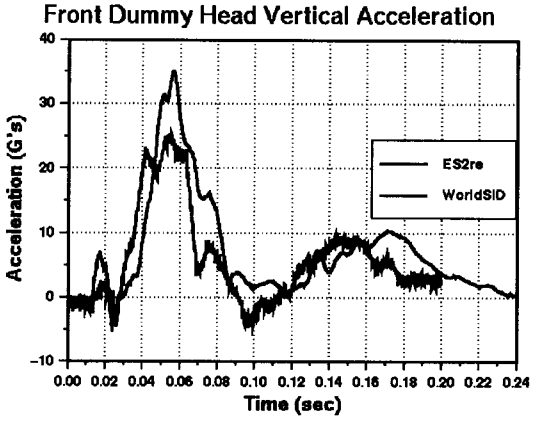

Upper Abdominal Rib
WORLDSID
Deflection (mm)
Time (sec)
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
-5
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.20

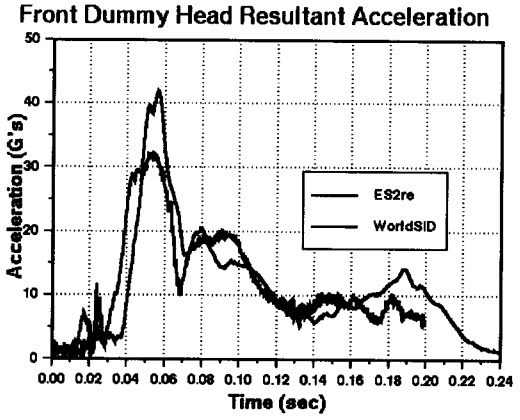

Lower Abdominal Rib
WORLDSID
Deflection (mm)
Time (sec)
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
-5
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.20

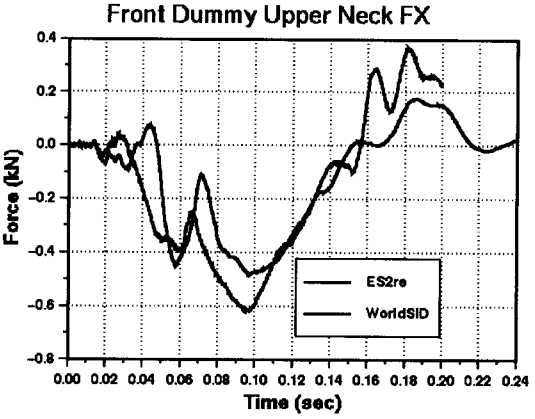
Small-Sized Sedan MDB Cart Data

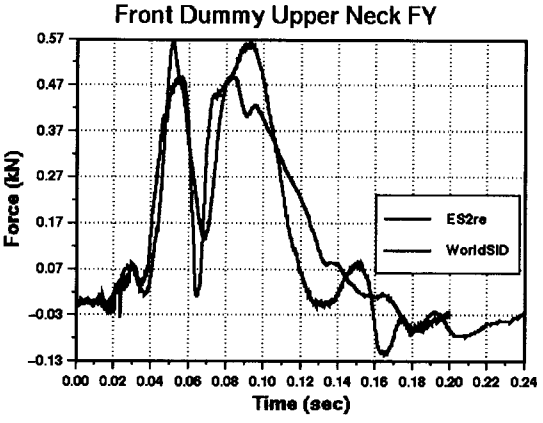


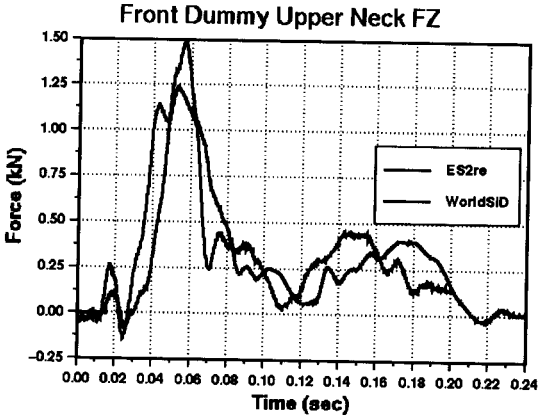


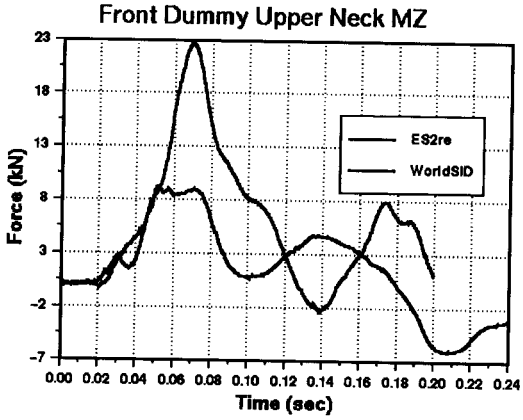


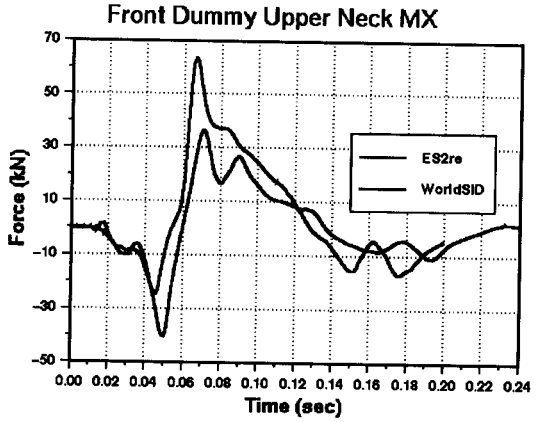


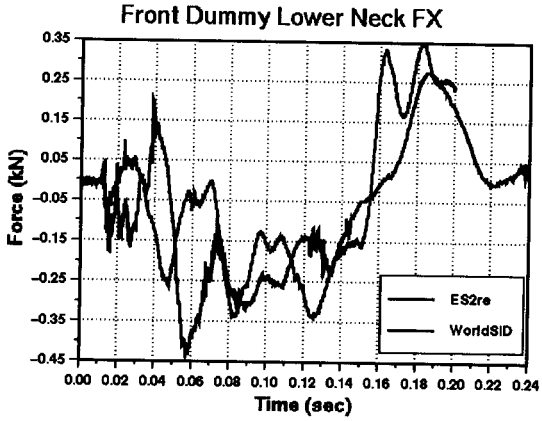


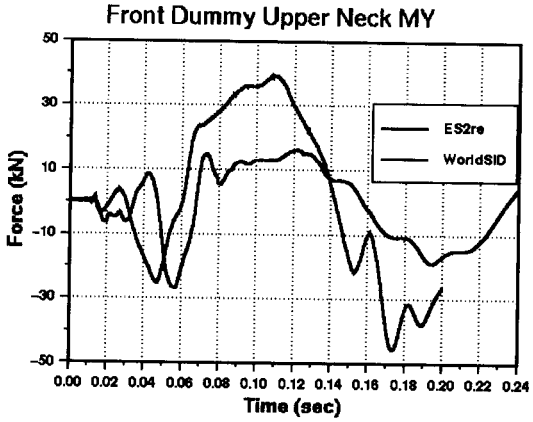


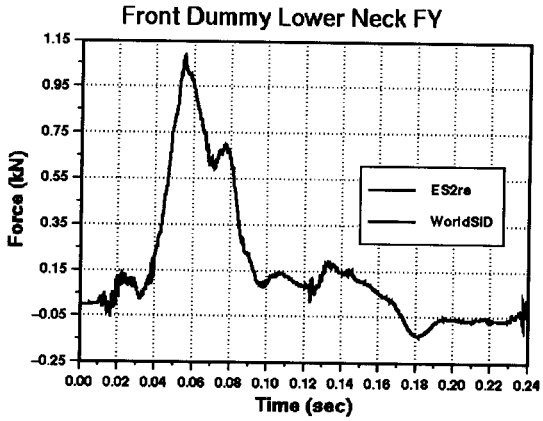

Front Dummy Upper Neck FZ
Force (kN)
Time (sec)
ES2re
WorldSID

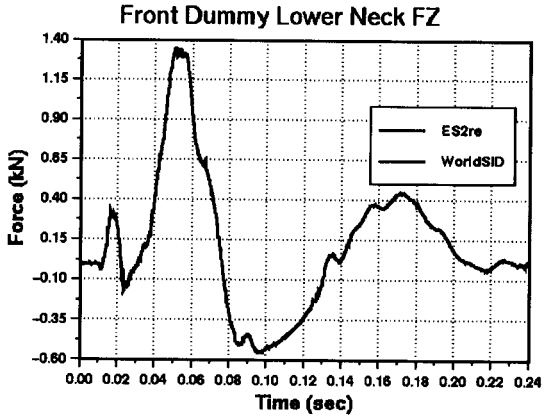

Front Dummy Upper Neck MZ
Force (kN)
Time (sec)
ES2re
WorldSID

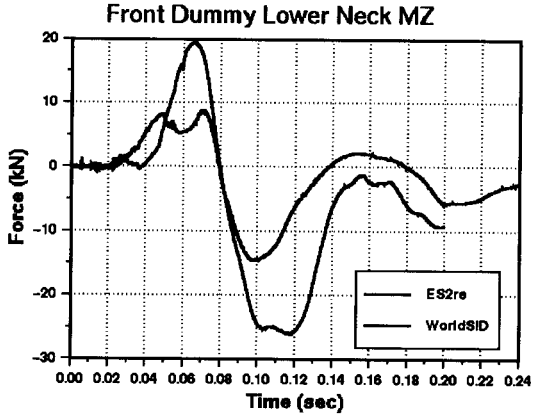

Front Dummy Upper Neck MX
Force (kN)
Time (sec)
ES2re
WorldSID

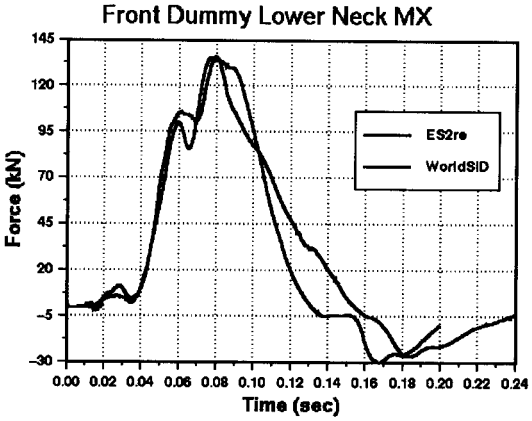

Front Dummy Lower Neck FX
Force (kN)
Time (sec)
ES2re
WorldSID

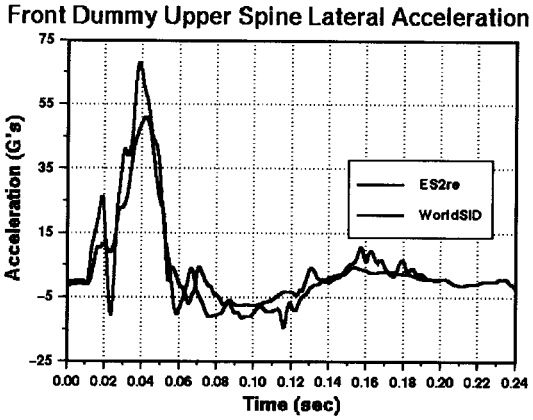

Front Dummy Upper Neck MY
Force (kN)
Time (sec)
ES2re
WorldSID

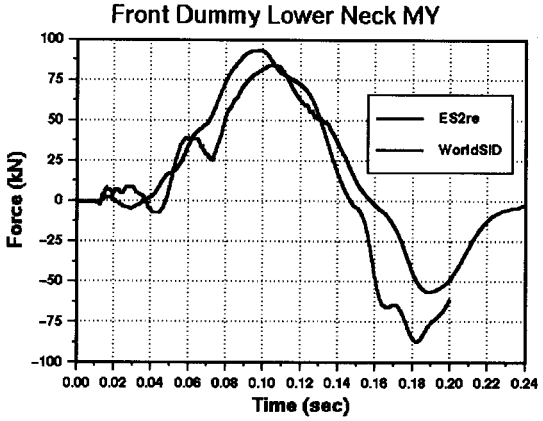

Front Dummy Lower Neck FY
Force (kN)
Time (sec)
ES2re
WorldSID

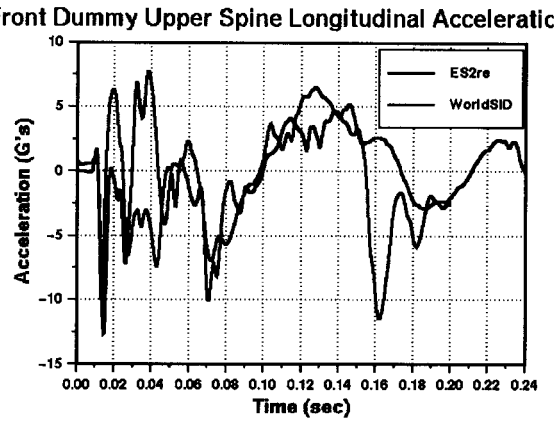

Front Dummy Lower Neck FZ
Force (kN)
Time (sec)
ES2re
WorldSID


Front Dummy Lower Neck MZ
Force (kN)
Time (sec)
ES2re
WorldSID

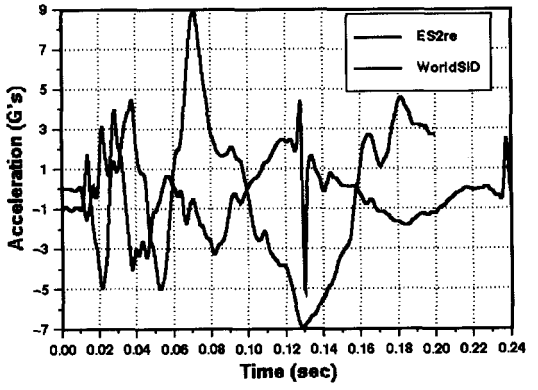

Front Dummy Lower Neck MX
Force (kN)
Time (sec)
ES2re
WorldSID


Front Dummy Upper Spine Lateral Acceleration
Acceleration (G's)
Time (sec)
ES2re
WorldSID

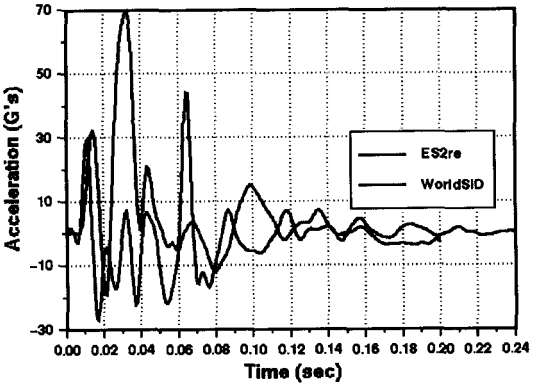

Front Dummy Lower Neck MY
Force (kN)
Time (sec)
ES2re
WorldSID


Front Dummy Upper Spine Longitudinal Acceleratic
Acceleration (G's)
Time (sec)
ES2re
WorldSID

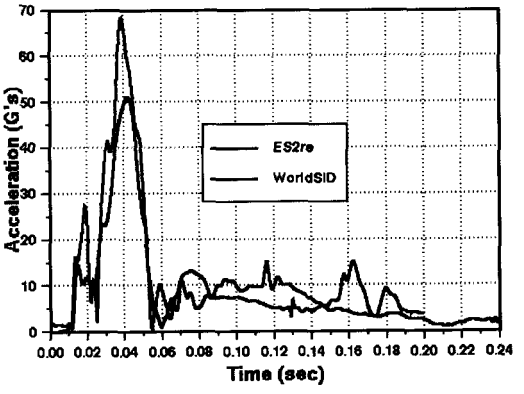
Front Dummy Upper Spine Vertical Acceleration



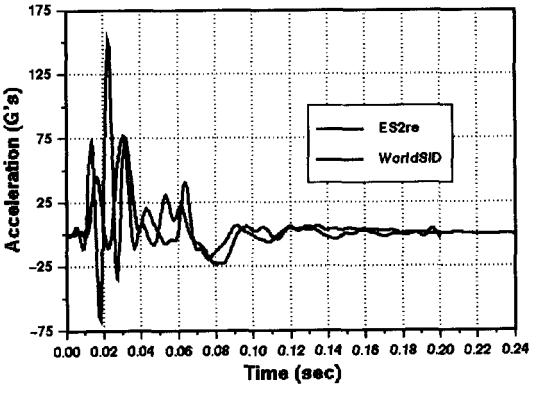
Front Dummy Center Rib Acceleration



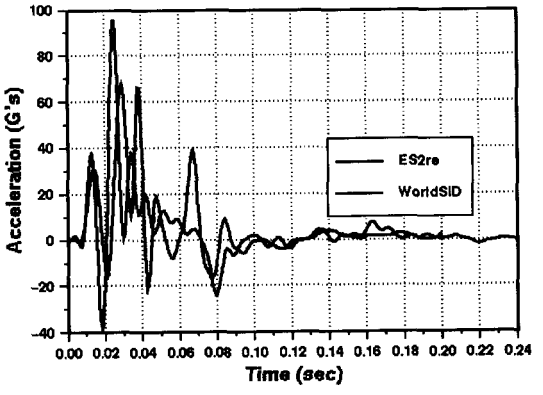
Front Dummy Upper Spine Resultant Acceleration



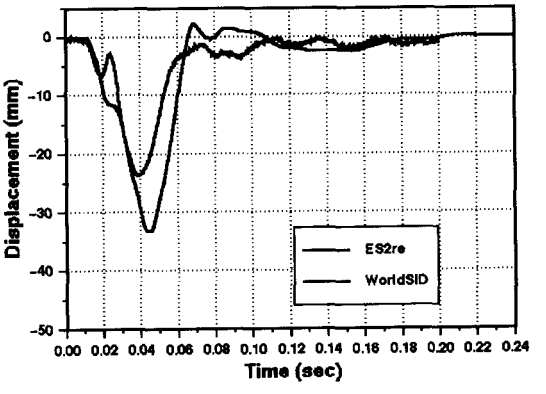
Front Dummy Lower Rib Acceleration



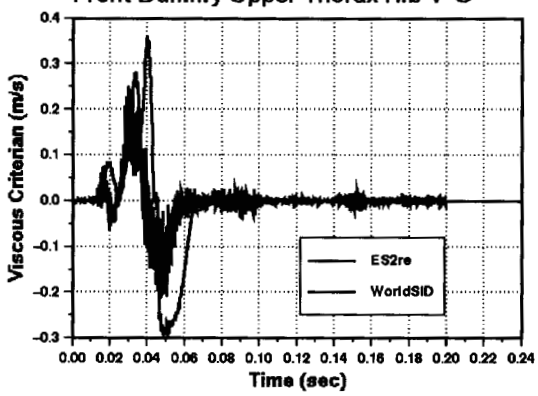
Front Dummy Upper Rib Acceleration



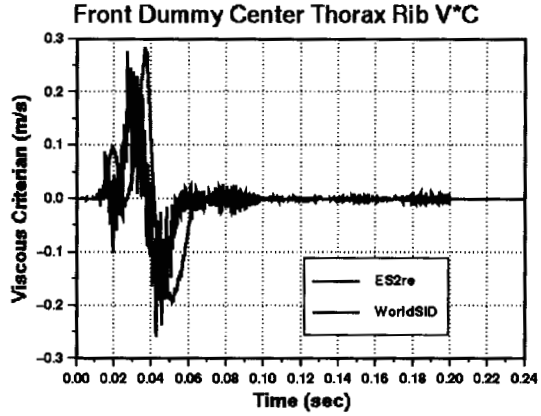
Front Dummy Upper Thorax Rib Displacement



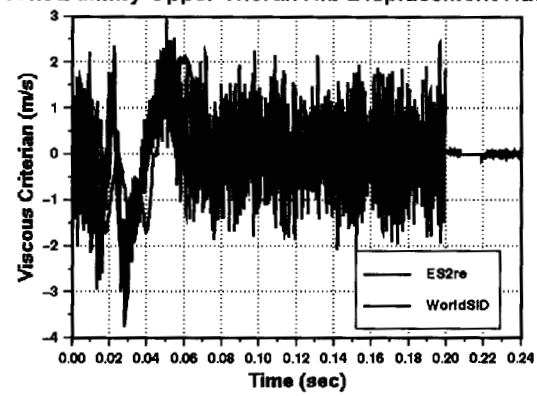
Front Dummy Upper Thorax Rib V*C



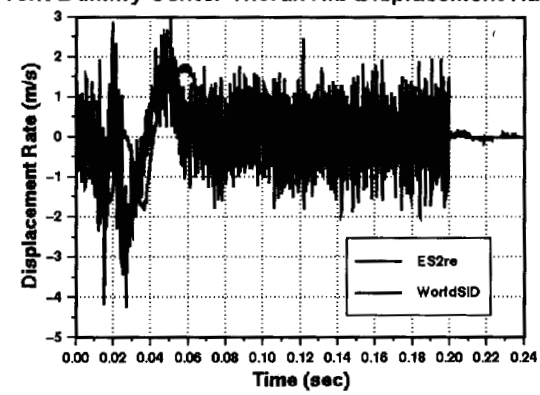
Front Dummy Center Thorax Rib V*C



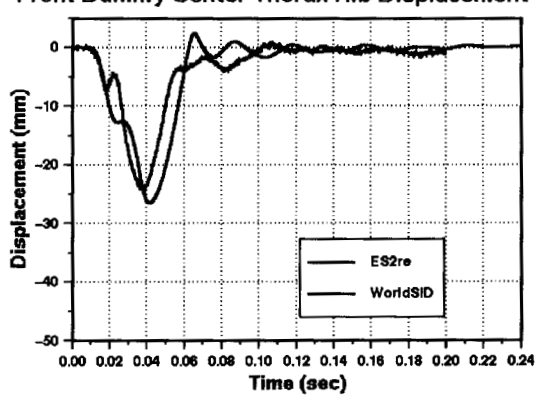
Front Dummy Upper Thorax Rib Displacement Rate



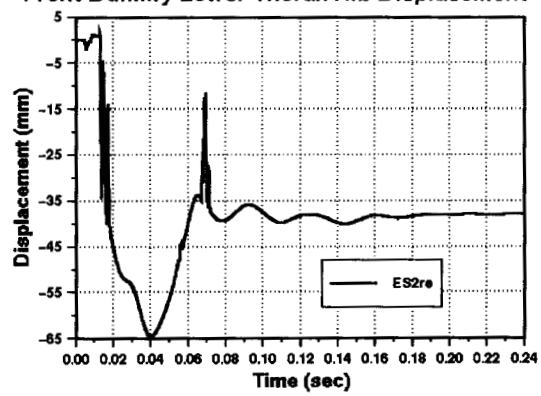
Front Dummy Center Thorax Rib Displacement Rat



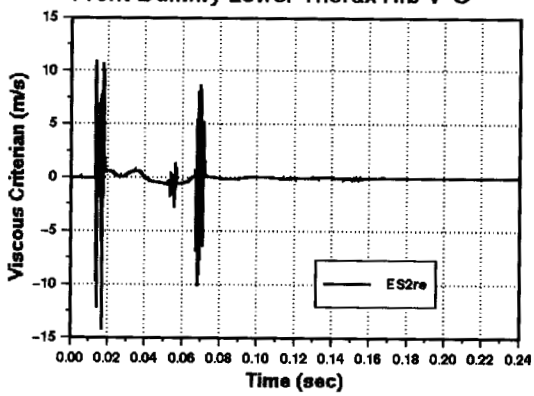
Front Dummy Center Thorax Rib Displacement



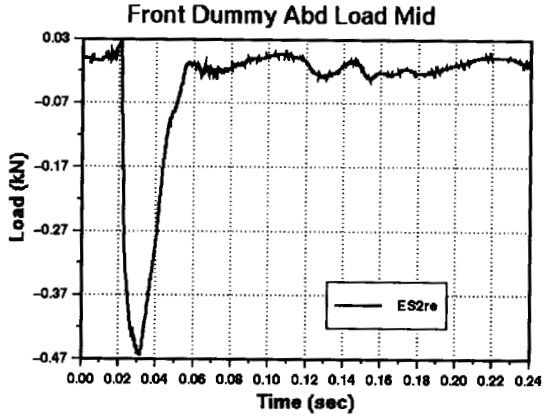
Front Dummy Lower Thorax Rib Displacement



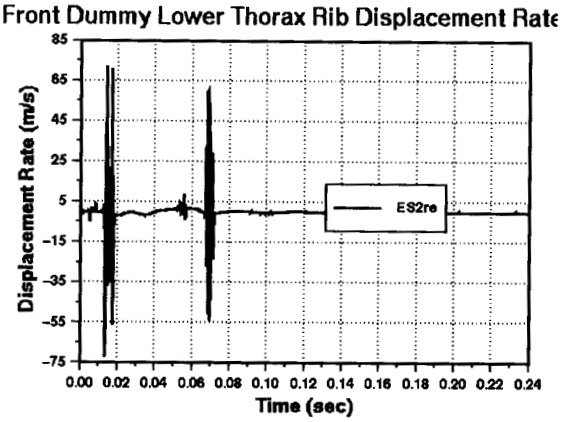
Front Dummy Lower Thorax Rib V*C



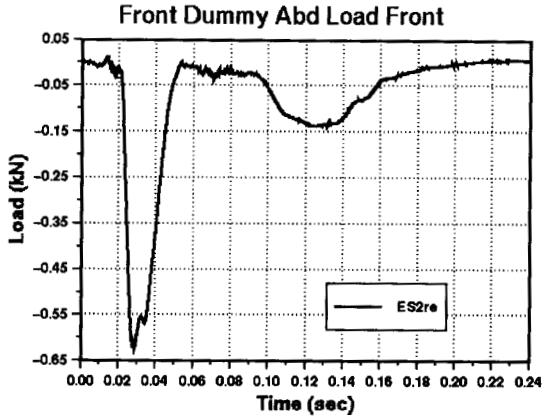
Front Dummy Abd Load Mid



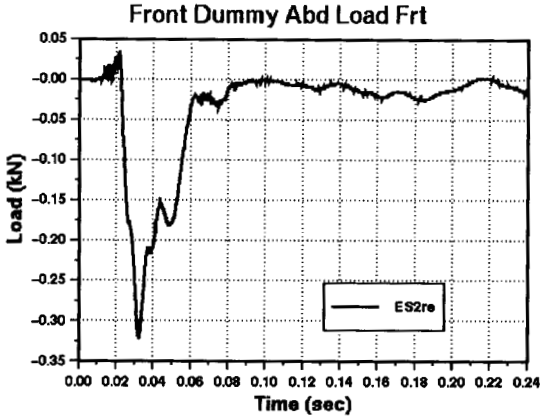
Front Dummy Lower Thorax Rib Displacement Rate



