292437

Memorandum

US Department
Of Transportation

National Highway
Traffic Safety
Administration

Vehicle Research and Test Center P.O. Box B37
East Liberty, Ohio 43319
(937) 666-4511

Subject: Docket Submission of Technical Report "Repeatability And Reproducibility Analysis of the SID-IIs FRG Dummy In the Sled Test Environment

Date: JUL 23 2004

From: Joseph N. Kanianthra, Ph.D.
Associate Administrator for Vehicle Safety Research

Reply to Attn. Of: NVS-300

To: Docket # NHTSA-2004-17694 - 16

Thru: Jacqueline Glassman
for Office of Chief Counsel

Attached is a technical report titled, "Repeatability and Reproducibility Analysis of the SID-IIs FRG Dummy in the Sled Test Environment," that we are submitting to Docket number NHTSA-2004-17694. This report documents the repeatability and reproducibility analysis of the SID-IIs FRG dummy in the sled environment and is being submitted as supporting information for the FMVSS 214 NPRM.

Attachment

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PDF version will also be docketed.

Repeatability and Reproducibility Analysis of the SID-IIs FRG Dummy in the Sled Test Environment

March 2004

Heather Rhule
VRTC
Alena Hagedorn
TRC, Inc.

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Introduction

As part of the SID-IIs FRG dummy evaluation of the National Highway Traffic Safety Administration (NHTSA), repeatability and reproducibility (R&R) of the SID-IIs FRG dummy were analyzed. In December 2003, two SID-IIs dummies of the FRG design configuration (described in detail in "Development of the SID-IIs FRG," Rhule et al, November 2003) were tested on the Hyge sled at TRC.

Methods

Two test conditions were selected for R&R assessment of the SID-IIs FRG: a 6.7 m/s Rigid Flat Wall test and a 6.7 m/s Rigid Abdomen Offset test. After five 6.7 m/s flat wall tests were performed, it was discovered that the shoulder rib sometimes contacted its rib stop, as its peak deflection was just reaching maximum stroke. The flat wall and abdomen offset test speeds were reduced to 6.0 m/s in order to achieve a reasonable amount of rib deflection, without reaching maximum stroke, to allow analysis of the dummy's repeatability and reproducibility. The test matrix is shown in Table 1.

Table 1. SID-IIs FRG R&R Sled Test Matrix

Wall Configuration	Wall Stiffness	Impact Speed (m/s)	Quantity of Tests
Flat	Rigid	6.7	5
Flat	Rigid	6.0	5
Abdomen Offset	Rigid	6.0	6

Test Setup

Two SID-IIs FRG dummies, serial numbers 032 and 056, were seated in either the left or right buck position on the Dual Occupant Side Impact sled buck (Figure 1). For the flat wall tests, the dummies were switched between the left and right buck positions partway through each series of five tests. For the offset tests, the dummy positions did not change; dummy 032 was seated in the right buck position and dummy 056 was seated in the left buck position. For the flat wall tests, the dummies' impact-side arm was positioned down such that the arm would make first contact with the wall. During the abdomen offset tests, the dummies were positioned with their arms up so that the ribs would make first contact with the offset. Before each test was conducted, the dummies were positioned at a specified distance from the wall such that the dummy-to-wall interaction would occur as the sled reached constant velocity. In order to provide a most repeatable test environment, precautions were taken to reduce any factors of variability due to the test setup. Pre-test setup measurements of the dummy target locations were taken for the first test of each series. For each subsequent test in the series, these dimensions were matched to within 10 mm or better in order to position the dummies consistently from test to test.

The buck was designed such that two dummies could be tested simultaneously, each being subjected to the same sled pulse, thereby reducing the test-to-test variability in this repeatability and reproducibility series. Each dummy was positioned on a Teflon-covered bench seat, with two Teflon-covered rails to support the dummy from behind as shown in Figure 2.

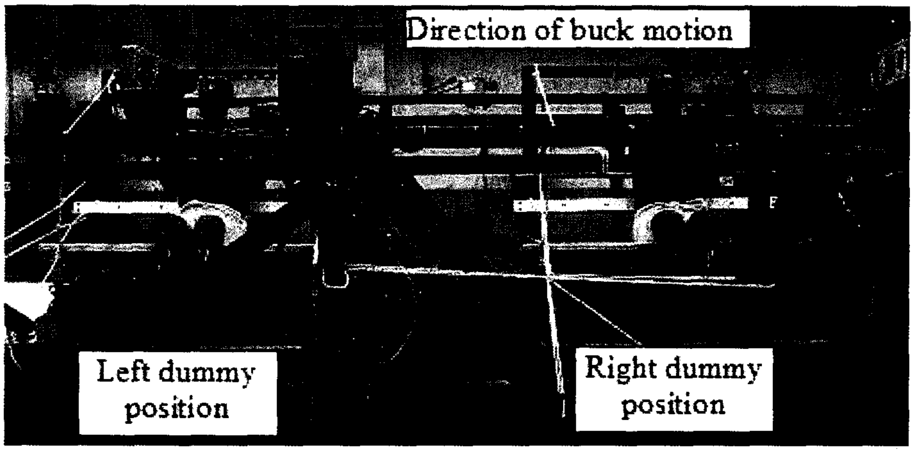

Figure 1. Dual Occupant Side Impact sled buck, showing left and right dummy positions

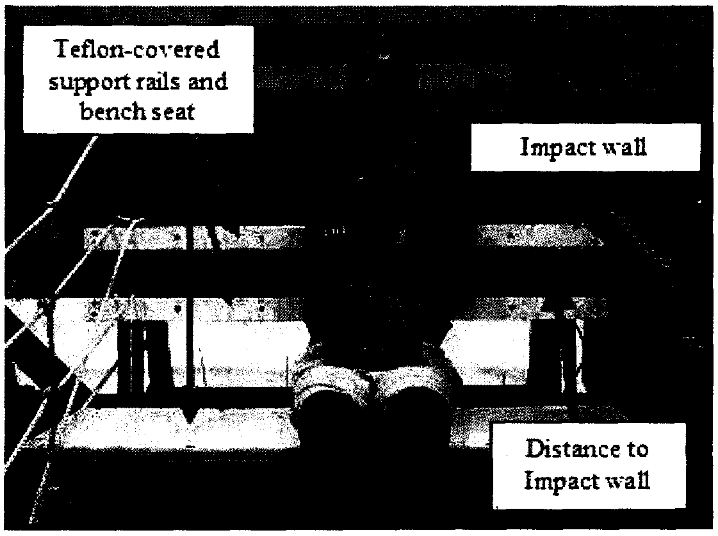

Figure 2. Flat wall test setup

For the flat wall test condition, the wall was 253 mm high from the front edge of the seat, and extended from behind the seat back surface to 26 mm before the front edge of the seat, as shown in Figure 3. For the offset test condition, the same flat wall was used, with a wooden offset block attached such that the dummy's lower thoracic rib and both abdominal ribs would impact it. The block was designed to provide a test environment with severe loading of the abdominal region. The location of the offset block on the impact wall is shown in Figure 3 and a drawing of the offset is shown in Figure 4. Figure 5 shows a photo of the pre-test setup for the offset tests.

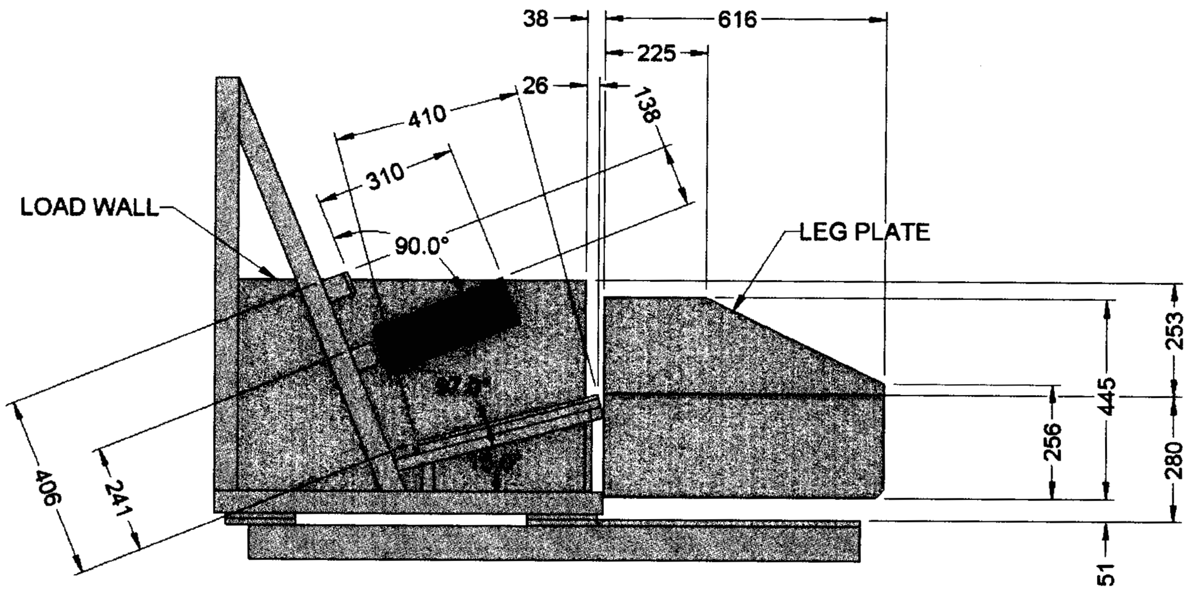

Figure 3. Side view of Dual Occupant Side Impact sled buck shown with offset block

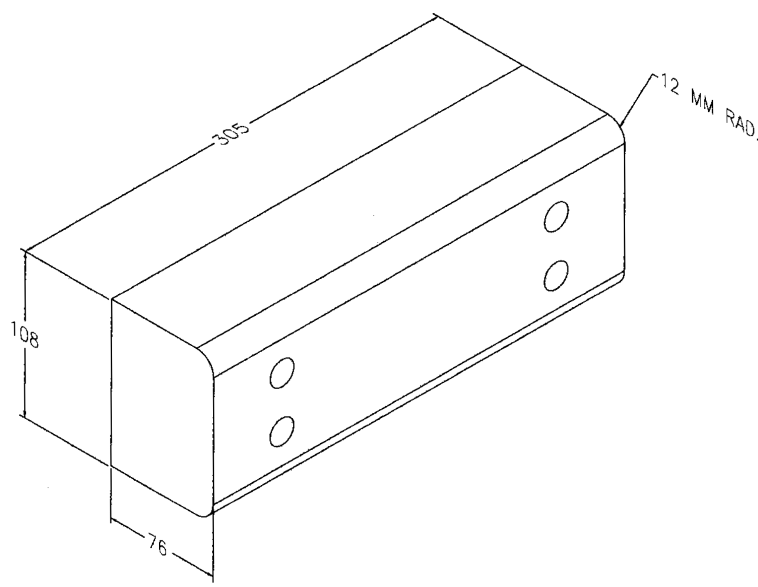

Figure 4. Offset block dimensions

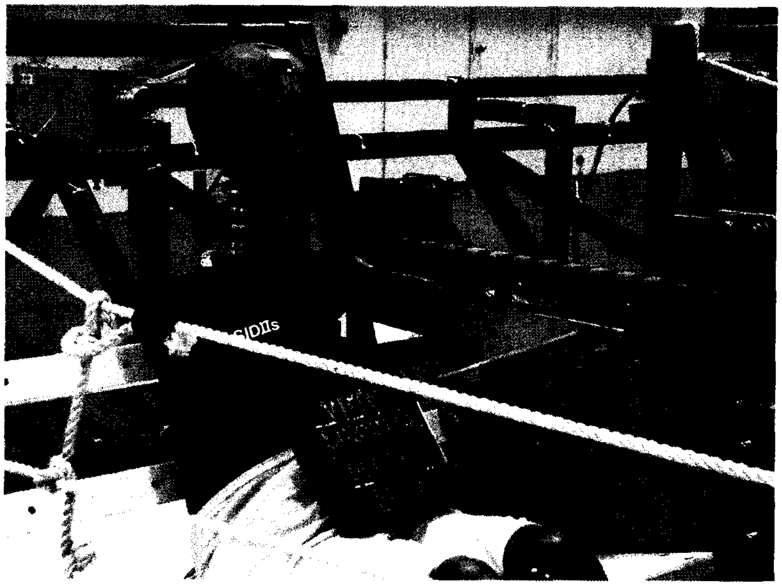

Figure 5. Abdomen Offset test setup

Sled Pulse

The sled pulse for each test condition was a half sine wave, with the peak accelerations and durations shown in Table 2. Figures A.1, B.1 and C.1 in Appendices A, B and C, respectively, show overlays of the repeated sled acceleration data traces for each test condition. Figures A.2, B.2 and C.2 in Appendices A, B and C, respectively, show overlays of the repeated sled velocity data traces for each test condition.

Table 2. Sled Pulse Specifications

	Target Impact Speed (m/s)	Peak Acceleration (g)	Peak Duration (ms)
Flat Rigid Wall	6.7	13.41	80
Flat Rigid Wall	6.0	12	80
Rigid Abdomen Offset	6.0	12	80

Data Collection

Instrumentation used in the two dummies during sled tests is shown in Table 3. The dummies were instrumented with sensors to record the proposed measures for injury criteria[1]: HIC 36, peak resultant lower spine (T12) acceleration, peak thorax and abdomen rib deflections, and the sum of acetabulum and iliac wing forces. Data was collected at 12,500 Hz and filtered according to SAE J211, where appropriate, except for proposed injury criteria measures that required a different filter class. Filter classes used are shown in Tables 4, 5 and 6 in the Results and Discussion section. A contact switch was positioned on each dummy to indicate when contact of the dummy to the wall occurred.

[1] Kuppa, S., "Injury Criteria for Side Impact Dummies", May 2004.

Table 3. Instrumentation for SID-IIs FRG R&R Sled Series

	Location	Measurement	Direction	# channels Dummy SN 032	# channels Dummy SN 056	Total # channels per test
Dummy	Head	Acceleration	X, Y, Z	9	9	74
	Upper Neck	Force	X, Y, Z	3	3	
		Moment	X, Y, Z	3	3	
	Shoulder	Acceleration	X, Y, Z	3	3	
	T1	Acceleration	X, Y, Z	3	3	
	T12	Acceleration	X, Y, Z	3	3	
	Ribs	Displacement	Y	6	6	
	Lumbar	Force	Y	1	1	
		Moment	X	1	1	
	Acetabulum	Force	Y	1	1	
	Iliac Wing	Force	Y	1	1	
	Pelvis	Acceleration	X, Y, Z	3	3	
Sled	Sled	Acceleration	X	1		4
	Sled	Velocity	X	1		
	Load Wall	Event	N/A	1	1	
TOTAL						**78**

Head Motion

High-speed digital video cameras were positioned in front of each dummy in order to capture head translation. In order to evaluate whether the head maximum translation was repeatable and reproducible, the lateral and vertical positions of the dummy's head at maximum lateral translation were recorded for each test. All head translations were calculated relative to the initial position noted in Figure 6.

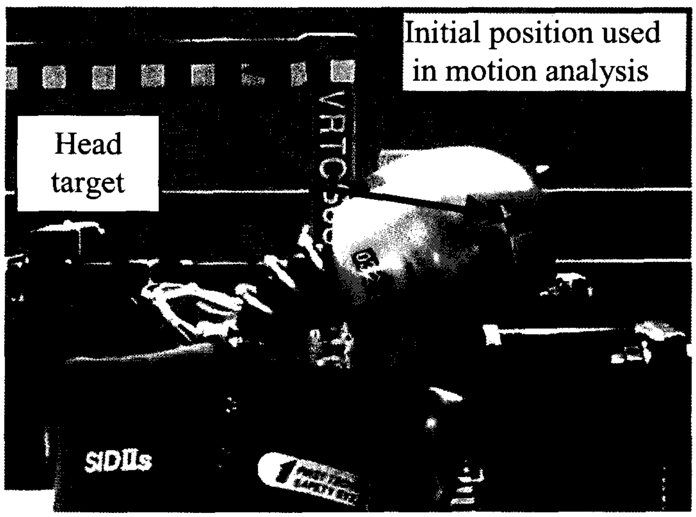

Figure 6. Typical high-speed digital video frame showing dummy head at maximum lateral translation, with head target and initial position used in motion analysis labeled.

Results and Discussion

6.7 m/s Flat Wall Tests

The shoulder displacement and upper spine (T1) acceleration measurements were not included in the R&R analysis for the 6.7 m/s Rigid Flat Wall tests since the shoulder rib potentiometer almost always reached maximum stroke, affecting the upper spine accelerations. Figure 7 shows a typical occurrence during the 6.7 m/s Flat Wall tests. The crosshair in Figure 7 denotes when the rate of change of the shoulder lateral acceleration begins to increase significantly, indicating that the shoulder rib has contacted its rib stops. At this same time, the upper spine lateral acceleration increases. Additionally, the R&R of the shoulder deflections cannot fairly be analyzed since the potentiometer reached maximum stroke during the tests. Due to the effect of the shoulder rib contacting its rib stops, the shoulder deflection and upper spine accelerations were not used in the R&R analysis for the 6.7 m/s Flat Wall tests. However, given that five repeat tests were performed with two dummies, the data from the remaining channels could still be used to analyze the R&R of the dummy. It should be noted that although the shoulder potentiometer reached maximum stroke, the dummy remained intact and did not sustain any damage. The improved rib stops proved to be successful at preventing damage to the instrumentation and dummy.

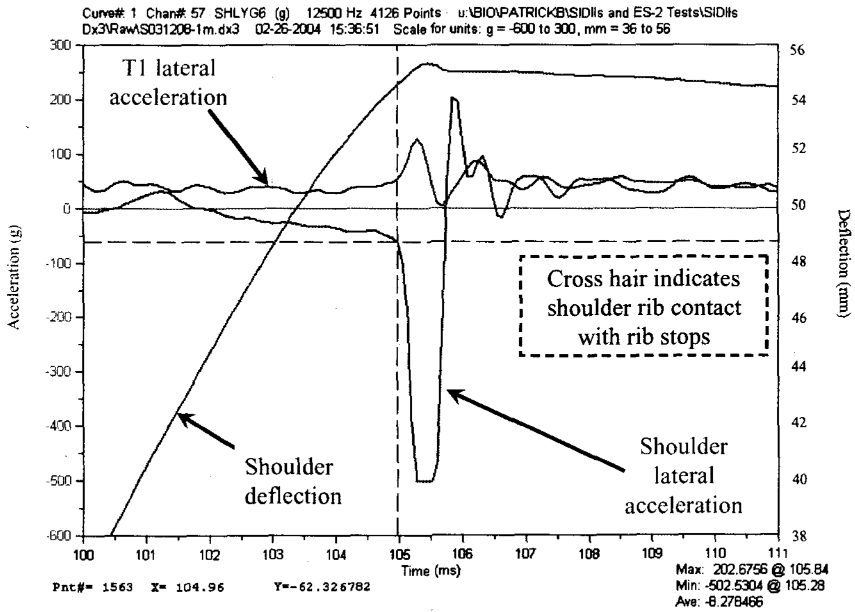

Figure 7. Shoulder deflection (green), upper spine (T1) lateral acceleration (red), and shoulder lateral acceleration (blue) for dummy 056 during Test 8-1 of the 6.7 m/s Rigid Flat Wall sled test series, showing effect on acceleration as shoulder rib potentiometer reaches maximum stroke.

Table 4 shows the average, standard deviation and percent coefficient of variation (%CV) for each pertinent peak dummy response individually, and both dummy responses together, from the 6.7 m/s Rigid Flat Wall sled tests. The dummy rating practice of the ISO/TC22/SC12/WG5 indicates that a CV between 0 and 5% is considered excellent; between 5% and 10% is good, with the CV becoming borderline acceptable as it approaches 10%. Any CV above 10% is considered poor. The CV's are color-coded in the table for easy identification: green indicates a CV between 0 and 5%; yellow indicates a CV between 5.1 and 10%; and pink indicates a CV above 10%. Tables A.1 and A.2 in Appendix A show the peak values and statistical analyses, respectively, for pertinent responses during the 6.7 m/s Rigid Flat Wall tests. Figures A.1 through A.23 in Appendix A show overlay plots of the repeat data traces for each dummy.

Although the pelvis lateral acceleration responses appear to have acceptable R&R, it should be noted that the maximum values in Table 4 were taken from the second set of peaks in the data traces. Figures 8 and 9 show the double peak that occurs in the lateral pelvis acceleration data traces for dummy 032 and dummy 056, respectively. As shown in Figures 8 and 9, the second pelvis lateral acceleration peak is much more consistent than the first. If the highest peak is used, an inconsistent set of data is being used to calculate the statistics since the maximum acceleration for each test does not always occur at the same time. Since the second peak lateral pelvis acceleration is consistent and the first peak response is inconsistent, the first peak response is undesirable. Further investigation is required to determine what is responsible for the initial peak and subsequent valley in the lateral pelvis acceleration response.

Table 4 shows that dummies 032 and 056 demonstrate excellent or good repeatability in all measurements, except for the lumbar force and moment measurements for dummy 056 where the CV's are 10.3% and 16.1%, respectively. Figures 10 and 11 show overlay plots of the lumbar force and moment data traces, respectively, for dummy 056 during the 6.7 m/s Rigid Flat Wall tests. The curves for the lumbar force and moment for the last two tests have a different shape than those for the previous three tests. The lumbar force curves have single-peak shapes for the last two tests, whereas the first three tests have a double-peak shape. The peaks of the single-peak test data are larger than the others, causing the standard deviation for lumbar force to be large, thereby increasing the CV. Although the CV's for lumbar force and moment are relatively large, these responses are primarily used for research and do not appear to negatively affect the responses of adjacent body segments. However, it is suspected that the cause of the inconsistent first peak and subsequent valley observed in the lateral pelvis acceleration response may also be affecting the measurements in the lumbar region.

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Table 4. Statistical Analysis for 6.7 m/s Rigid Flat Wall Sled Tests

				Test Condition	6.7 m/s Flat Rigid Wall								
				Dummy Serial Number	32			56			032 & 056		
				Dummy Position	left & right			left & right			left & right		
Location	**Measurement**	**Direction**	**Units**	**Filter Class / Statistical Parameters**	AVG	SD	%CV	AVG	SD	%CV	AVG	SD	% CV
Head	Max Displacement	lateral	mm	n/a	270.8	4.9	1.8	281.4	4.2	1.5	276.1	7.0	2.6
Head	Max Displacement	vertical	mm	n/a	120.0	9.4	7.9	117.0	7.7	6.6	118.5	8.3	7.0
Head	Time of Max Displacement	n/a	ms	n/a	134.8	1.3	1.0	133.6	1.8	1.4	134.2	1.6	1.2
Head	Acceleration	Y	g	CFC 1000	16.8	0.6	3.7	15.1	0.5	3.4	16.0	1.0	6.5
Head	Acceleration	Z	g	CFC 1000	38.8	2.5	6.5	39.3	3.9	9.9	39.1	3.1	8.0
Head	Acceleration	Resultant	g	CFC 1000	40.4	2.8	6.9	41.1	4.1	9.9	40.7	3.3	8.2
Head	**HIC 36**	**n/a**	**n/a**	**CFC 1000**	**123.7**	**7.7**	**6.2**	**132.7**	**5.6**	**4.2**	**128.2**	**7.9**	**6.2**
Upper Neck	Force	Y	N	CFC 1000	574.1	16.1	2.8	556.3	15.5	2.8	565.2	17.6	3.1
Upper Neck	Force	Z	N	CFC 1000	1284.7	77.0	6.0	1372.2	127.6	9.3	1328.5	109.5	8.2
Upper Neck	Moment	+X	N-m	CFC 600	34.4	1.2	3.4	31.9	0.5	1.5	33.2	1.5	4.6
Upper Neck	Moment	-X	N-m	CFC 600	-25.0	0.4	-1.8	-30.2	0.7	-2.4	-27.6	2.8	[illegible]
Upper Neck	Moment	Z	N-m	CFC 600	13.4	0.8	5.8	13.5	0.5	3.5	13.4	0.6	4.5
T12	**Acceleration**	Y	g	CFC 180	52.8	1.8	3.4	50.8	1.9	3.6	51.8	2.0	3.9
T12	**Acceleration**	**Resultant**	**g**	**CFC 180**	**53.2**	**1.8**	**3.4**	**51.7**	**1.9**	**3.7**	**52.4**	**1.9**	**3.7**
Thorax Rib 1	**Displacement**	**Y**	**mm**	**CFC 180**	**47.5**	**0.5**	**1.0**	**45.7**	**1.2**	**2.6**	**46.6**	**1.3**	**2.8**
Thorax Rib 2	**Displacement**	**Y**	**mm**	**CFC 180**	**51.9**	**1.0**	**2.0**	**49.0**	**1.7**	**3.4**	**50.4**	**2.0**	**4.0**
Thorax Rib 3	**Displacement**	**Y**	**mm**	**CFC 180**	**54.2**	**1.9**	**3.4**	**53.9**	**2.3**	**4.2**	**54.1**	**2.0**	**3.6**
Abdomen Rib 1	**Displacement**	**Y**	**mm**	**CFC 180**	**48.5**	**3.5**	**7.2**	**49.0**	**2.5**	**5.0**	**48.8**	**2.9**	**5.9**
Abdomen Rib 2	**Displacement**	**Y**	**mm**	**CFC 180**	**21.5**	**2.0**	**9.3**	**22.9**	**0.7**	**3.2**	**22.2**	**1.6**	**7.3**
Lumbar	Force	Y	N	CFC 1000	-853.9	37.9	-4.4	-991.7	101.7	[illegible]	-922.8	102.5	[illegible]
Lumbar	Moment	X	N-m	CFC 1000	-59.7	5.3	-9.0	-69.5	11.2	[illegible]	-64.6	9.8	[illegible]
Acetabulum	Force	Y	N	CFC 600	4123.1	209.8	5.1	3941.9	275.4	7.0	4032.5	249.8	6.2
Iliac Wing	Force	Y	N	CFC 600	-313.9	11.8	-3.8	-298.0	26.4	-8.8	-306.0	21.0	-6.9
Sum of Acetabulum and Iliac	**Force**	**Y**	**N**	**CFC 600**	**4085.3**	**240.0**	**5.9**	**4034.8**	**396.5**	**9.8**	**4060.0**	**310.1**	**7.6**
Pelvis*	Acceleration	Y	g	CFC 1000	89.0	2.6	2.9	93.1	7.1	7.6	91.0	5.5	6.0
Pelvis*	Acceleration	Resultant	g	CFC 1000	89.5	2.0	2.2	94.6	7.6	8.0	92.1	5.9	6.4
Sled	Acceleration	X	g	CFC 60	-13.1	0.0	-0.3	-13.1	0.0	-0.3	-13.1	0.0	-0.3
Sled	Velocity	X	m/s	CFC 60	-6.9	0.0	-0.3	-6.9	0.0	-0.3	-6.9	0.0	-0.3

Bold type indicates proposed injury criteria measures

*For Pelvis Y Acceleration, second peak is shown in table.