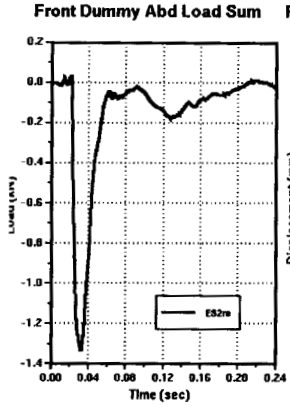
Front Dummy Abd Load Front



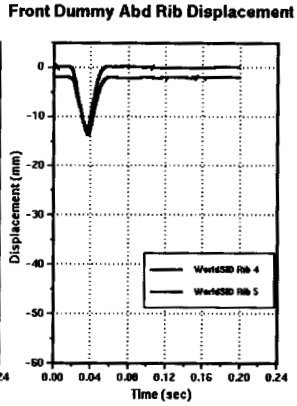
Front Dummy Abd Load Frt



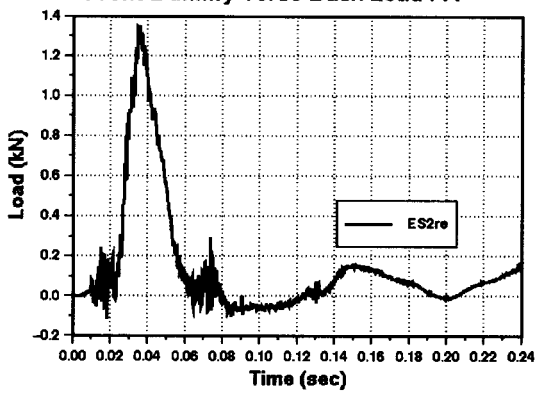
Front Dummy Abd Load Sum



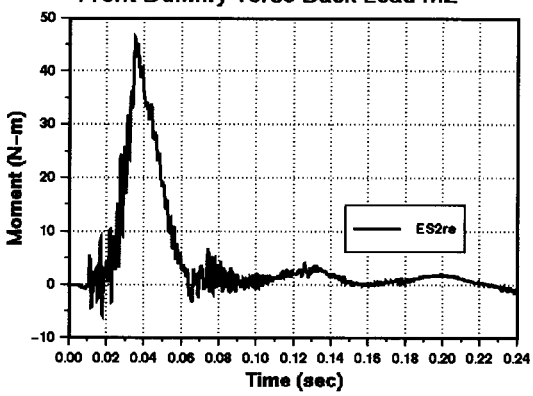
Front Dummy Abd Rib Displacement



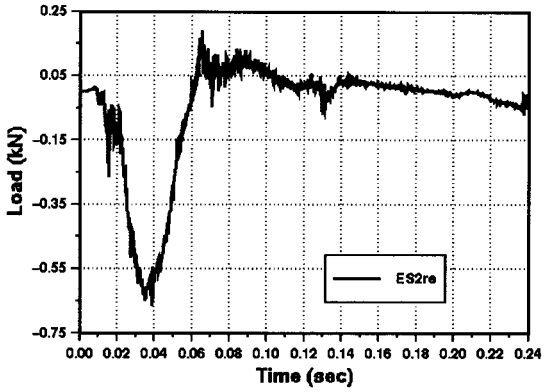
Front Dummy Torso Back Load FX



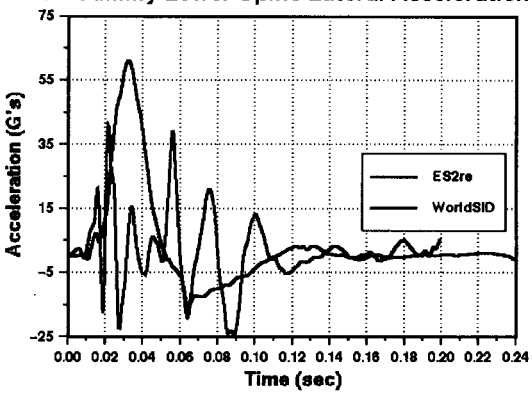
Front Dummy Torso Back Load MZ



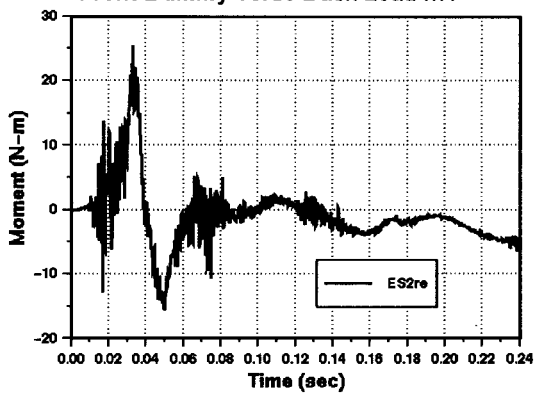
Front Dummy Torso Back Load FY



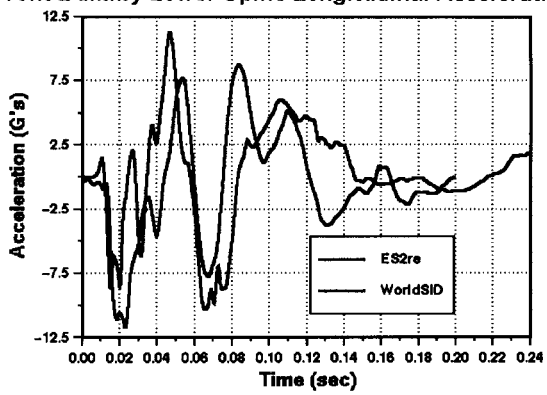
Front Dummy Lower Spine Lateral Acceleration



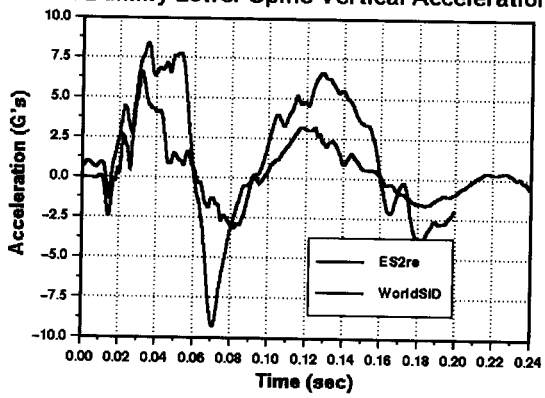
Front Dummy Torso Back Load MY



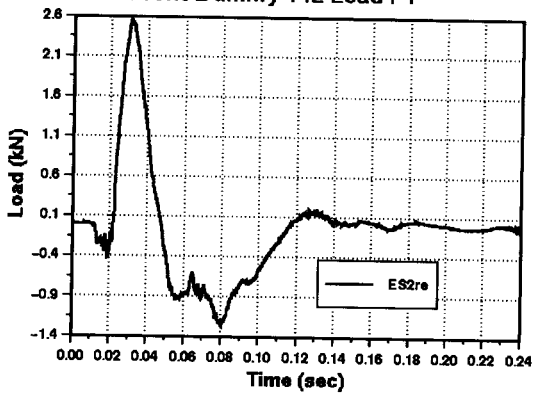
Front Dummy Lower Spine Longitudinal Acceleratio



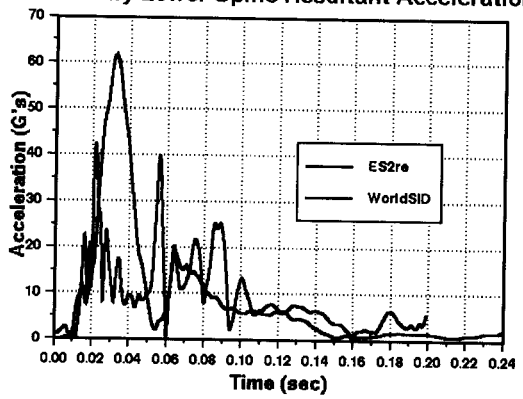
Front Dummy Lower Spine Vertical Acceleration



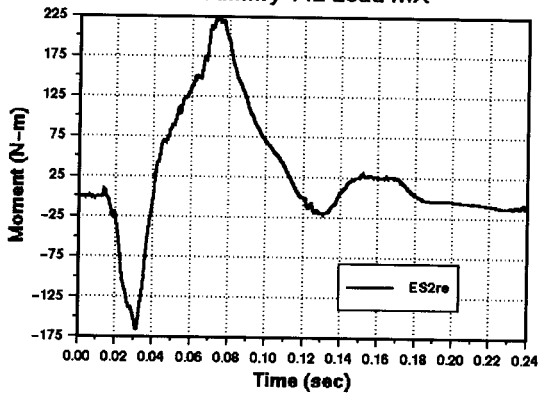
Front Dummy T12 Load FY



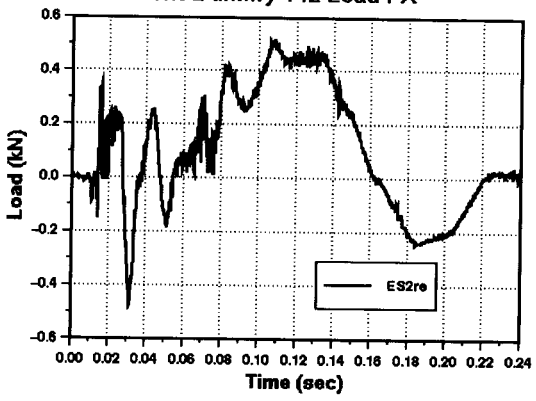
Front Dummy Lower Spine Resultant Acceleration



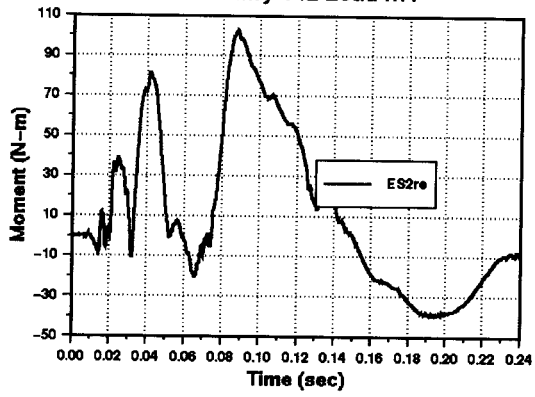
Front Dummy T12 Load MX



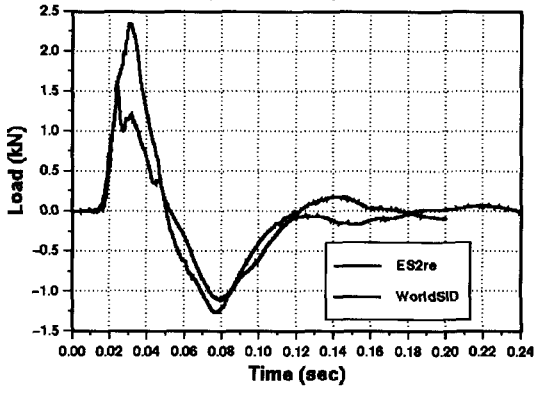
Front Dummy T12 Load FX



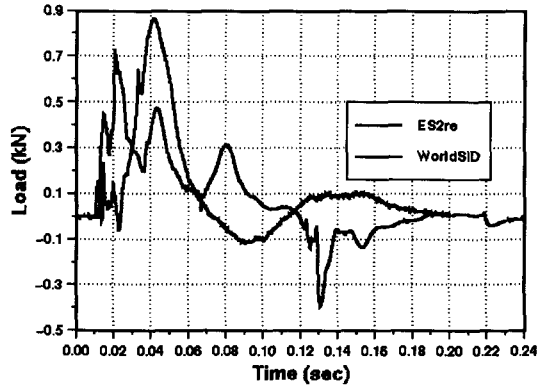
Front Dummy T12 Load MY



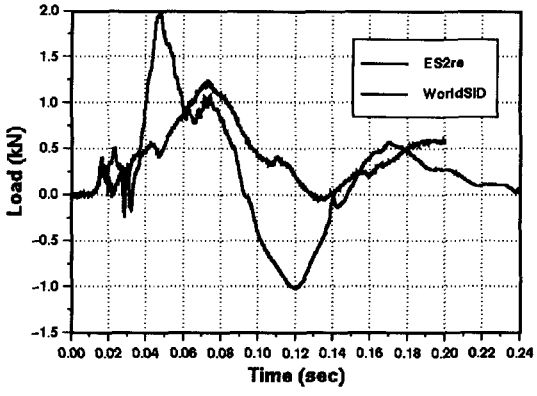
Front Dummy Lumbar Spine Load FY



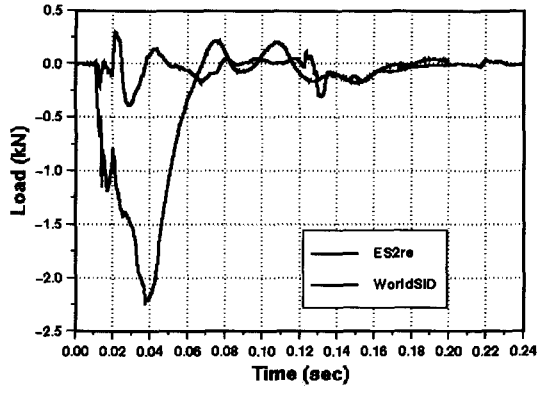
Front Dummy Shoulder Load FX



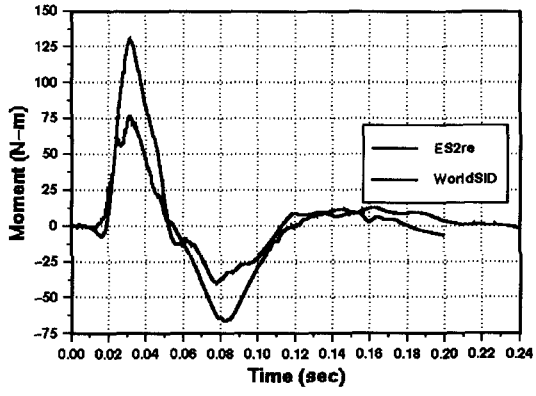
Front Dummy Lumbar Spine Load FZ



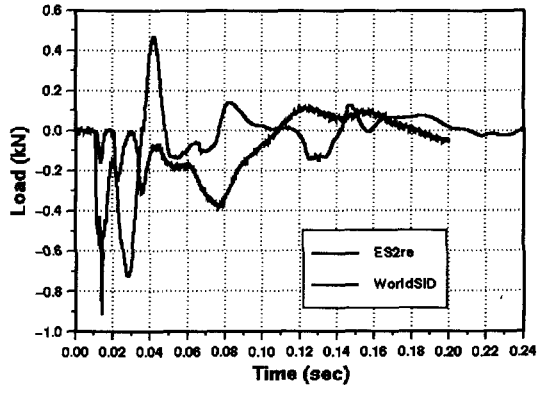
Front Dummy Shoulder Load FY

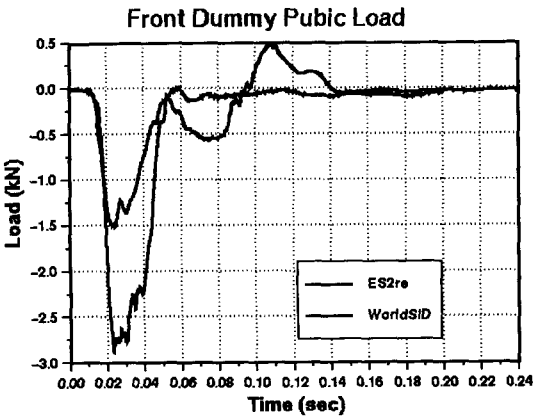


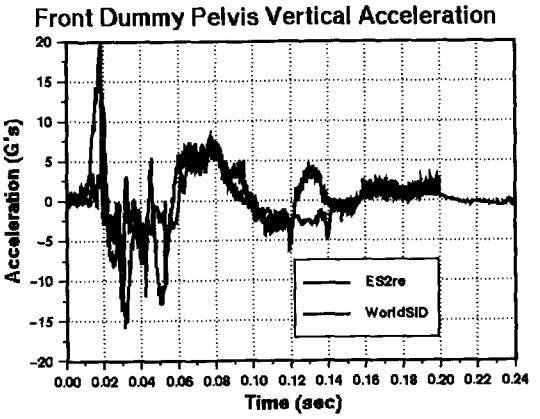
Front Dummy Lumbar Spine Load MX

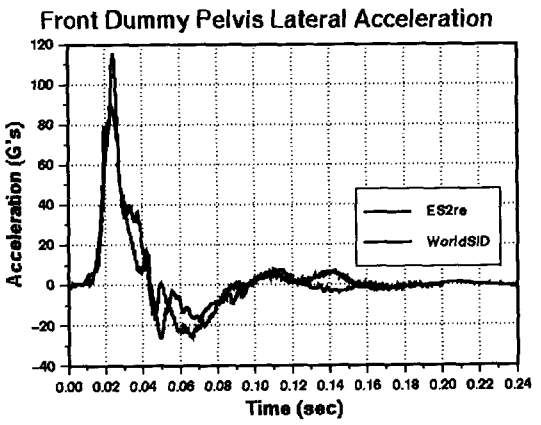


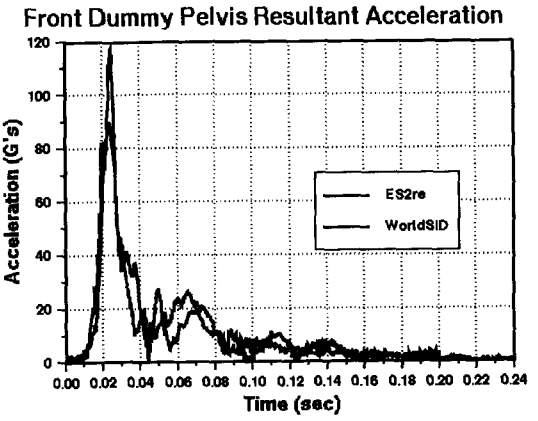
Front Dummy Shoulder Load FZ

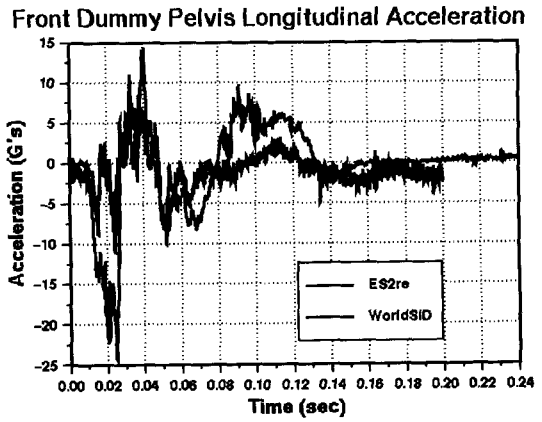


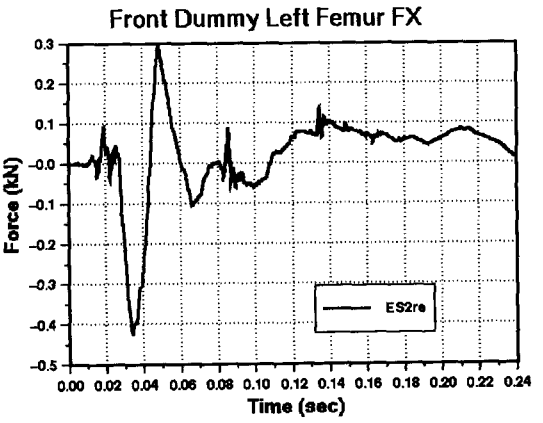

Front Dummy Pubic Load
Load (kN)
Time (sec)
ES2re
WorldSID

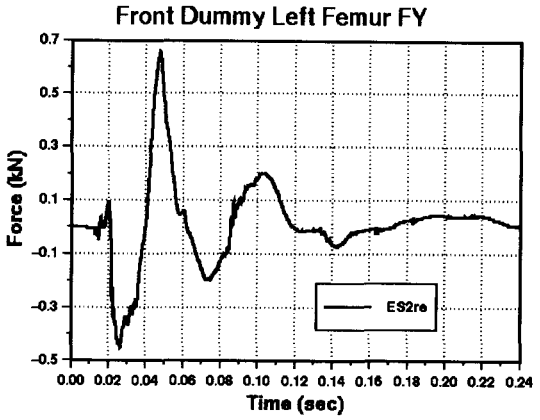

Front Dummy Pelvis Vertical Acceleration
Acceleration (G's)
Time (sec)
ES2re
WorldSID

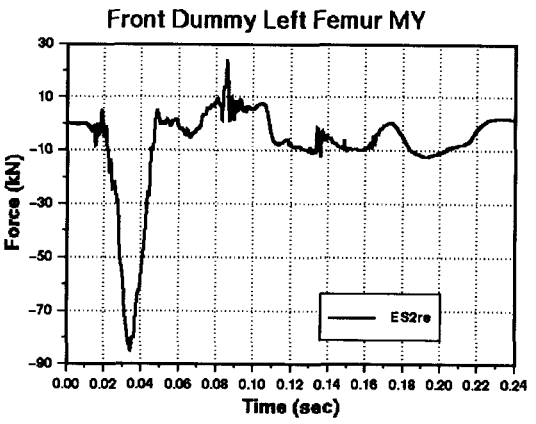

Front Dummy Pelvis Lateral Acceleration
Acceleration (G's)
Time (sec)
ES2re
WorldSID

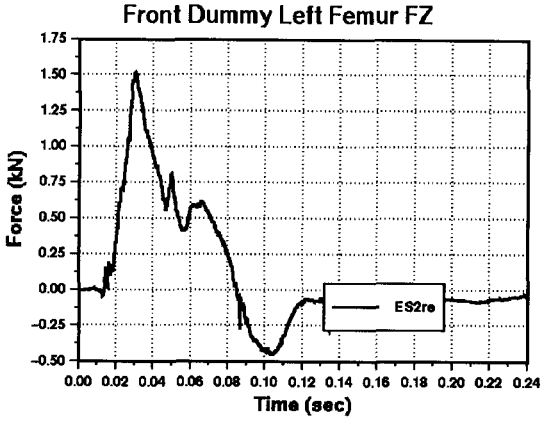

Front Dummy Pelvis Resultant Acceleration
Acceleration (G's)
Time (sec)
ES2re
WorldSID

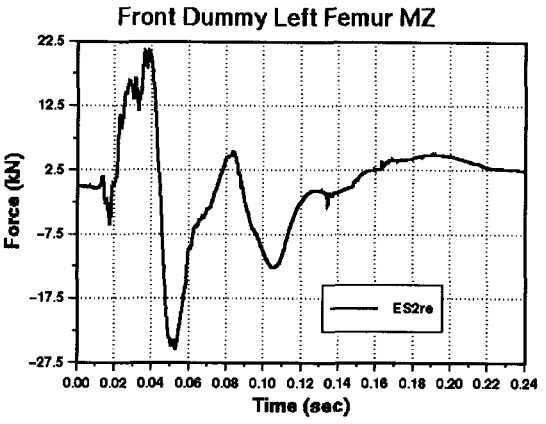

Front Dummy Pelvis Longitudinal Acceleration
Acceleration (G's)
Time (sec)
ES2re
WorldSID

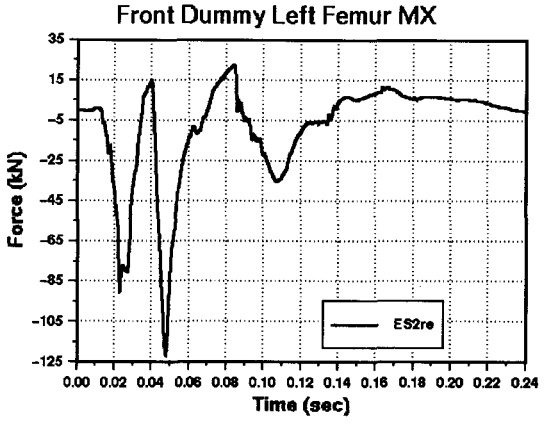

Front Dummy Left Femur FX
Force (kN)
Time (sec)
ES2re

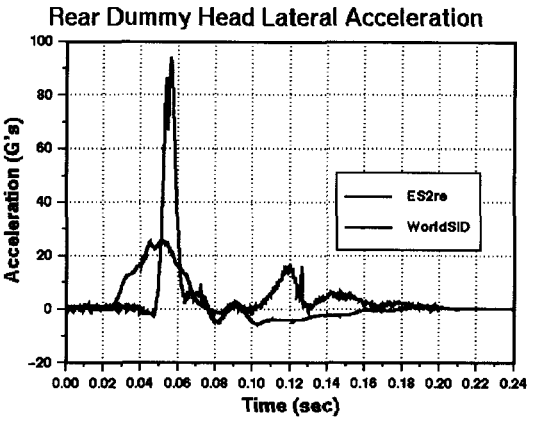

Front Dummy Left Femur FY
Force (kN)
Time (sec)
ES2re


Front Dummy Left Femur MY
Force (kN)
Time (sec)
ES2re

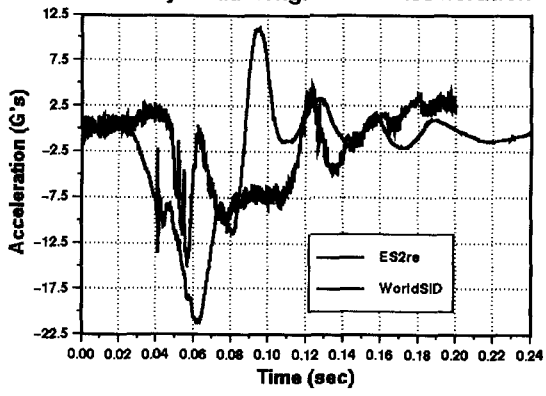

Front Dummy Left Femur FZ
Force (kN)
Time (sec)
ES2re


Front Dummy Left Femur MZ
Force (kN)
Time (sec)
ES2re

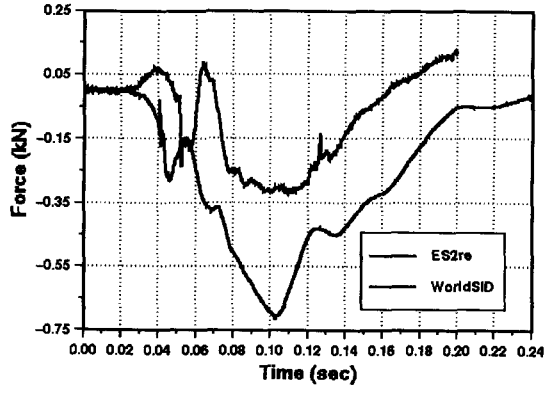

Front Dummy Left Femur MX
Force (kN)
Time (sec)
ES2re


Rear Dummy Head Lateral Acceleration
Acceleration (G's)
Time (sec)
ES2re
WorldSID

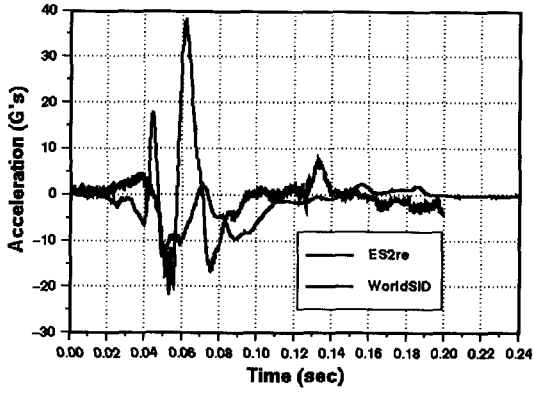
Rear Dummy Head Longitudinal Acceleration



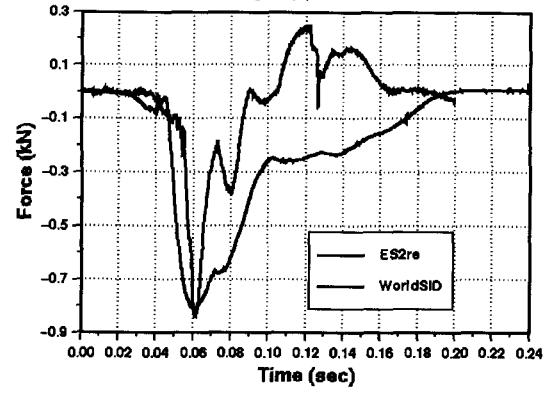
Rear Dummy Upper Neck FX



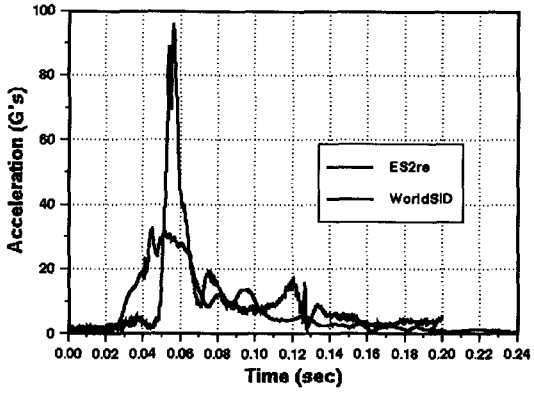
Rear Dummy Head Vertical Acceleration



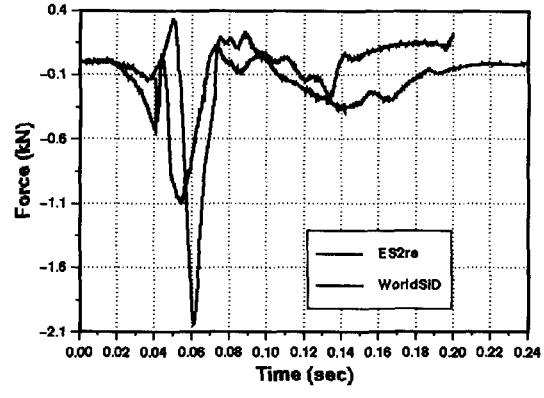
Rear Dummy Upper Neck FY

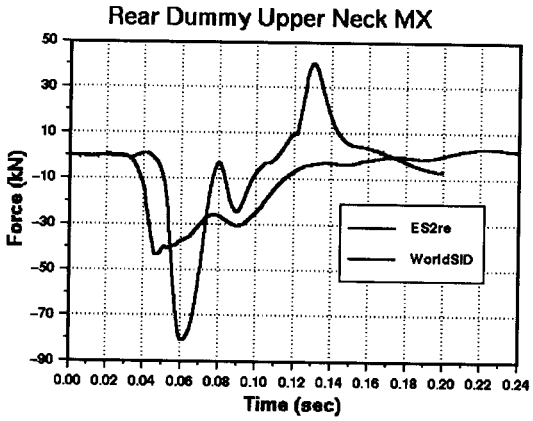


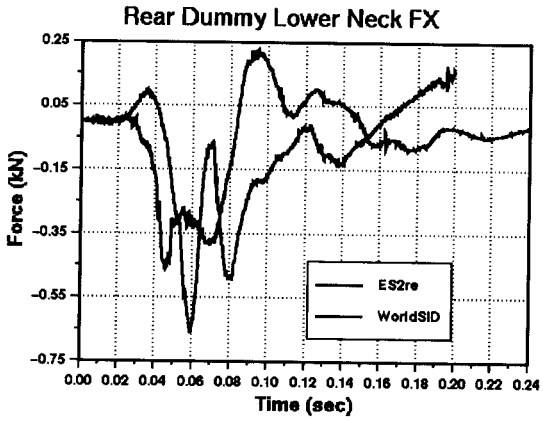
Rear Dummy Head Resultant Acceleration

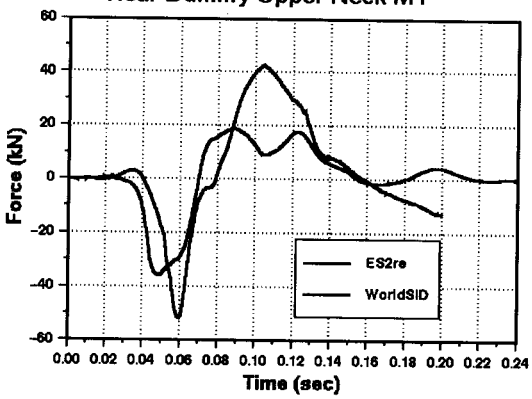


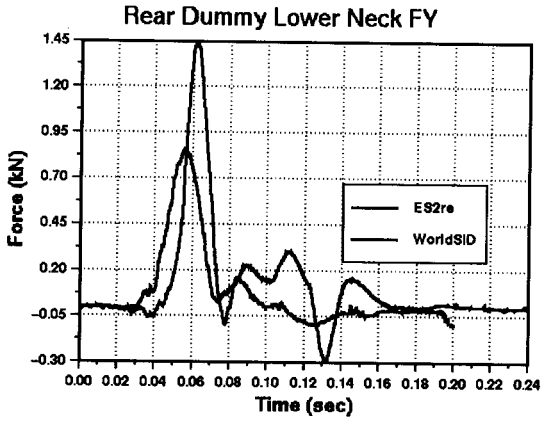
Rear Dummy Upper Neck FZ

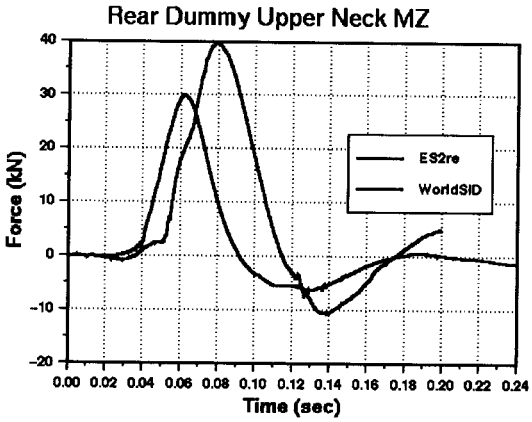


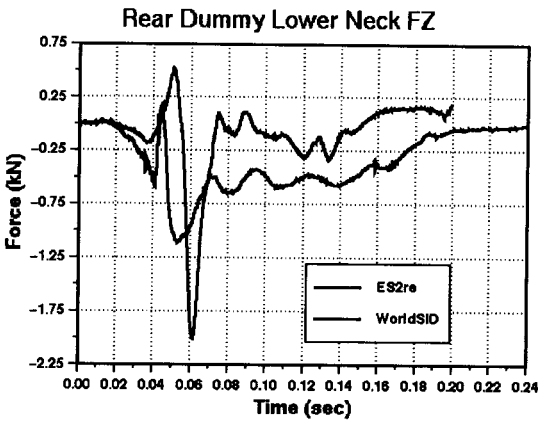

Rear Dummy Upper Neck MX
Force (kN)
Time (sec)
ES2re
WorldSID


Rear Dummy Lower Neck FX
Force (kN)
Time (sec)
ES2re
WorldSID

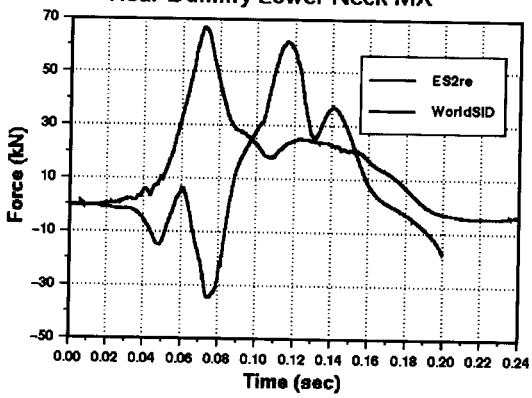

Rear Dummy Upper Neck MY
Force (kN)
Time (sec)
ES2re
WorldSID


Rear Dummy Lower Neck FY
Force (kN)
Time (sec)
ES2re
WorldSID

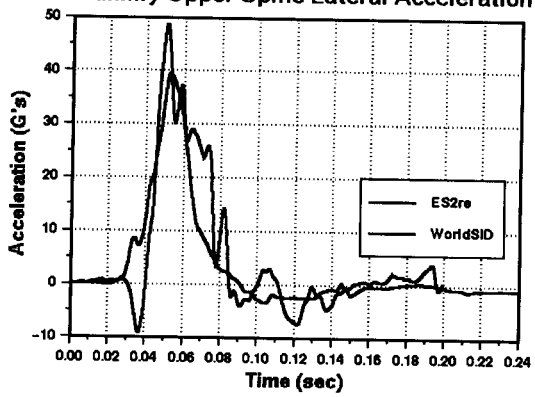

Rear Dummy Upper Neck MZ
Force (kN)
Time (sec)
ES2re
WorldSID


Rear Dummy Lower Neck FZ
Force (kN)
Time (sec)
ES2re
WorldSID

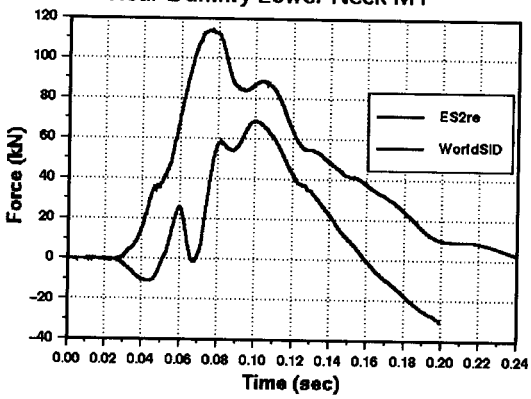
Rear Dummy Lower Neck MX



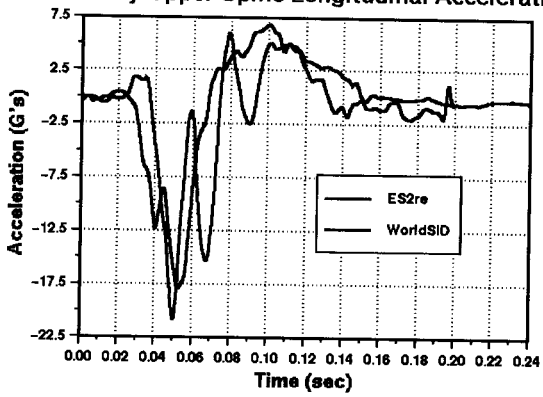
Rear Dummy Upper Spine Lateral Acceleration



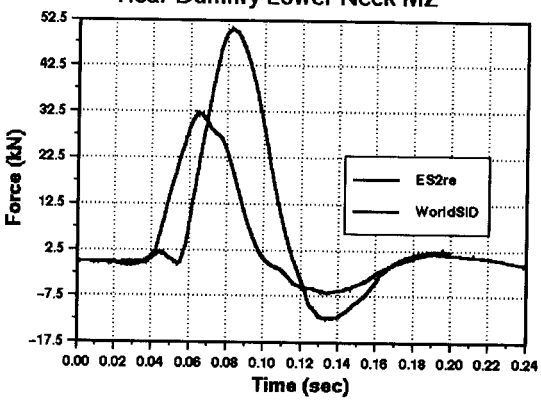
Rear Dummy Lower Neck MY



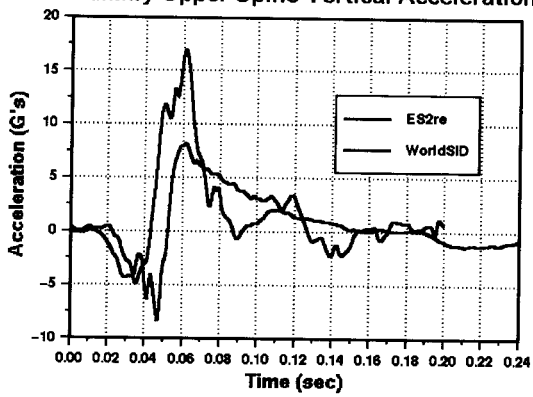
Rear Dummy Upper Spine Longitudinal Acceleratio



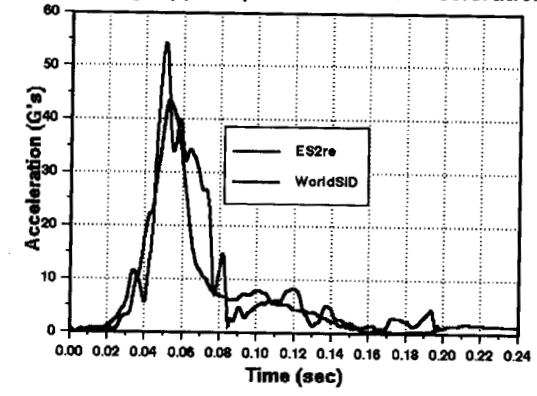
Rear Dummy Lower Neck MZ



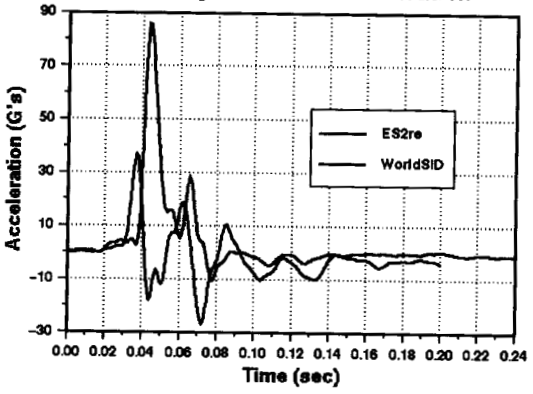
Rear Dummy Upper Spine Vertical Acceleration



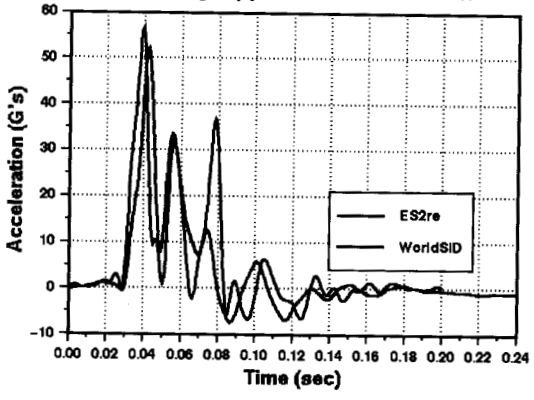
Rear Dummy Upper Spine Resultant Acceleration



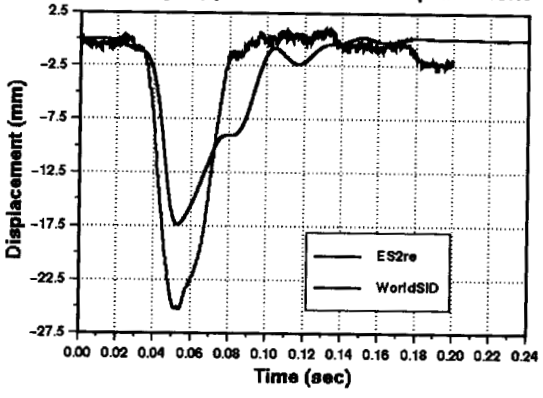
Rear Dummy Lower Rib Acceleration



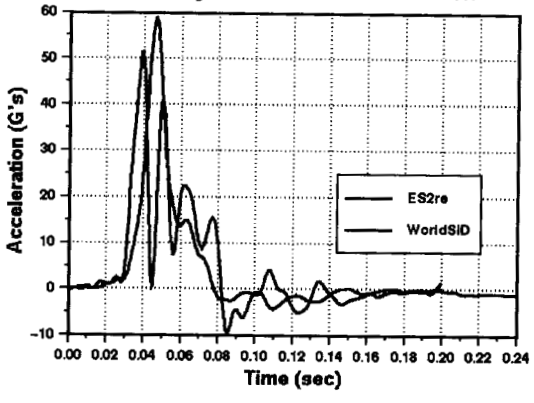
Rear Dummy Upper Rib Acceleration



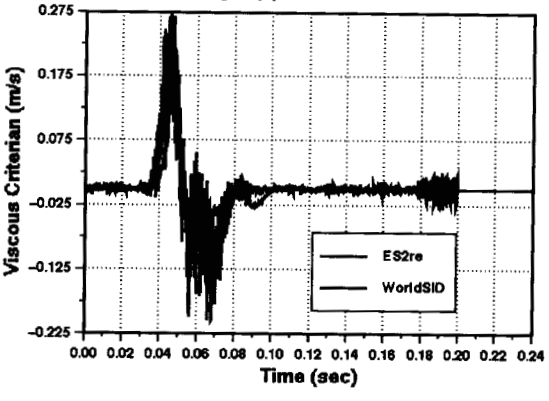
Rear Dummy Upper Thorax Rib Displacement



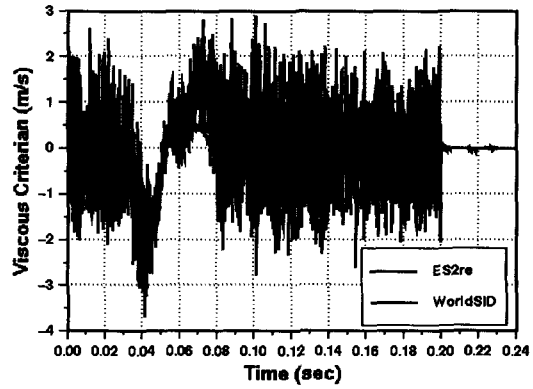
Rear Dummy Center Rib Acceleration



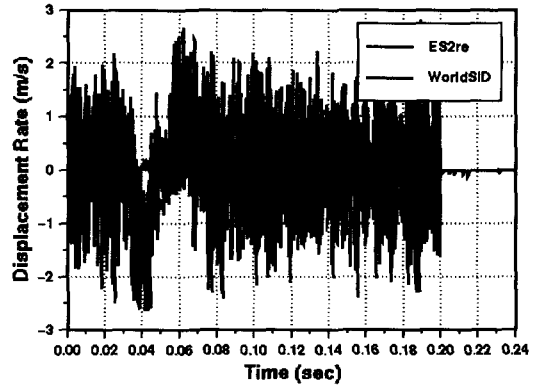
Rear Dummy Upper Thorax Rib V*C



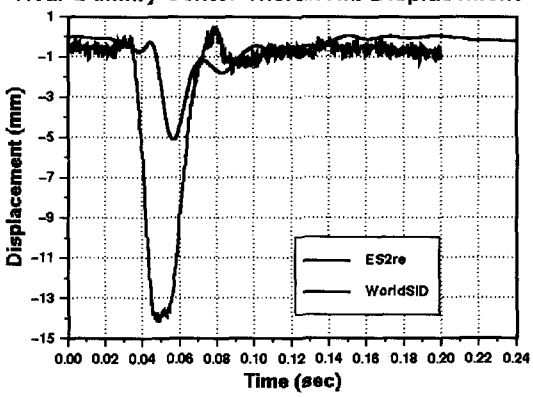
Rear Dummy Upper Thorax Rib Displacement Rate



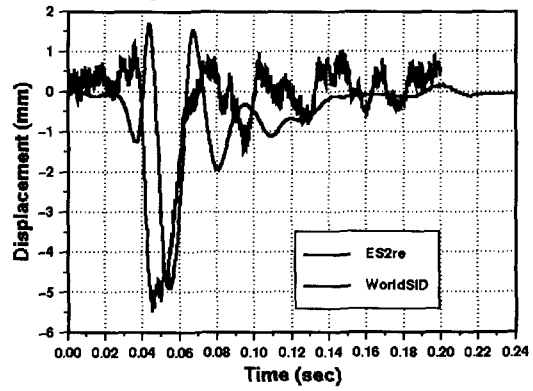
Rear Dummy Center Thorax Rib Displacement Rate



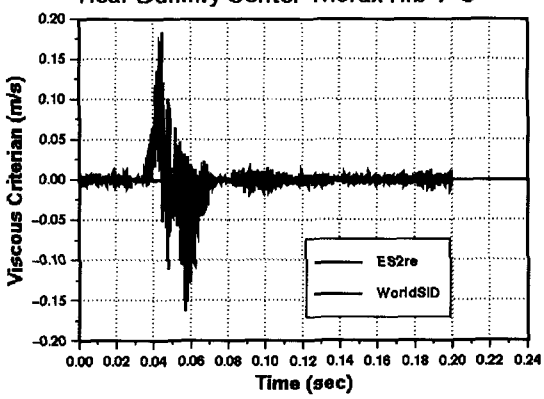
Rear Dummy Center Thorax Rib Displacement



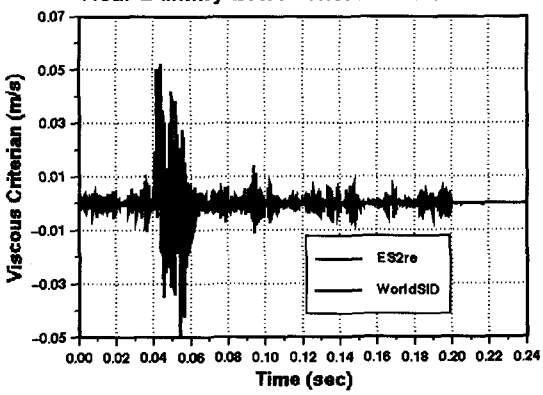
Rear Dummy Lower Thorax Rib Displacement



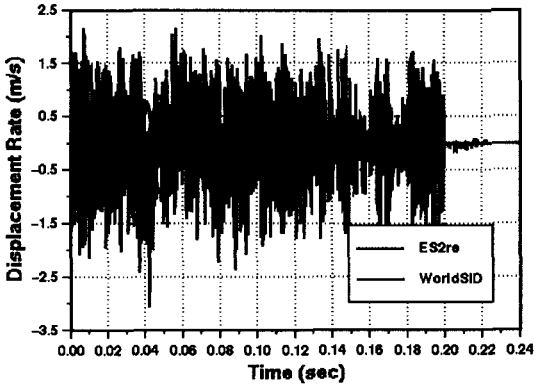
Rear Dummy Center Thorax Rib V*C



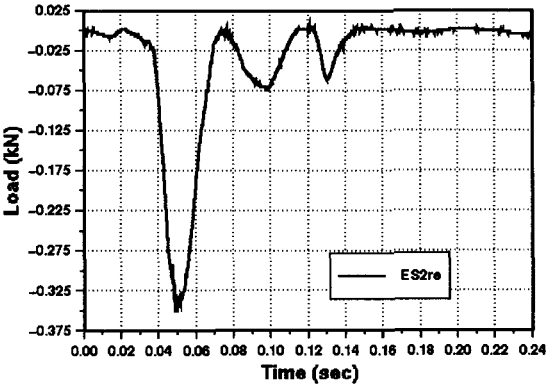
Rear Dummy Lower Thorax Rib V*C



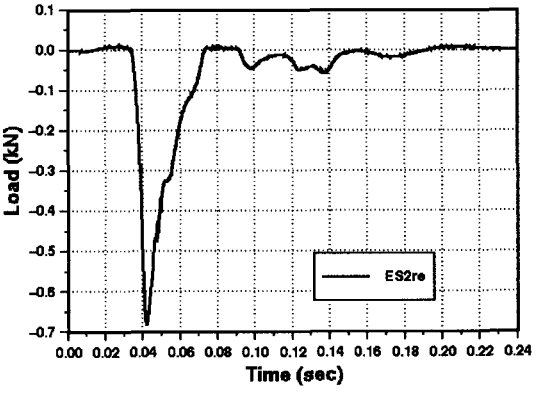
Rear Dummy Lower Thorax Rib Displacement Rate