%CV<=5.0 5.1%<CV<=10.0% CV>10.0%

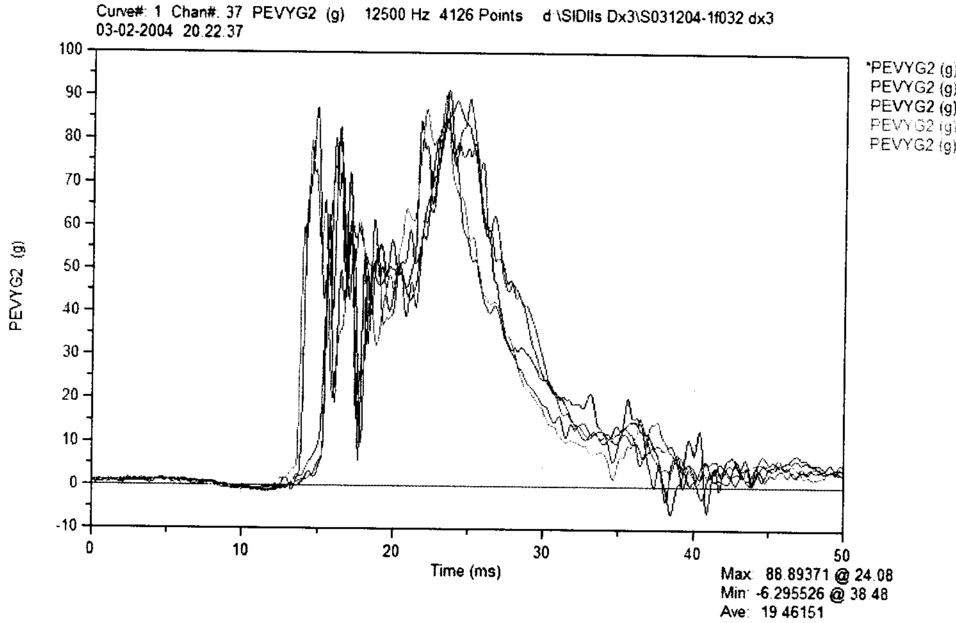

Figure 8. Pelvis lateral acceleration data traces for dummy 032 during 6.7 m/s Rigid Flat Wall sled tests.

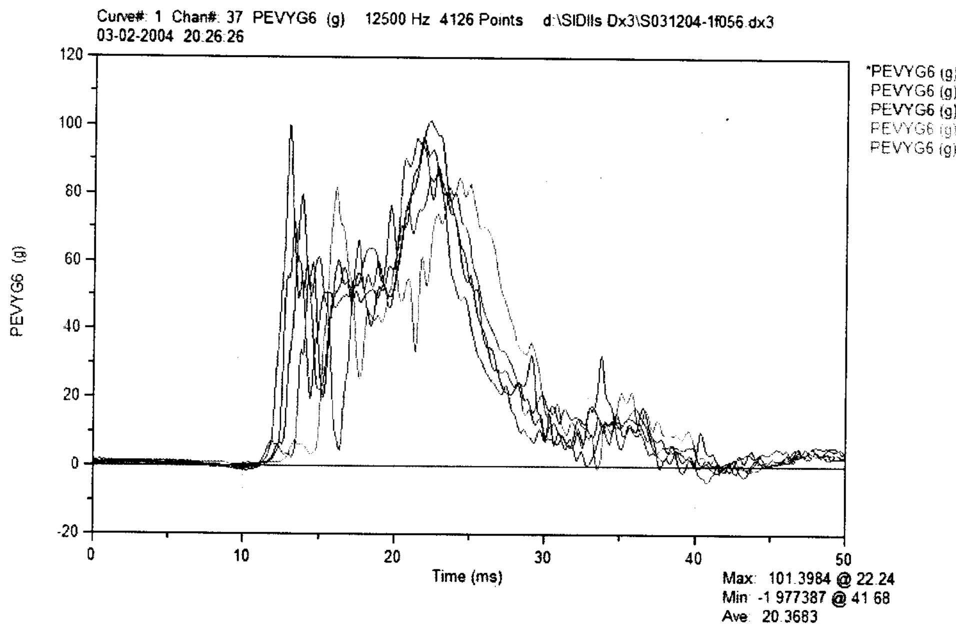

Figure 9. Pelvis lateral acceleration data traces for dummy 056 during 6.7 m/s Rigid Flat Wall sled tests.

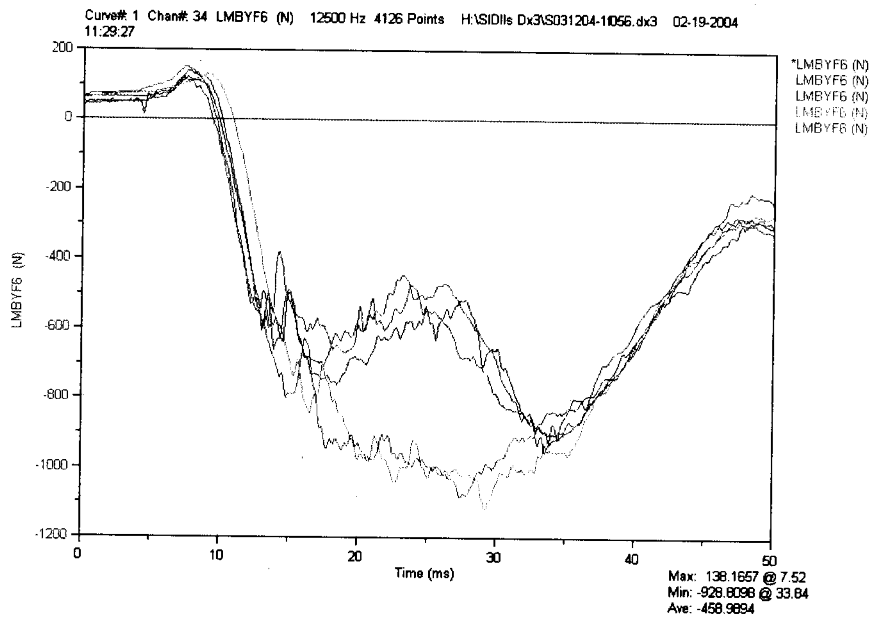

Figure 10. Lumbar lateral shear force data traces for dummy 056 during 6.7 m/s Rigid Flat Wall sled tests.

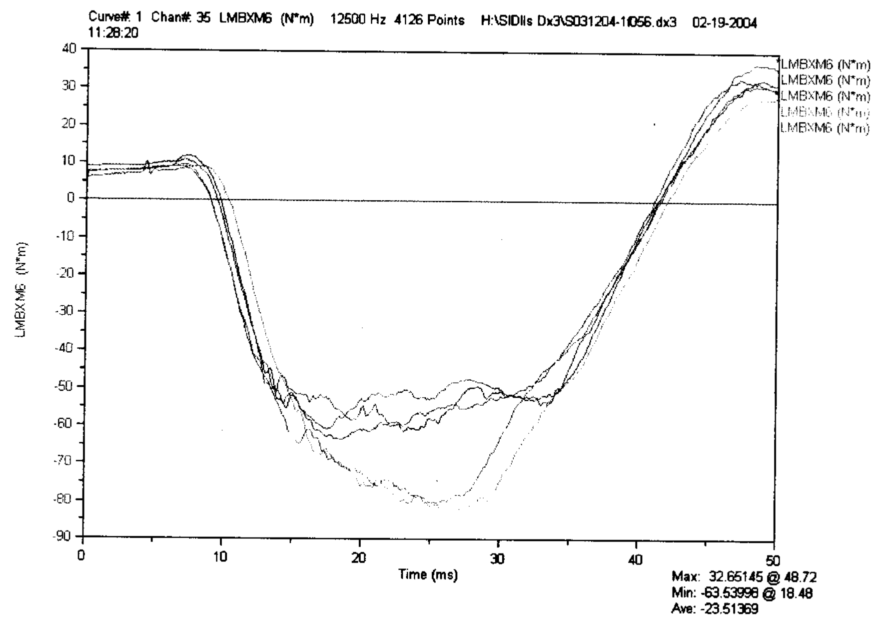

Figure 11. Lumbar lateral bending moment data traces for dummy 056 during 6.7 m/s Rigid Flat Wall sled tests.

When the data for both dummies are combined, Table 4 shows that both dummies demonstrate excellent or good reproducibility for all measurements except the upper neck x moment, lumbar force and lumbar moment. The lack of reproducibility of the lumbar force and moment is due to the response of dummy 056 in the last two tests of the series, discussed above. The high CV of the negative upper neck lateral bending (-x) moment is explained by the difference in averages of the two dummies. The average negative peak upper neck lateral bending (-x) moment for dummy 032 is 25.0 N-m and for dummy 056 is 30.2 N-m. Figure 12 shows an overlay plot of the upper neck lateral bending moment data traces for dummies 032 and 056 during 6.7 m/s Rigid Flat Wall sled tests. Each dummy's repeatability of the negative peak upper neck x moment is excellent, with CV's of 1.8% and 2.4%. Although the neck moment reproducibility appears relatively poor, the head displacement data shows good and excellent R&R and the certification data shows the two necks to perform similarly.

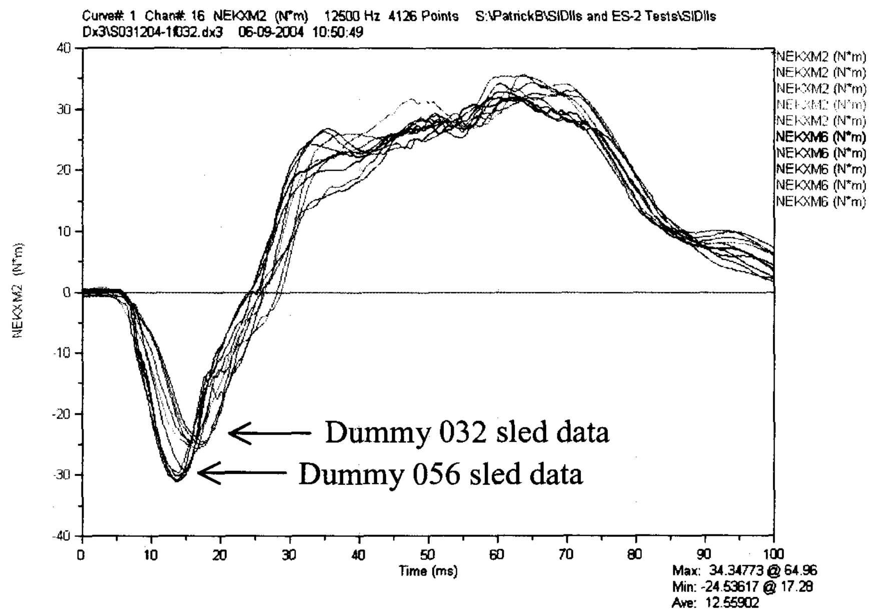

Figure 12. Upper neck lateral bending moment data traces for dummies 032 and 056 during 6.7 m/s Rigid Flat Wall sled tests.

6.0 m/s Flat Wall Tests

Table 5 shows the average, standard deviation and percent CV for each peak dummy response individually, and both dummies' responses together, from the 6.0 m/s Rigid Flat Wall sled tests. Tables B.1 and B.2 in Appendix B show the peak values and statistical analyses, respectively, for pertinent responses during the 6.0 m/s Rigid Flat Wall tests. Figures B.1 through B.24 in Appendix B show overlay plots of the repeat data traces for each dummy. Table 5 shows that dummies 032 and 056 demonstrate excellent or good repeatability in all measurements, except for the vertical head displacement for dummy 032 and the resultant pelvis accelerations for both dummies.

Although the maximum vertical head displacement of dummy 032 yields a CV of 13%, the standard deviation is only 13.8mm, which is quite small. In addition, since lateral translation represents the primary measurement of interest, the 13% CV in the vertical direction is not a problem.

The resultant pelvis acceleration reflects the inconsistency of the first peak of the lateral pelvis acceleration (see Figures B.20.a – B.21.b in Appendix B), resulting in poor repeatability. In addition, dummy 032 experienced a spike in the x direction during Test 10-1, exaggerating the spread in the standard deviation (see Figure 13).

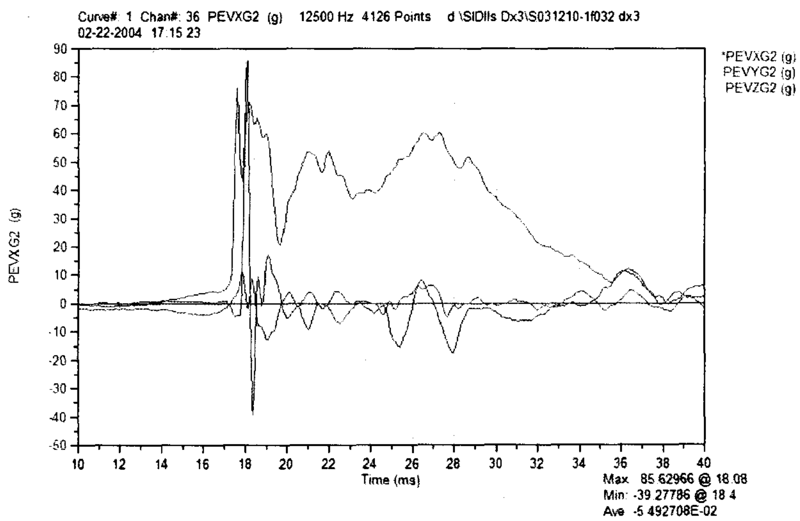

Figure 13. Pelvis x (blue), y (red), and z (green) accelerations for dummy 032 during Test 10-1 of the 6.0 m/s Rigid Flat Wall Sled test series.

Table 5. Analysis of Peak Responses During 6.0 m/s Rigid Flat Wall Sled Tests

				Test Condition	6.0 m/s Flat Rigid Wall								
				Dummy Serial Number	32			56			032 & 056		
				Dummy Position	left & right			left & right			left & right		
Location	**Measurement**	**Direction**	**Units**	**Filter Class / Statistical Parameters**	AVG	SD	%CV	AVG	SD	%CV	AVG	SD	% CV
Head	Max Displacement	lateral	mm	n/a	247.0	7.1	2.9	255.2	3.9	1.5	251.1	6.9	2.7
		vertical	mm	n/a	106.0	13.8	[redacted]	102.4	6.5	6.4	104.2	10.3	9.9
	Time of Max Displacement	n/a	ms	n/a	143.8	4.4	3.1	145.0	2.7	1.9	144.4	3.5	2.4
	Acceleration	Y	g	CFC 1000	14.1	0.4	3.1	13.1	0.2	1.2	13.6	0.6	4.6
		Z	g	CFC 1000	26.0	0.5	2.1	28.9	1.2	4.2	27.4	1.7	6.3
		Resultant	g	CFC 1000	27.5	0.5	1.9	30.0	1.2	4.1	28.8	1.6	5.5
	HIC 36	**n/a**	**n/a**	**CFC 1000**	**69.0**	**1.0**	**1.5**	**74.3**	**3.3**	**4.5**	**71.6**	**3.7**	**5.1**
Upper Neck	Force	Y	N	CFC 1000	469.1	11.6	2.5	461.3	6.9	1.5	465.2	9.9	2.1
		Z	N	CFC 1000	880.8	12.8	1.5	1038.1	28.7	2.8	959.4	85.6	8.9
	Moment	+X	N-m	CFC 600	28.2	0.8	2.9	26.0	0.4	1.5	27.1	1.3	4.9
		-X	N-m	CFC 600	-18.4	1.2	-6.6	-24.2	0.4	-1.6	-21.3	3.2	[redacted]
		Z	N-m	CFC 600	11.6	0.4	3.2	10.9	0.3	2.9	11.2	0.5	4.2
T1	Acceleration	Y	g	CFC 180	37.0	1.1	2.9	41.0	0.8	2.0	39.0	2.3	5.9
		Resultant	g	CFC 180	37.5	0.9	2.3	41.1	0.8	2.0	39.3	2.1	5.2
T12	**Acceleration**	Y	g	CFC 180	39.0	2.0	5.2	38.1	1.9	5.0	38.6	1.9	4.9
		Resultant	**g**	**CFC 180**	**39.0**	**2.0**	**5.2**	**38.4**	**1.9**	**4.9**	**38.7**	**1.9**	**4.9**
Shoulder Rib	Displacement	Y	mm	CFC 600	43.3	0.7	1.6	44.8	0.8	1.7	44.0	1.1	2.4
Thorax Rib 1	**Displacement**	**Y**	**mm**	**CFC 180**	**37.6**	**0.5**	**1.3**	**35.2**	**0.8**	**2.2**	**36.4**	**1.4**	**3.8**
Thorax Rib 2	**Displacement**	**Y**	**mm**	**CFC 180**	**41.6**	**0.6**	**1.6**	**37.8**	**0.8**	**2.1**	**39.7**	**2.1**	**5.4**
Thorax Rib 3	**Displacement**	**Y**	**mm**	**CFC 180**	**43.9**	**1.0**	**2.4**	**40.1**	**1.0**	**2.4**	**42.0**	**2.3**	**5.4**
Abdomen Rib 1	**Displacement**	**Y**	**mm**	**CFC 180**	**37.7**	**1.7**	**4.6**	**36.1**	**1.2**	**3.2**	**36.9**	**1.6**	**4.4**
Abdomen Rib 2	**Displacement**	**Y**	**mm**	**CFC 180**	**15.8**	**1.1**	**6.9**	**14.8**	**0.6**	**4.0**	**15.3**	**1.0**	**6.6**
Lumbar	Force	Y	N	CFC 1000	-840.6	17.3	-2.1	-996.7	60.9	-6.1	-918.7	92.5	[redacted]
	Moment	X	N-m	CFC 1000	-60.1	3.9	-6.4	-65.5	4.5	-6.8	-62.8	4.8	-7.7
Acetabulum	Force	Y	N	CFC 600	3388.7	152.8	4.5	3212.5	230.8	7.2	3300.6	206.6	6.3
Iliac Wing	Force	Y	N	CFC 600	-296.1	14.3	-4.8	-292.7	18.6	-6.3	-294.4	15.7	-5.3
Sum of Acetabulum and Iliac	**Force**	**Y**	**N**	**CFC 600**	**3151.4**	**147.9**	**4.7**	**3027.3**	**226.5**	**7.5**	**3089.4**	**191.8**	**6.2**
Pelvis*	Acceleration	Y	g	CFC 1000	62.0	2.2	3.6	65.8	3.6	5.4	63.9	3.4	5.4
		Resultant	g	CFC 1000	79.1	17.6	[redacted]	72.3	7.9	[redacted]	75.7	13.4	[redacted]
Sled	Acceleration	X	g	CFC 60	-11.7	0.0	-0.3	-11.7	0.0	-0.3	-11.7	0.0	-0.3
Sled	Velocity	X	m/s	CFC 60	-5.8	0.0	-0.2	-5.8	0.0	-0.2	-5.8	0.0	-0.2

Bold type indicates proposed injury criteria measures

*For Pelvis Y Acceleration, second peak is shown in table.

%CV<=5.0 5.1%<CV<=10.0% CV>10.0%

The reproducibility CV's of the upper neck negative x moment, lumbar y force, and resultant pelvis acceleration are larger than ten percent.

The high CV of the negative upper neck lateral bending (-x) moment is explained by the difference in averages of the two dummies. The average negative peak upper neck lateral bending (-x) moment for dummy 032 is 18.4 N-m and for dummy 056 it is 24.2 N-m. Each dummy's repeatability of the negative peak upper neck x moment is acceptable, with CV's of 6.6% and 1.6%. This behavior is similar to the observation of the 6.7 m/s Flat Wall tests, where the average negative upper neck x moment of dummy 032 was 25.0 N-m and for dummy 056 was 30.2 N-m, each demonstrating acceptable repeatability. The upper neck negative x moment of dummy 032 is consistently lower than that of dummy 056. Figure 14 shows an overlay plot of the upper neck lateral bending moment data traces for dummies 032 and 056 during 6.0 m/s Rigid Flat Wall sled tests.

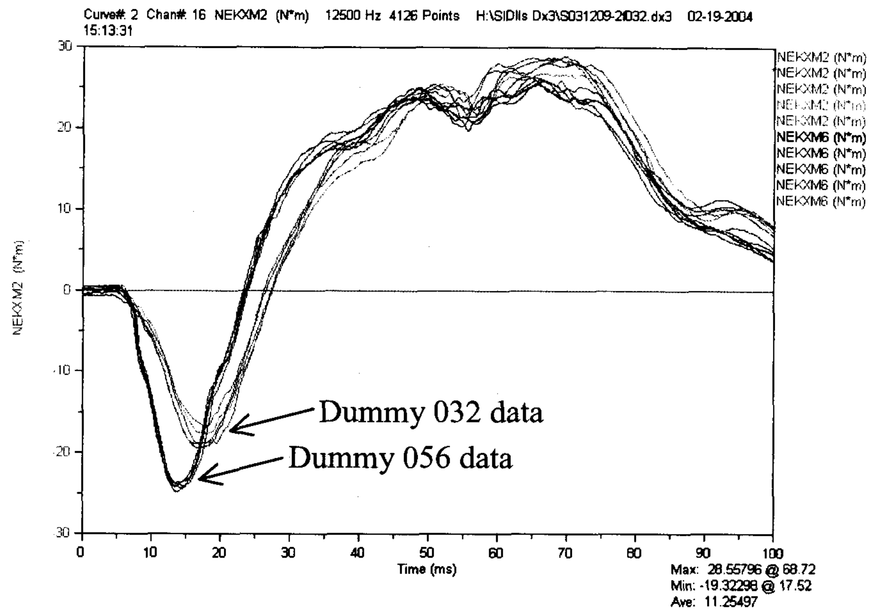

Figure 14. Upper neck lateral bending moment data traces for dummies 032 and 056 during 6.0 m/s Rigid Flat Wall sled tests

Figures 15 and 16 show overlays of the lumbar y force data traces from the 6.0 m/s Rigid Flat Wall tests for dummies 032 and 056, respectively. The data traces for dummy 032 illustrate a double- peak response. All of the traces for dummy 056 show a single-peak response. These results are similar to those from the 6.7 m/s Rigid Flat Wall tests in that sometimes a single peak is observed and other times a double peak is observed.

The non-reproducibility of the resultant pelvis acceleration is due to the initial peak in the lateral acceleration, as discussed previously. Further investigation is required to determine what is responsible for the variability in response.

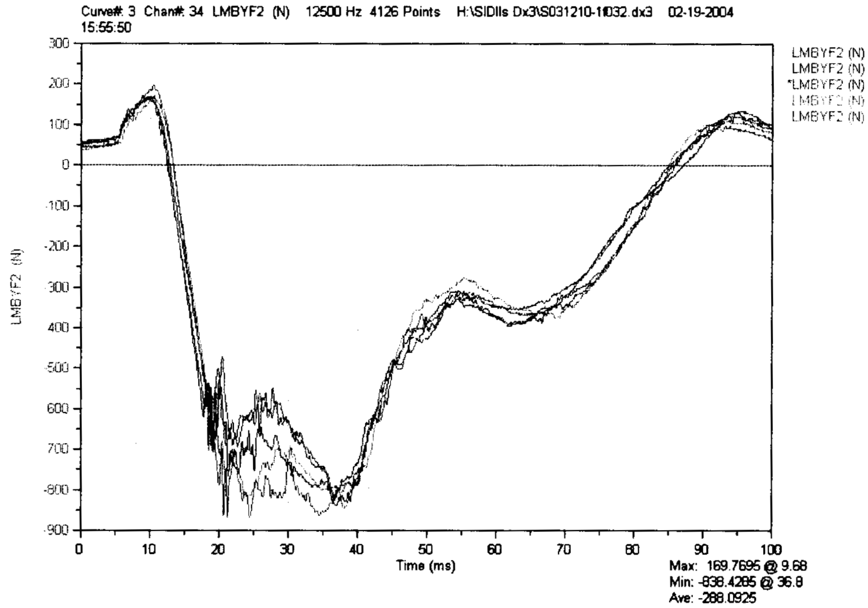

Figure 15. Lumbar lateral shear force data traces for dummy 032 during 6.0 m/s Rigid Flat Wall sled tests

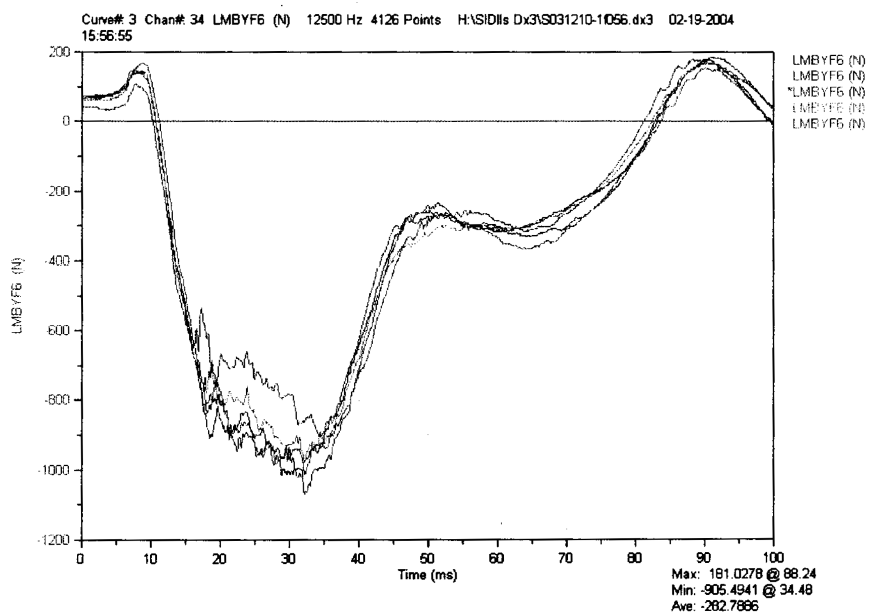

Figure 16. Lumbar lateral shear force data traces for dummy 056 during 6.0 m/s Rigid Flat Wall sled tests

6.0 m/s Rigid Abdomen Offset Tests

At the beginning of the sled series for the abdomen offset tests, both offsets were configured at the same height relative to the seat pan. Assuming the dummies were dimensionally the same[2], they should have experienced the same input from the offset contact. However, the results of the first abdomen offset test (Test 11-1) indicated that the dummies experienced differing rib deflections (Figures 17-19). Upon further investigation, dummy 056 was discovered to have a pelvis height approximately 10mm higher than dummy 032. The increased seating height of dummy 056 resulted in offset contact approximately 10mm lower on the ribs compared to dummy 032 (Figure 20).