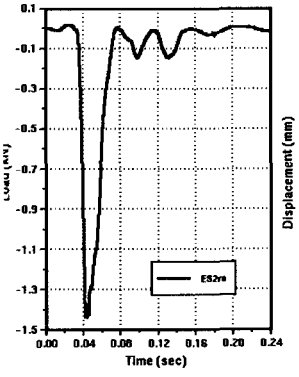
Rear Dummy Abd Load Rear



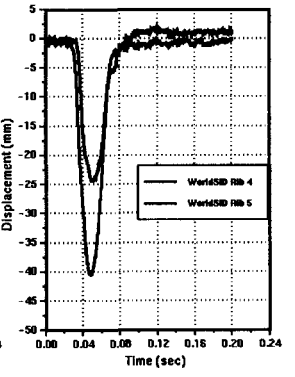
Rear Dummy Abd Load Frt



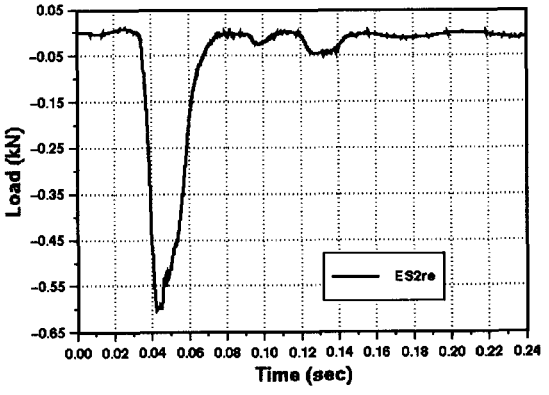
Rear Dummy Abd Load Sum



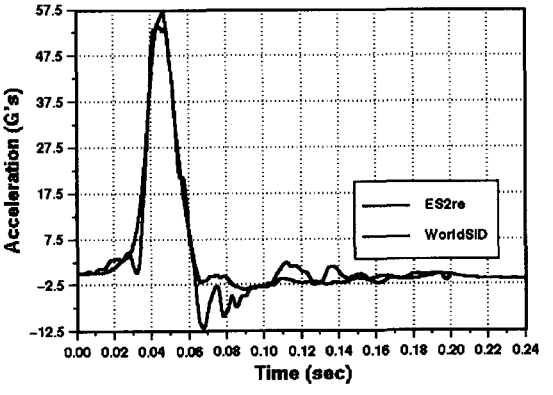
Rear Dummy Abd Rib Displacement



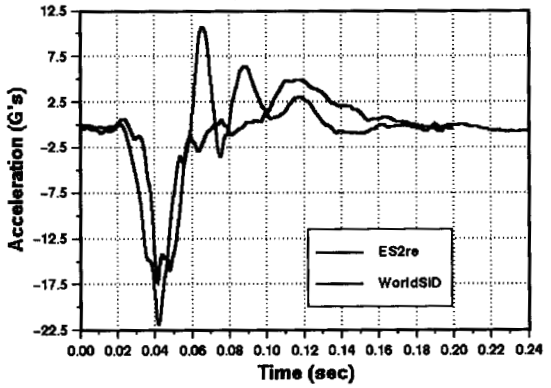
Rear Dummy Abd Load Mid



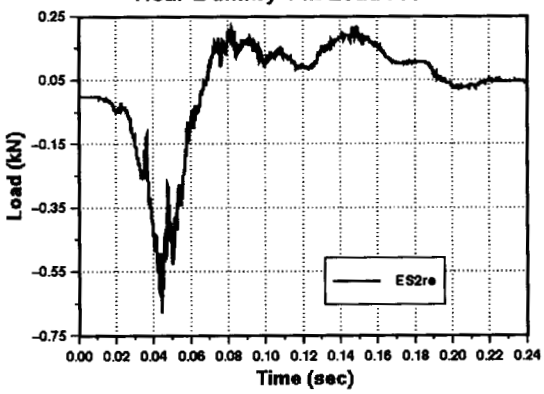
Rear Dummy Lower Spine Lateral Acceleration



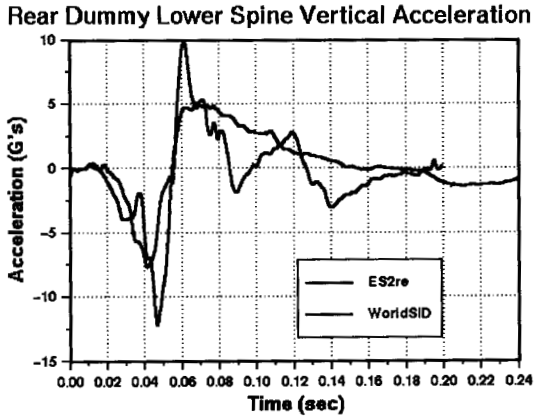
Rear Dummy Lower Spine Longitudinal Acceleratio



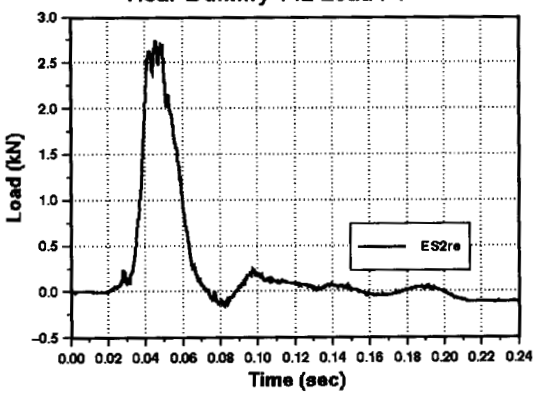
Rear Dummy T12 Load FX



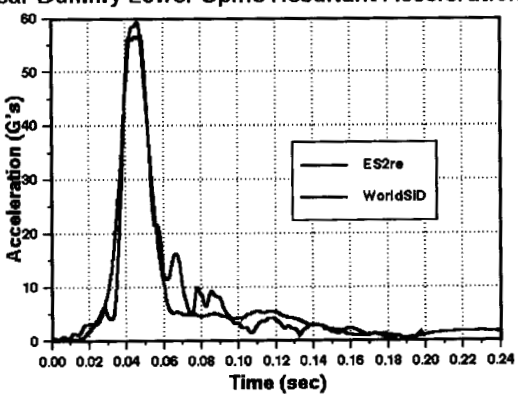
Rear Dummy Lower Spine Vertical Acceleration



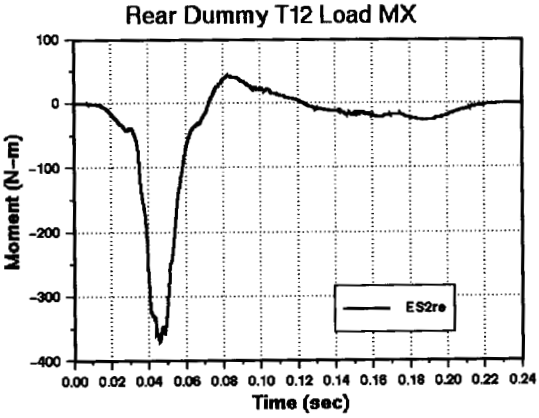
Rear Dummy T12 Load FY



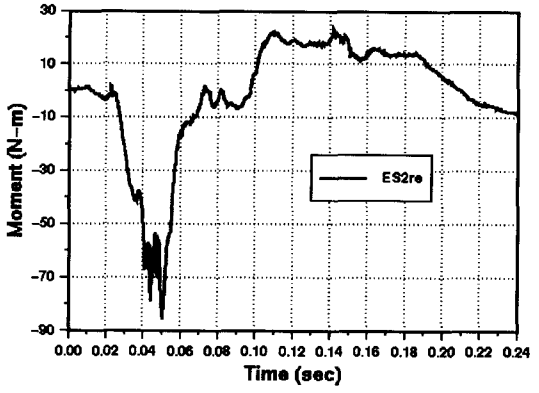
Rear Dummy Lower Spine Resultant Acceleration



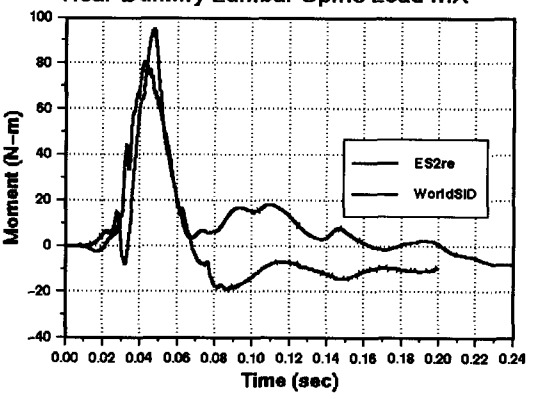
Rear Dummy T12 Load MX



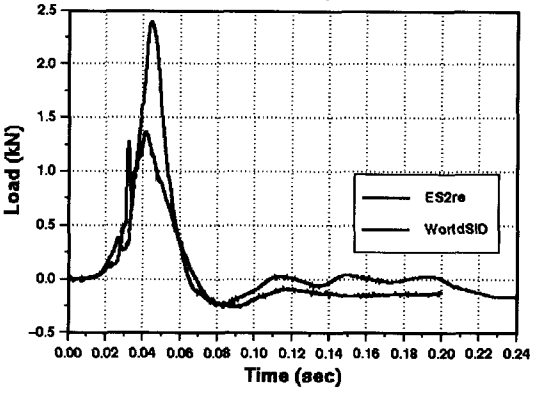
Rear Dummy T12 Load MY



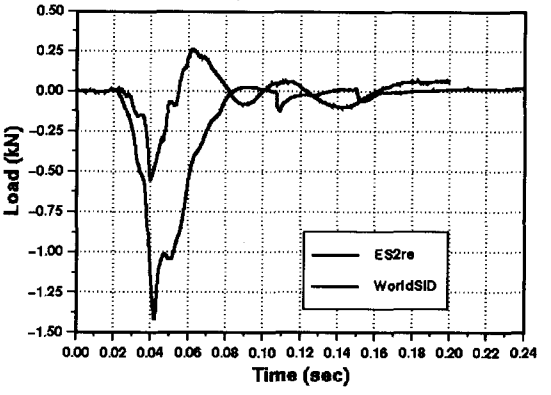
Rear Dummy Lumbar Spine Load MX



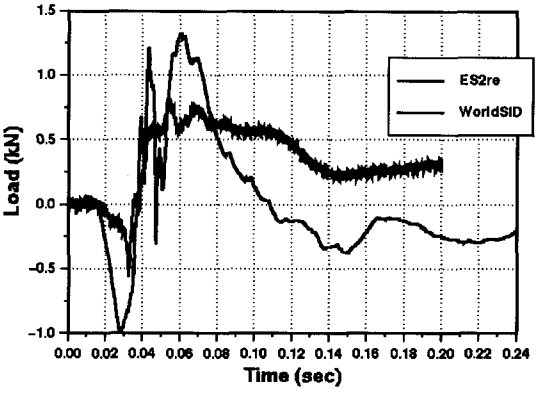
Rear Dummy Lumbar Spine Load FY



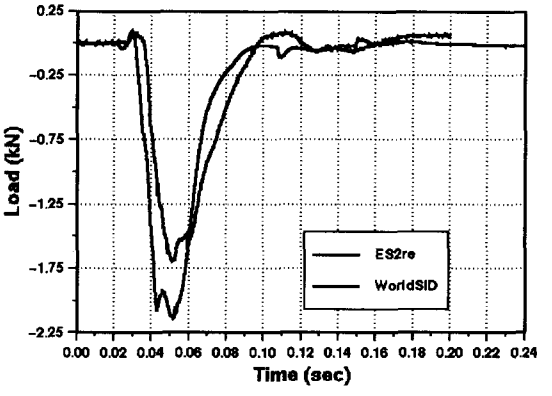
Rear Dummy Shoulder Load FX

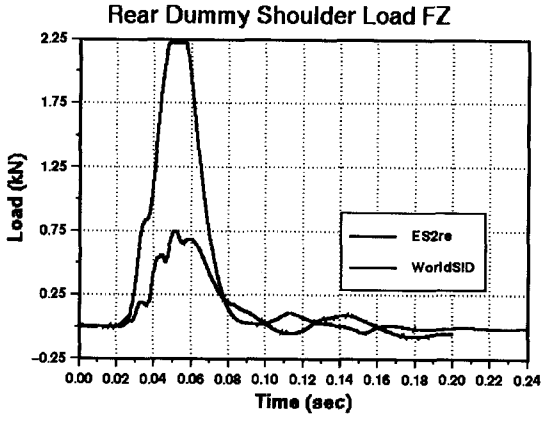


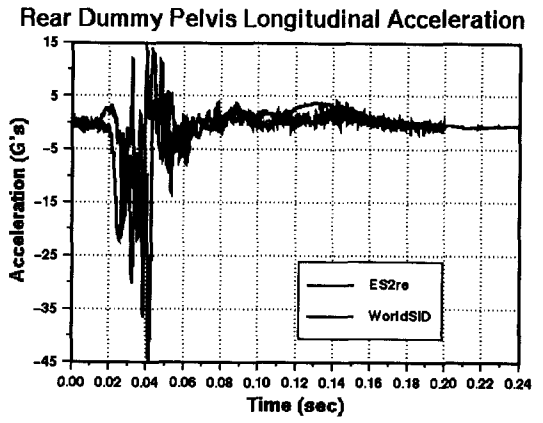
Rear Dummy Lumbar Spine Load FZ

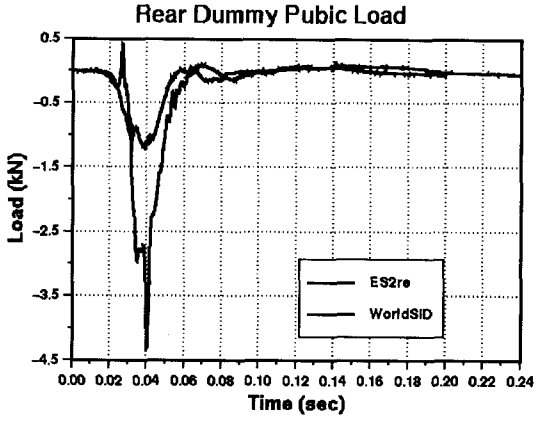


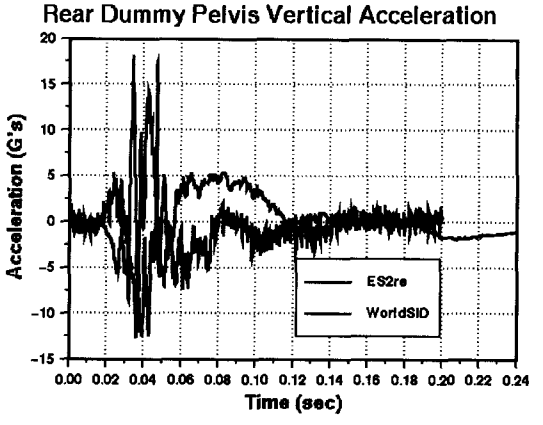
Rear Dummy Shoulder Load FY

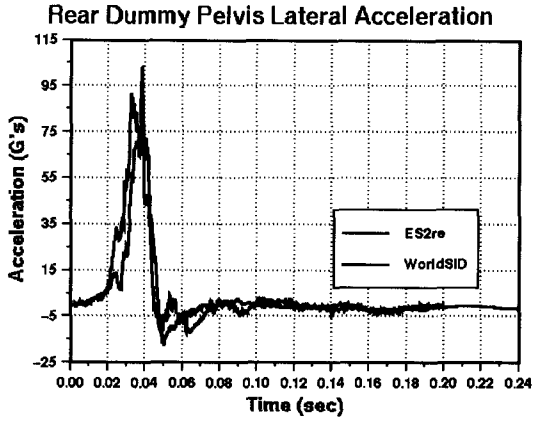


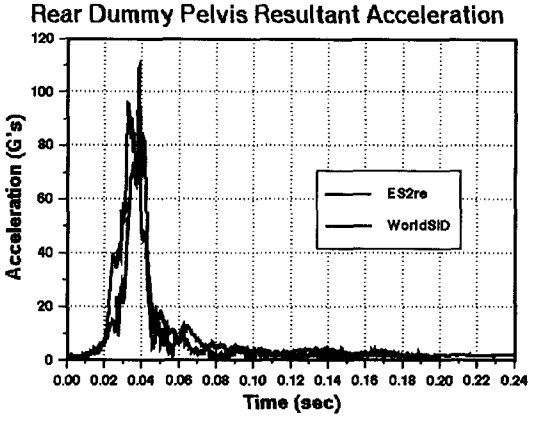

Rear Dummy Shoulder Load FZ
Load (kN)
Time (sec)
ES2re
WorldSID

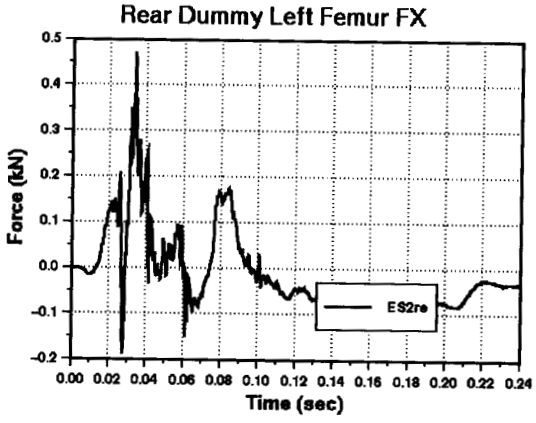

Rear Dummy Pelvis Longitudinal Acceleration
Acceleration (G's)
Time (sec)
ES2re
WorldSID

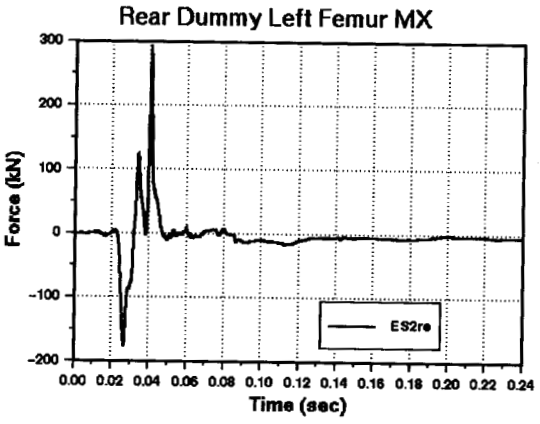

Rear Dummy Pubic Load
Load (kN)
Time (sec)
ES2re
WorldSID

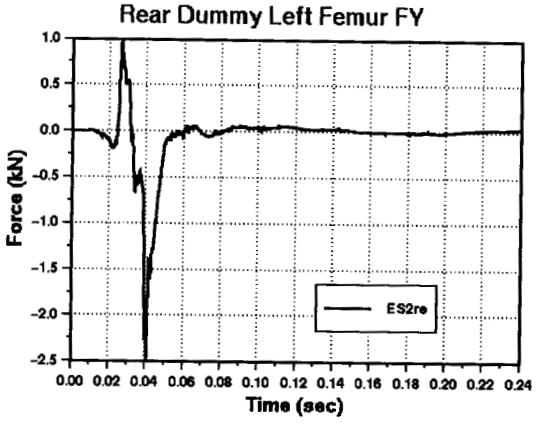

Rear Dummy Pelvis Vertical Acceleration
Acceleration (G's)
Time (sec)
ES2re
WorldSID

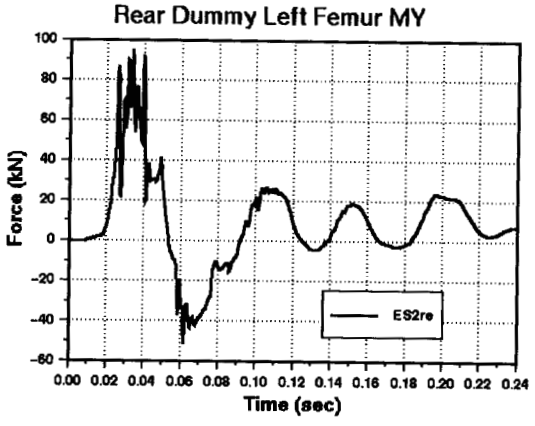

Rear Dummy Pelvis Lateral Acceleration
Acceleration (G's)
Time (sec)
ES2re
WorldSID

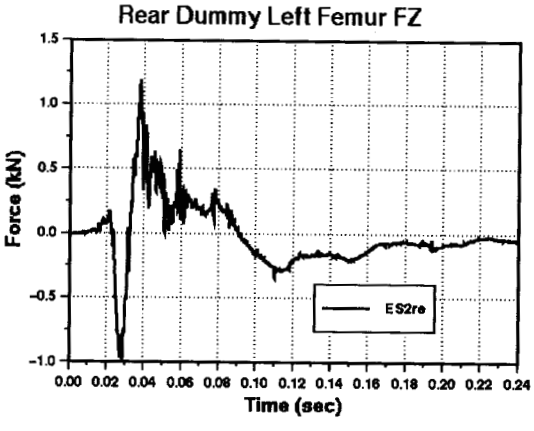

Rear Dummy Pelvis Resultant Acceleration
Acceleration (G's)
Time (sec)
ES2re
WorldSID

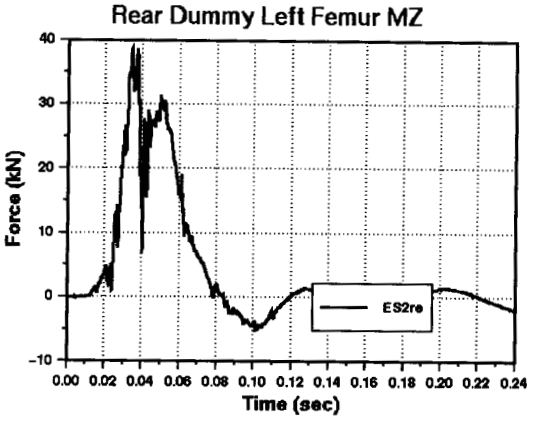

Rear Dummy Left Femur FX
Force (kN)
Time (sec)
ES2re


Rear Dummy Left Femur MX
Force (kN)
Time (sec)
ES2re


Rear Dummy Left Femur FY
Force (kN)
Time (sec)
ES2re

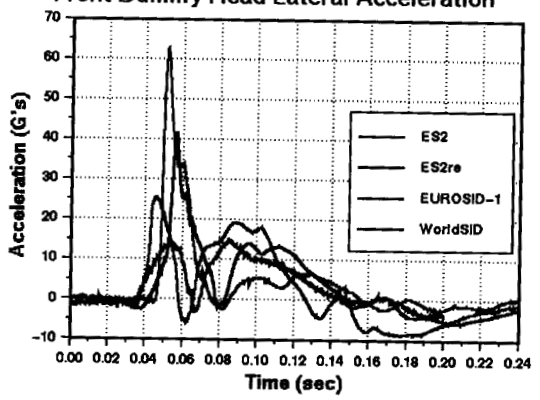

Rear Dummy Left Femur MY
Force (kN)
Time (sec)
ES2re


Rear Dummy Left Femur FZ
Force (kN)
Time (sec)
ES2re

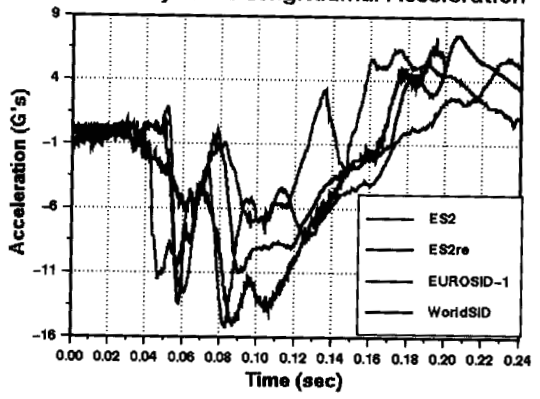

Rear Dummy Left Femur MZ
Force (kN)
Time (sec)
ES2re

Mid-Sized Sedan MDB Cart Data

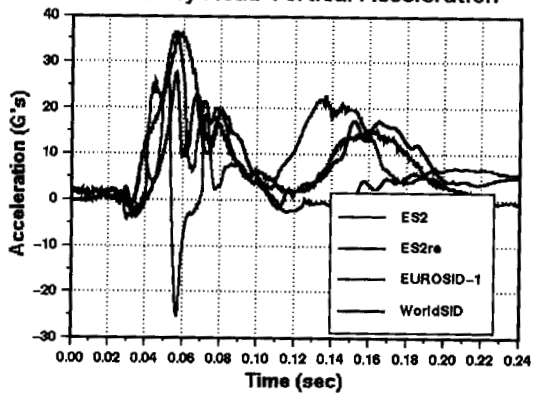
Front Dummy Head Lateral Acceleration



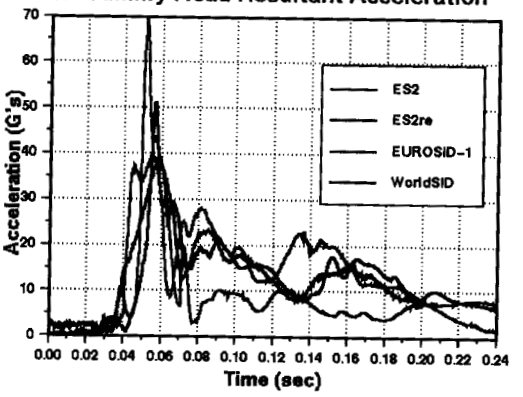
Front Dummy Head Longitudinal Acceleration



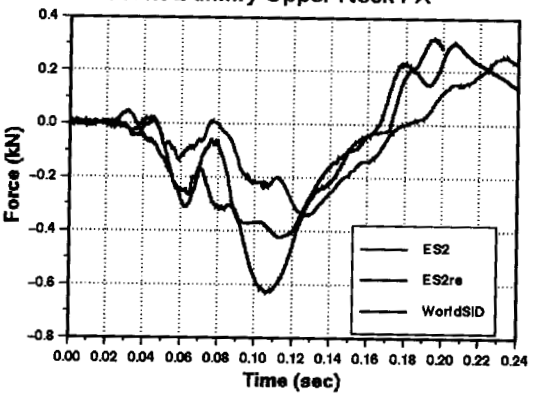
Front Dummy Head Vertical Acceleration



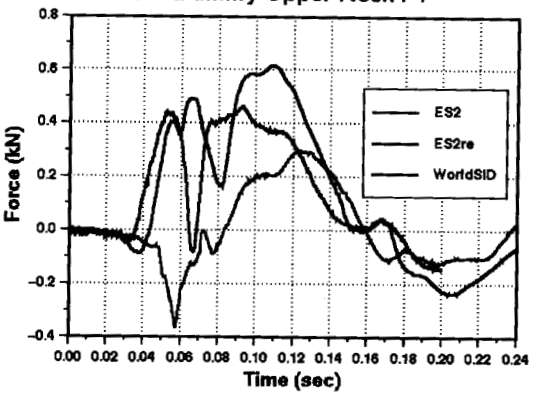
Front Dummy Head Resultant Acceleration

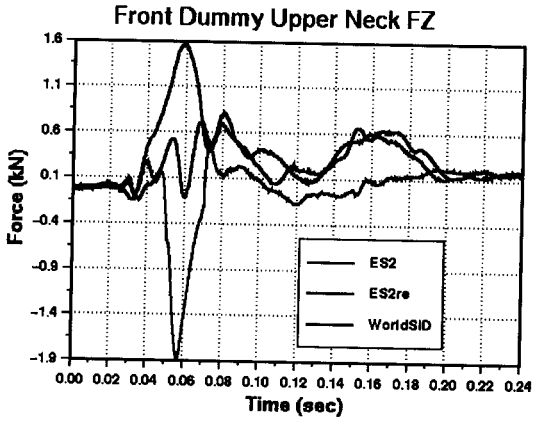


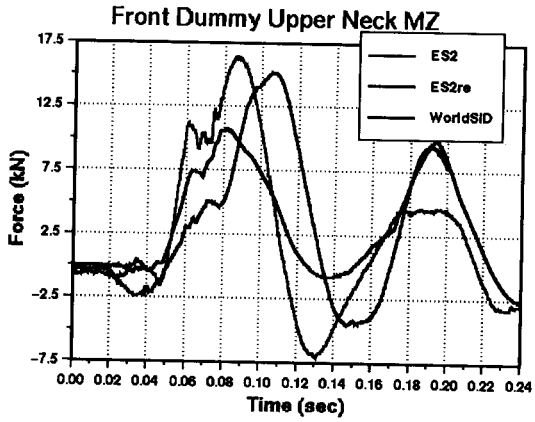
Front Dummy Upper Neck FX

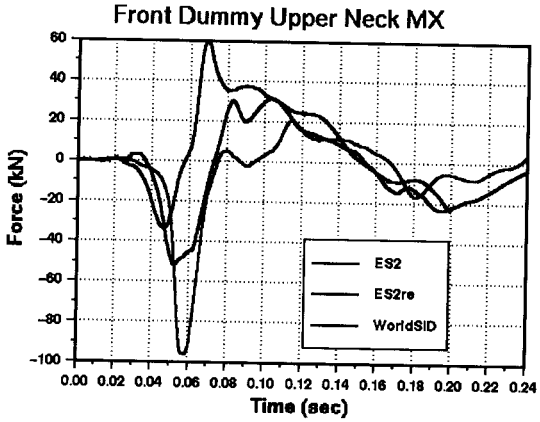


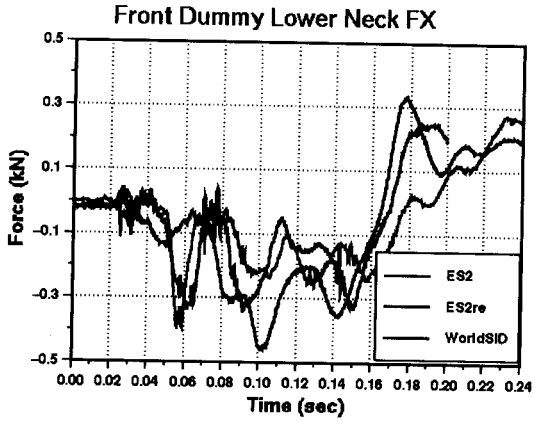
Front Dummy Upper Neck FY

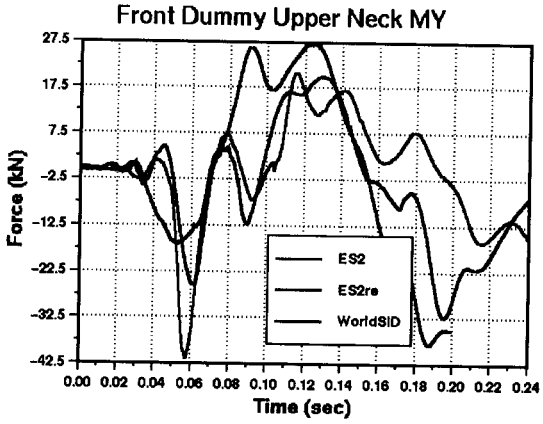


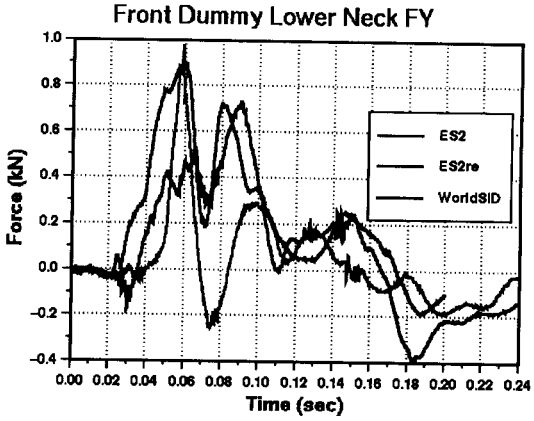

Front Dummy Upper Neck FZ
Force (kN)
Time (sec)
ES2
ES2re
WorldSID


Front Dummy Upper Neck MZ
Force (kN)
Time (sec)
ES2
ES2re
WorldSID

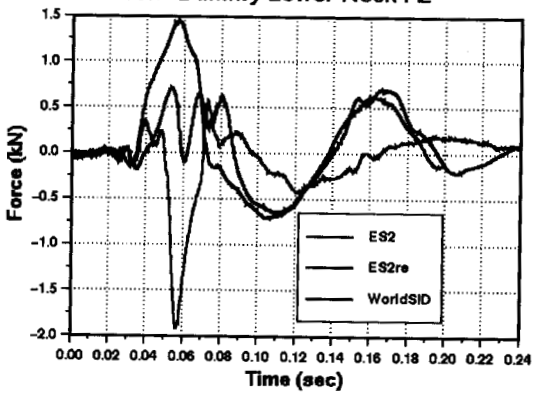

Front Dummy Upper Neck MX
Force (kN)
Time (sec)
ES2
ES2re
WorldSID


Front Dummy Lower Neck FX
Force (kN)
Time (sec)
ES2
ES2re
WorldSID

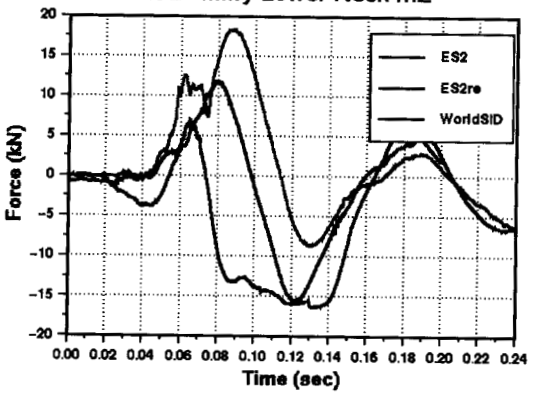

Front Dummy Upper Neck MY
Force (kN)
Time (sec)
ES2
ES2re
WorldSID


Front Dummy Lower Neck FY
Force (kN)
Time (sec)
ES2
ES2re
WorldSID

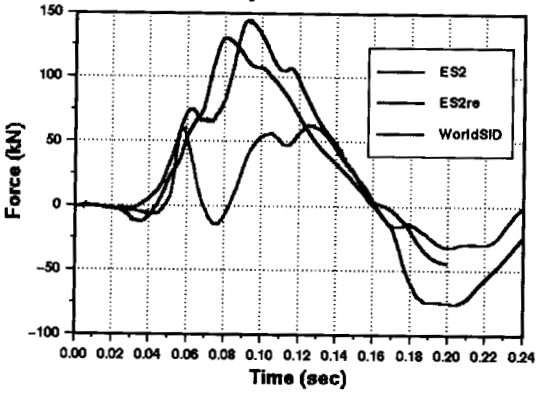
Front Dummy Lower Neck FZ



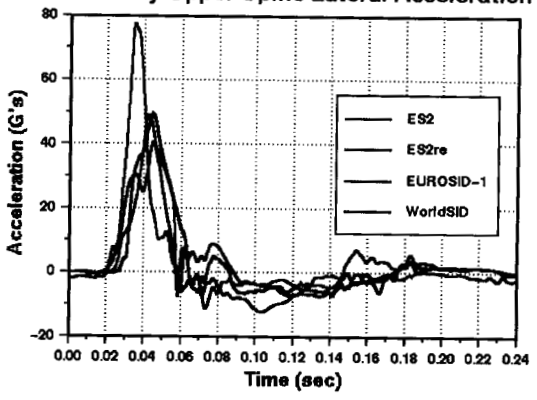
Front Dummy Lower Neck MZ



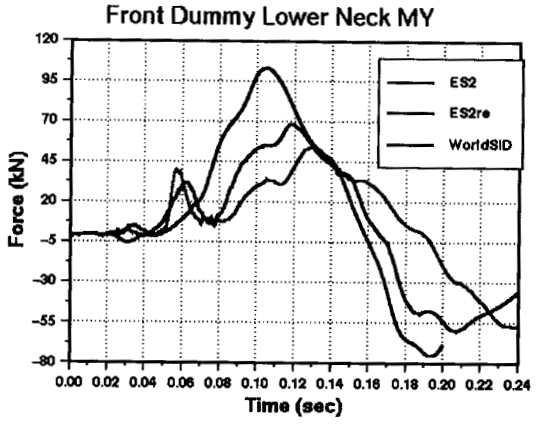
Front Dummy Lower Neck MX



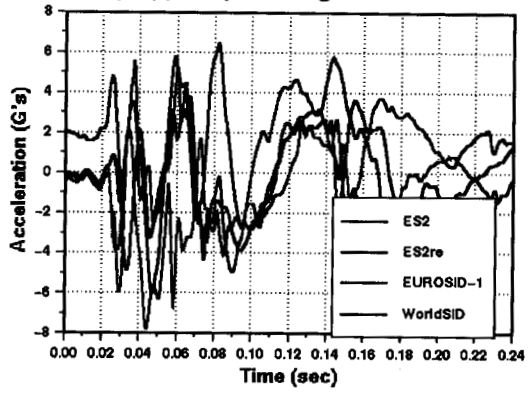
Front Dummy Upper Spine Lateral Acceleration



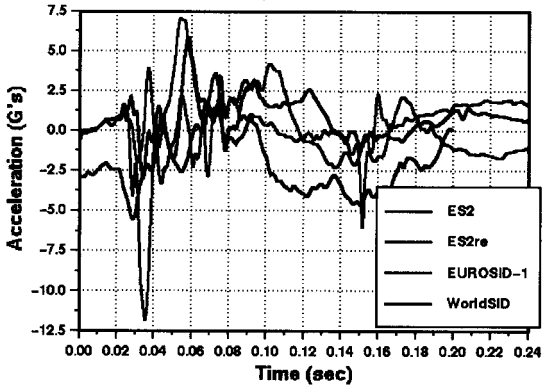
Front Dummy Lower Neck MY



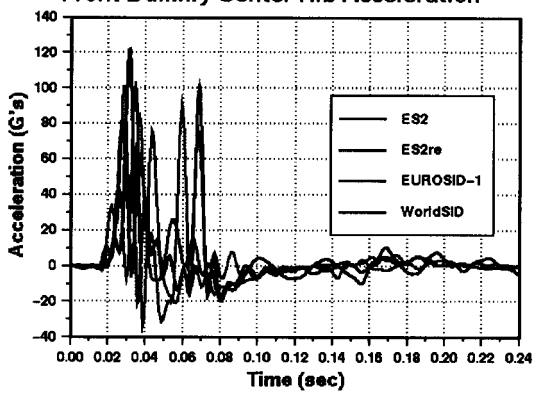
Front Dummy Upper Spine Longitudinal Acceleratic



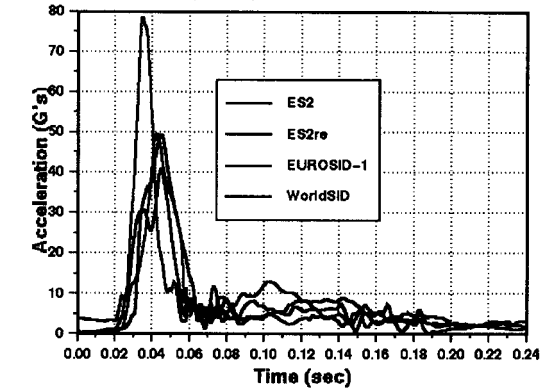
Front Dummy Upper Spine Vertical Acceleration



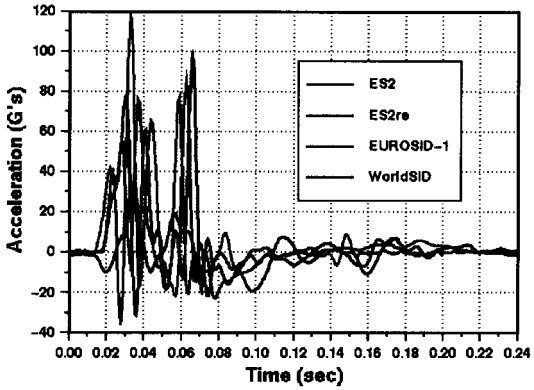
Front Dummy Center Rib Acceleration



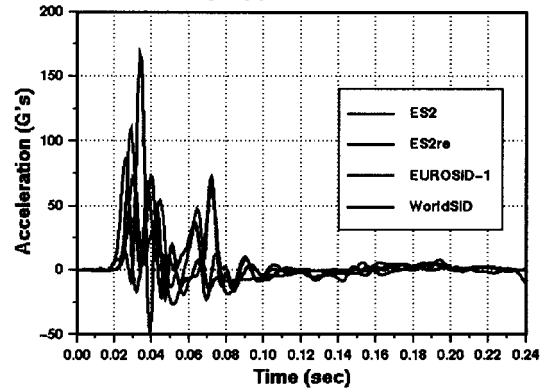
Front Dummy Upper Spine Resultant Acceleration



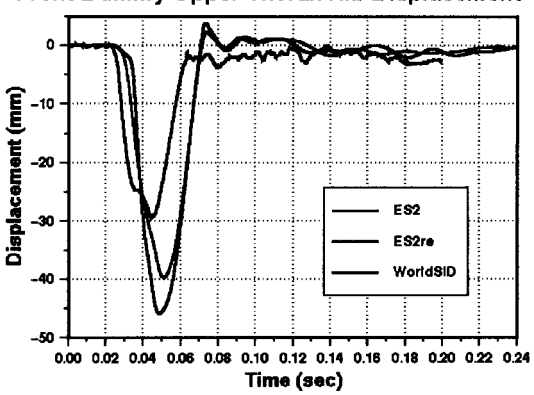
Front Dummy Lower Rib Acceleration



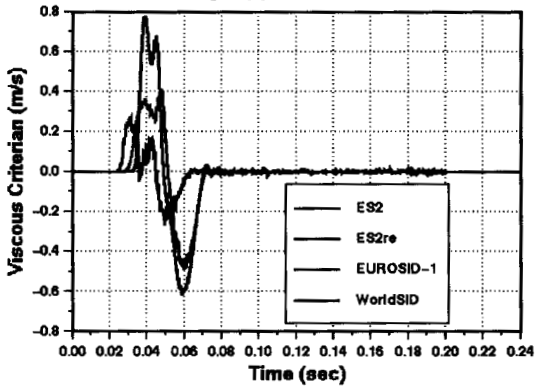
Front Dummy Upper Rib Acceleration



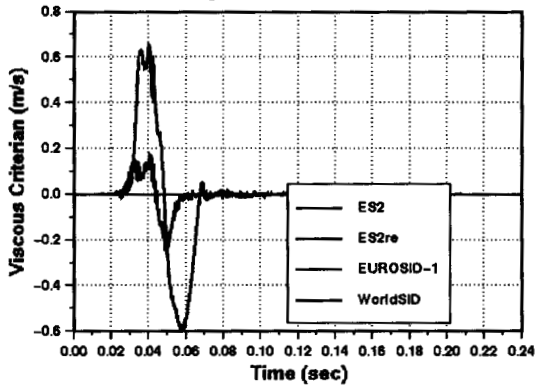
Front Dummy Upper Thorax Rib Displacement



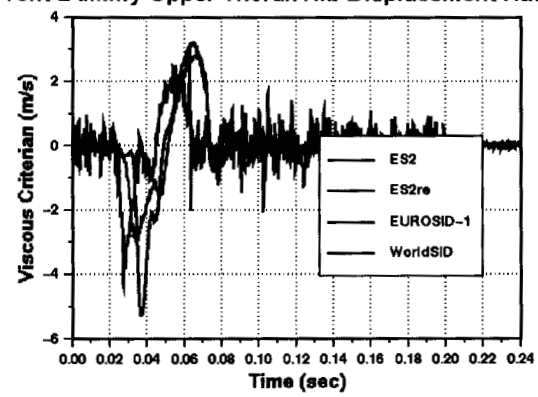
Front Dummy Upper Thorax Rib V*C



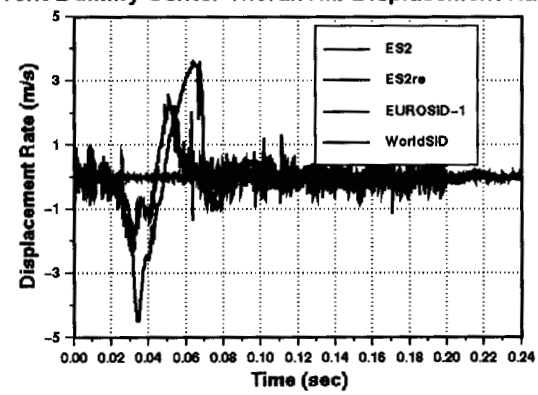
Front Dummy Center Thorax Rib V*C



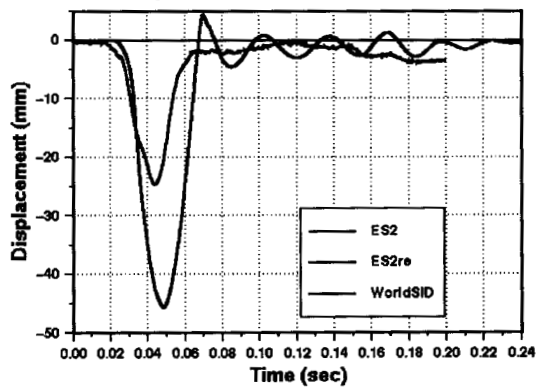
Front Dummy Upper Thorax Rib Displacement Rate



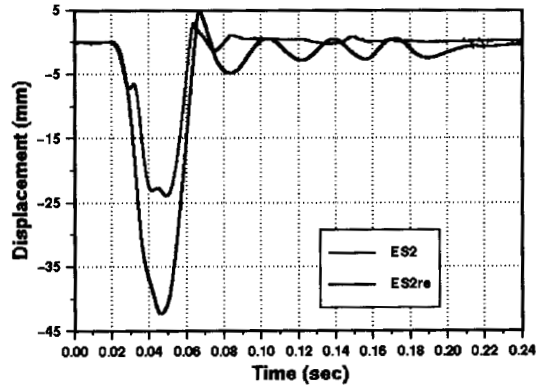
Front Dummy Center Thorax Rib Displacement Rate



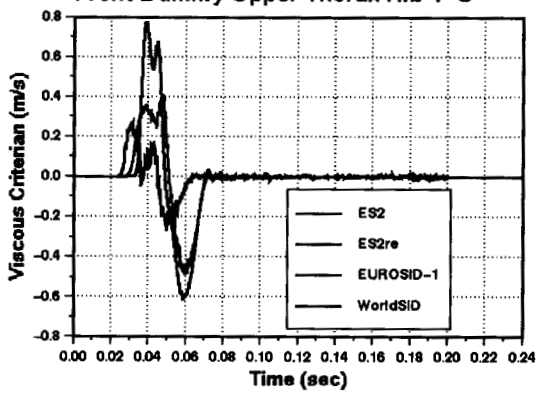
Front Dummy Center Thorax Rib Displacement



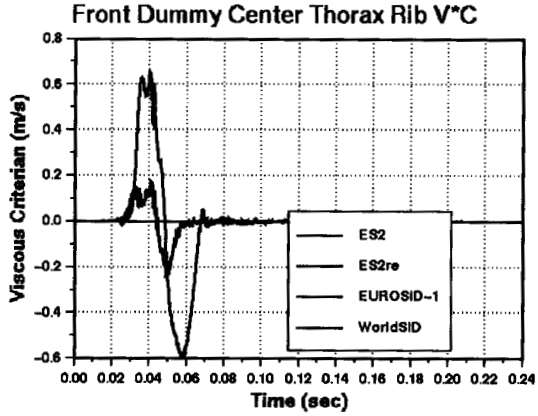
Front Dummy Lower Thorax Rib Displacement



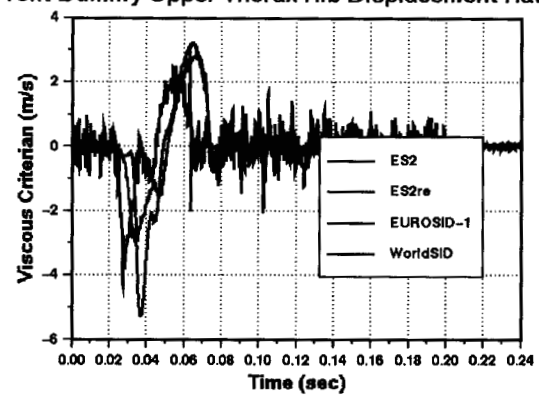
Front Dummy Upper Thorax Rib V*C



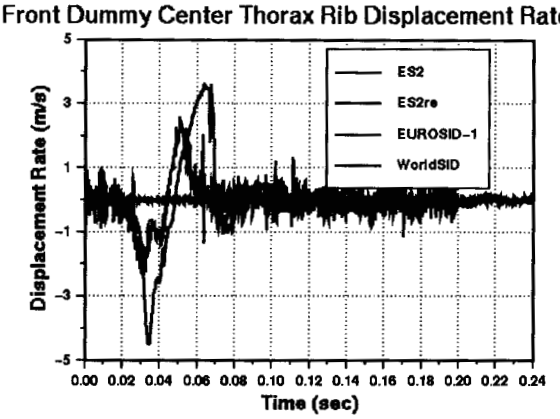
Front Dummy Center Thorax Rib V*C



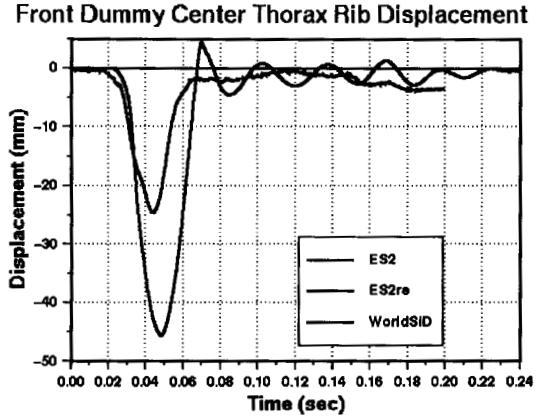
Front Dummy Upper Thorax Rib Displacement Rate



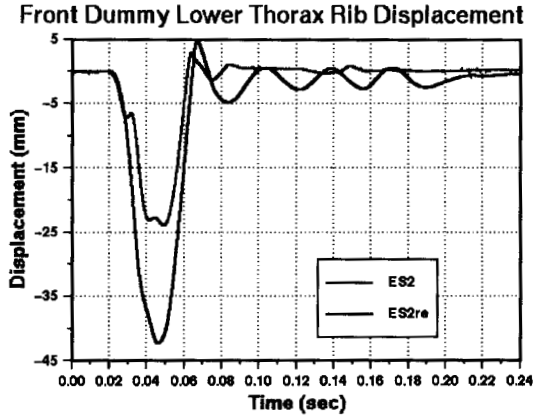
Front Dummy Center Thorax Rib Displacement Rate

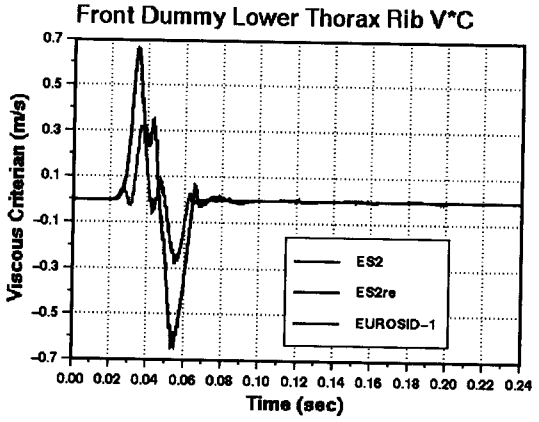


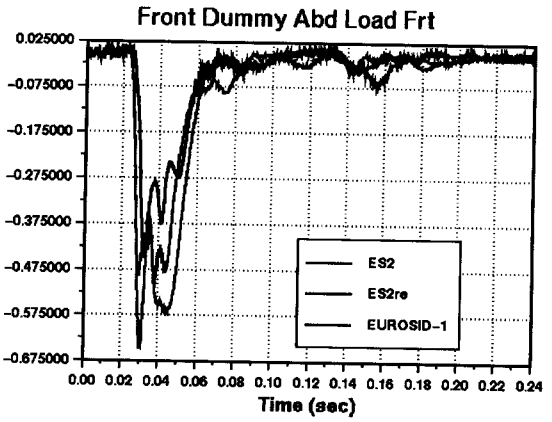
Front Dummy Center Thorax Rib Displacement

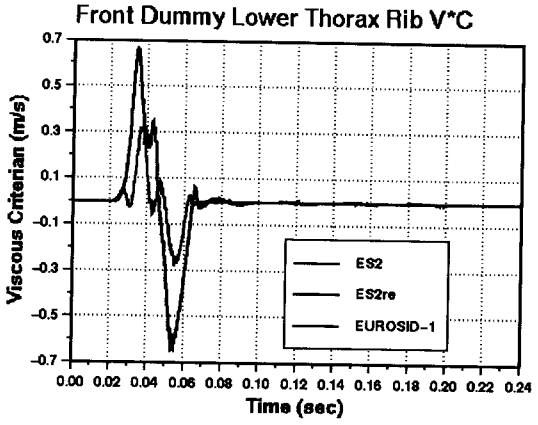


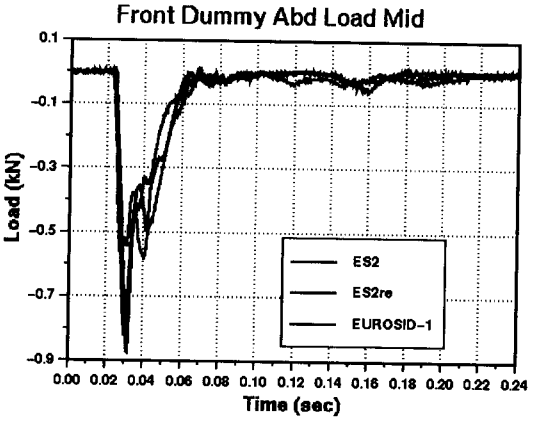
Front Dummy Lower Thorax Rib Displacement