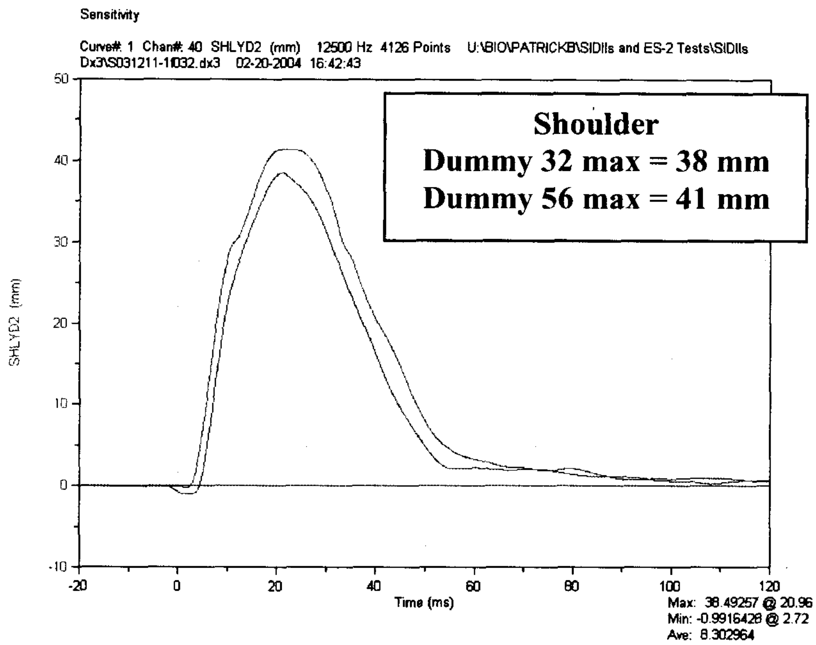

Figure 17. Shoulder deflection comparison between dummies with 10mm seating height difference during Test 11-1

[2] Dummies were not formally inspected prior to testing since a drawing package to confirm correct anthropometry/specifications was not yet available.

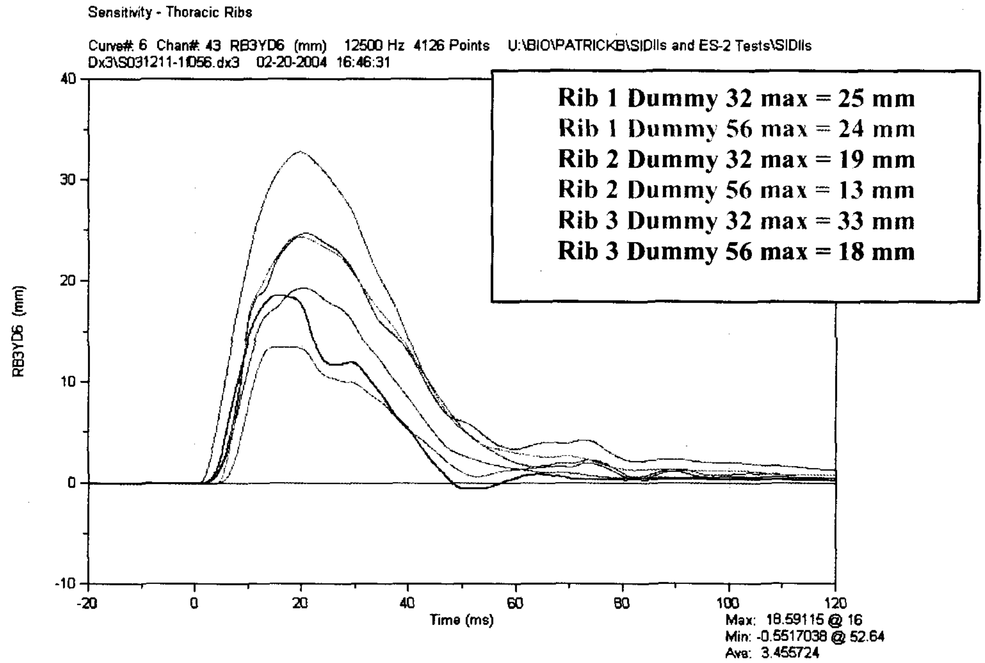

Figure 18. Thoracic rib deflection comparison between dummies with 10mm seating height difference during Test 11-1

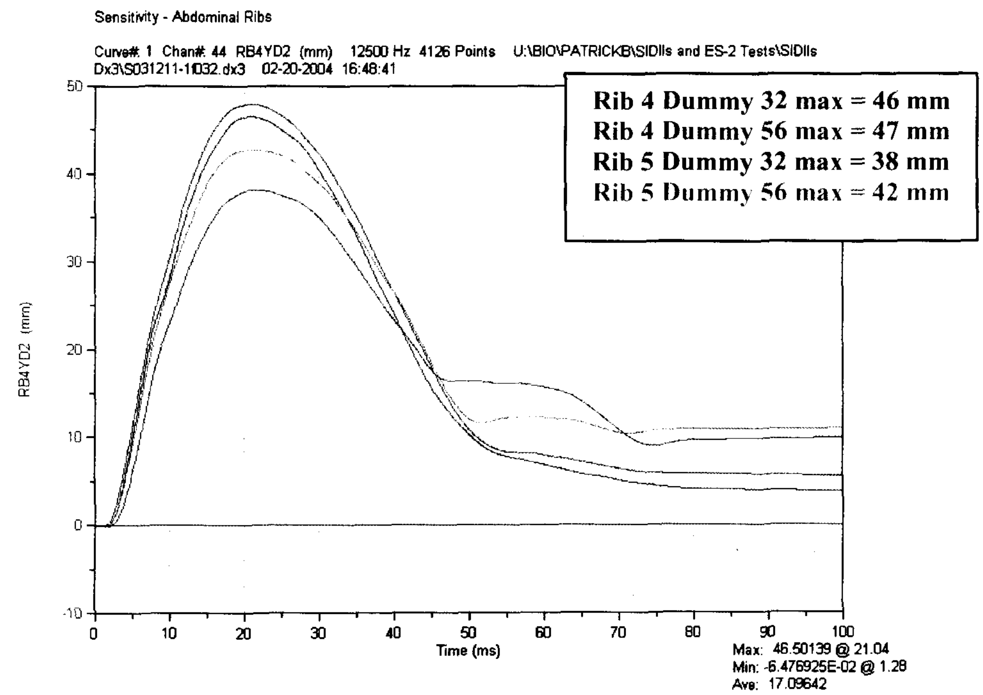

Figure 19. Abdominal rib deflection comparison between dummies with 10mm seating height difference during Test 11-1

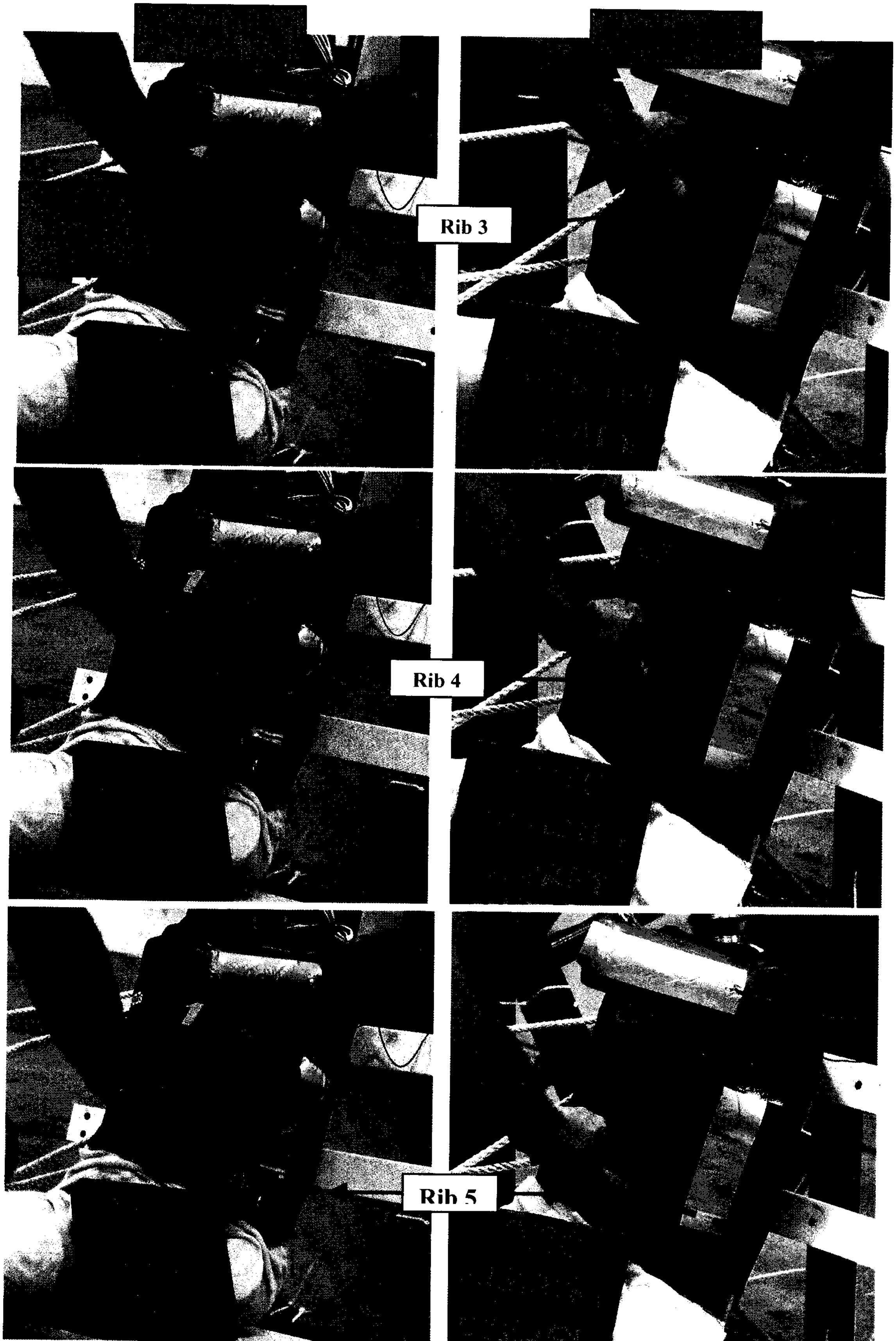

Figure 20. Location of offset block impact relative to ribs for both dummies in Test 11-1

For SID-IIs 032, the 10mm difference in contact height resulted in the majority of impact being directed at ribs 3 and 4 (Table 6). For dummy 056, the offset primarily contacted ribs 4 and 5. Rib 3 deflections showed the greatest difference between dummies due to the offset block interaction with rib 3 in dummy 032, which was absent in dummy 056. These test results indicate that the SID-IIs dummy is capable of detecting slight variations in input.

Table 6. Dummy Rib Deflection Comparison Resulting from 10mm Variation in Seating Height for Test 11-1

	Dummy 032	Offset Block	Dummy 056	Offset Block
Shoulder Rib (mm)	39	**Contacts**	41	**Contacts**
Rib 1 (mm)	25	**Ribs 3 &4**	24	**Ribs 4&5**
Rib 2 (mm)	[redacted]		[redacted]	
Rib 3 (mm)	[redacted]	◀.....	[redacted]	
Rib 4 (mm)	47	◀.....	48	◀.....
Rib 5 (mm)	[redacted]		[redacted]	◀.....

If a drawing package had been available, the pelvis height difference would likely have been discovered and corrected prior to R&R testing. In order to proceed with R&R testing after the pelvis height difference was discovered, the offset location was adjusted relative to each dummy's ribs in subsequent abdomen offset tests to compensate for the 10mm height difference. In addition, the width of the offset block was increased to encompass three ribs rather than two. These adjustments were necessary to assure that the dummies experienced identical inputs during offset interaction.

Table 7 shows the average, standard deviation and percent CV for each dummy response individually, and both dummies' responses together, from the 6.0 m/s Rigid Abdomen Offset sled tests. Tables C.1 and C.2 in Appendix C show the peak values and statistical analyses, respectively, for pertinent responses during the 6.0 m/s Rigid Abdomen Offset tests. Figures C.1 through C.24 in Appendix C show overlay plots of the repeat data traces for each dummy.

Table 7 shows that dummies 032 and 056 demonstrate excellent or good repeatability and reproducibility in all measurements, except for the repeatability of the peak resultant pelvis acceleration for dummy 056. Figures 21 and 22 show that for dummies 032 and 056 the maximum resultant pelvis acceleration for the abdomen offset tests always occurs in the initial peak (see Figures C.20.a and C.20.b in Appendix C). It is believed that the pelvis plug is the primary cause of this phenomenon. Further investigation will be required to determine what is causing the variability in the lateral pelvis acceleration responses during the three R&R test conditions.

Also of interest is the reproducibility CV for the upper neck negative x moment of 3.7%. For some reason, the two dummy necks are not exhibiting the dissimilar behavior observed during the flat wall tests.

Table 7. Analysis of Peak Responses During 6.0 m/s Rigid Abdomen Offset Sled Tests

Location	Measurement	Direction	Units	Filter Class / Statistical Parameters	032 AVG	032 SD	032 %CV	056 AVG	056 SD	056 %CV	032 & 056 AVG	032 & 056 SD	032 & 056 % CV
Test Condition					6.0 m/s Rigid Abdomen Offset								
Dummy Serial Number					032			056			032 & 056		
Dummy Position					left & right			left & right			left & right		
Head	Max Displacement	lateral	mm	n/a	236.8	1.8	0.8	240.4	1.7	0.7	238.6	2.5	1.0
		vertical	mm	n/a	128.4	9.0	7.0	114.8	5.2	4.5	121.6	10.0	8.2
	Time of Max Displacement	n/a	ms	n/a	134.0	2.9	2.2	133.0	1.9	1.4	133.5	2.4	1.8
	Acceleration	Y	g	CFC 1000	14.6	0.2	1.6	13.8	0.2	1.7	14.2	0.5	3.6
		Z	g	CFC 1000	32.4	0.8	2.6	33.5	0.5	1.5	32.9	0.9	2.7
		Resultant	g	CFC 1000	34.3	0.8	2.3	35.3	0.6	1.7	34.8	0.8	2.4
	HIC 36	**n/a**	**n/a**	**CFC 1000**	**77.7**	**2.6**	**3.4**	**80.6**	**2.1**	**2.6**	**79.1**	**2.7**	**3.4**
Upper Neck	Force	Y	N	CFC 1000	483.1	5.8	1.2	490.1	7.6	1.6	486.6	7.4	1.5
		Z	N	CFC 1000	1138.8	19.1	1.7	1209.8	22.7	1.9	1174.3	42.3	3.6
	Moment	+X	N-m	CFC 600	30.7	0.2	0.7	30.8	1.0	3.3	30.7	0.7	2.2
		-X	N-m	CFC 600	-25.8	0.3	-1.0	-27.1	1.0	-3.7	-26.4	1.0	-3.7
		Z	N-m	CFC 600	12.2	0.2	1.3	13.0	0.3	2.6	12.6	0.5	4.2
T1	Acceleration	Y	g	CFC 180	43.9	0.6	1.4	48.5	3.0	6.2	46.2	3.1	6.8
		Resultant	g	CFC 180	44.2	0.6	1.4	48.8	2.9	6.0	46.5	3.1	6.7
T12	**Acceleration**	Y	g	CFC 180	40.6	0.6	1.6	43.6	0.6	1.4	42.1	1.7	4.0
		Resultant	**g**	**CFC 180**	**41.2**	**0.8**	**1.9**	**43.8**	**0.7**	**1.7**	**42.5**	**1.6**	**3.7**
Shoulder Rib	Displacement	Y	mm	CFC 600	36.2	0.4	1.0	40.0	1.0	2.4	38.1	2.1	5.6
Thorax Rib 1	**Displacement**	**Y**	**mm**	**CFC 180**	**24.5**	**0.5**	**1.9**	**23.2**	**1.2**	**5.2**	**23.9**	**1.1**	**4.6**
Thorax Rib 2	**Displacement**	**Y**	**mm**	**CFC 180**	**26.9**	**0.8**	**3.1**	**24.0**	**1.0**	**4.1**	**25.5**	**1.8**	**7.0**
Thorax Rib 3	**Displacement**	**Y**	**mm**	**CFC 180**	**48.8**	**0.7**	**1.5**	**48.3**	**0.8**	**1.6**	**48.5**	**0.8**	**1.6**
Abdomen Rib 1	**Displacement**	**Y**	**mm**	**CFC 180**	**47.1**	**0.8**	**1.7**	**47.6**	**0.5**	**1.1**	**47.4**	**0.7**	**1.4**
Abdomen Rib 2	**Displacement**	**Y**	**mm**	**CFC 180**	**40.6**	**0.9**	**2.3**	**41.3**	**0.6**	**1.5**	**40.9**	**0.8**	**2.0**
Lumbar	Force	Y	N	CFC 1000	-1570.7	31.8	-2.0	-1605.5	60.8	-3.8	-1588.1	49.3	-3.1
	Moment	X	N-m	CFC 1000	-80.1	1.8	-2.3	-87.4	2.1	-2.4	-83.8	4.3	-5.1
Acetabulum	Force	Y	N	CFC 600	2668.2	146.1	5.5	2835.6	131.5	4.6	2751.9	158.0	5.7
Iliac Wing	Force	Y	N	CFC 600	-312.6	20.8	-6.7	-276.4	7.1	-2.6	-294.5	24.1	-8.2
Sum of Acetabulum and Iliac	**Force**	**Y**	**N**	**CFC 600**	**2425.9**	**164.0**	**6.8**	**2660.9**	**138.3**	**5.2**	**2543.4**	**189.2**	**7.4**
Pelvis*	Acceleration	Y	g	CFC 1000	54.2	1.0	1.8	65.0	2.6	4.0	59.6	6.0	10.0
		Resultant	g	CFC 1000	74.7	3.6	4.9	81.2	8.5	[illegible]	77.9	7.0	9.0
Sled	Acceleration	X	g	CFC 60	-11.7	0.0	-0.3	-11.7	0.0	-0.3	-11.7	0.0	-0.3
Sled	Velocity	X	m/s	CFC 60	-5.8	0.0	-0.3	-5.8	0.0	-0.3	-5.8	0.0	-0.3

Bold type indicates proposed injury criteria measures

*For Pelvis Y Acceleration, second peak is shown in table.

Legend: %CV<=5.0 | 5.1%<CV<=10.0% | CV>10.0%

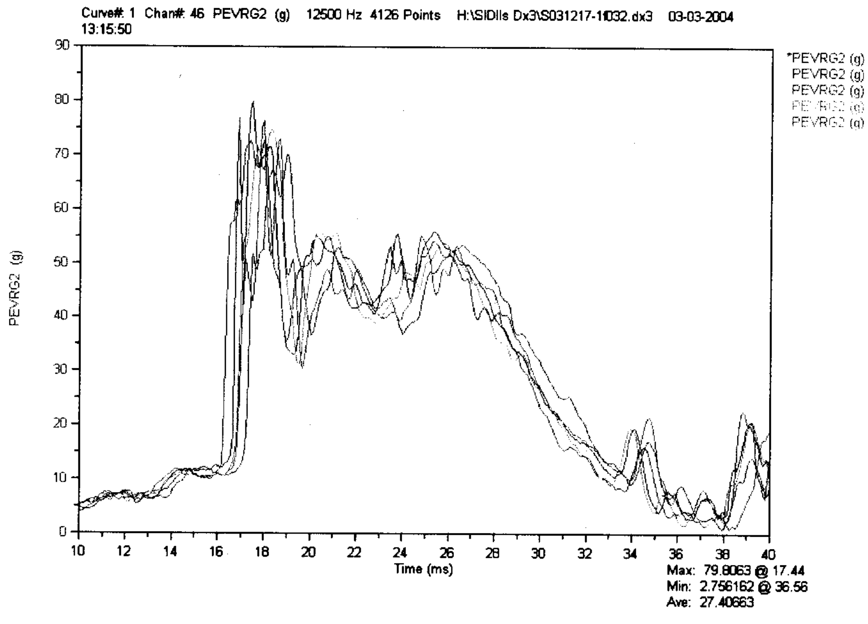

Figure 21. Pelvis resultant acceleration data traces for dummy 032 during 6.0 m/s Rigid Abdomen Offset sled tests

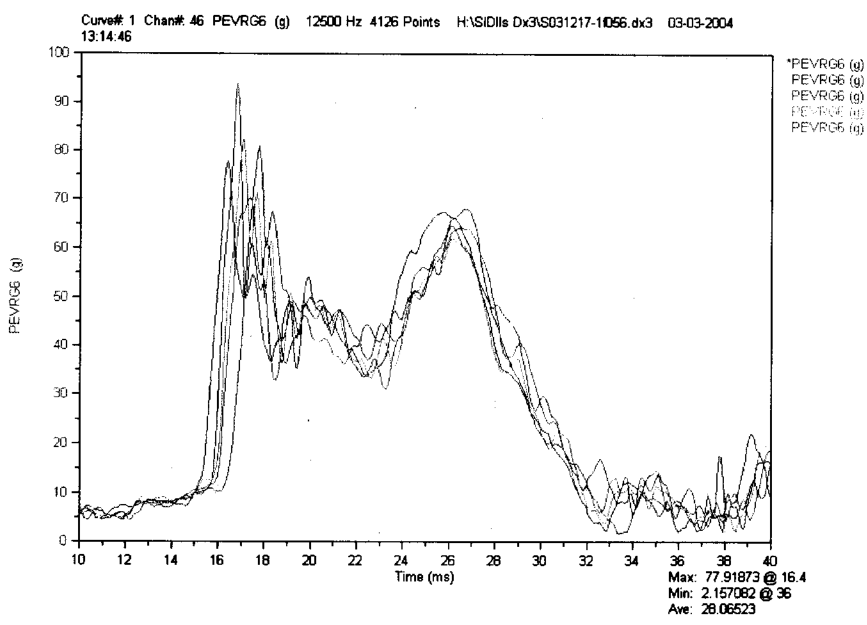

Figure 22. Pelvis resultant acceleration data traces for dummy 056 during 6.0 m/s Rigid Abdomen Offset sled tests

Summary

The following discussion will focus on the responses during the three test conditions relative to the proposed injury criteria. For brevity, the following abbreviations will be utilized: Rigid Flat Wall (RFW), Rigid Abdomen Offset (RAO).

Sled Pulse Parameters

The peak sled acceleration and peak sled velocity provided extremely repeatable and reproducible test conditions with CV values less than 0.4% for all tests. This was important to ensure minimal test-to-test variations.

Head Responses

The head acceleration responses were of low magnitude as there was no head contact occurring during any of the events. The proposed injury criteria limit for HIC_{36} is 1000 (Kuppa, 2004); the average HIC_{36} responses for both dummies were only 128, 72 and 79 for the 6.7 m/s RFW, 6.0 m/s RFW, and 6.0 m/s RAO test conditions, respectively. Despite the low magnitude of the response, the HIC_{36} responses exhibited acceptable repeatability and reproducibility for both dummies, with the highest CV being 6.2% for dummy 032 in the 6.7 m/s RFW condition, as well as for both dummies in that same condition.

Spine Accelerations

The average responses of the lower spine resultant acceleration (T12) were below the proposed injury criteria (mean response of both dummies = 52 g for 6.7 m/s RFW; 39 g for 6.0 m/s RFW, 43 g for 6.0 m/s RAO; proposed injury criteria = 82 g (Kuppa, 2004)). The repeatability and reproducibility of the dummies' responses were acceptable with the highest CV being 5.2% for dummy 032 in the 6.0 m/s RFW condition.

Rib Displacements

Although there is no proposed injury criterion for the ribs, the displacement of the ribs will be monitored in FMVSS tests. The Injury Assessment Reference Value (IARV) for maximum thoracic rib displacement is 38 mm (corresponding to 50% risk of AIS 3+ injury), and for maximum abdominal rib displacement is 44 mm (corresponding to 5% risk of AIS 4+ injury) (Kuppa, 2004). In the three test conditions, the thoracic ribs had mean peak displacements greater than 38 mm, and the abdominal ribs had mean peak displacements of 49 mm for the 6.7 m/s RFW condition, 37 mm for the 6.0 m/s RFW condition, and 47 mm for the 6.0 m/s RAO condition, indicating the severity of the test conditions.

Thoracic Rib Displacements

For each dummy in each test condition, the maximum thoracic rib displacement (lower thoracic rib for each test condition) provided acceptable repeatability and reproducibility, with the highest CV being 5.4% for both dummies in the 6.0 RFW test condition.

Abdominal Rib Displacement

For each dummy in each test condition, the maximum abdominal rib displacement (upper abdominal rib for each test condition) provided acceptable repeatability and reproducibility, with the highest CV being 7.2% for dummy 032 in the 6.7 m/s RFW tests.

Sum of Acetabulum and Iliac Wing Loads

The injury criterion for the pelvis states that the peak of the sum of the acetabulum and iliac lateral loads must be less than 5100 N (Kuppa, 2004). To compute the sum of the acetabulum and iliac wing loads, the time-history responses of the acetabulum and iliac wing lateral loads are summed; the maximum summed load is not necessarily equal to the sum of the individual peaks for each load cell.

The average peak summed response for both dummies was 4060 N for the 6.7 m/s RFW condition; 3089 N for the 6.0 m/s RFW condition; and 2543 N for the 6.0 m/s RAO condition, all below the proposed injury criterion. The repeatability and reproducibility of the maximum summed load responses were acceptable for both dummies, having CV values of less than 10%. However, the data traces show signs of correlation to the variable response of the pelvis acceleration. Figures 23 and 24 show overlay plots of the data traces for the pelvis lateral acceleration and the left iliac wing and left acetabulum lateral forces, respectively, during Test 17-1 of the RAO test condition. The iliac wing force magnitude typically increases during the initial rise of the pelvis lateral acceleration, and again during its second rise. It is suspected that whatever is causing the double peak response in the pelvis acceleration is also affecting the iliac wing response. The acetabulum force typically increases dramatically with the first increase in pelvis acceleration, but continues to rise instead of replicating the valley that occurs in the pelvis acceleration and iliac wing data traces. It is suspected that whatever is causing the initial peak and valley in the acceleration and iliac wing responses occurs on the medial side of the acetabulum load cell since the valley seen in the other data traces is not observed in those of the acetabulum. Since the cause of the variable pelvis response affects the proposed pelvis injury criterion measures, further investigation is necessary.

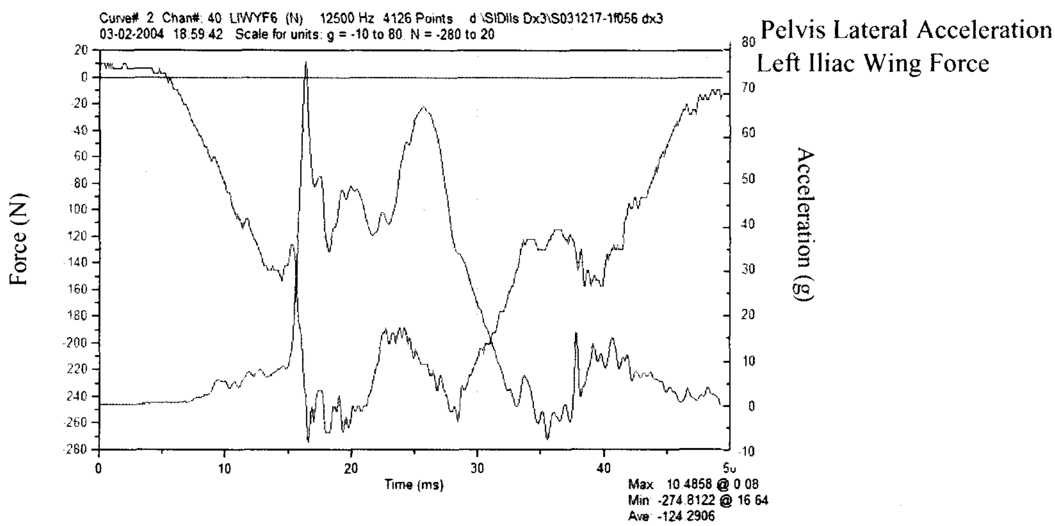

Figure 23. Pelvis lateral acceleration (blue) and left iliac wing lateral load (red) data traces for dummy 056 during Test 17-1 of the 6.0 m/s Rigid Abdomen Offset sled test series.

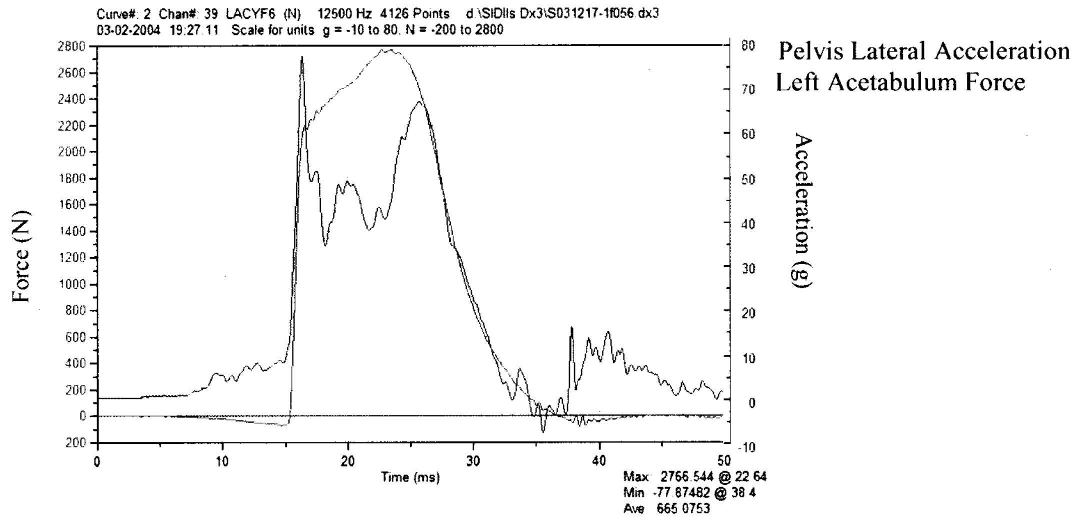

Figure 24. Pelvis lateral acceleration (blue) and left acetabulum lateral load (red) data traces for dummy 056 during Test 17-1 of the 6.0 m/s Rigid Abdomen Offset sled test series.

<u>Other Responses</u>

The head displacements as measured in the high-speed digital video analysis were of particular interest since the upgraded FMVSS tests will include supplemental restraint systems for head protection. The peak lateral displacement proved to be very repeatable and reproducible with the highest CV of 2.9% for dummy 032 in the 6.0 m/s RFW condition. The peak vertical displacement was acceptably repeatable and reproducible for each dummy in all tests, except for dummy 032 in the 6.0 m/s RFW condition. Although the maximum vertical head translation of dummy 032 yields a CV of 13%, the standard deviation is only 13.5mm, which is quite small. In addition, since lateral translation represents the primary measurement of interest, the 13% CV in the vertical direction is not a problem. The time of peak head displacement exhibited excellent repeatability and reproducibility with the highest CV value of 3.1 % for dummy 032 in the 6.0 m/s RFW condition. These results indicate that the motion of the head exhibits acceptable R&R.

Conclusions

Two SID-IIs FRG dummies were exposed to three series of five Hyge sled tests, plus a trial RAO test, for a total of 16 test exposures per dummy in order to evaluate the repeatability and reproducibility of the dummy. The three test conditions subjected the dummies to rigorous loading conditions. In the 6.7 m/s flat wall and 6.0 m/s abdomen offset test conditions, the dummies' thoracic and abdominal rib displacement responses exceeded the injury assessment reference values, while in the 6.0 m/s flat wall test condition, only the dummies' thoracic rib displacement responses exceeded the IARV. Since there was no head contact in any of the tests, the dummy head acceleration responses did not exceed the proposed head injury criterion. The lower spine acceleration and pelvis load proposed injury criteria were also not exceeded.

The R&R analysis indicates that the dummies were able to provide responses that were acceptable, good or excellent for every proposed injury measure. However, further examination is required to determine what is responsible for the variability in the lateral pelvis acceleration response, which also appears to affect the iliac and acetabulum lateral force responses (proposed injury criterion measures), and possibly lumbar force and moment responses as well. As per the FTSS User's Manual, the foam pelvis plug must be replaced after each impact, including after certification tests, prior to crash tests. The disposable plug procedure was followed for the sled tests so that a new plug was used in each test. It is suspected that this uncertified, protruding plug may be related to the variable responses observed in the pelvis. Repeated tests impacting a dummy with a single plug in the certification environment, for various plugs and dummies, are planned. The effect of multiple impacts to a single plug, as well as recovery time, will be researched. Static testing of the foam plugs is also planned. Investigation into the pelvis variability issue is underway.

Since the drawing package was not available to allow the dummies to be inspected against the design specifications prior to testing, the difference in pelvis heights between the dummies was not discovered until after the first abdomen offset sled test. During this test it was learned that the SID-IIs dummy is sensitive to small changes in its impact environment, even as little as a 10mm pelvis height difference.

References

First Technology Safety Systems, "SID-IIs Small Side Impact Crash Test Dummy User's Manual" Rev. 3, February 2002.

Kuppa, S., "Injury Criteria for Side Impact Dummies", May 2004, NHTSA docket #NHTSA-2004-17694.

Rhule, H. and Hagedorn, A., "Development of the SID-IIs FRG", November 2003, NHTSA docket #NHTSA-2004-17694.

Appendix A.
6.7 m/s Rigid Flat Wall Sled Test Responses

Table A.1. Peak Responses During 6.7 m/s Rigid Flat Wall Sled Tests

				Test Condition	6.7 m/s Flat Rigid Wall									
				Dummy Serial Number	32					56				
				Dummy Position	right	right	right	left	left	left	left	left	right	right
Location	**Measurement**	**Direction**	**Units**	**Filter Class / Test # S0312—**	04-1	04-2	05-1	05-2	08-1	04-1	04-2	05-1	05-2	08-1
Head	Max Displacement	lateral	mm	n/a	269	273	275	263	274	277	281	278	287	284
Head	Max Displacement	vertical	mm	n/a	113	121	133	109	124	121	104	117	119	124
Head	Time of Max Displacement	n/a	ms	n/a	133	135	136	134	136	134	131	134	133	136
Head	Acceleration	Y	g	CFC 1000	16.9	15.7	16.9	17.4	17.0	15.3	15.0	15.9	14.9	14.5
Head	Acceleration	Z	g	CFC 1000	36.7	35.8	39.4	40.6	41.8	36.6	34.6	38.9	43.0	43.5
Head	Acceleration	Resultant	g	CFC 1000	37.7	37.1	41.0	42.6	43.3	38.3	36.1	40.7	45.0	45.4
Head	**HIC 36**	**n/a**	**n/a**	**CFC 1000**	**121.0**	**112.3**	**133.0**	**127.0**	**125.2**	**131.7**	**124.8**	**130.9**	**138.1**	**138.1**
Upper Neck	Force	Y	N	CFC 1000	579.0	545.9	586.6	578.4	580.5	571.0	546.5	573.8	551.5	538.6
Upper Neck	Force	Z	N	CFC 1000	1220.9	1183.7	1335.1	1329.4	1354.6	1258.5	1234.0	1367.5	1508.3	1492.9
Upper Neck	Moment	+X	N-m	CFC 600	34.3	33.0	35.5	33.5	35.6	31.8	31.9	32.7	31.9	31.4
Upper Neck	Moment	-X	N-m	CFC 600	-24.5	-25.7	-24.7	-25.0	-25.1	-31.0	-30.2	-30.8	-29.4	-29.6
Upper Neck	Moment	Z	N-m	CFC 600	13.4	12.6	13.2	14.7	13.1	14.3	13.5	13.5	13.1	13.1
T12	**Acceleration**	Y	g	CFC 180	53.3	55.4	50.6	53.0	51.9	52.1	50.8	53.0	49.6	48.4
T12	**Acceleration**	**Resultant**	**g**	**CFC 180**	**53.7**	**55.6**	**50.6**	**53.2**	**52.6**	**52.9**	**51.7**	**53.6**	**51.7**	**48.5**
Thorax Rib 1	**Displacement**	**Y**	**mm**	**CFC 180**	**47.8**	**47.5**	**46.8**	**47.4**	**48.1**	**46.5**	**46.9**	**46.0**	**44.4**	**44.5**
Thorax Rib 2	**Displacement**	**Y**	**mm**	**CFC 180**	**52.4**	**52.6**	**50.8**	**50.7**	**52.9**	**50.1**	**50.7**	**49.8**	**47.1**	**47.3**
Thorax Rib 3	**Displacement**	**Y**	**mm**	**CFC 180**	**55.3**	**55.6**	**53.4**	**51.4**	**55.6**	**55.2**	**56.2**	**55.1**	**51.4**	**51.5**
Abdomen Rib 1	**Displacement**	**Y**	**mm**	**CFC 180**	**50.0**	**51.4**	**48.3**	**42.6**	**50.3**	**50.2**	**51.0**	**51.1**	**46.3**	**46.4**
Abdomen Rib 2	**Displacement**	**Y**	**mm**	**CFC 180**	**21.6**	**23.9**	**21.4**	**18.4**	**22.1**	**23.0**	**23.7**	**23.6**	**22.3**	**22.0**
Lumbar	Force	Y	N	CFC 1000	-894.8	-875.1	-863.6	-796.1	-839.7	-928.8	-953.7	-879.2	-1115.5	-1081.3
Lumbar	Moment	X	N-m	CFC 1000	-62.5	-54.7	-67.7	-56.5	-57.1	-63.5	-60.7	-59.9	-83.0	-80.3
Acetabulum	Force	Y	N	CFC 600	4249.6	4366.9	3933.5	4188.3	3877.1	4021.1	3867.8	4282.7	4009.4	3528.5
Iliac Wing	Force	Y	N	CFC 600	-330.1	-315.6	-300.4	-319.1	-304.5	-289.8	-273.8	-276.2	-334.4	-316.1
Sum of Acetabulum and Iliac	**Force**	**Y**	**N**	**CFC 600**	**4111.1**	**4376.8**	**3786.0**	**4242.0**	**3910.4**	**4228.2**	**4231.7**	**4424.5**	**3864.6**	**3425.0**
Pelvis*	Acceleration	Y	g	CFC 1000	88.9	91.5	84.7	90.3	89.4	101.4	96.7	95.9	84.9	86.4
Pelvis*	Acceleration	Resultant	g	CFC 1000	89.1	91.8	86.5	90.5	89.8	102.4	97.3	100.2	85.4	87.7
Sled	Acceleration	X	g	CFC 60	-13.1	-13.1	-13.1	-13.1	-13.1	-13.1	-13.1	-13.1	-13.1	-13.1
Sled	Velocity	X	m/s	CFC 60	-7.0	-6.9	-6.9	-6.9	-6.9	-7.0	-6.9	-6.9	-6.9	-6.9

Bold type indicates proposed injury criteria measures

*For Pelvis Y Acceleration, second peak is shown in table.

Table A.2. Statistical Analysis for 6.7 m/s Rigid Flat Wall Sled Tests

Location	Measurement	Direction	Units	Test Condition / Dummy Serial Number / Dummy Position / Filter Class / Statistical Parameters	6.7 m/s Flat Rigid Wall: 32, left & right AVG	SD	%CV	56, left & right AVG	SD	%CV	032 & 056, left & right AVG	SD	% CV
Head	Max Displacement	lateral	mm	n/a	270.8	4.9	1.8	281.4	4.2	1.5	276.1	7.0	2.6
		vertical	mm	n/a	120.0	9.4	7.9	117.0	7.7	6.6	118.5	8.3	7.0
	Time of Max Displacement	n/a	ms	n/a	134.8	1.3	1.0	133.6	1.8	1.4	134.2	1.6	1.2
	Acceleration	Y	g	CFC 1000	16.8	0.6	3.7	15.1	0.5	3.4	16.0	1.0	6.5
		Z	g	CFC 1000	38.8	2.5	6.5	39.3	3.9	9.9	39.1	3.1	8.0
		Resultant	g	CFC 1000	40.4	2.8	6.9	41.1	4.1	9.9	40.7	3.3	8.2
	HIC 36	**n/a**	**n/a**	**CFC 1000**	**123.7**	**7.7**	**6.2**	**132.7**	**5.6**	**4.2**	**128.2**	**7.9**	**6.2**
Upper Neck	Force	Y	N	CFC 1000	574.1	16.1	2.8	556.3	15.5	2.8	565.2	17.6	3.1
		Z	N	CFC 1000	1284.7	77.0	6.0	1372.2	127.6	9.3	1328.5	109.5	8.2
	Moment	+X	N-m	CFC 600	34.4	1.2	3.4	31.9	0.5	1.5	33.2	1.5	4.6
		-X	N-m	CFC 600	-25.0	0.4	-1.8	-30.2	0.7	-2.4	-27.6	2.8	[illegible]
		Z	N-m	CFC 600	13.4	0.8	5.8	13.5	0.5	3.5	13.4	0.6	4.5
T12	**Acceleration**	Y	g	CFC 180	52.8	1.8	3.4	50.8	1.9	3.6	51.8	2.0	3.9
		Resultant	**g**	**CFC 180**	**53.2**	**1.8**	**3.4**	**51.7**	**1.9**	**3.7**	**52.4**	**1.9**	**3.7**
Thorax Rib 1	**Displacement**	**Y**	**mm**	**CFC 180**	**47.5**	**0.5**	**1.0**	**45.7**	**1.2**	**2.6**	**46.6**	**1.3**	**2.8**
Thorax Rib 2	**Displacement**	**Y**	**mm**	**CFC 180**	**51.9**	**1.0**	**2.0**	**49.0**	**1.7**	**3.4**	**50.4**	**2.0**	**4.0**
Thorax Rib 3	**Displacement**	**Y**	**mm**	**CFC 180**	**54.2**	**1.9**	**3.4**	**53.9**	**2.3**	**4.2**	**54.1**	**2.0**	**3.6**
Abdomen Rib 1	**Displacement**	**Y**	**mm**	**CFC 180**	**48.5**	**3.5**	**7.2**	**49.0**	**2.5**	**5.0**	**48.8**	**2.9**	**5.9**
Abdomen Rib 2	**Displacement**	**Y**	**mm**	**CFC 180**	**21.5**	**2.0**	**9.3**	**22.9**	**0.7**	**3.2**	**22.2**	**1.6**	**7.3**
Lumbar	Force	Y	N	CFC 1000	-853.9	37.9	-4.4	-991.7	101.7	[illegible]	-922.8	102.5	[illegible]
	Moment	X	N-m	CFC 1000	-59.7	5.3	-9.0	-69.5	11.2	[illegible]	-64.6	9.8	[illegible]
Acetabulum	Force	Y	N	CFC 600	4123.1	209.8	5.1	3941.9	275.4	7.0	4032.5	249.8	6.2
Iliac Wing	Force	Y	N	CFC 600	-313.9	11.8	-3.8	-298.0	26.4	-8.8	-306.0	21.0	-6.9
Sum of Acetabulum and Iliac	**Force**	**Y**	**N**	**CFC 600**	**4085.3**	**240.0**	**5.9**	**4034.8**	**396.5**	**9.8**	**4060.0**	**310.1**	**7.6**
Pelvis*	Acceleration	Y	g	CFC 1000	89.0	2.6	2.9	93.1	7.1	7.6	91.0	5.5	6.0
		Resultant	g	CFC 1000	89.5	2.0	2.2	94.6	7.6	8.0	92.1	5.9	6.4
Sled	Acceleration	X	g	CFC 60	-13.1	0.0	-0.3	-13.1	0.0	-0.3	-13.1	0.0	-0.3
Sled	Velocity	X	m/s	CFC 60	-6.9	0.0	-0.3	-6.9	0.0	-0.3	-6.9	0.0	-0.3

Bold type indicates proposed injury criteria measures
*For Pelvis Y Acceleration, second peak is shown in table.