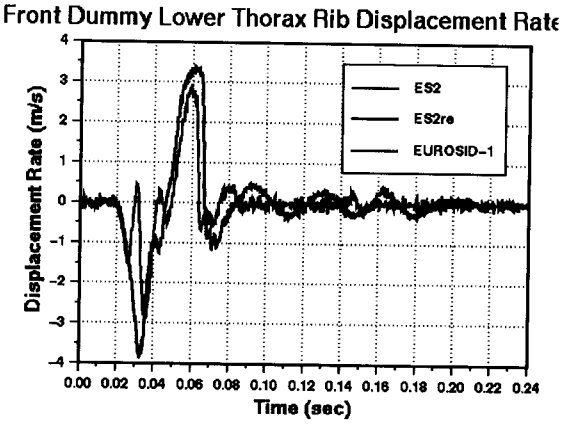


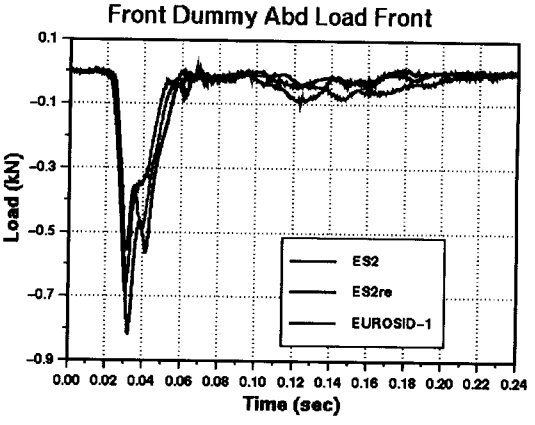

Front Dummy Lower Thorax Rib V*C
Viscous Criterian (m/s)
Time (sec)
ES2
ES2re
EUROSID-1


Front Dummy Abd Load Frt
Time (sec)
ES2
ES2re
EUROSID-1

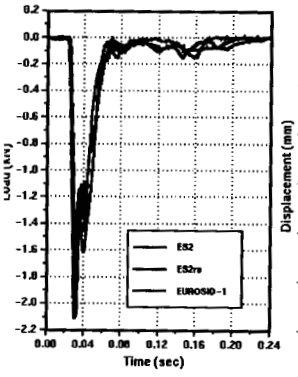

Front Dummy Lower Thorax Rib V*C
Viscous Criterian (m/s)
Time (sec)
ES2
ES2re
EUROSID-1


Front Dummy Abd Load Mid
Load (kN)
Time (sec)
ES2
ES2re
EUROSID-1

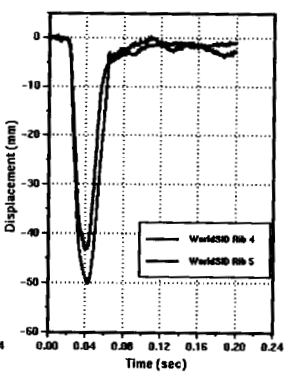

Front Dummy Lower Thorax Rib Displacement Rate
Displacement Rate (m/s)
Time (sec)
ES2
ES2re
EUROSID-1


Front Dummy Abd Load Front
Load (kN)
Time (sec)
ES2
ES2re
EUROSID-1

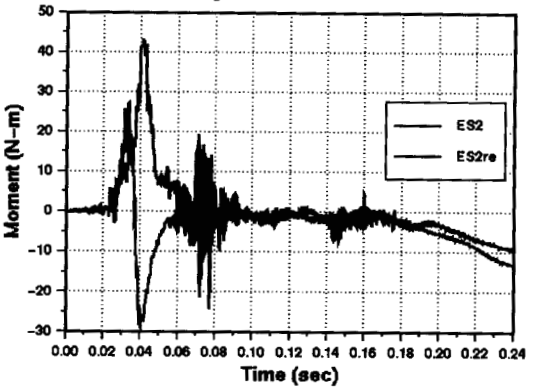
Front Dummy Abd Load Sum



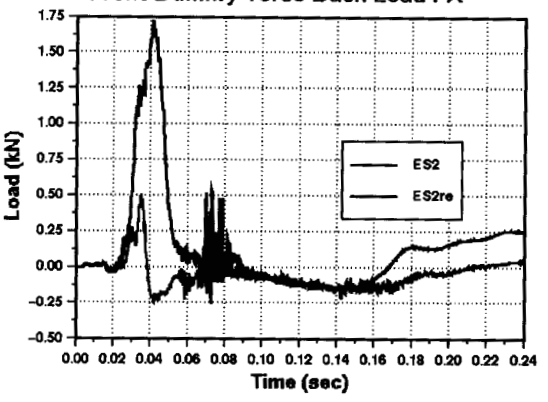
Front Dummy Abd Rib Displacement



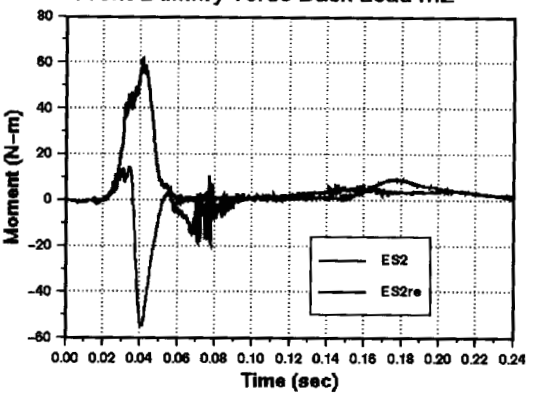
Front Dummy Torso Back Load MY



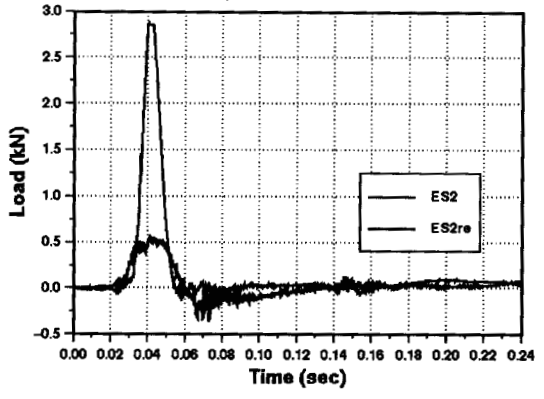
Front Dummy Torso Back Load FX



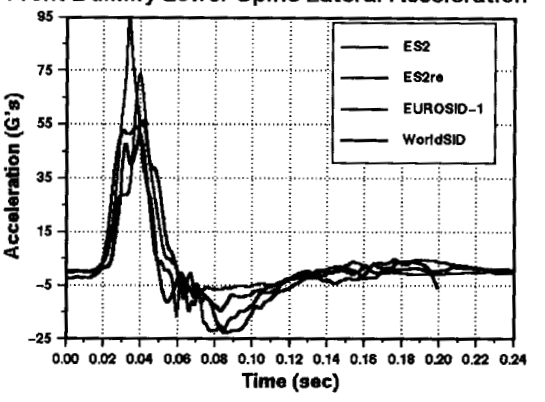
Front Dummy Torso Back Load MZ



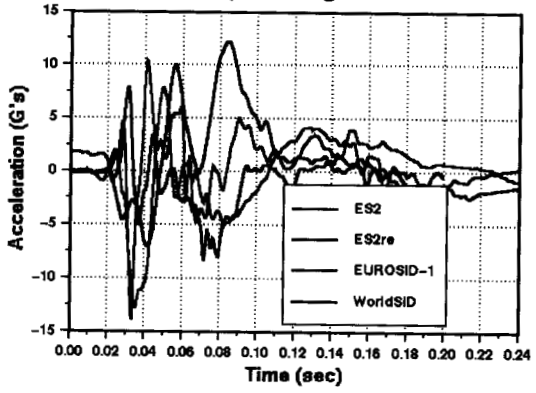
Front Dummy Torso Back Load FY



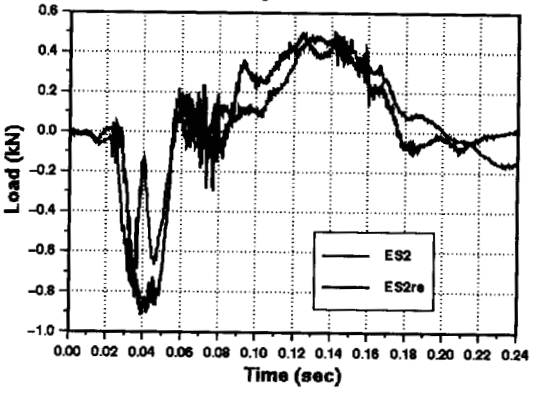
Front Dummy Lower Spine Lateral Acceleration



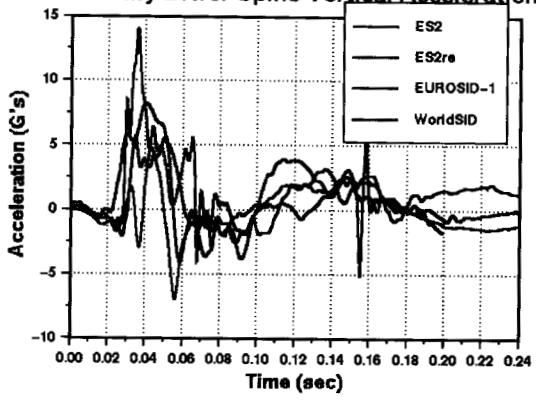
Front Dummy Lower Spine Longitudinal Acceleratio



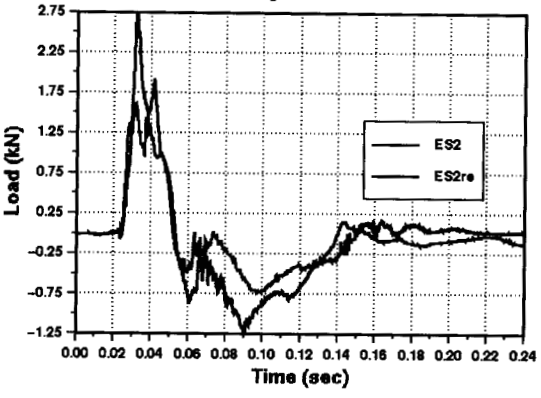
Front Dummy T12 Load FX



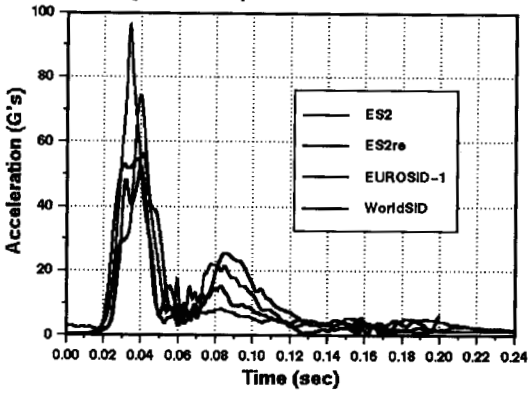
Front Dummy Lower Spine Vertical Acceleration



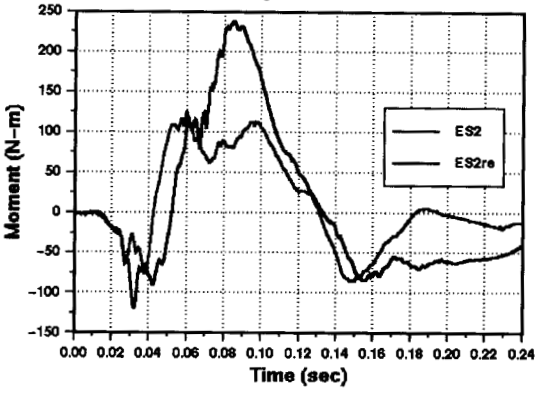
Front Dummy T12 Load FY

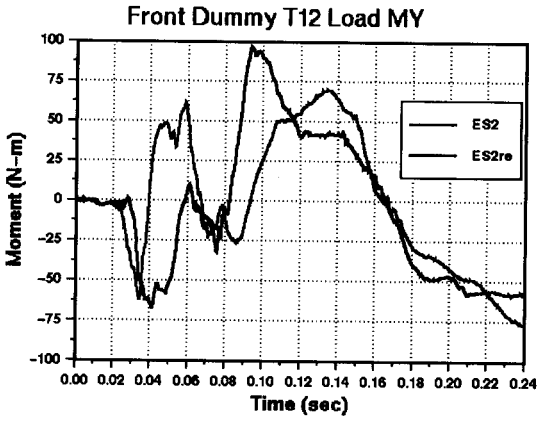


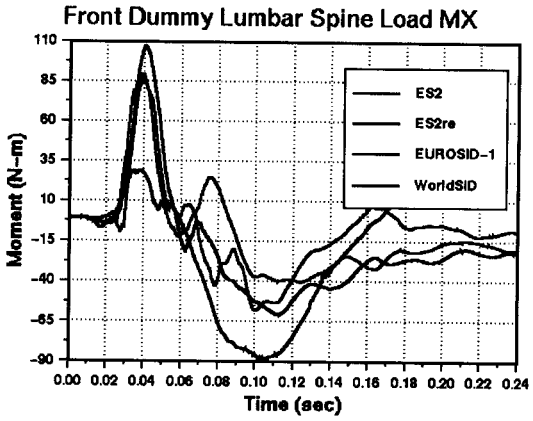
Front Dummy Lower Spine Resultant Acceleration

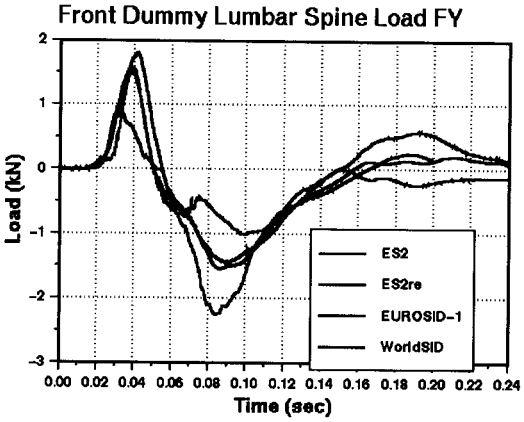


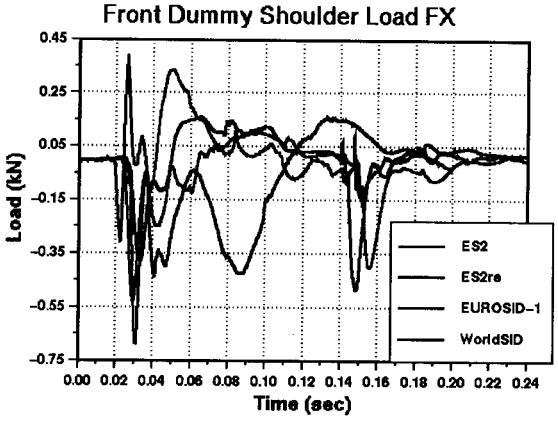
Front Dummy T12 Load MX

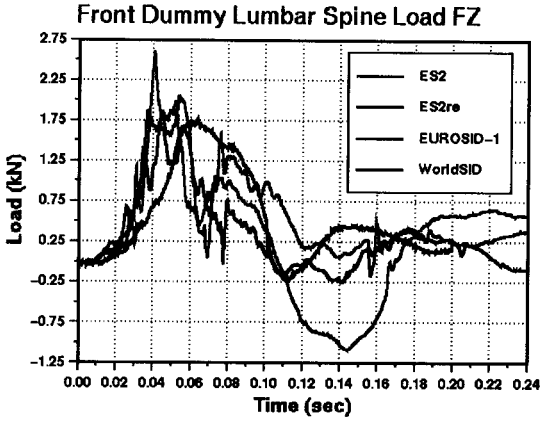


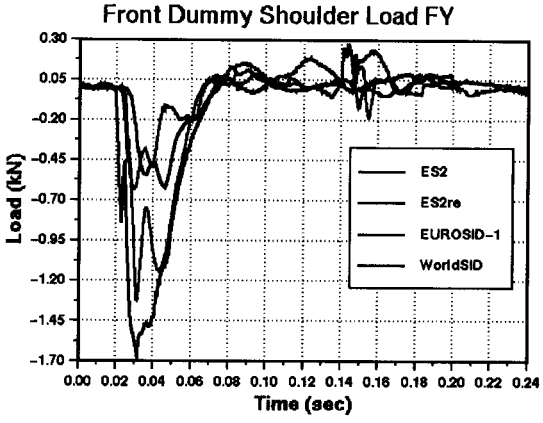

Front Dummy T12 Load MY
Moment (N-m)
Time (sec)
ES2
ES2re


Front Dummy Lumbar Spine Load MX
Moment (N-m)
Time (sec)
ES2
ES2re
EUROSID-1
WorldSID

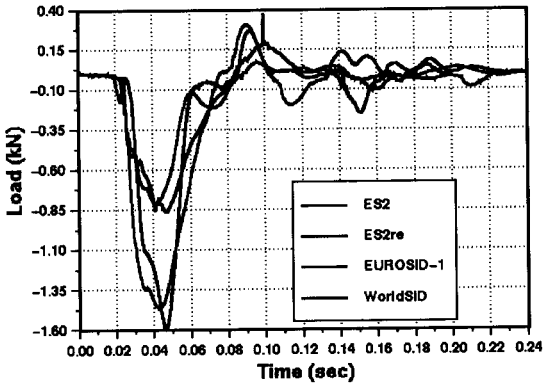

Front Dummy Lumbar Spine Load FY
Load (kN)
Time (sec)
ES2
ES2re
EUROSID-1
WorldSID


Front Dummy Shoulder Load FX
Load (kN)
Time (sec)
ES2
ES2re
EUROSID-1
WorldSID

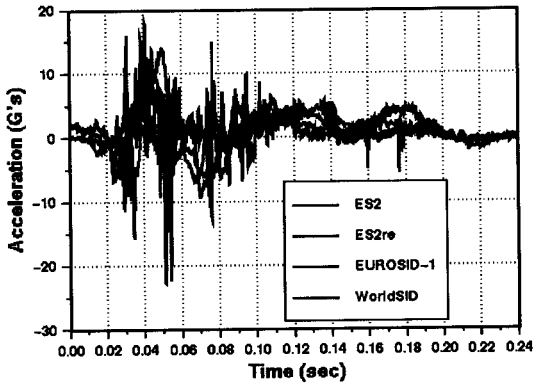

Front Dummy Lumbar Spine Load FZ
Load (kN)
Time (sec)
ES2
ES2re
EUROSID-1
WorldSID


Front Dummy Shoulder Load FY
Load (kN)
Time (sec)
ES2
ES2re
EUROSID-1
WorldSID

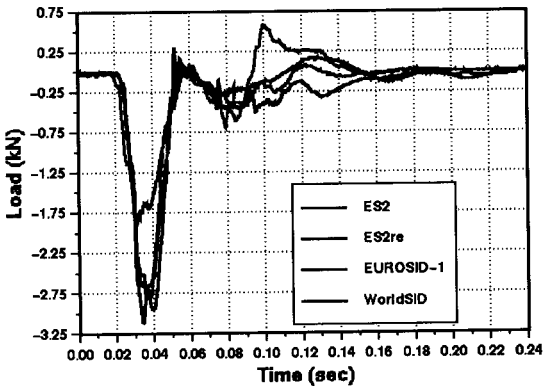
Front Dummy Shoulder Load FZ



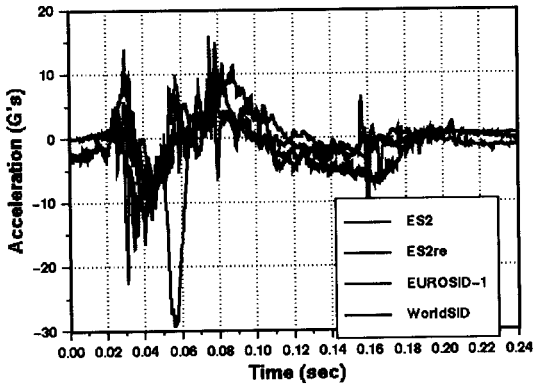
Front Dummy Pelvis Longitudinal Acceleration



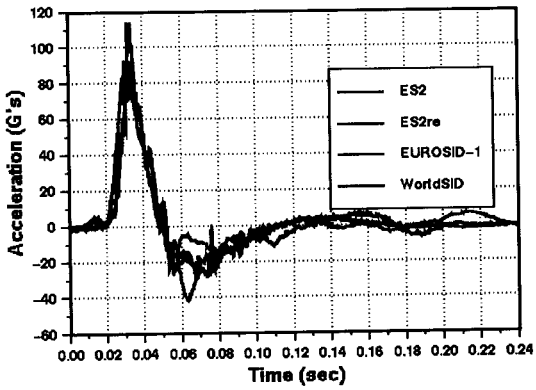
Front Dummy Pubic Load



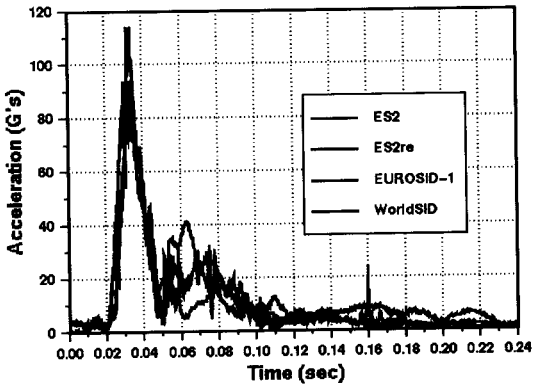
Front Dummy Pelvis Vertical Acceleration

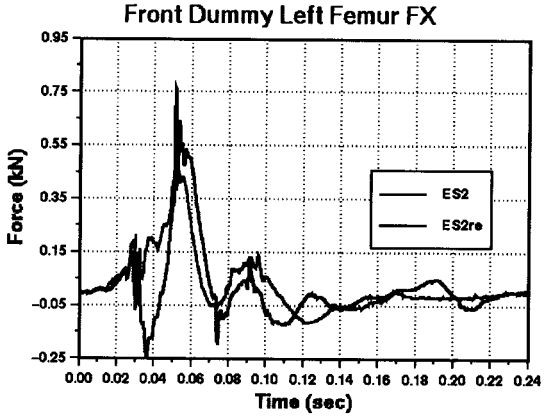


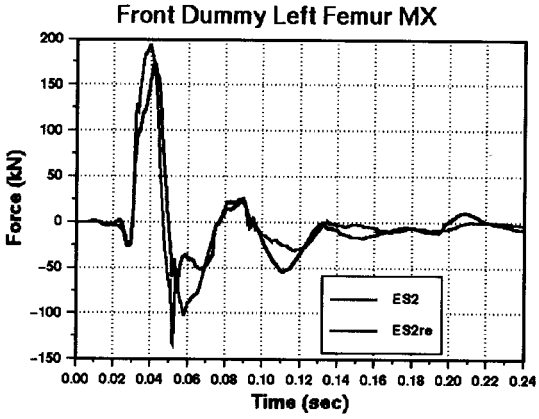
Front Dummy Pelvis Lateral Acceleration

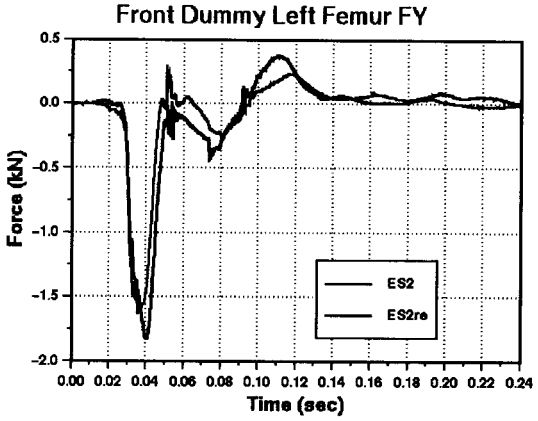


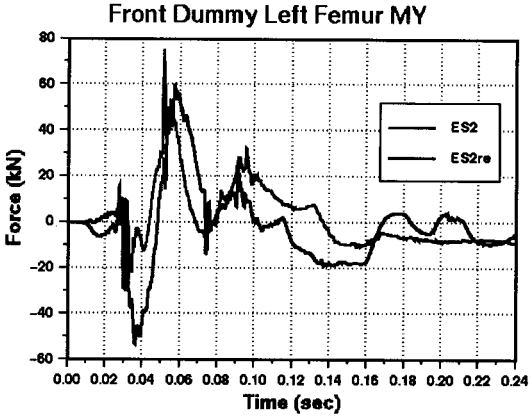
Front Dummy Pelvis Resultant Acceleration