%CV<=5.0 | 5.1%<CV<=10.0% | CV>10.0%

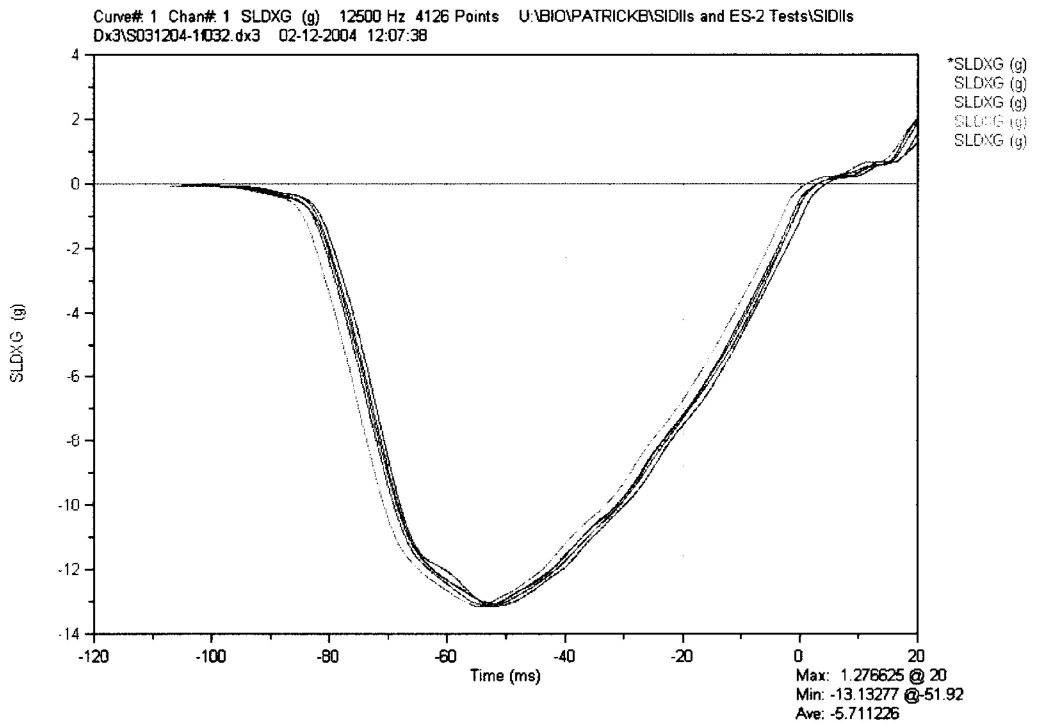

Figure A.1. Sled Acceleration Pulse

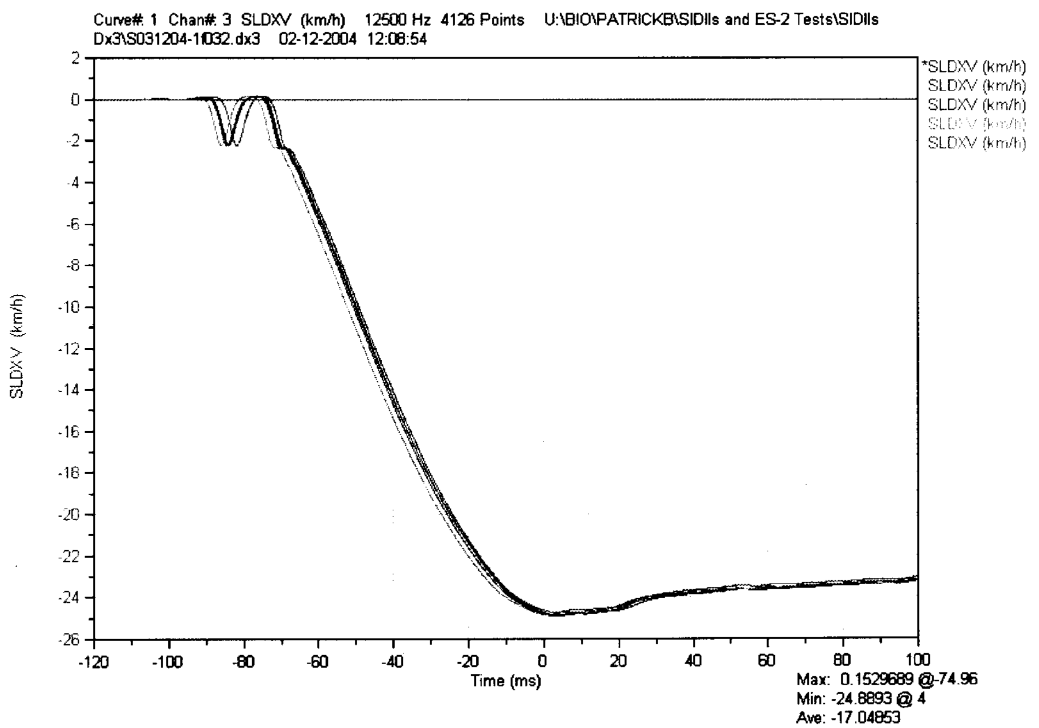

Figure A.2. Sled Velocity

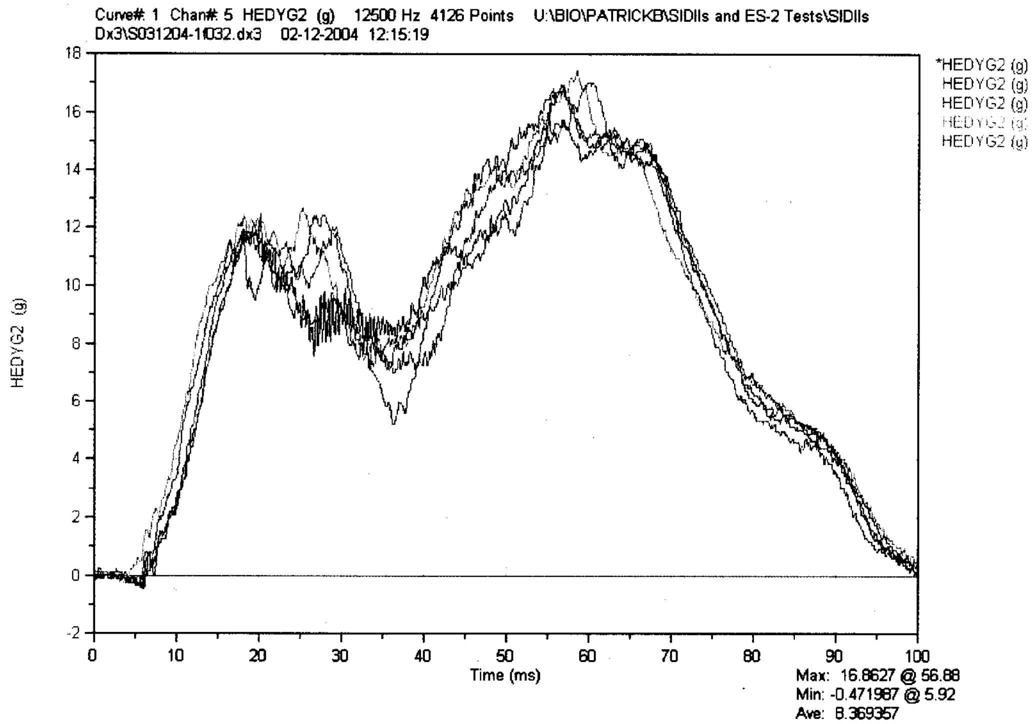

Figure A.3.a. Lateral Head Acceleration – Dummy 032

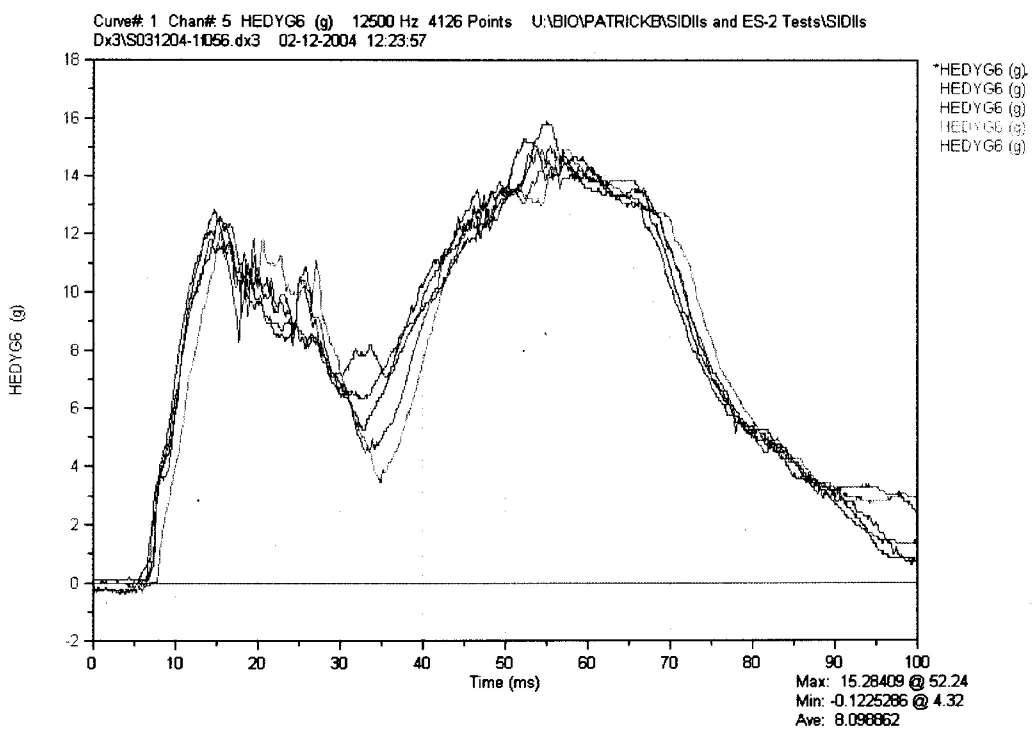

Figure A.3.b. Lateral Head Acceleration – Dummy 056

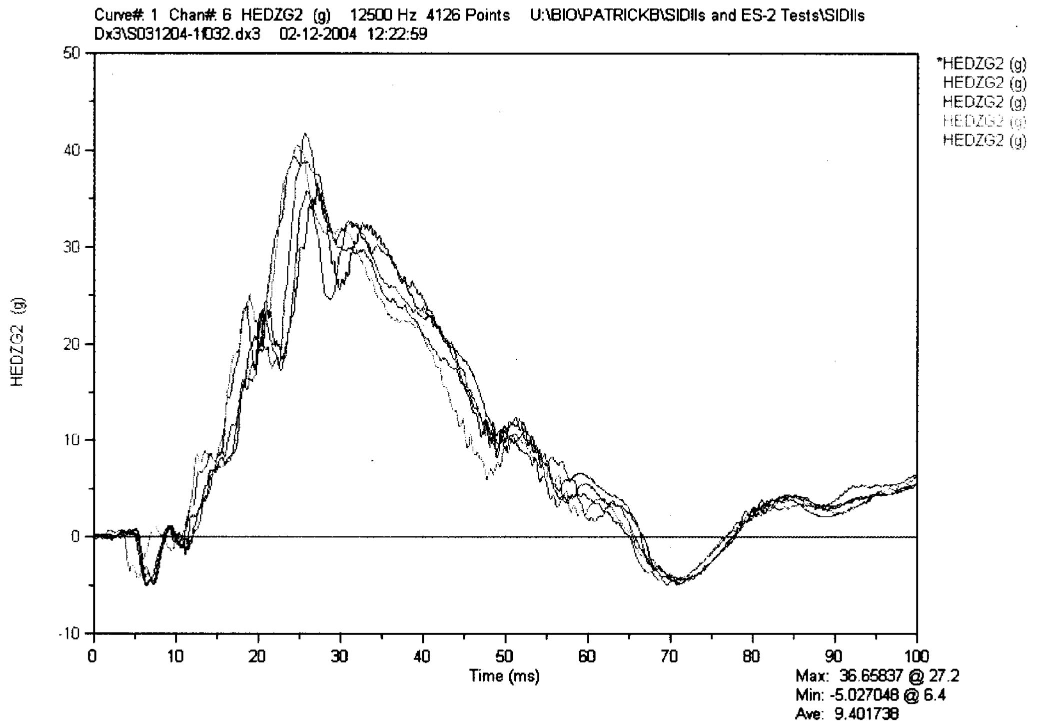

Figure A.4.a. Vertical Head Acceleration – Dummy 032

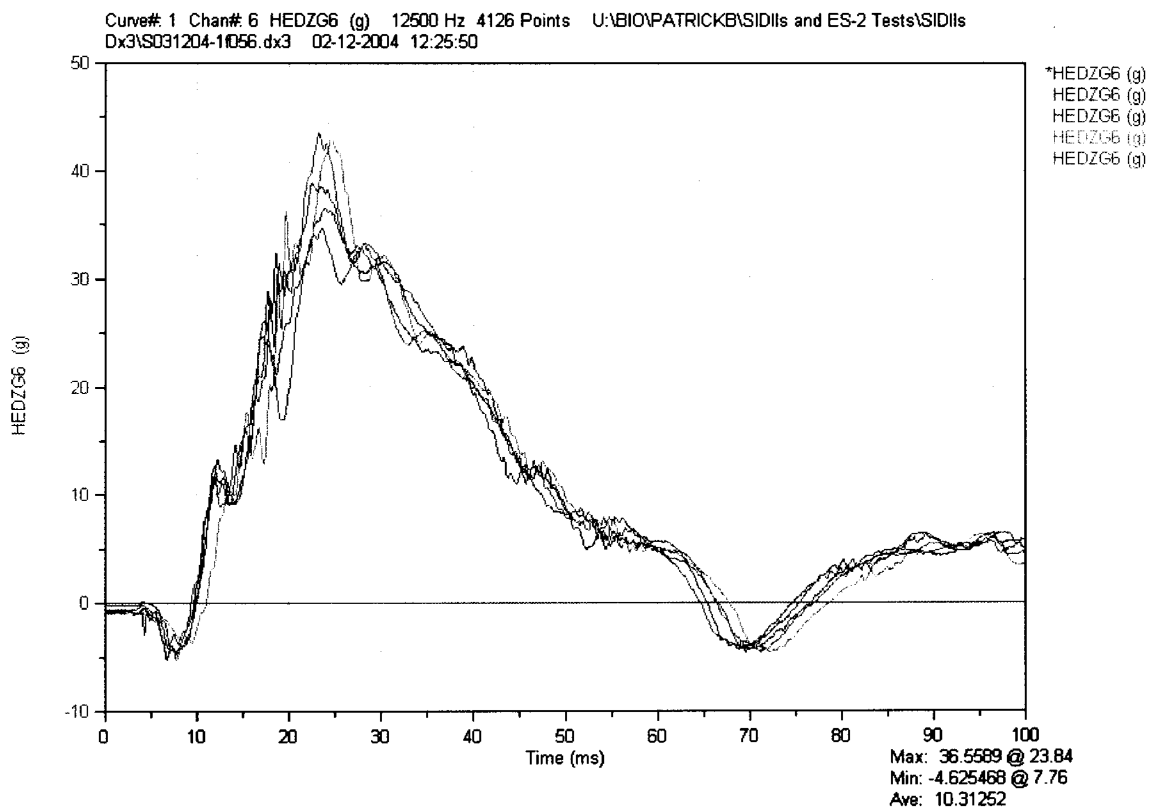

Figure A.4.b. Vertical Head Acceleration – Dummy 056

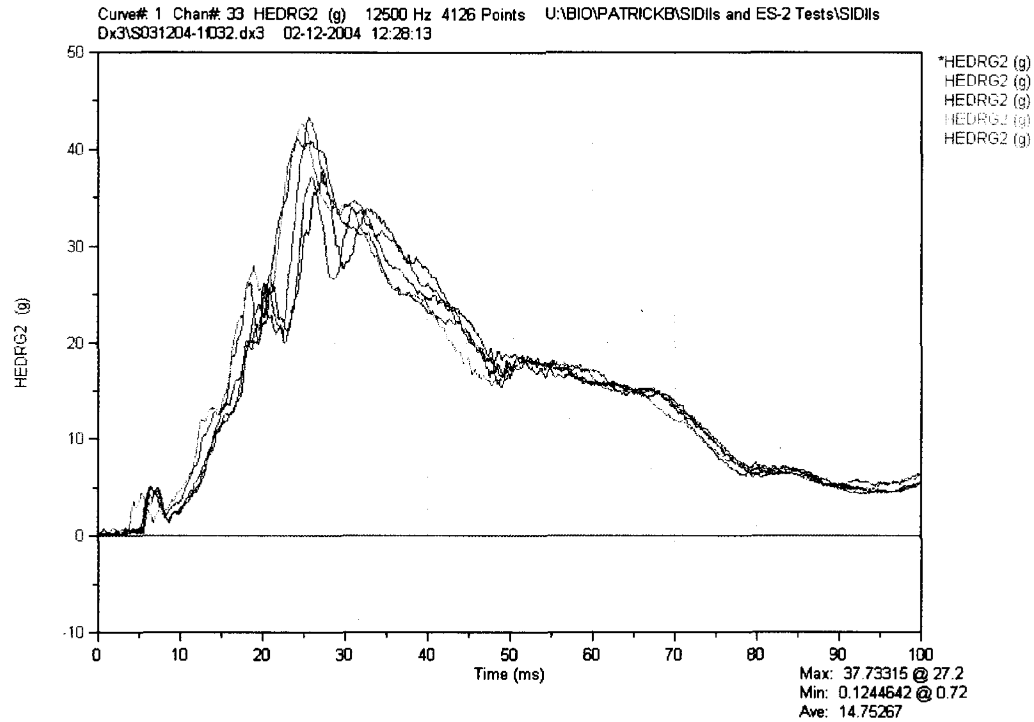

Figure A.5.a. Resultant Head Acceleration – Dummy 032

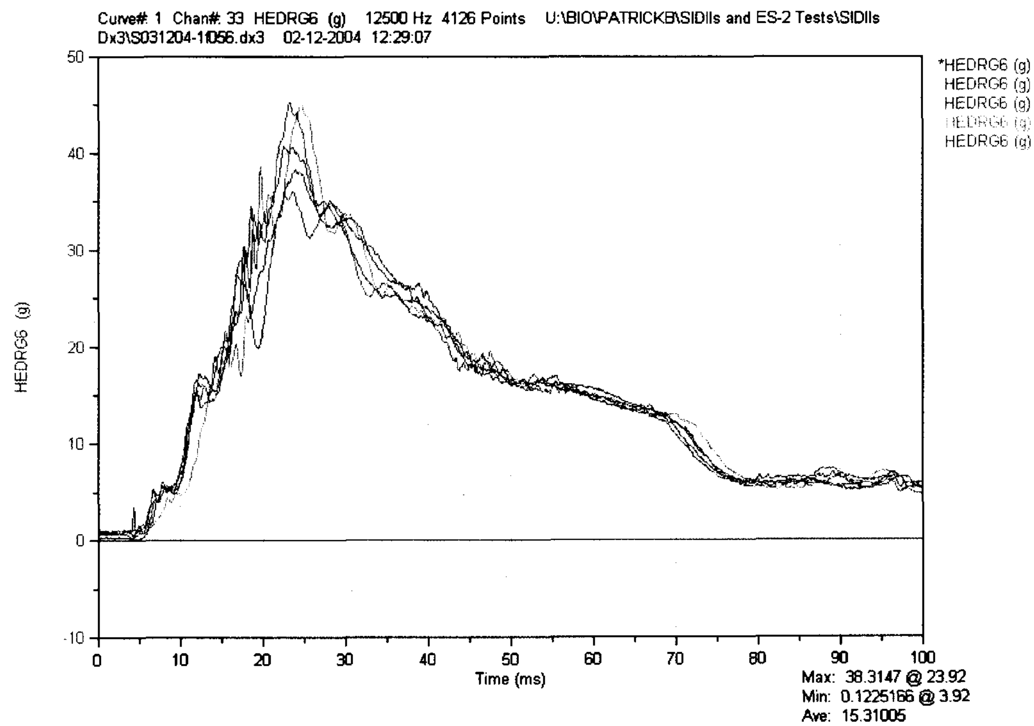

Figure A.5.b. Resultant Head Acceleration – Dummy 056

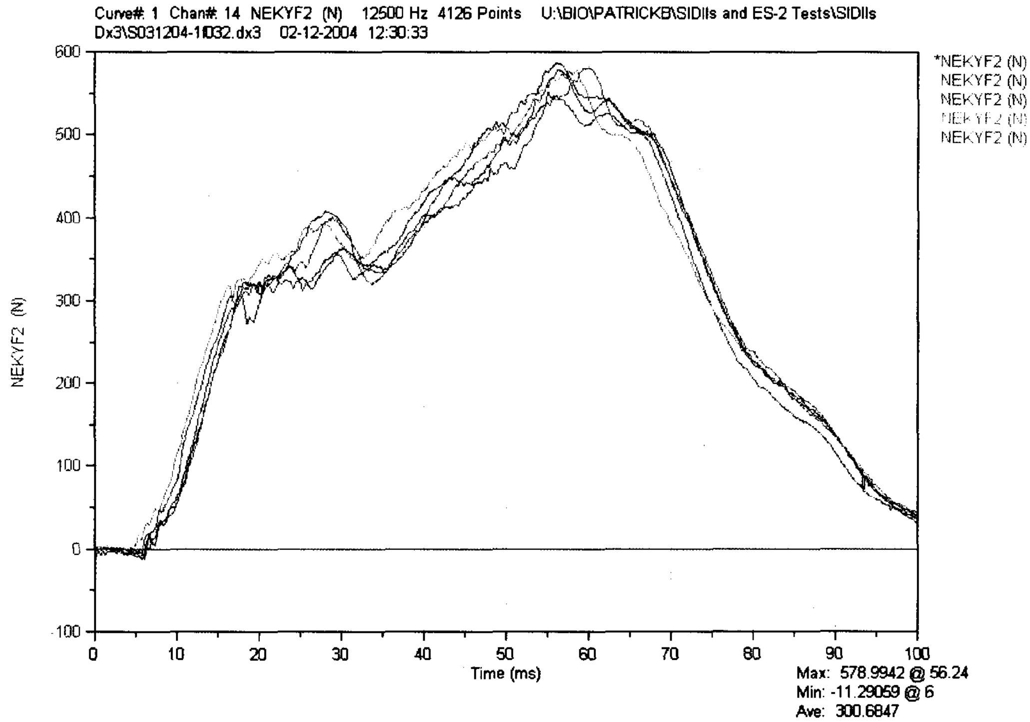

Figure A.6.a. Upper Neck Lateral Shear Force – Dummy 032

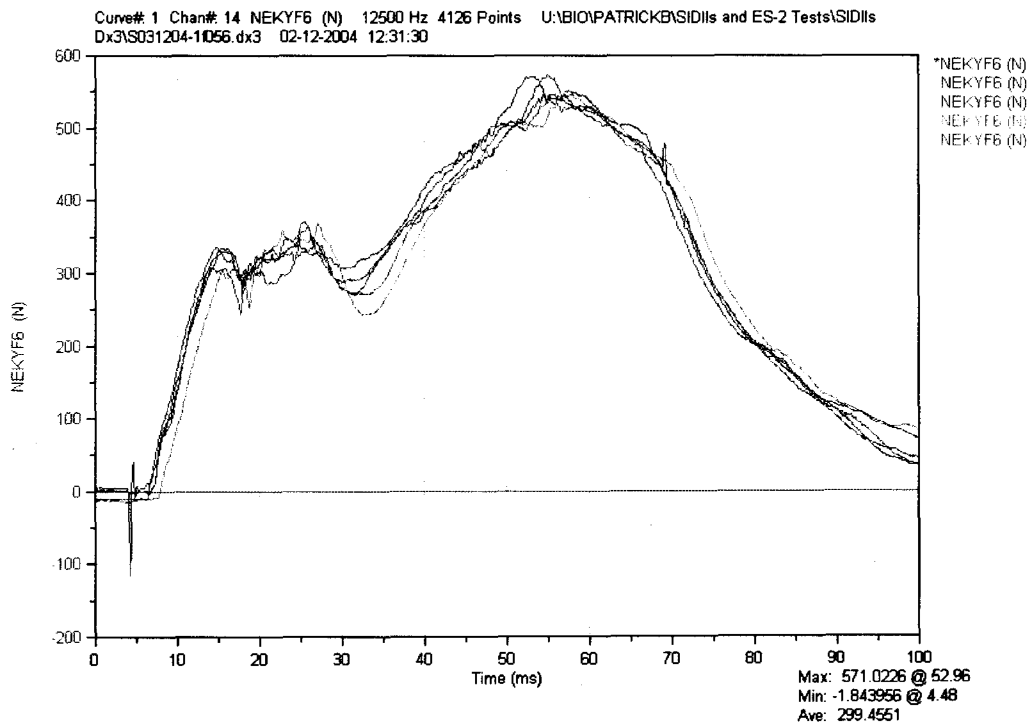

Figure A.6.b. Upper Neck Lateral Shear Force – Dummy 056

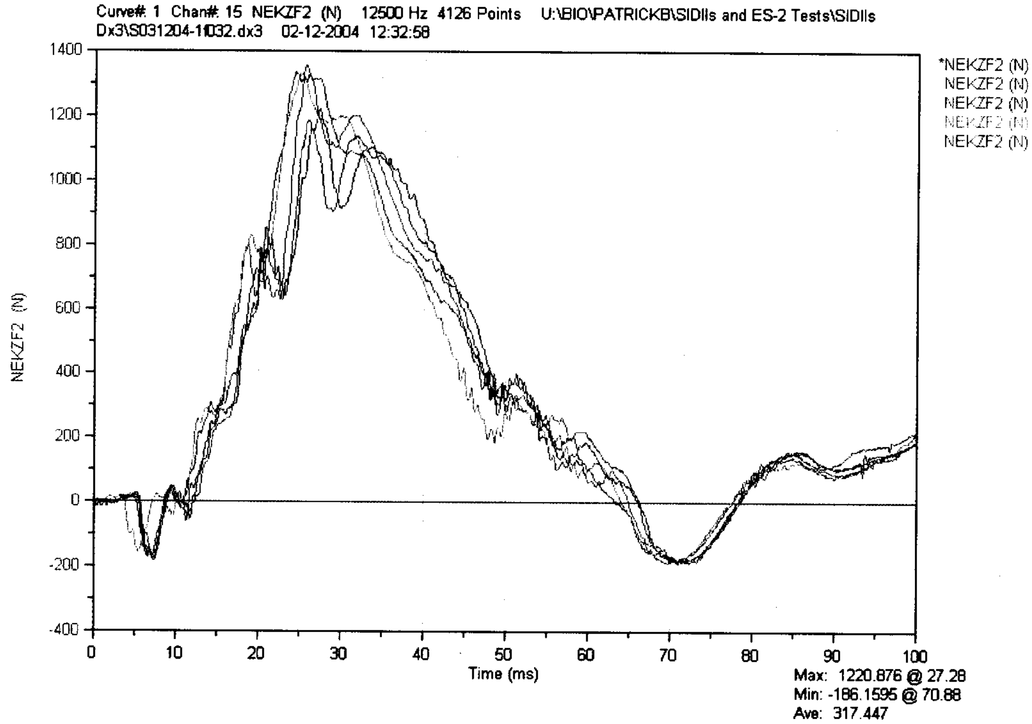

Figure A.7.a. Upper Neck Axial Force – Dummy 032

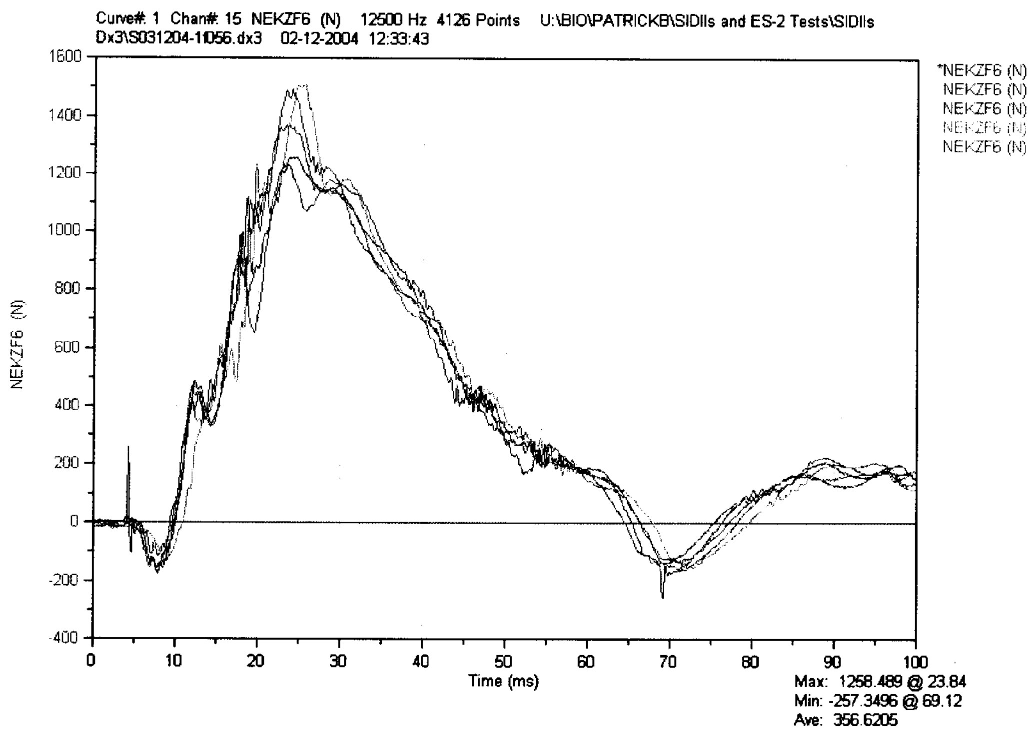

Figure A.7.b. Upper Neck Axial Force – Dummy 056

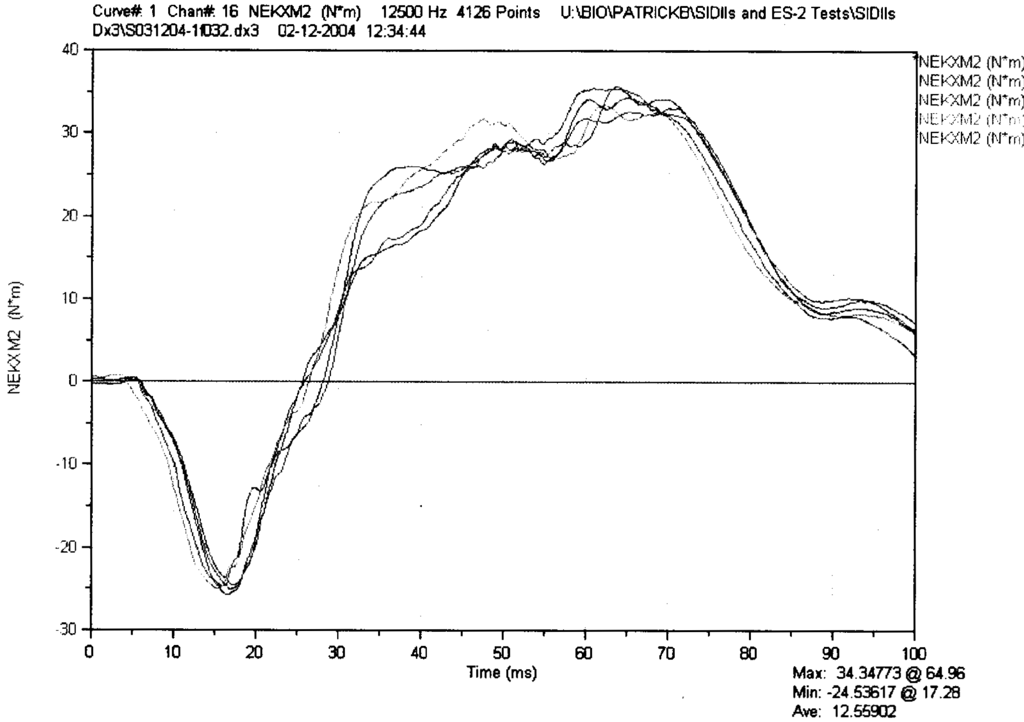

Figure A.8.a. Upper Neck Lateral Bending Moment – Dummy 032

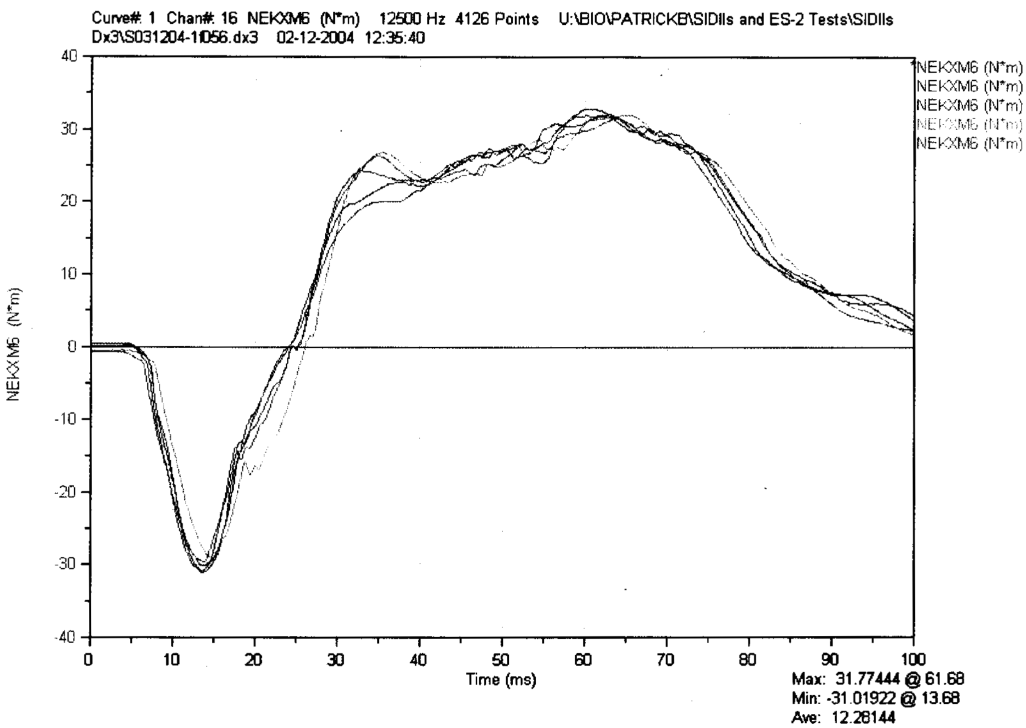

Figure A.8.b. Upper Neck Lateral Bending Moment – Dummy 056

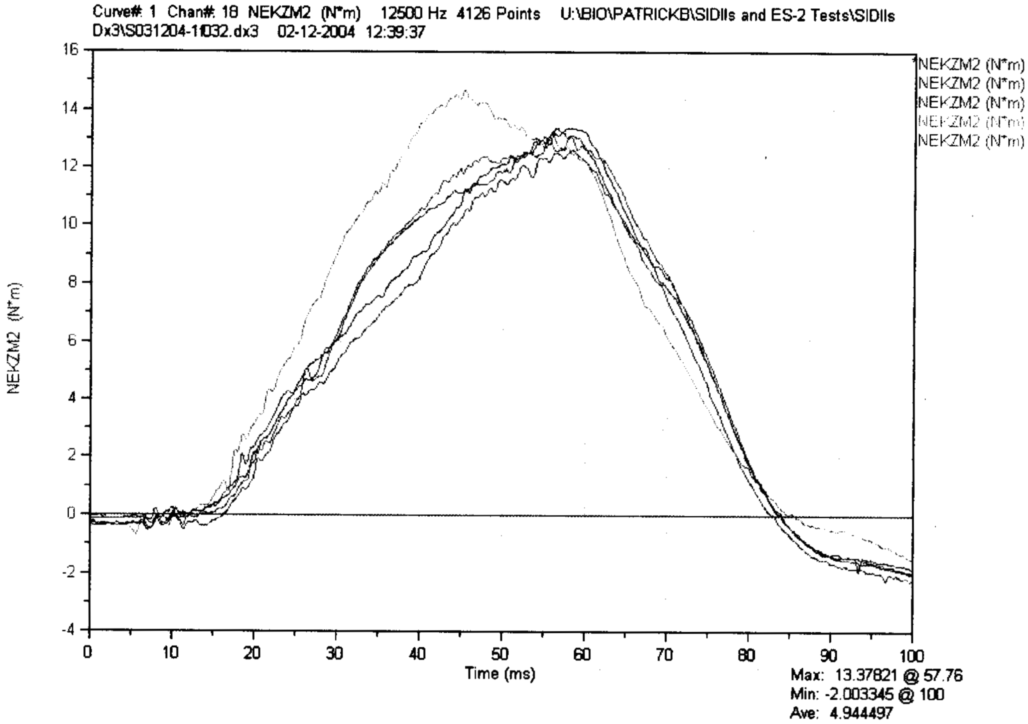

Figure A.9.a. Upper Neck Axial Moment – Dummy 032

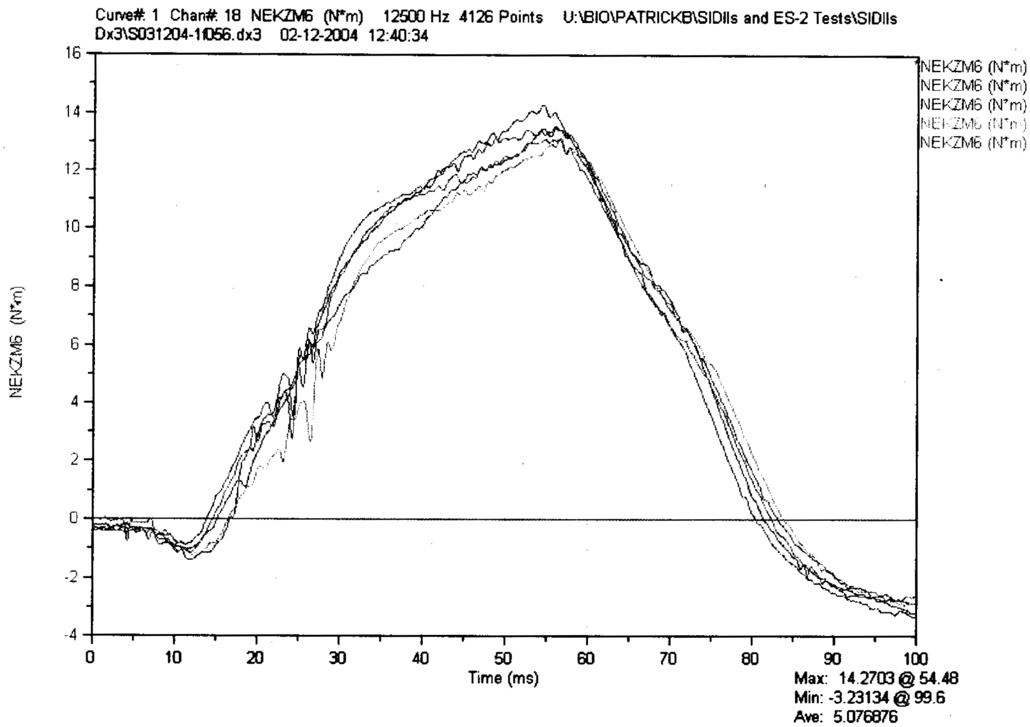

Figure A.9.b. Upper Neck Axial Moment – Dummy 056

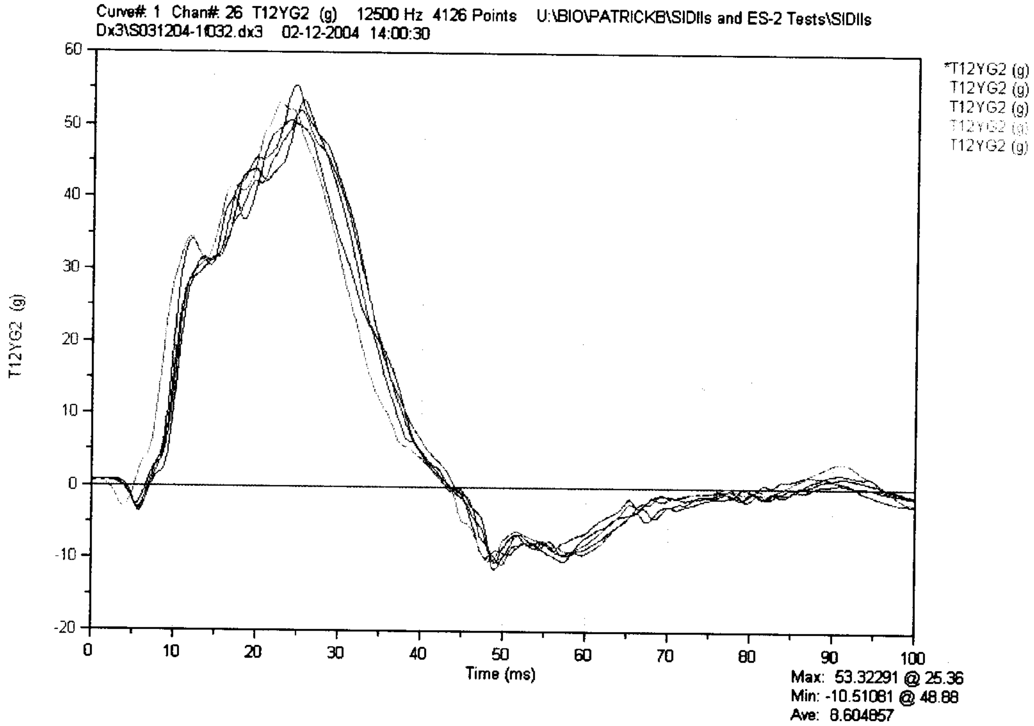

Figure A.10.a. Lower Spine Lateral Acceleration – Dummy 032

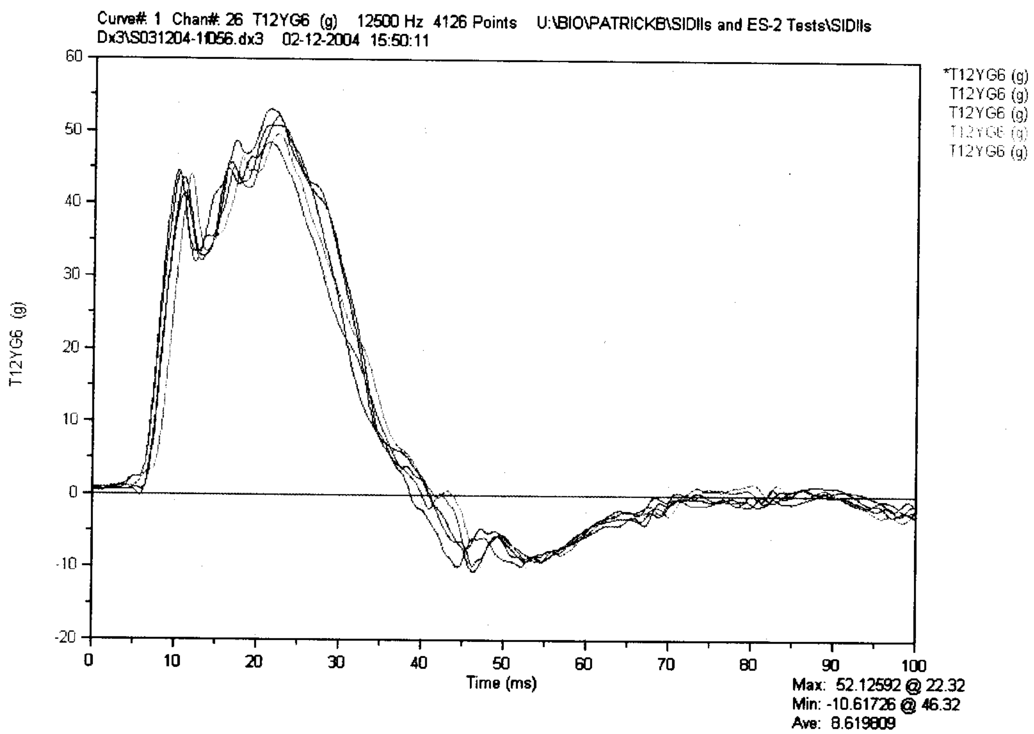

Figure A.10.b. Lower Spine Lateral Acceleration – Dummy 056

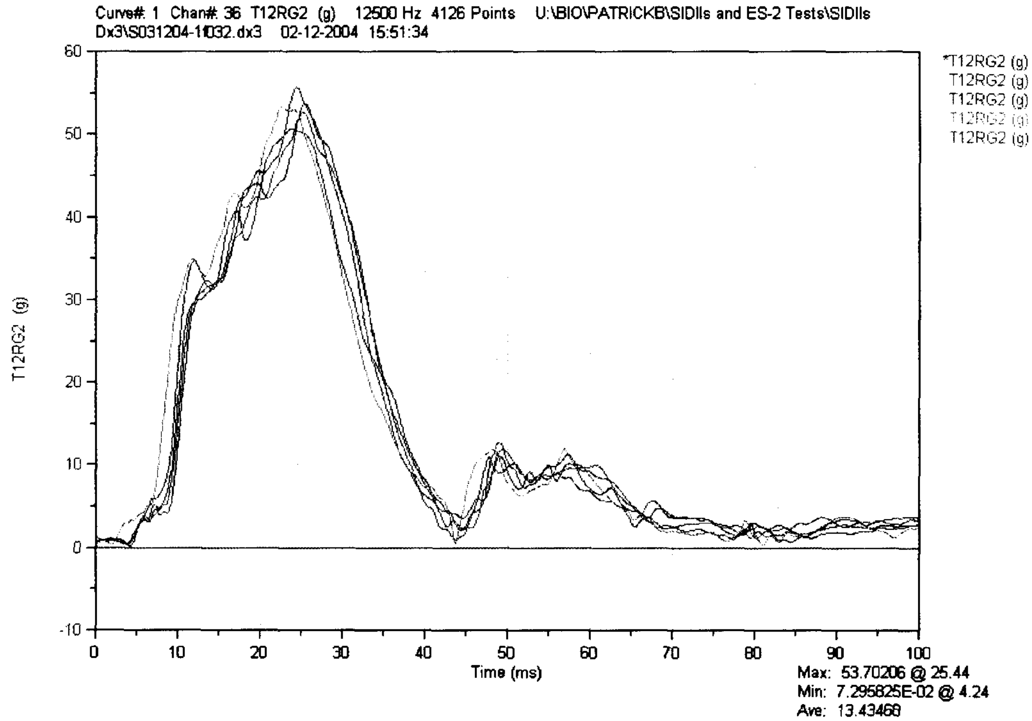

Figure A.11.a. Lower Spine Resultant Acceleration – Dummy 032

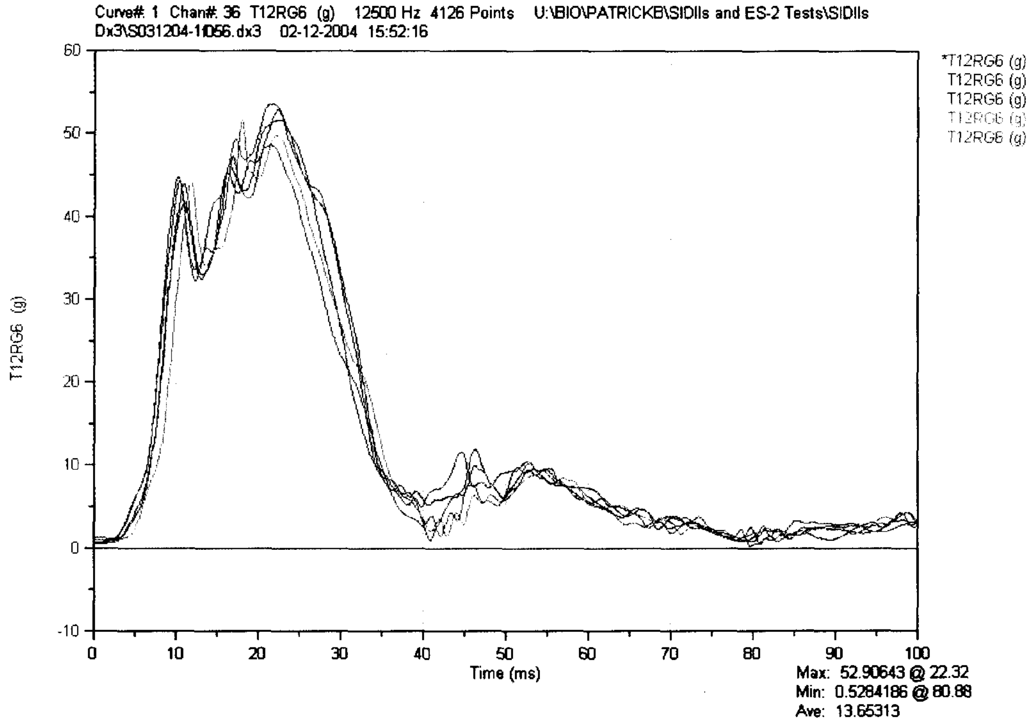

Figure A.11.b. Lower Spine Resultant Acceleration – Dummy 056

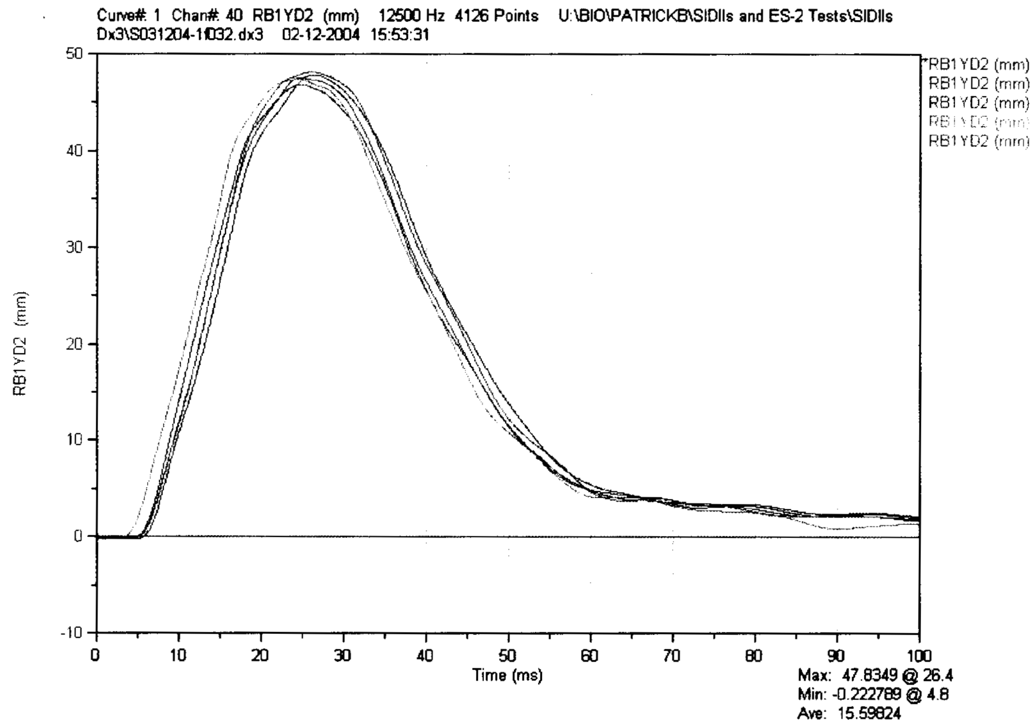

Figure A.12.a. Upper Thoracic Rib Deflection – Dummy 032

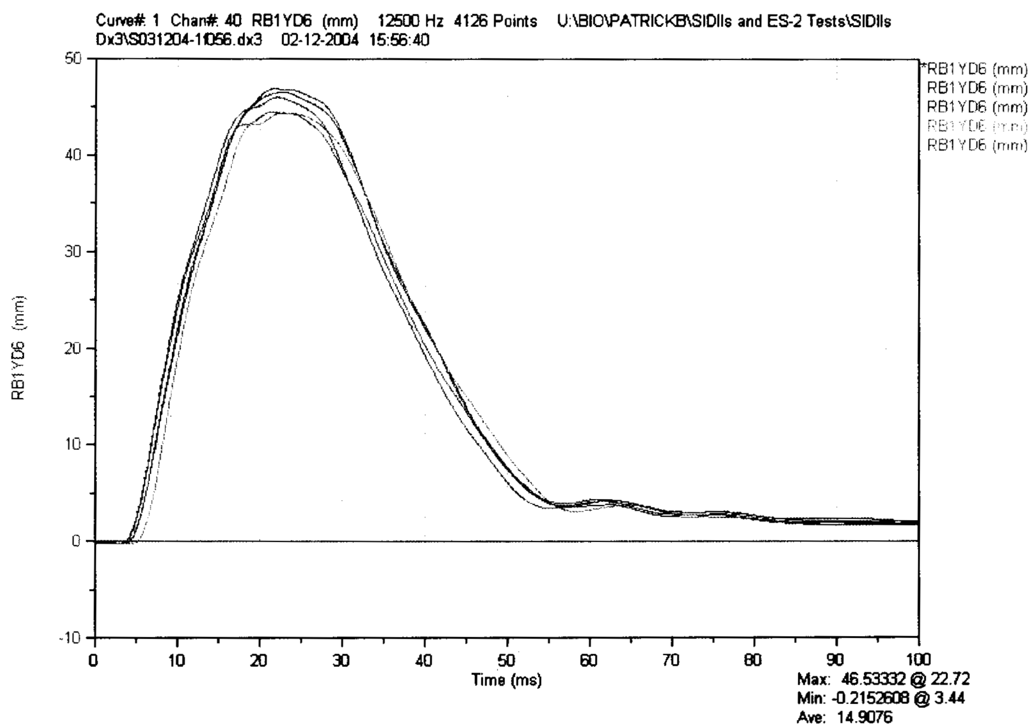

Figure A.12.b. Upper Thoracic Rib Deflection – Dummy 056

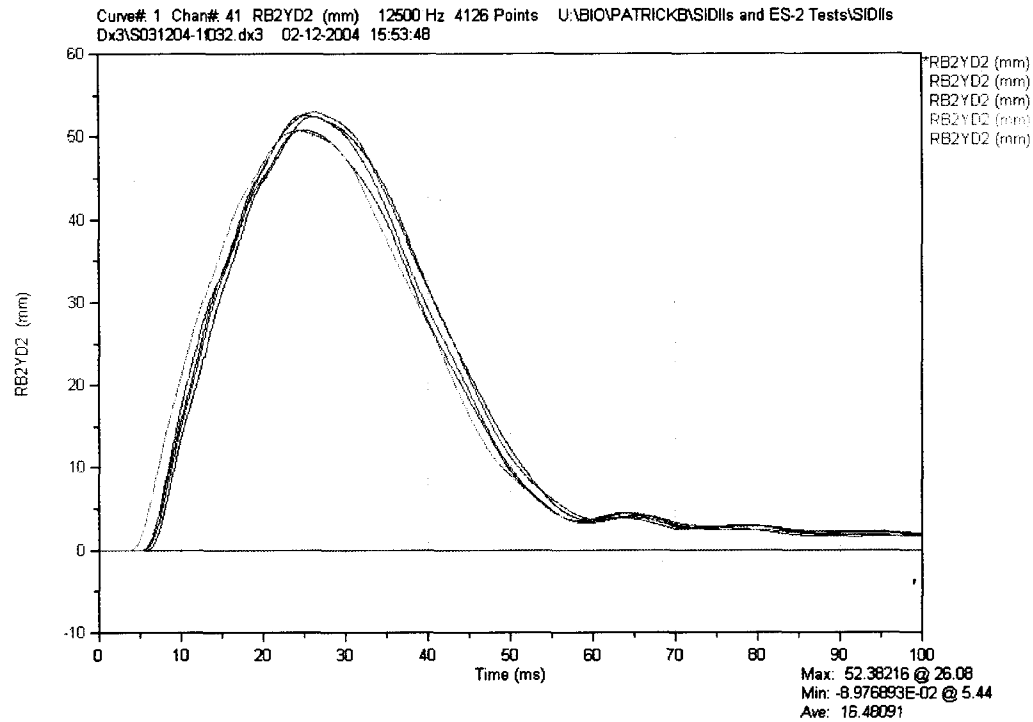

Figure A.13.a. Middle Thoracic Rib Deflection – Dummy 032

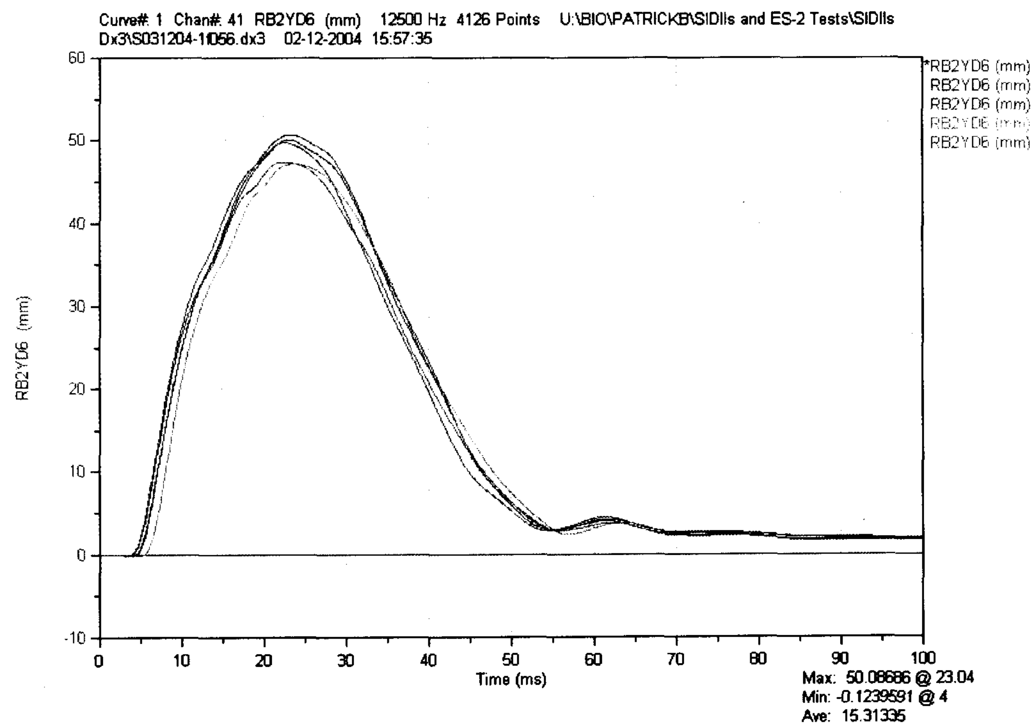

Figure A.13.b. Middle Thoracic Rib Deflection – Dummy 056

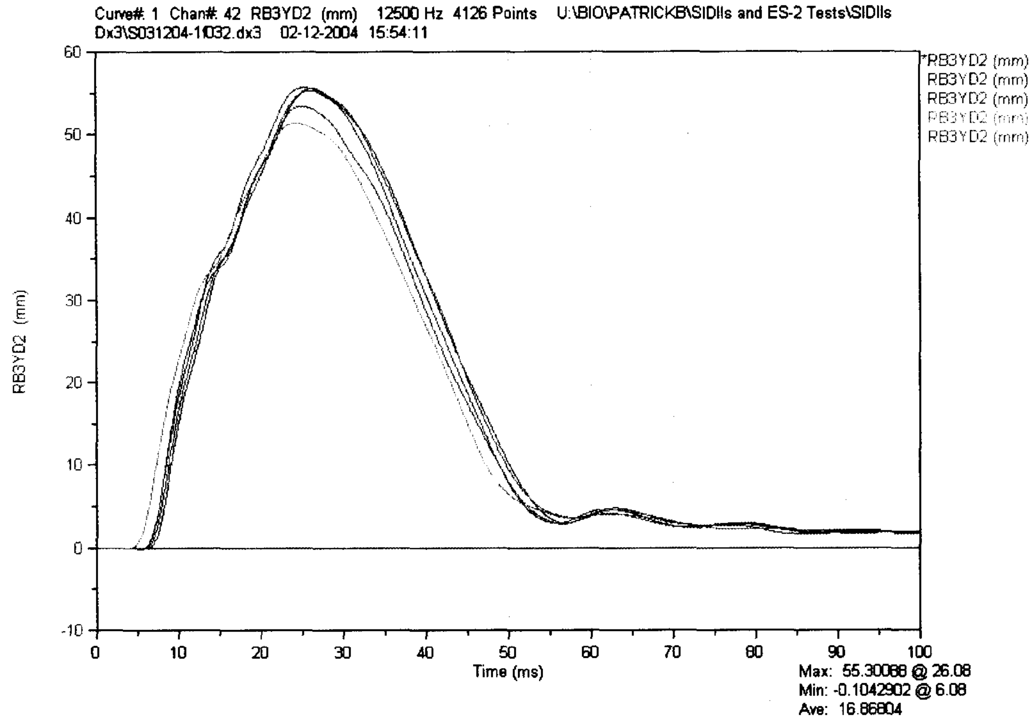

Figure A.14.a. Lower Thoracic Rib Deflection – Dummy 032

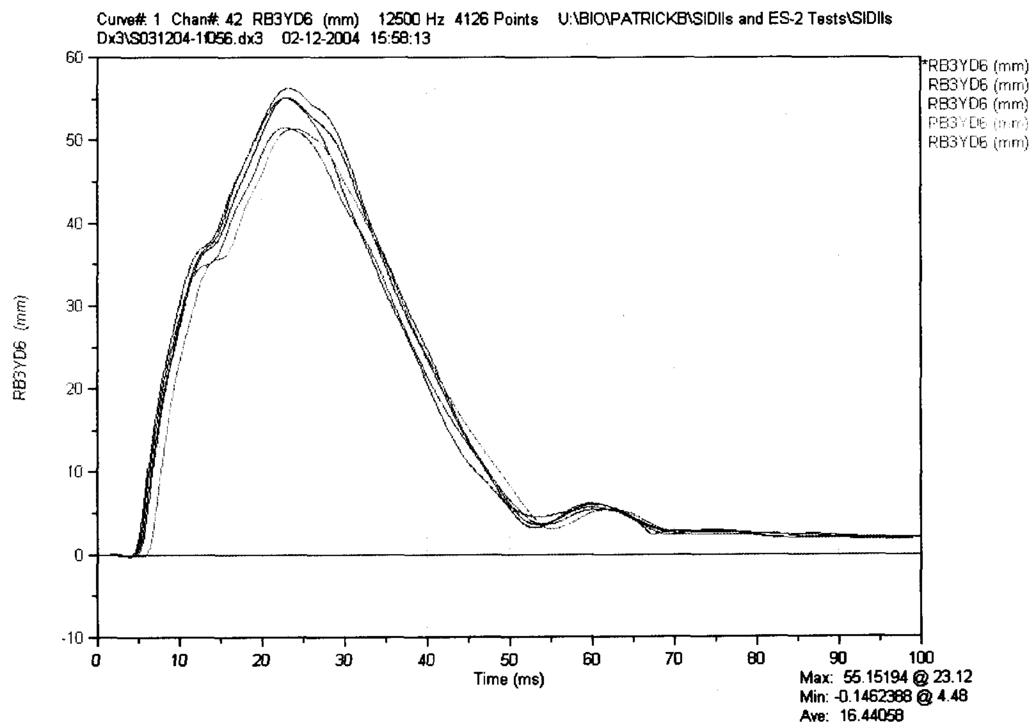

Figure A.14.b. Lower Thoracic Rib Deflection – Dummy 056

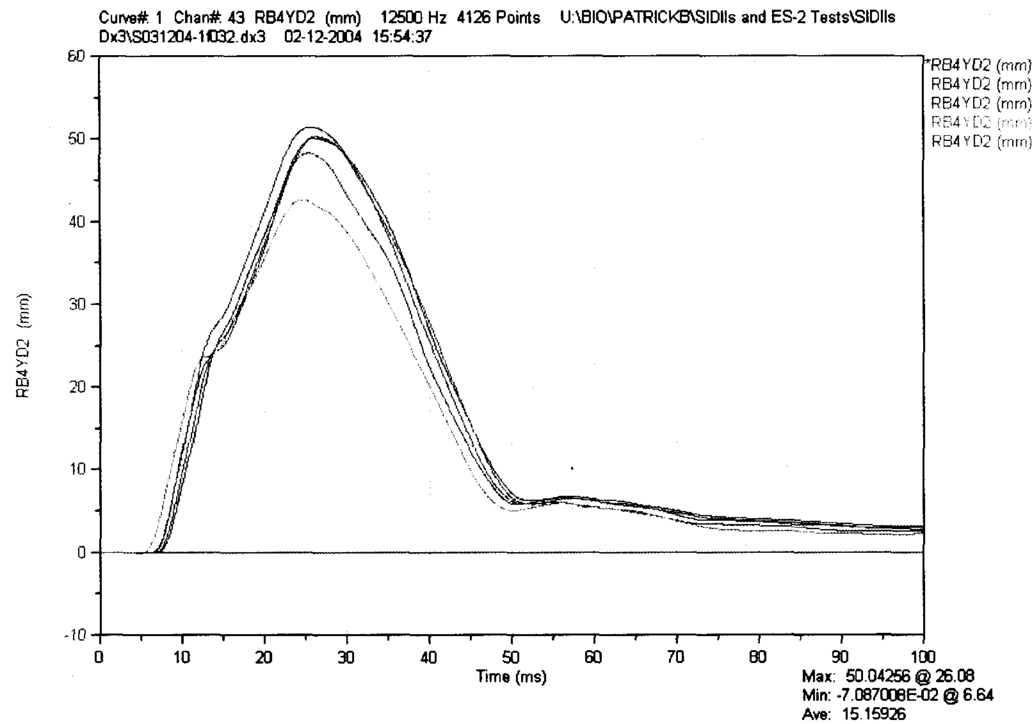

Figure A.15.a. Upper Abdominal Rib Deflection – Dummy 032

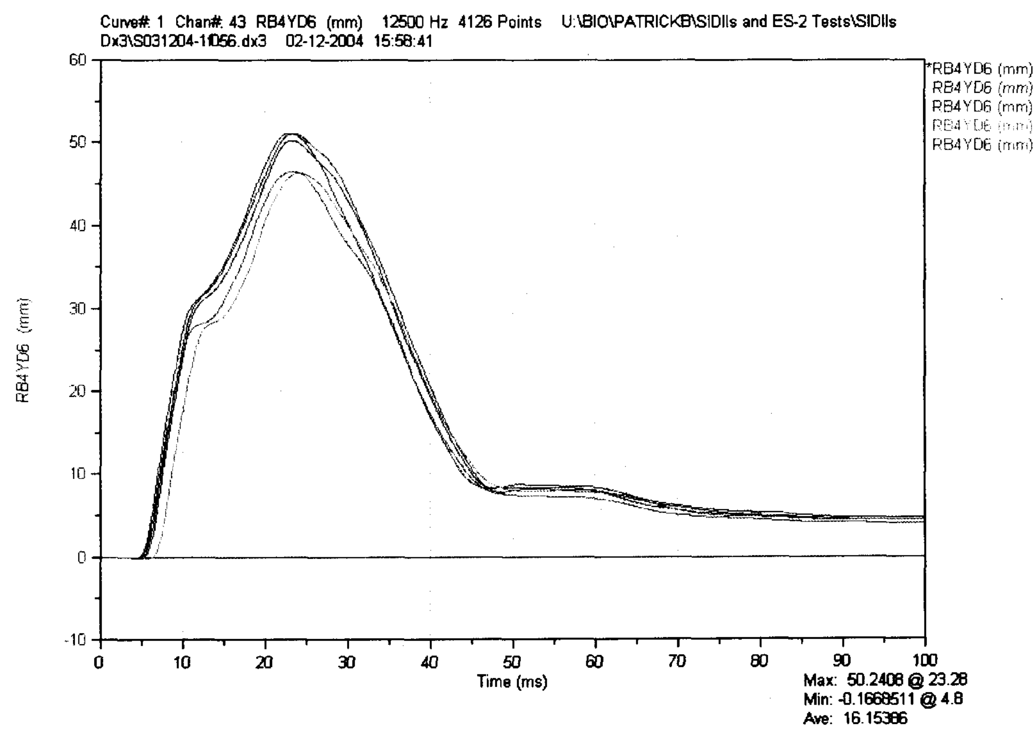

Figure A.15.b. Upper Abdominal Rib Deflection – Dummy 056

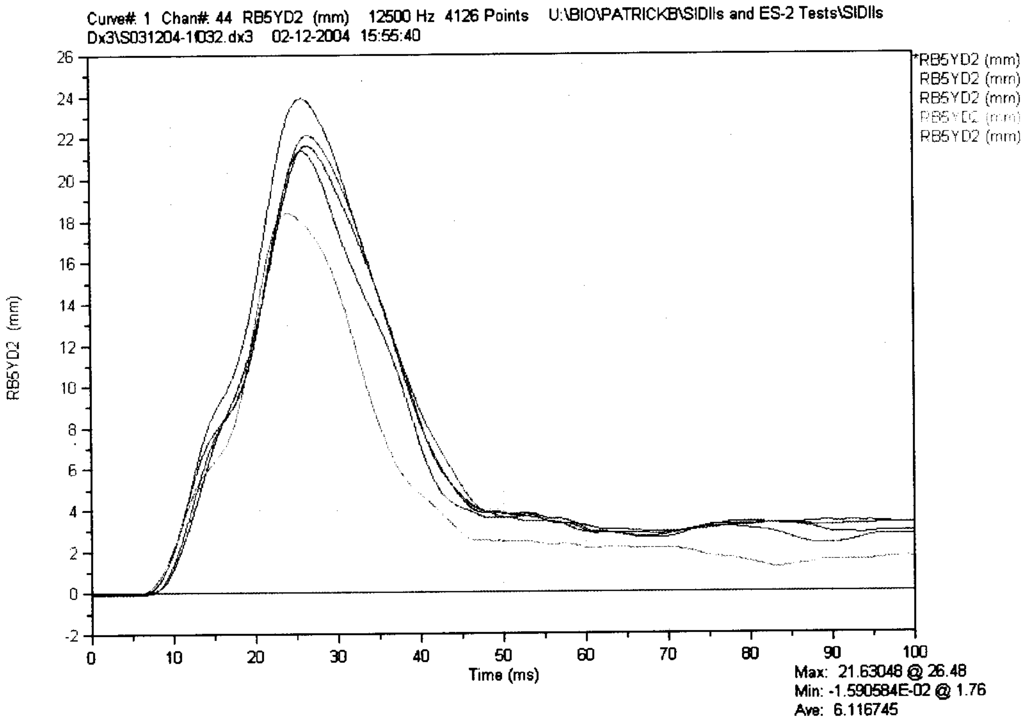

Figure A.16.a. Lower Abdominal Rib Deflection – Dummy 032

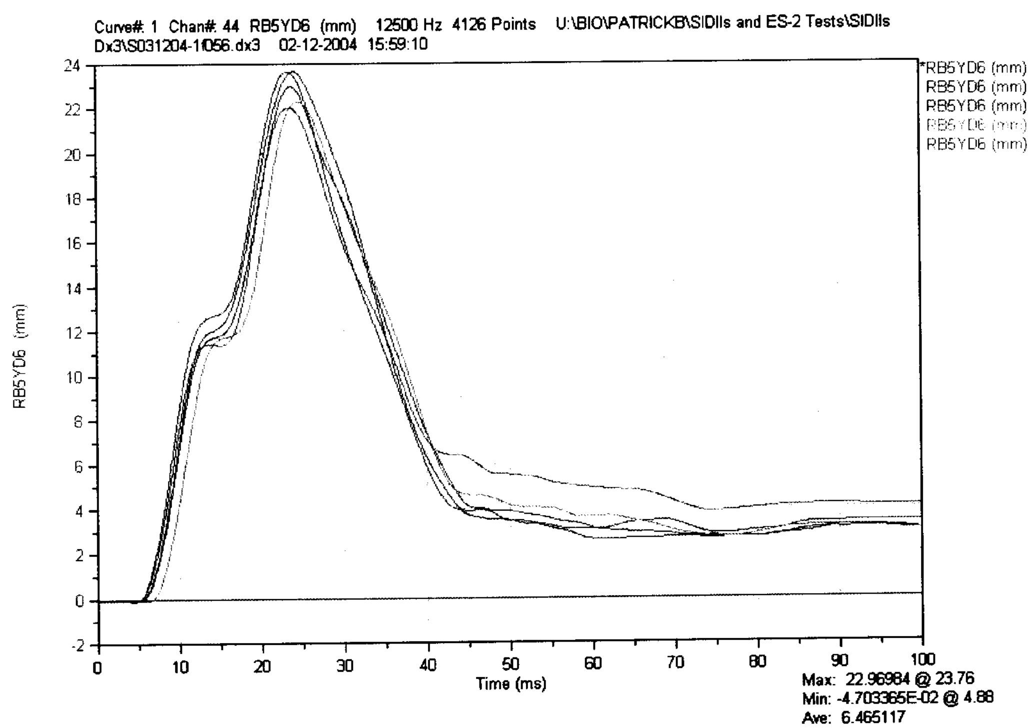

Figure A.16.b. Lower Abdominal Rib Deflection – Dummy 056

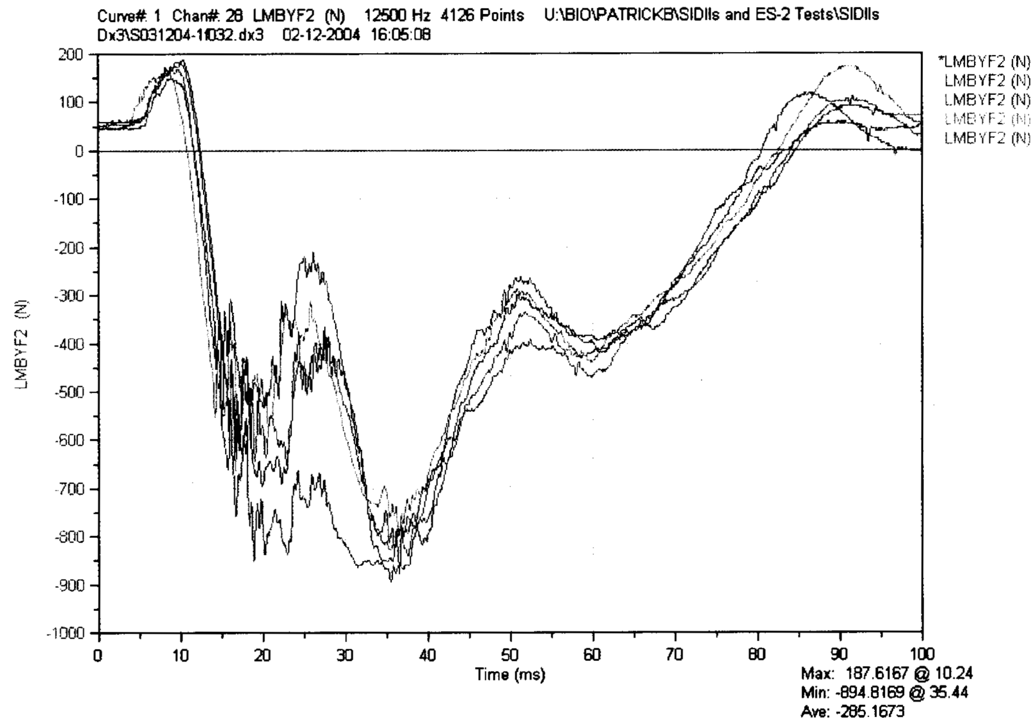

Figure A.17.a. Lumbar Lateral Shear Force – Dummy 032

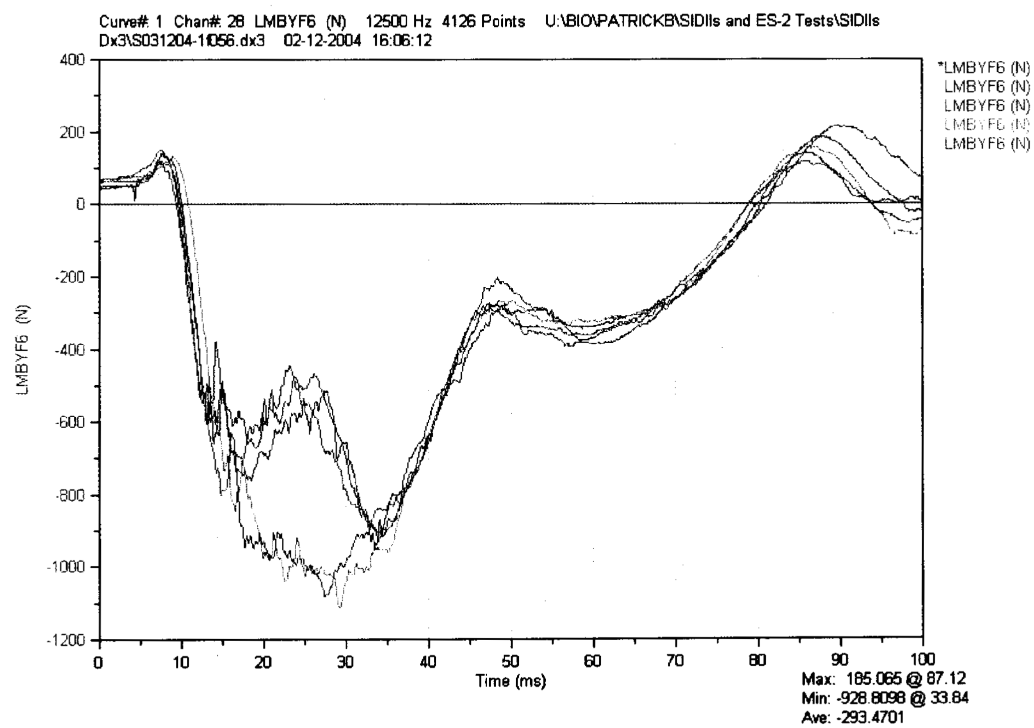

Figure A.17.b. Lumbar Lateral Shear Force – Dummy 056

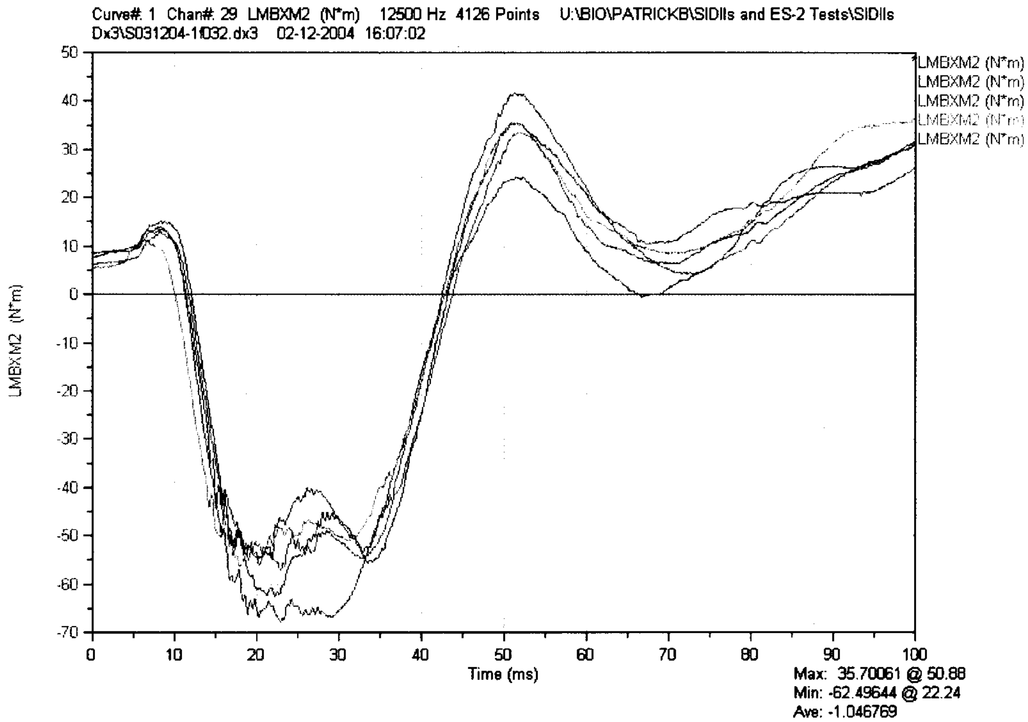

Figure A.18.a. Lumbar Lateral Bending Moment – Dummy 032

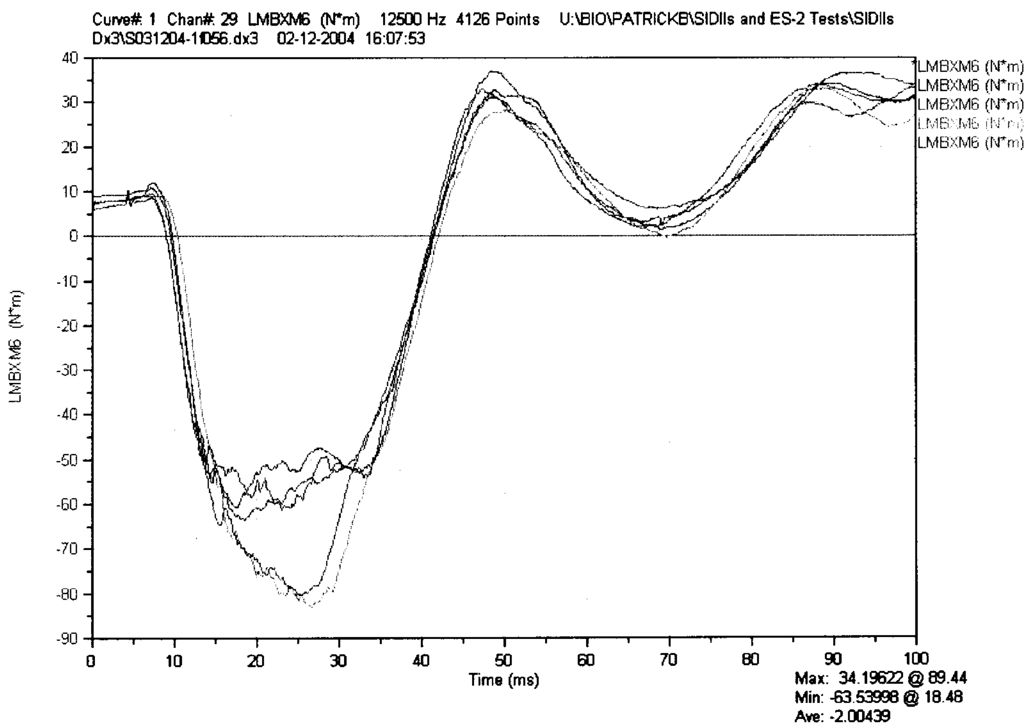

Figure A.18.b. Lumbar Lateral Bending Moment – Dummy 056

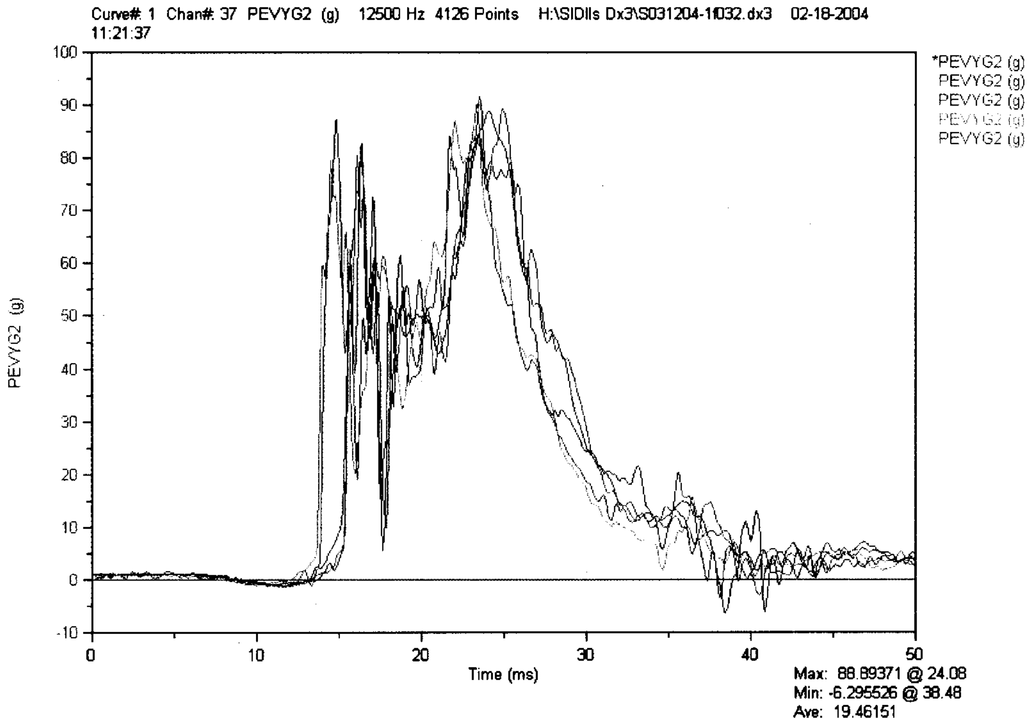

Figure A.19.a. Pelvis Lateral Acceleration – Dummy 032

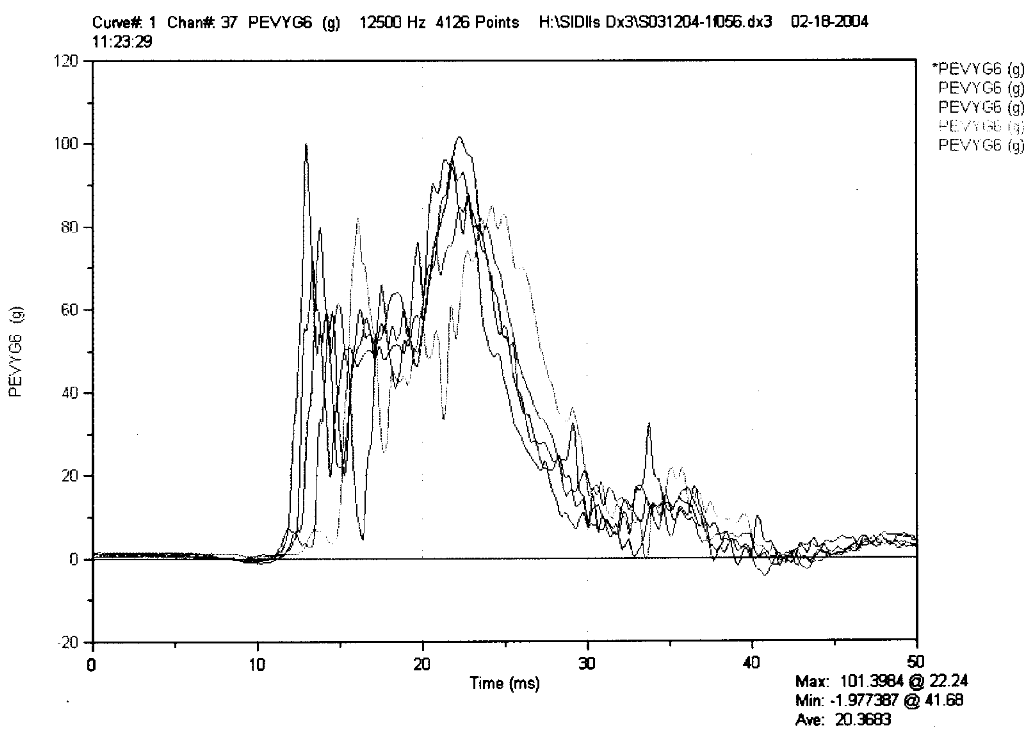

Figure A.19.b. Pelvis Lateral Acceleration – Dummy 056

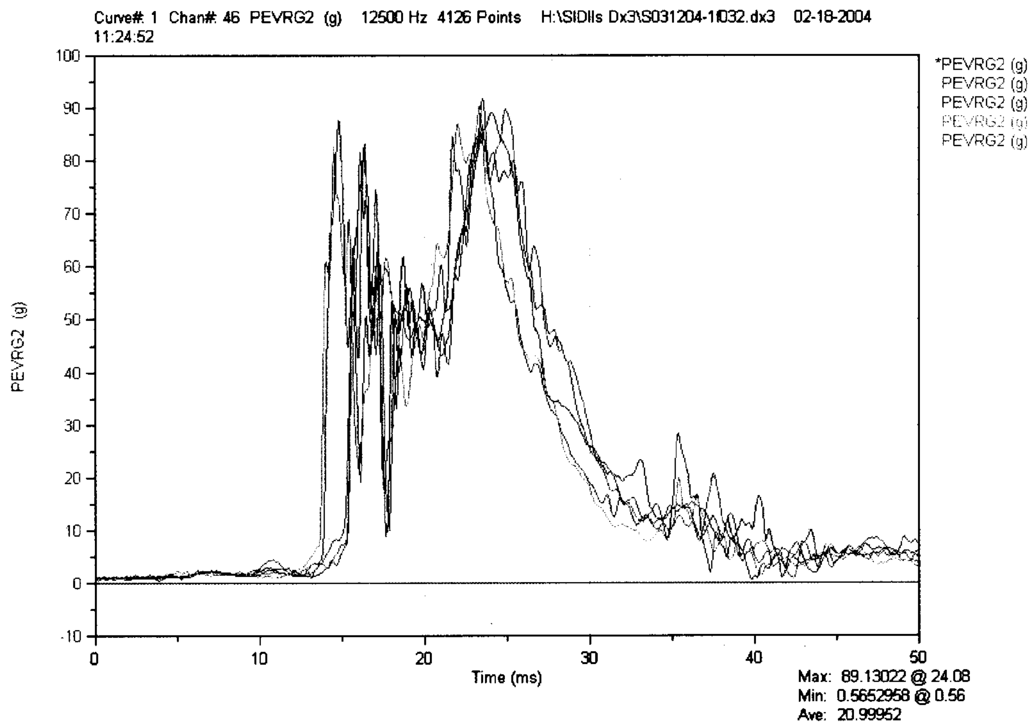

Figure A.20.a. Pelvis Resultant Acceleration – Dummy 032

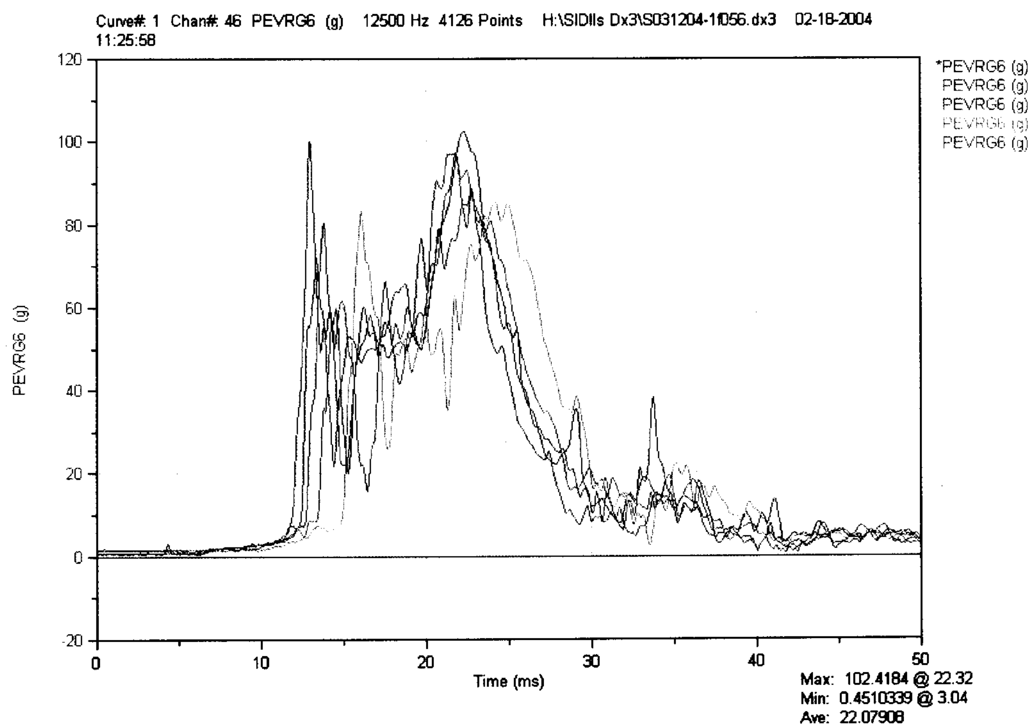

Figure A.20.b. Pelvis Resultant Acceleration – Dummy 056

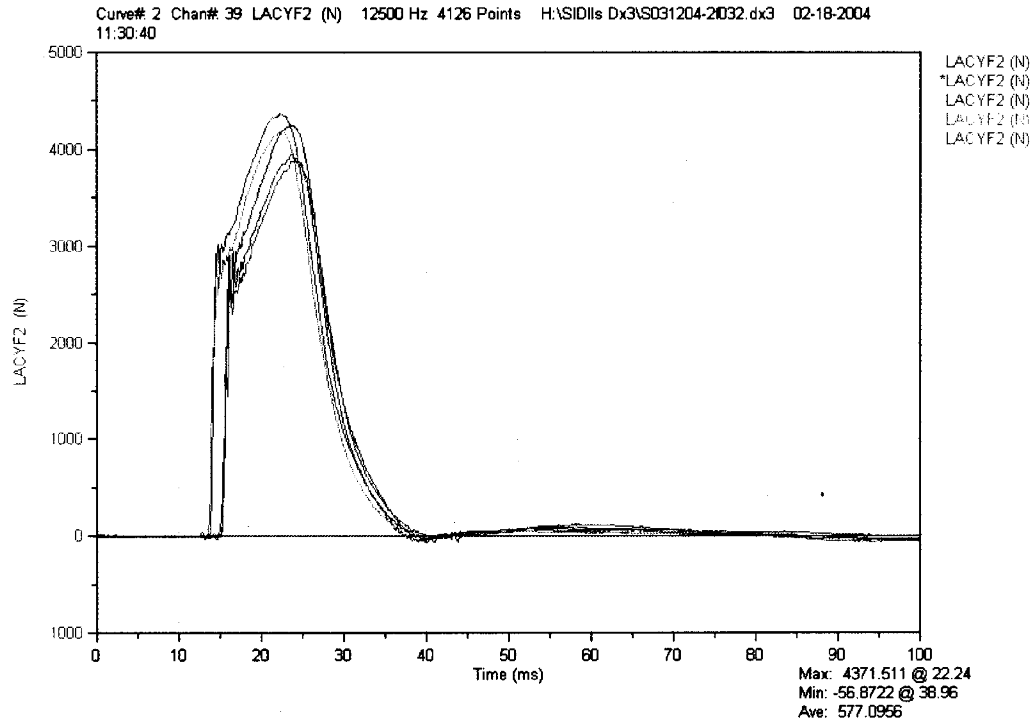

Figure A.21.a. Left Acetabulum Lateral Force – Dummy 032

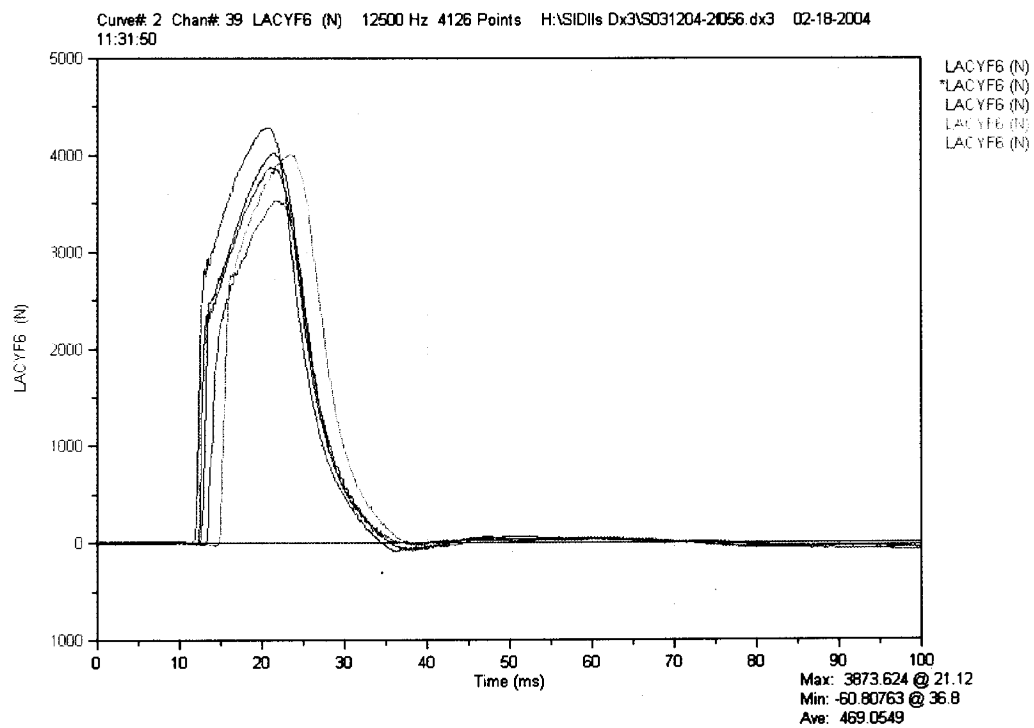

Figure A.21.b. Left Acetabulum Lateral Force – Dummy 056

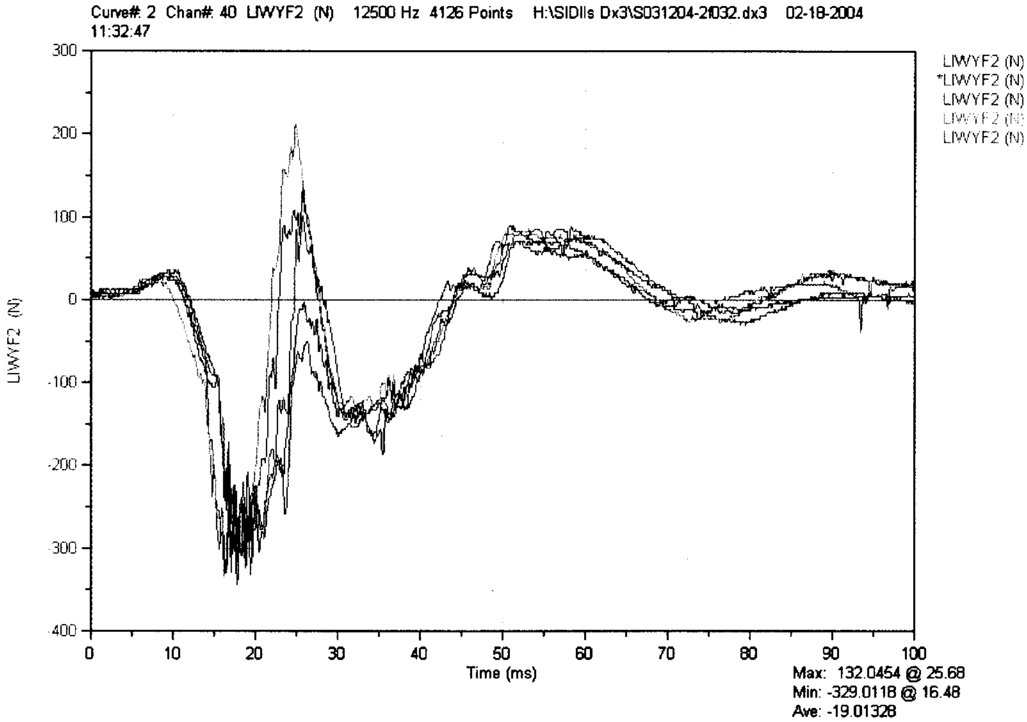

Figure A.22.a. Left Iliac Wing Lateral Force – Dummy 032

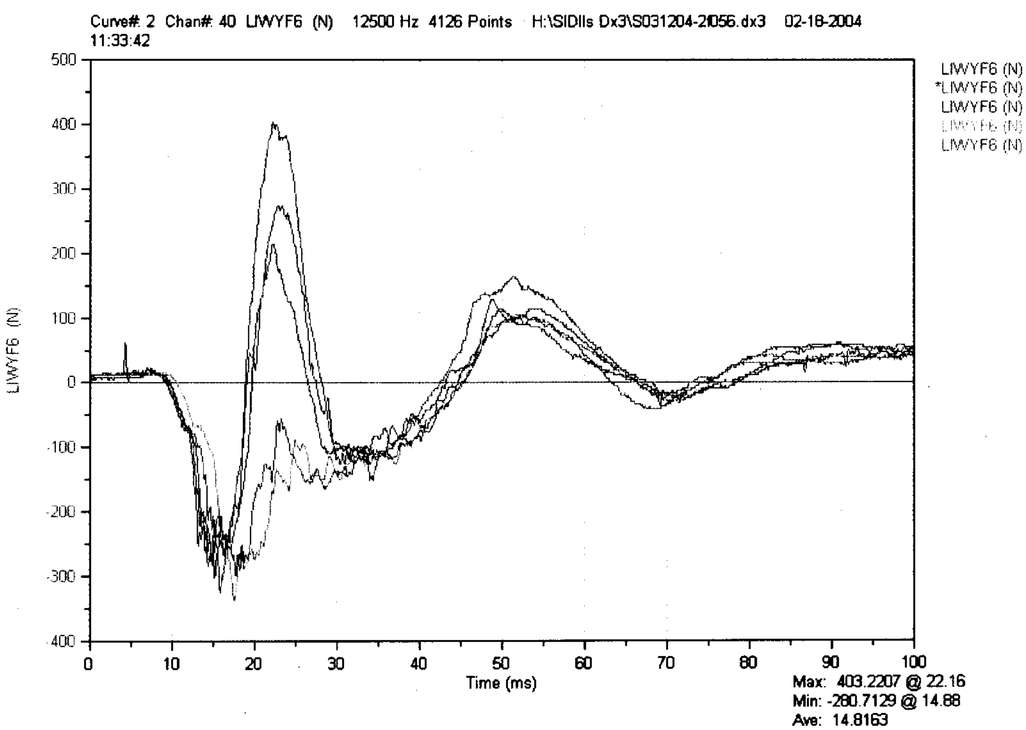