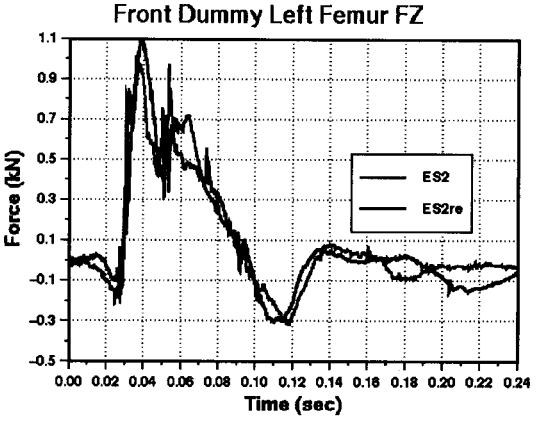


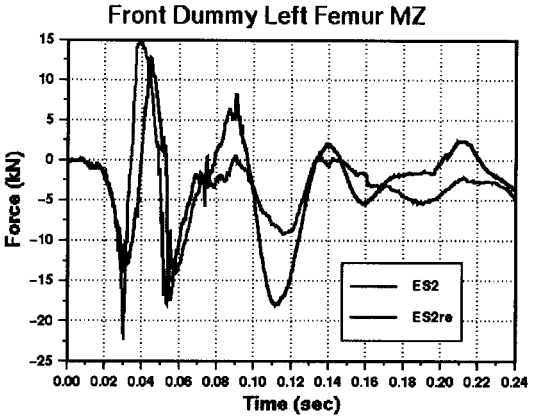

Front Dummy Left Femur FX
Force (kN)
Time (sec)
ES2
ES2re


Front Dummy Left Femur MX
Force (kN)
Time (sec)
ES2
ES2re

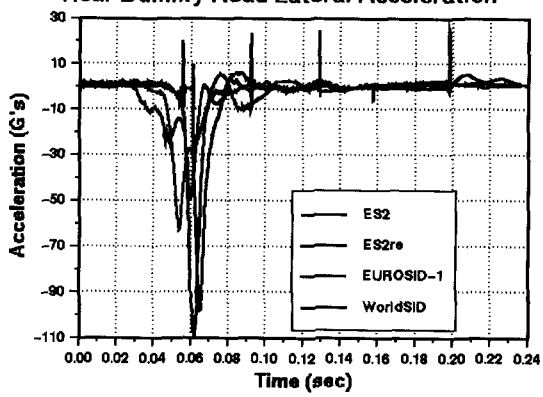

Front Dummy Left Femur FY
Force (kN)
Time (sec)
ES2
ES2re


Front Dummy Left Femur MY
Force (kN)
Time (sec)
ES2
ES2re

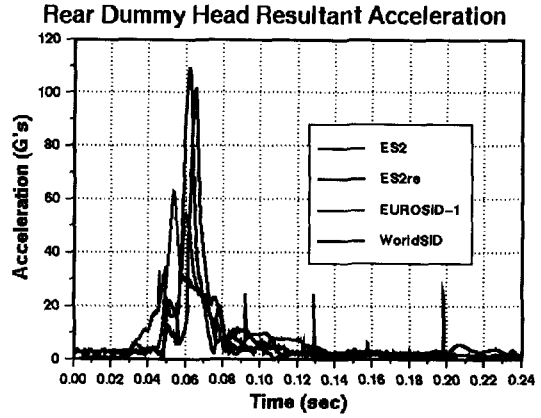

Front Dummy Left Femur FZ
Force (kN)
Time (sec)
ES2
ES2re


Front Dummy Left Femur MZ
Force (kN)
Time (sec)
ES2
ES2re

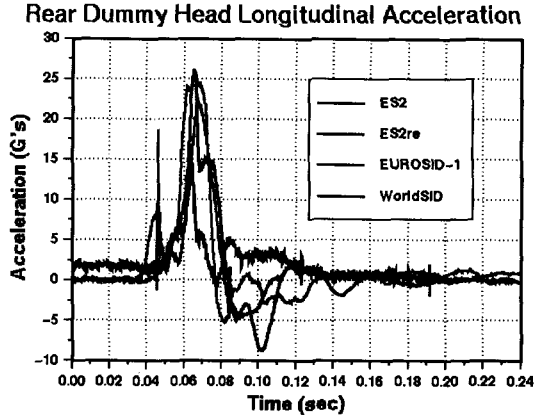
Rear Dummy Head Lateral Acceleration



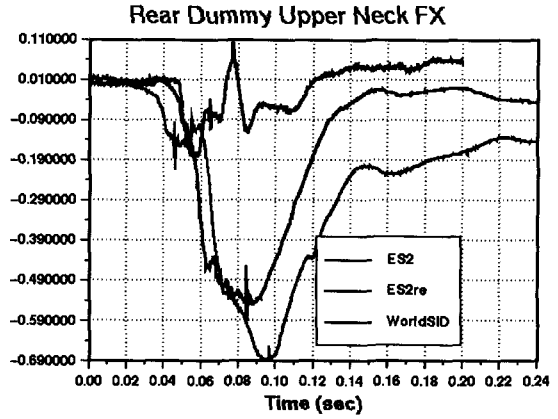
Rear Dummy Head Resultant Acceleration



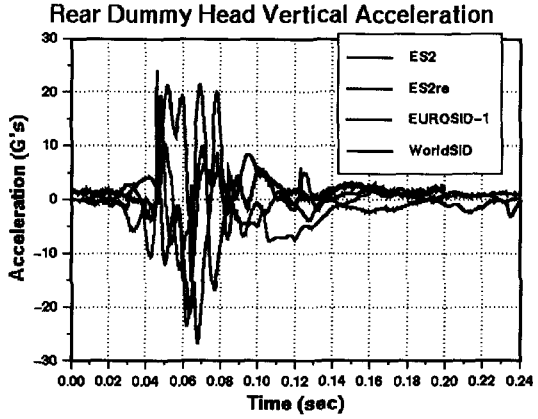
Rear Dummy Head Longitudinal Acceleration



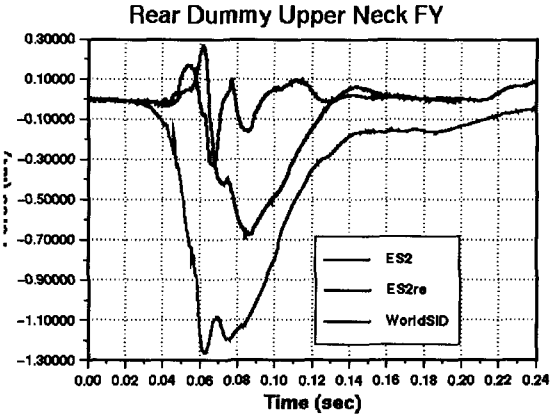
Rear Dummy Upper Neck FX

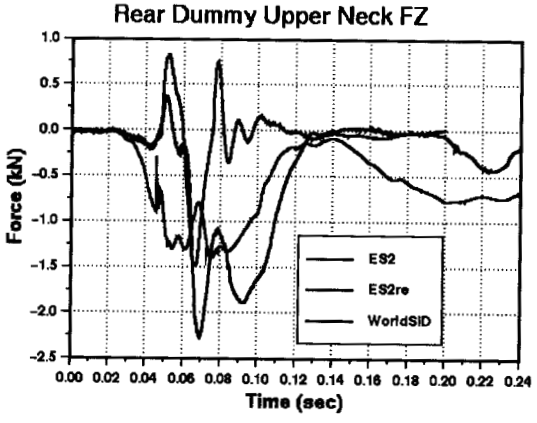


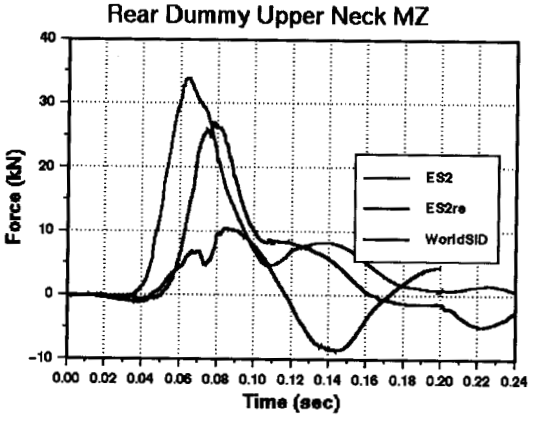
Rear Dummy Head Vertical Acceleration

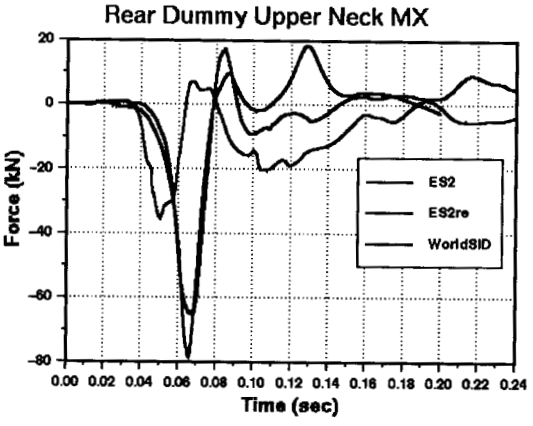


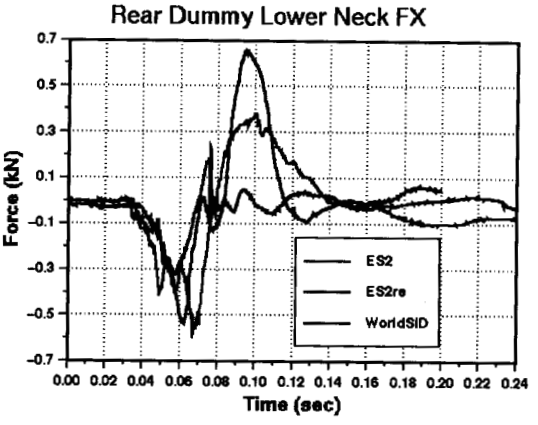
Rear Dummy Upper Neck FY

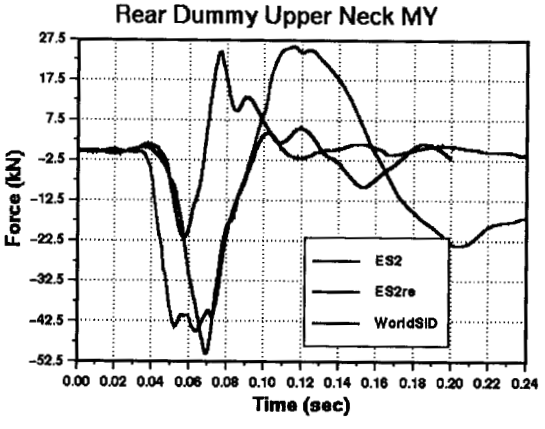


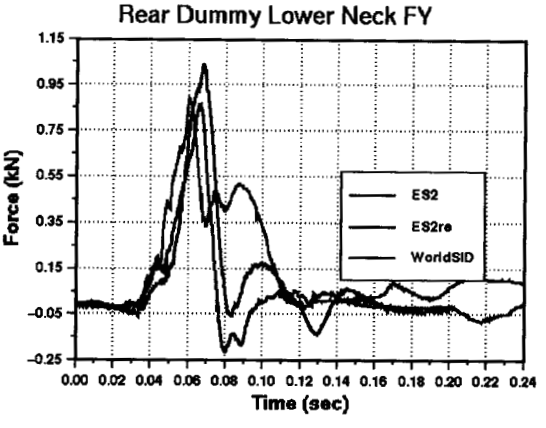

Rear Dummy Upper Neck FZ
Force (kN)
Time (sec)
ES2
ES2re
WorldSID


Rear Dummy Upper Neck MZ
Force (kN)
Time (sec)
ES2
ES2re
WorldSID

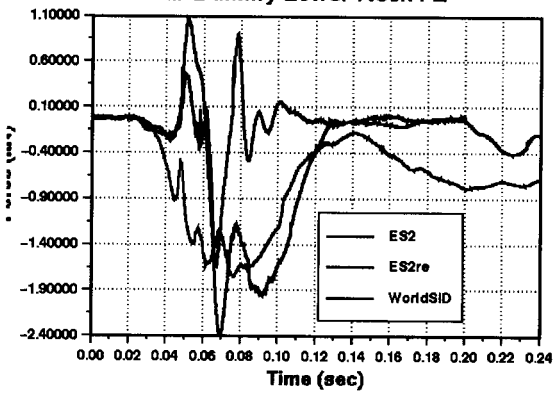

Rear Dummy Upper Neck MX
Force (kN)
Time (sec)
ES2
ES2re
WorldSID


Rear Dummy Lower Neck FX
Force (kN)
Time (sec)
ES2
ES2re
WorldSID

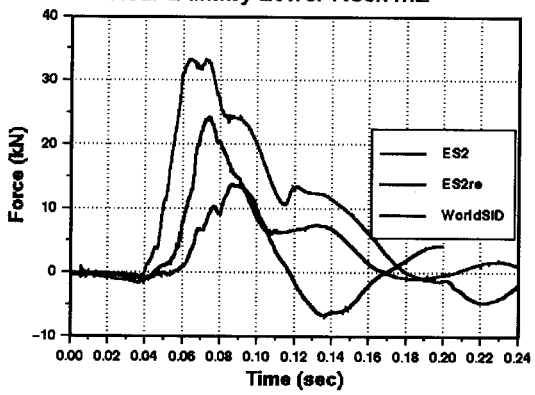

Rear Dummy Upper Neck MY
Force (kN)
Time (sec)
ES2
ES2re
WorldSID


Rear Dummy Lower Neck FY
Force (kN)
Time (sec)
ES2
ES2re
WorldSID

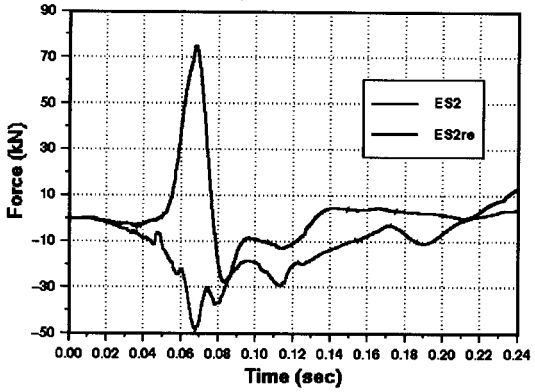
Rear Dummy Lower Neck FZ



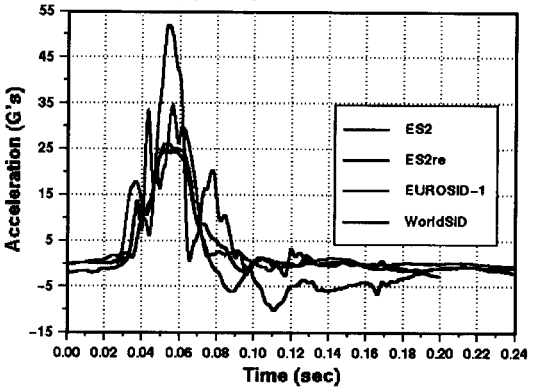
Rear Dummy Lower Neck MZ



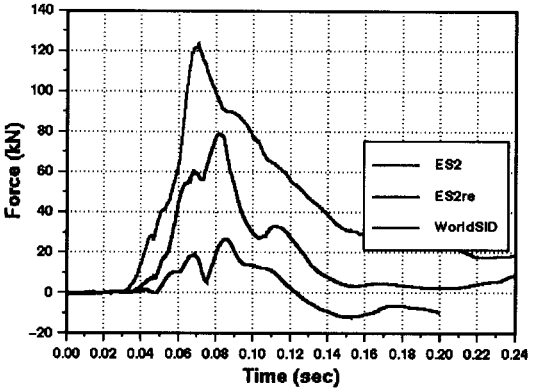
Rear Dummy Lower Neck MX



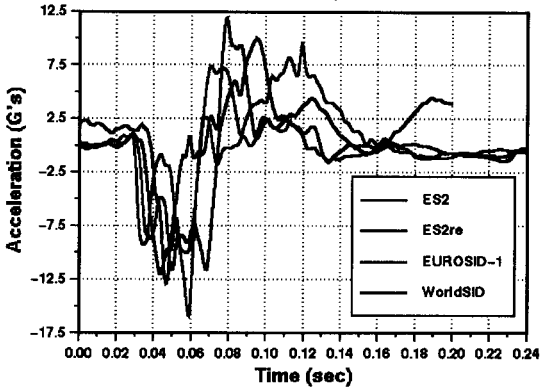
Rear Dummy Upper Spine Lateral Acceleration



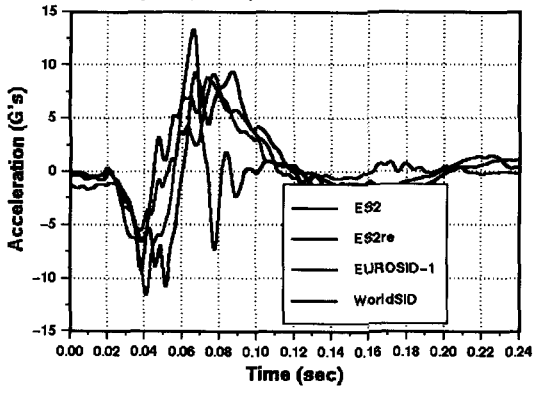
Rear Dummy Lower Neck MY



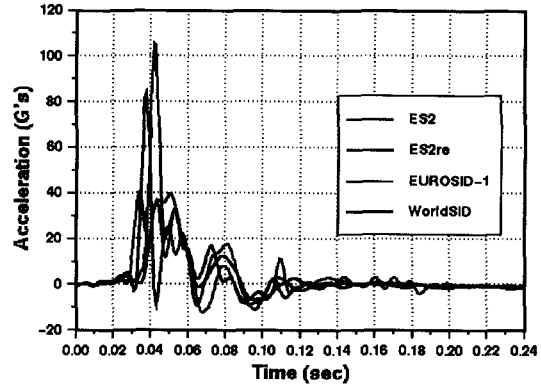
Rear Dummy Upper Spine Longitudinal Acceleratio



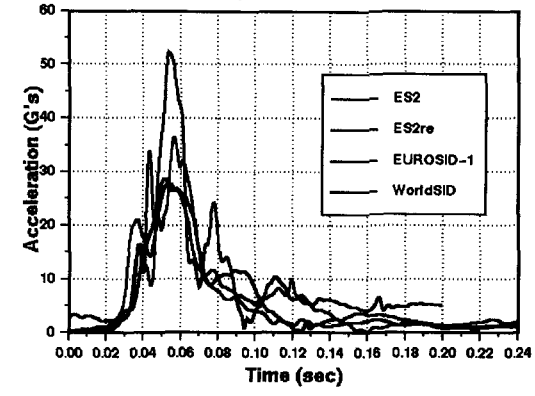
Rear Dummy Upper Spine Vertical Acceleration



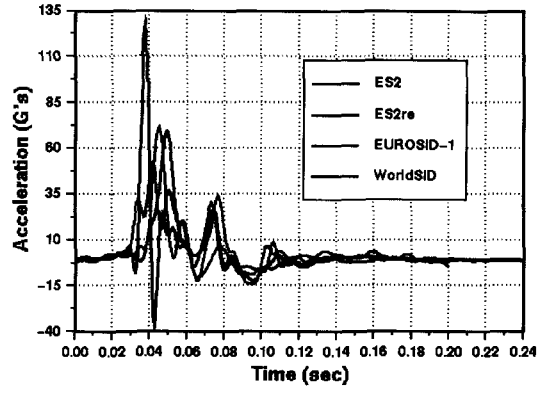
Rear Dummy Center Rib Acceleration



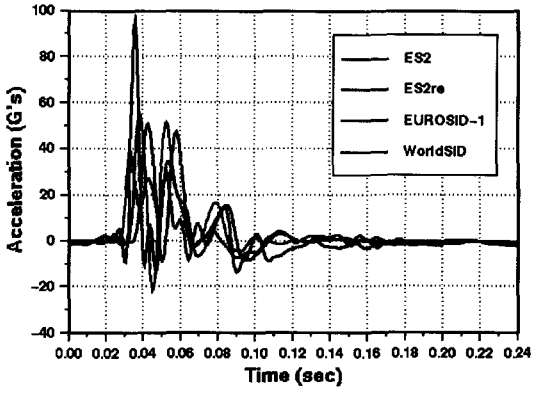
Rear Dummy Upper Spine Resultant Acceleration



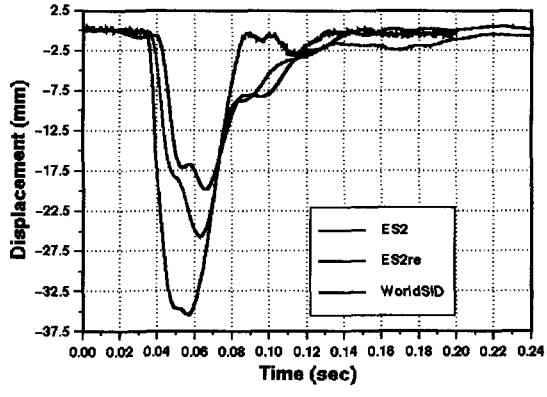
Rear Dummy Lower Rib Acceleration



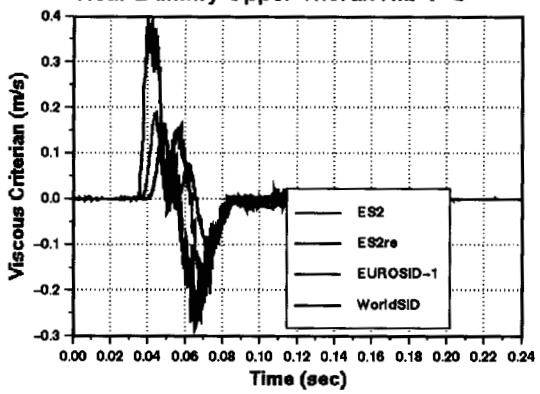
Rear Dummy Upper Rib Acceleration



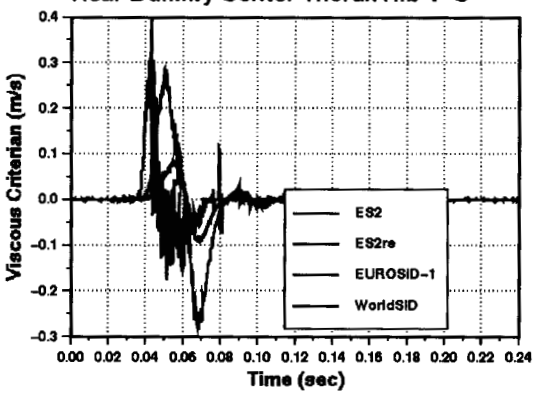
Rear Dummy Upper Thorax Rib Displacement



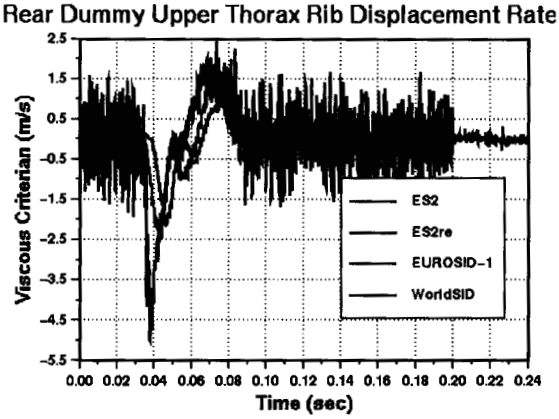
Rear Dummy Upper Thorax Rib V*C



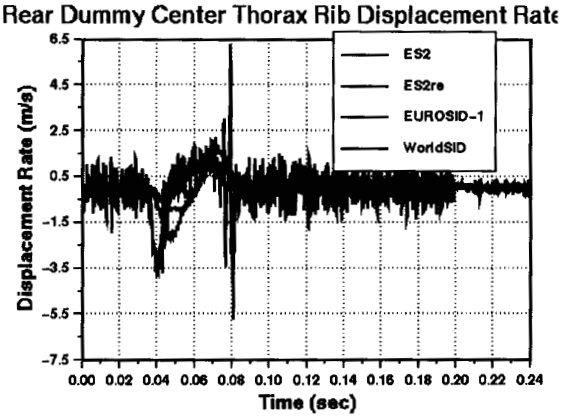
Rear Dummy Center Thorax Rib V*C



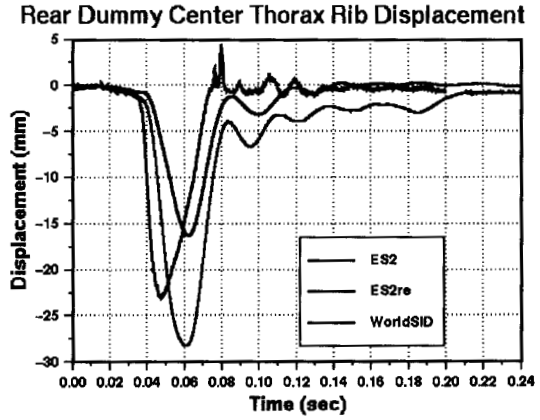
Rear Dummy Upper Thorax Rib Displacement Rate



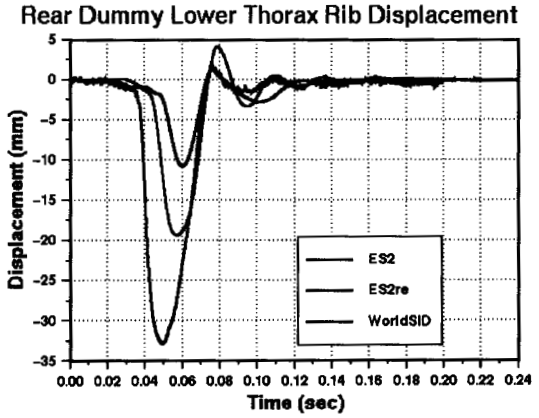
Rear Dummy Center Thorax Rib Displacement Rate



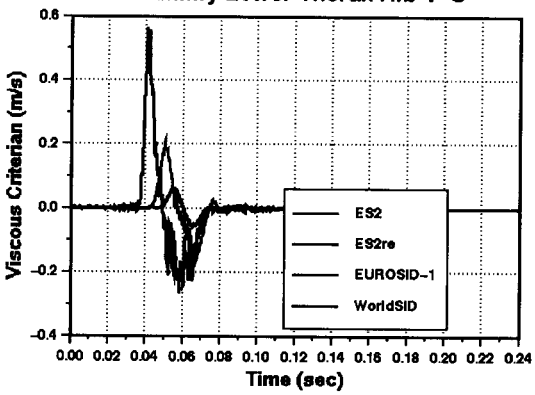
Rear Dummy Center Thorax Rib Displacement



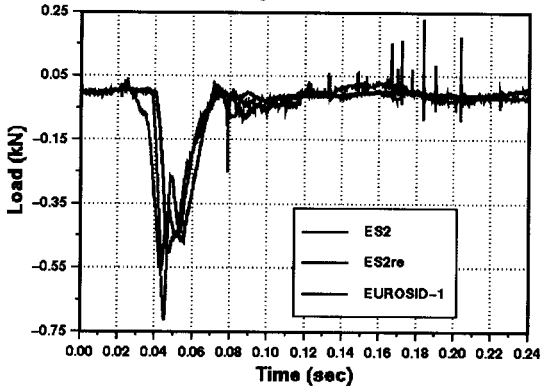
Rear Dummy Lower Thorax Rib Displacement



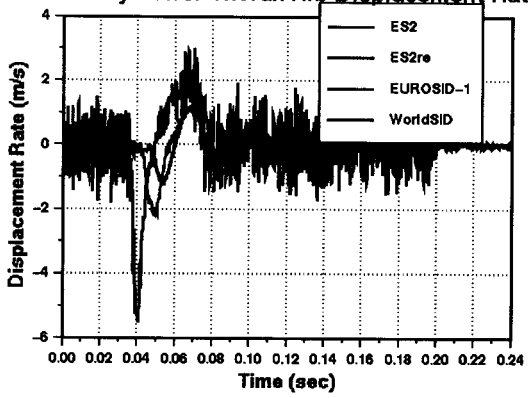
Rear Dummy Lower Thorax Rib V*C



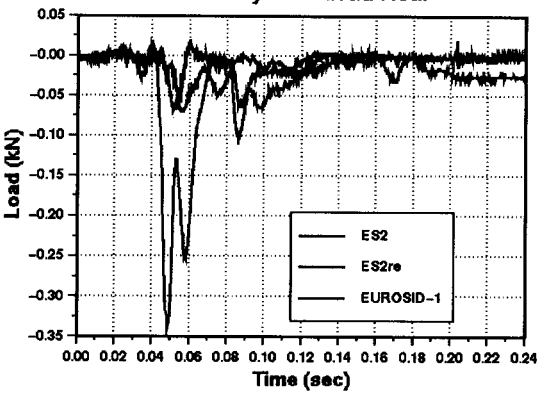
Rear Dummy Abd Load Mid



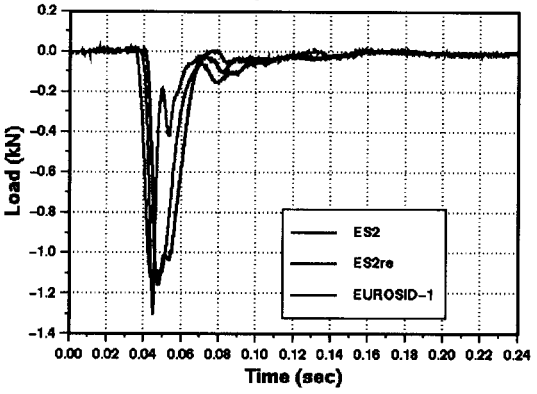
Rear Dummy Lower Thorax Rib Displacement Rate