Figure A.22.b. Left Iliac Wing Lateral Force – Dummy 056

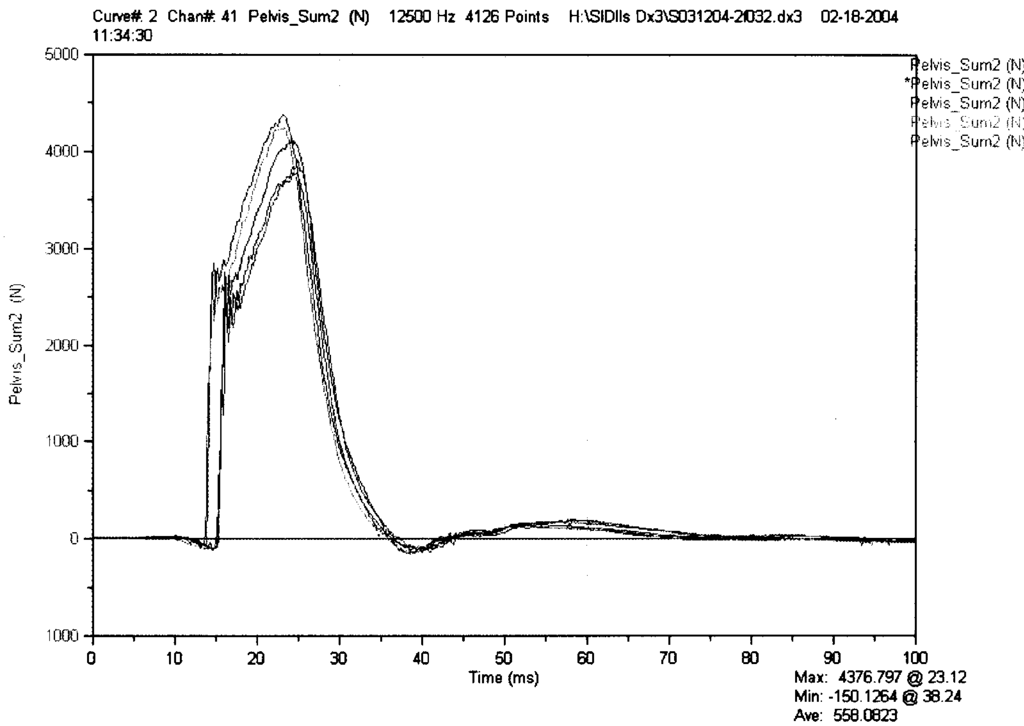

Figure A.23.a. Sum of Acetabulum and Iliac Wing Lateral Forces – Dummy 032

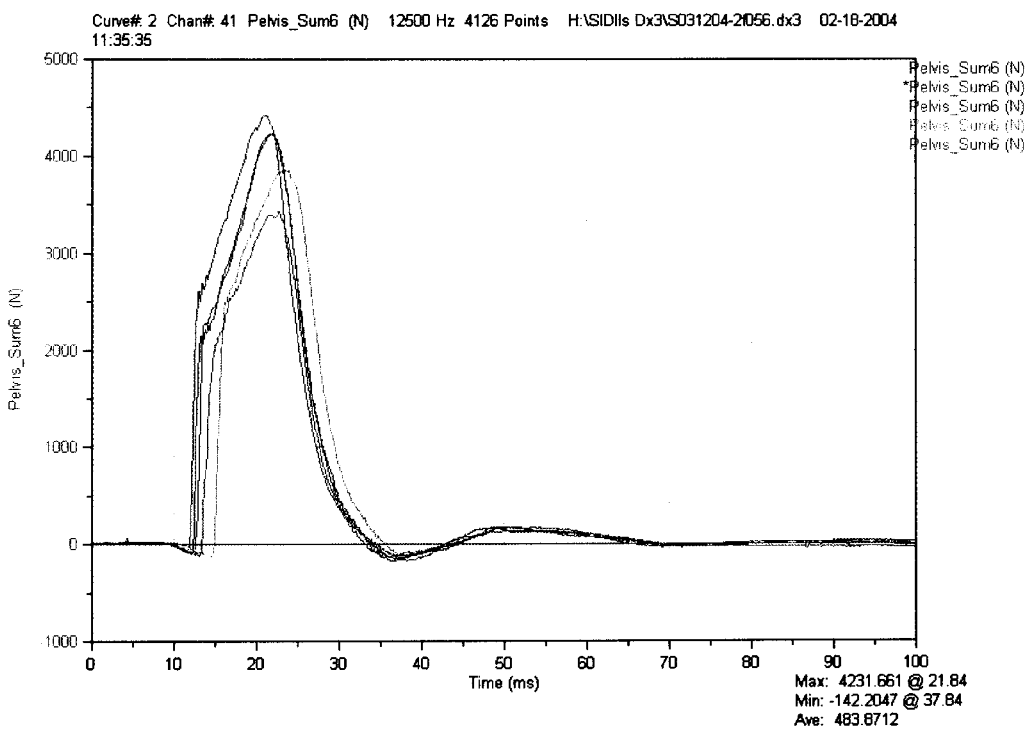

Figure A.23.b. Sum of Acetabulum and Iliac Wing Lateral Forces – Dummy 056

Appendix B.
6.0 m/s Rigid Flat Wall Sled Test Responses

Table B.1. Peak Responses During 6.0 m/s Rigid Flat Wall Sled Tests

				Test Condition	6.0 m/s Flat Rigid Wall									
				Dummy Serial Number	32					56				
				Dummy Position	left	left	left	right	right	right	right	right	left	left
Location	**Measurement**	**Direction**	**Units**	**Filter Class / Test # S0312---**	09-1	09-2	10-1	10-2	10-3	09-1	09-2	10-1	10-2	10-3
Head	Max Displacement	lateral	mm	n/a	245	243	247	241	259	259	255	249	258	255
		vertical	mm	n/a	106	91	106	99	128	112	104	95	98	103
	Time of Max Displacement	n/a	ms	n/a	145	141	142	140	151	149	146	142	143	145
	Acceleration	Y	g	CFC 1000	13.8	14.8	14.3	14.0	13.7	12.9	13.3	13.0	13.0	13.2
		Z	g	CFC 1000	25.5	26.3	25.4	26.6	26.4	27.6	30.2	28.4	28.0	30.1
		Resultant	g	CFC 1000	27.1	27.8	26.9	28.2	27.7	28.7	31.4	29.5	29.3	31.3
	HIC 36	**n/a**	**n/a**	**CFC 1000**	**67.5**	**70.0**	**68.9**	**68.5**	**69.9**	**71.6**	**77.6**	**71.6**	**72.6**	**78.3**
Upper Neck	Force	Y	N	CFC 1000	462.7	486.5	474.9	464.1	457.2	454.9	455.5	458.6	469.4	467.9
		Z	N	CFC 1000	878.9	883.6	868.1	901.0	872.2	1009.5	1066.7	1015.8	1028.1	1070.6
	Moment	+X	N-m	CFC 600	28.9	28.6	28.7	26.8	28.0	25.4	25.8	26.4	26.0	26.3
		-X	N-m	CFC 600	-19.4	-19.3	-18.9	-17.6	-16.6	-24.1	-24.8	-24.3	-23.7	-24.1
		Z	N-m	CFC 600	11.9	11.8	11.8	11.4	11.0	11.0	10.7	10.5	11.1	11.3
T1	Acceleration	Y	g	CFC 180	37.8	38.3	36.6	36.2	35.9	41.1	42.3	40.9	40.4	40.2
		Resultant	g	CFC 180	38.2	38.6	37.2	37.1	36.6	41.2	42.5	41.0	40.5	40.3
T12	**Acceleration**	Y	g	CFC 180	39.7	39.6	41.7	37.0	36.9	36.7	36.0	40.8	39.0	38.2
		Resultant	**g**	**CFC 180**	**39.7**	**39.7**	**41.8**	**37.1**	**37.0**	**36.7**	**36.5**	**41.0**	**39.2**	**38.3**