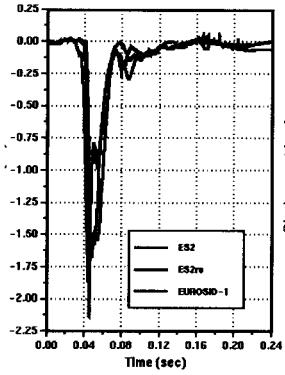
Rear Dummy Abd Load Rear



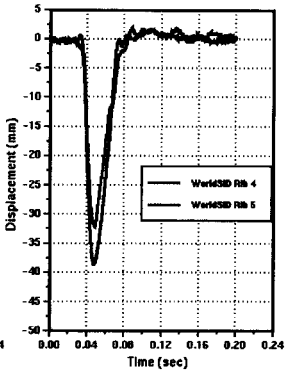
Rear Dummy Abd Load Frt



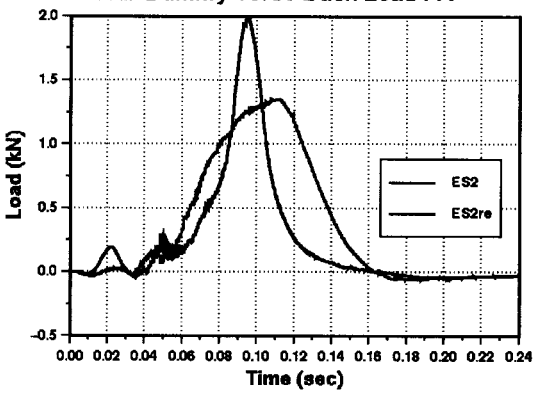
Rear Dummy Abd Load Sum



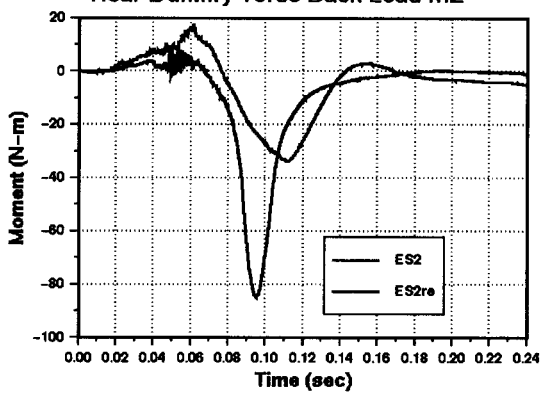
Rear Dummy Abd Rib Displacement



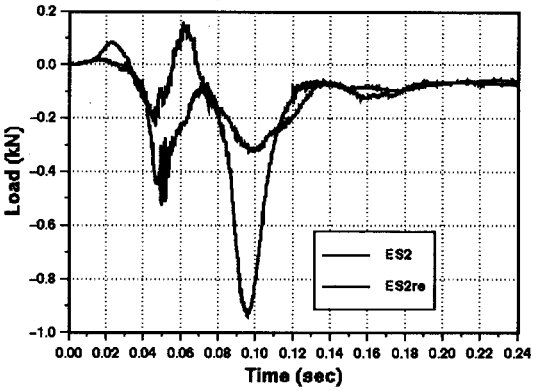
Rear Dummy Torso Back Load FX



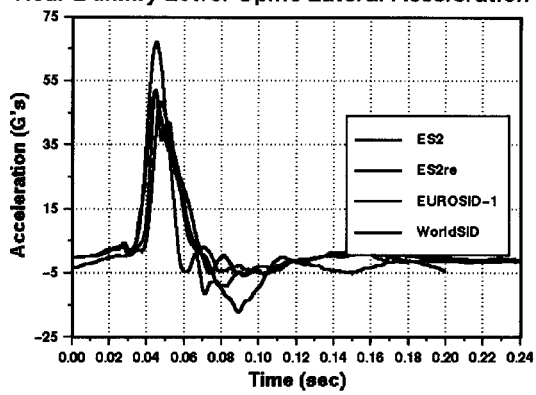
Rear Dummy Torso Back Load MZ



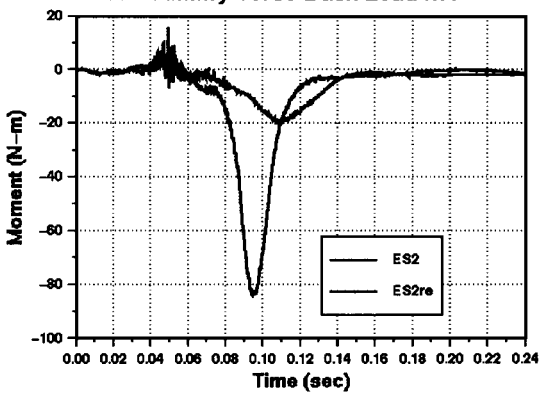
Rear Dummy Torso Back Load FY



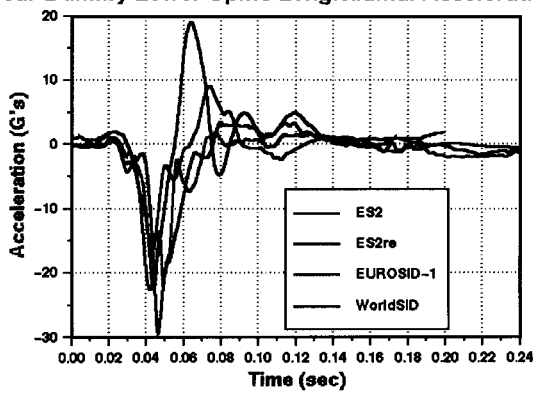
Rear Dummy Lower Spine Lateral Acceleration



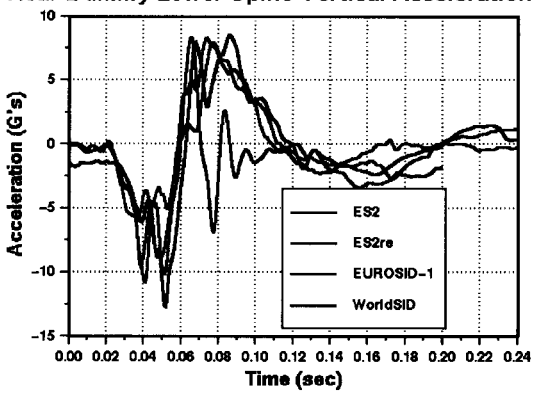
Rear Dummy Torso Back Load MY



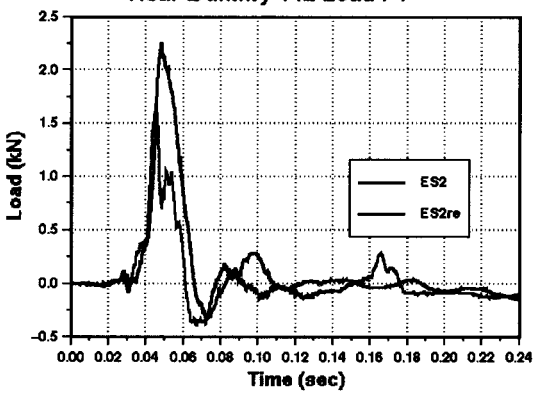
Rear Dummy Lower Spine Longitudinal Acceleratio



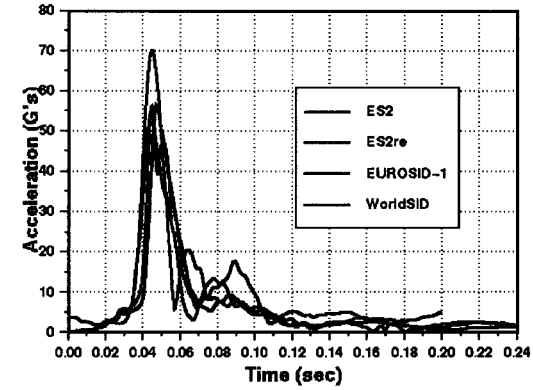
Rear Dummy Lower Spine Vertical Acceleration



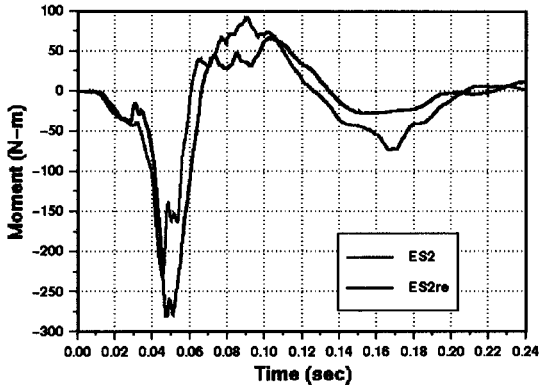
Rear Dummy T12 Load FY



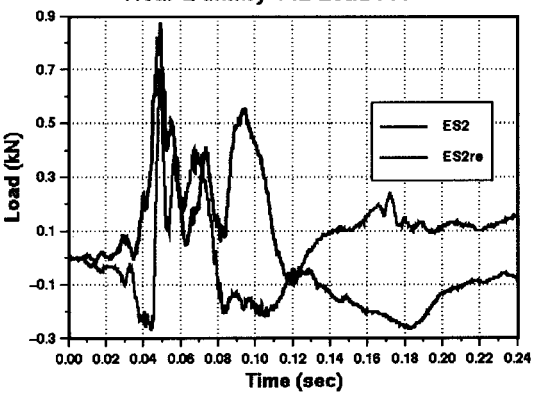
Rear Dummy Lower Spine Resultant Acceleration



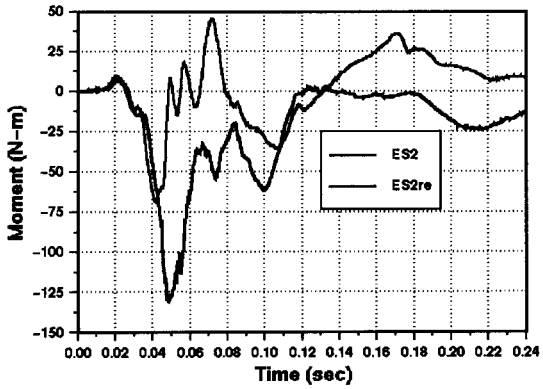
Rear Dummy T12 Load MX

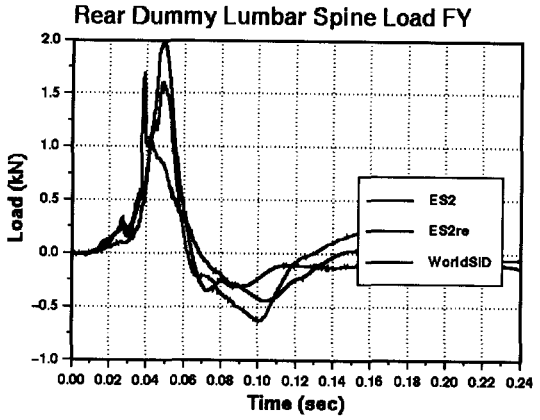


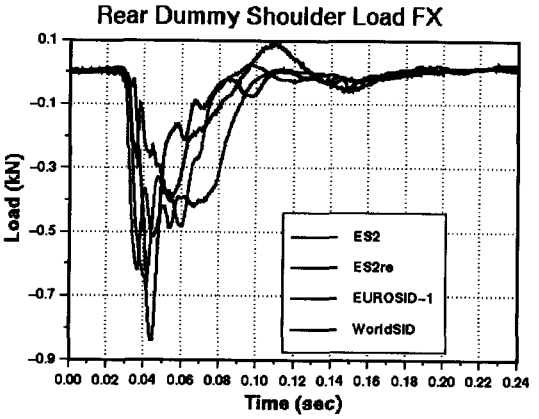
Rear Dummy T12 Load FX

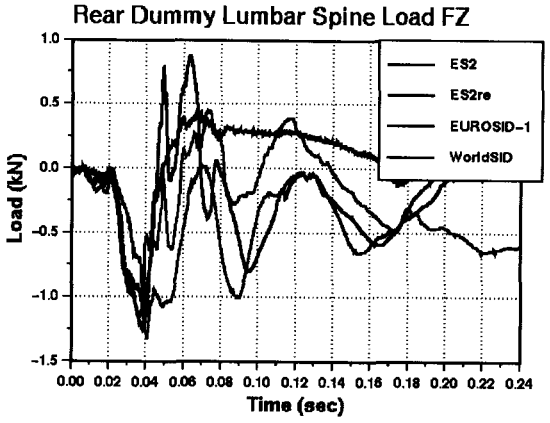


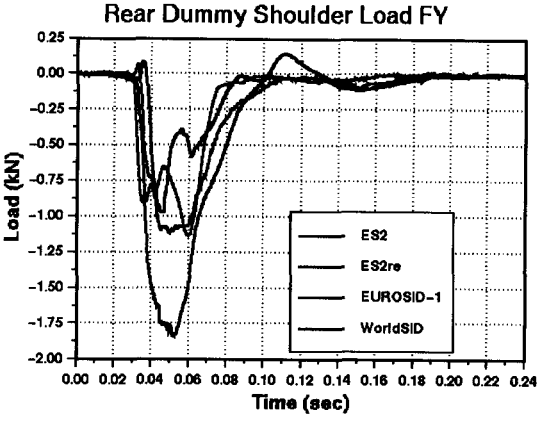
Rear Dummy T12 Load MY

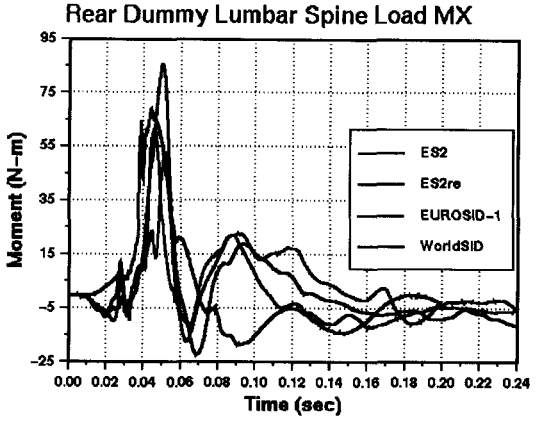


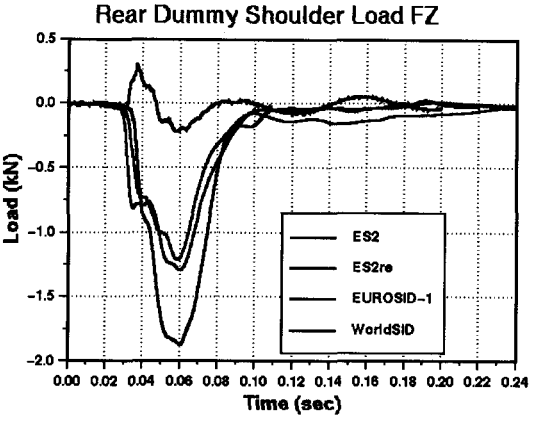

Rear Dummy Lumbar Spine Load FY
Load (kN)
Time (sec)
ES2
ES2re
WorldSID

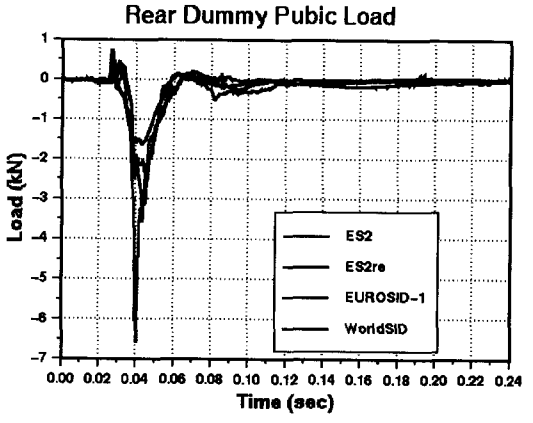

Rear Dummy Shoulder Load FX
Load (kN)
Time (sec)
ES2
ES2re
EUROSID-1
WorldSID

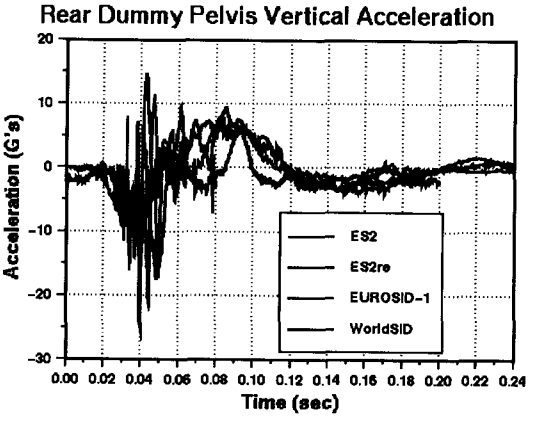

Rear Dummy Lumbar Spine Load FZ
Load (kN)
Time (sec)
ES2
ES2re
EUROSID-1
WorldSID

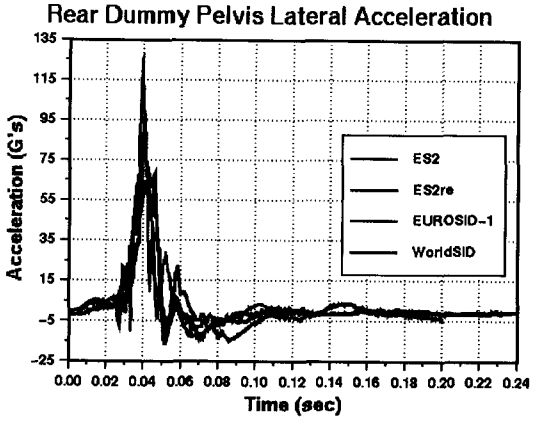

Rear Dummy Shoulder Load FY
Load (kN)
Time (sec)
ES2
ES2re
EUROSID-1
WorldSID

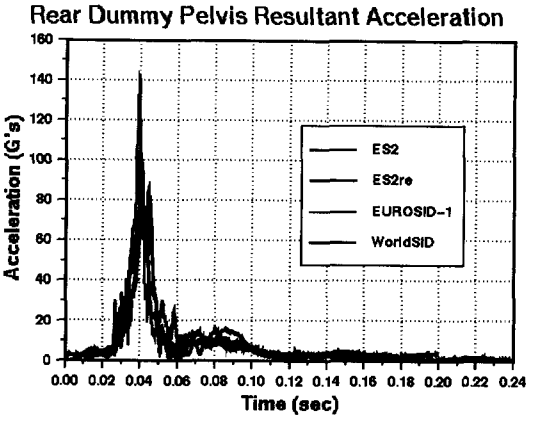

Rear Dummy Lumbar Spine Load MX
Moment (N-m)
Time (sec)
ES2
ES2re
EUROSID-1
WorldSID

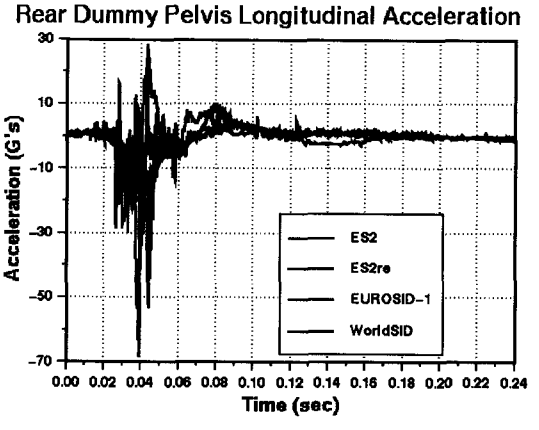

Rear Dummy Shoulder Load FZ
Load (kN)
Time (sec)
ES2
ES2re
EUROSID-1
WorldSID

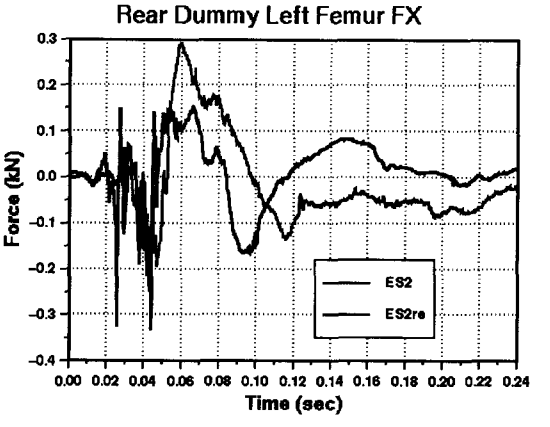

Rear Dummy Pubic Load
Load (kN)
Time (sec)
ES2
ES2re
EUROSID-1
WorldSID

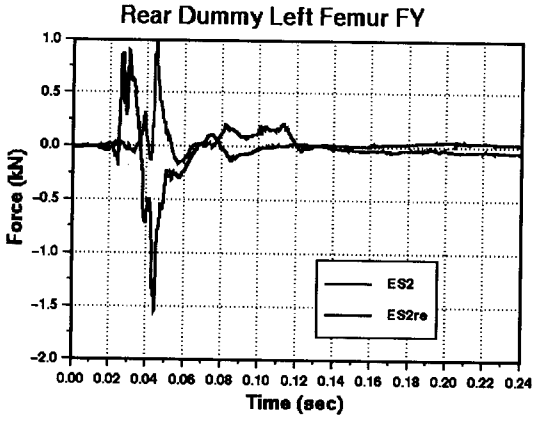

Rear Dummy Pelvis Vertical Acceleration
Acceleration (G's)
Time (sec)
ES2
ES2re
EUROSID-1
WorldSID

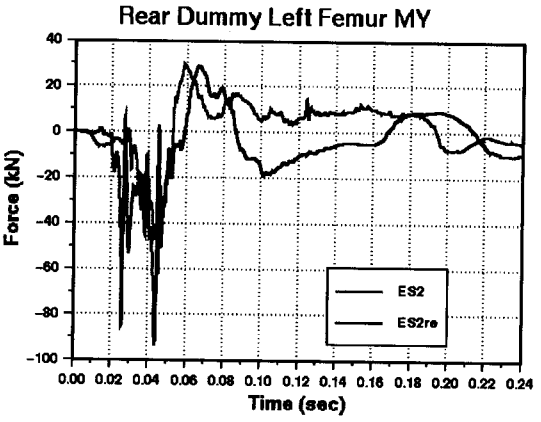

Rear Dummy Pelvis Lateral Acceleration
Acceleration (G's)
Time (sec)
ES2
ES2re
EUROSID-1
WorldSID

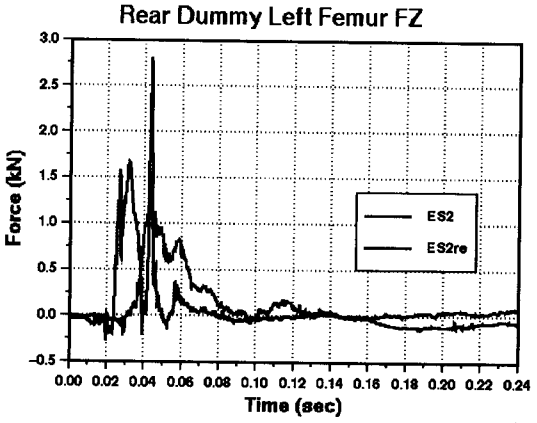

Rear Dummy Pelvis Resultant Acceleration
Acceleration (G's)
Time (sec)
ES2
ES2re
EUROSID-1
WorldSID

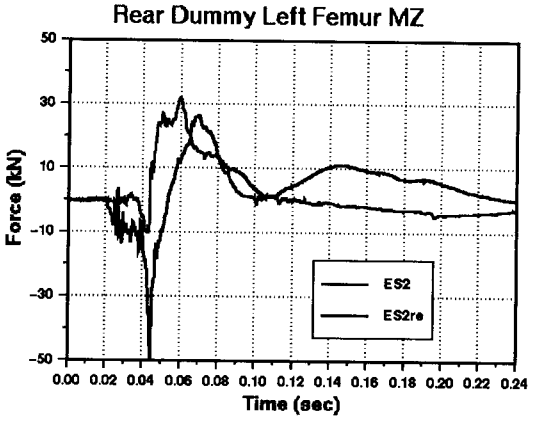

Rear Dummy Pelvis Longitudinal Acceleration
Acceleration (G's)
Time (sec)
ES2
ES2re
EUROSID-1
WorldSID

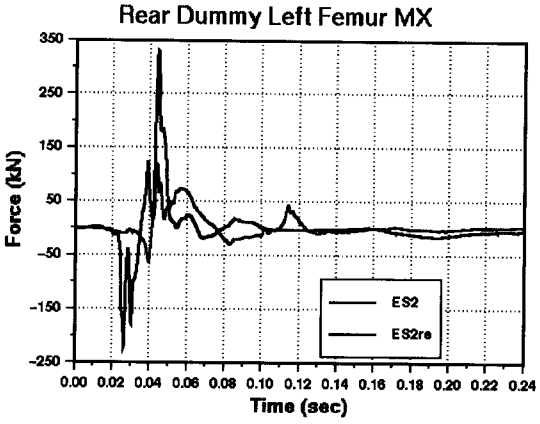

Rear Dummy Left Femur FX
Force (kN)
Time (sec)
ES2
ES2re


Rear Dummy Left Femur FY
Force (kN)
Time (sec)
ES2
ES2re


Rear Dummy Left Femur MY
Force (kN)
Time (sec)
ES2
ES2re


Rear Dummy Left Femur FZ
Force (kN)
Time (sec)
ES2
ES2re


Rear Dummy Left Femur MZ
Force (kN)
Time (sec)
ES2
ES2re


Rear Dummy Left Femur MX
Force (kN)
Time (sec)
ES2
ES2re