Shoulder Rib	Displacement	Y	mm	CFC 600	42.8	43.2	43.5	42.5	44.2	44.4	44.3	44.8	44.5	46.1
Thorax Rib 1	**Displacement**	**Y**	**mm**	**CFC 180**	**37.5**	**37.7**	**38.2**	**36.8**	**37.8**	**34.9**	**34.3**	**35.4**	**35.2**	**36.4**
Thorax Rib 2	**Displacement**	**Y**	**mm**	**CFC 180**	**41.8**	**42.1**	**42.3**	**41.0**	**40.9**	**37.3**	**36.8**	**38.3**	**37.7**	**38.8**
Thorax Rib 3	**Displacement**	**Y**	**mm**	**CFC 180**	**44.5**	**44.5**	**44.9**	**43.5**	**42.3**	**39.8**	**38.6**	**40.8**	**40.1**	**41.1**
Abdomen Rib 1	**Displacement**	**Y**	**mm**	**CFC 180**	**38.5**	**39.0**	**38.8**	**37.3**	**34.8**	**35.2**	**34.7**	**37.4**	**36.1**	**37.1**
Abdomen Rib 2	**Displacement**	**Y**	**mm**	**CFC 180**	**16.2**	**16.5**	**16.6**	**15.9**	**13.9**	**14.7**	**14.0**	**15.6**	**14.6**	**14.9**
Lumbar	Force	Y	N	CFC 1000	-824.7	-827.3	-838.4	-844.5	-868.0	-1020.7	-1069.7	-905.5	-976.9	-1011.0
	Moment	X	N-m	CFC 1000	-60.8	-56.0	-56.9	-61.3	-65.6	-67.1	-69.9	-58.7	-63.5	-68.2
Acetabulum	Force	Y	N	CFC 600	3250.5	3393.4	3612.9	3442.9	3243.7	3010.6	3232.8	3579.9	3219.1	3020.3
Iliac Wing	Force	Y	N	CFC 600	-281.8	-297.1	-304.3	-282.5	-315.0	-273.7	-304.2	-318.9	-287.1	-279.8
Sum of Acetabulum and Iliac	**Force**	**Y**	**N**	**CFC 600**	**3036.2**	**3158.4**	**3369.7**	**3197.3**	**2995.4**	**2834.0**	**3042.3**	**3384.7**	**3046.9**	**2828.7**
Pelvis*	Acceleration	Y	g	CFC 1000	62.3	63.3	60.4	64.8	59.2	69.5	61.6	69.4	64.9	63.5
		Resultant	g	CFC 1000	73.2	72.6	110.0	65.2	74.5	71.3	63.9	81.8	78.9	65.7
Sled	Acceleration	X	g	CFC 60	-11.6	-11.7	-11.7	-11.7	-11.7	-11.6	-11.7	-11.7	-11.7	-11.7
Sled	Velocity	X	m/s	CFC 60	-5.8	-5.8	-5.8	-5.8	-5.9	-5.8	-5.8	-5.8	-5.8	-5.9

Bold type indicates proposed injury criteria measures

*For Pelvis Y Acceleration, second peak is shown in table.

Table B.2. Statistical Analysis for 6.0 m/s Rigid Flat Wall Sled Tests

Location	Measurement	Direction	Units	Filter Class / Statistical Parameters	32 AVG	32 SD	32 %CV	56 AVG	56 SD	56 %CV	032 & 056 AVG	032 & 056 SD	032 & 056 % CV
				Test Condition	6.0 m/s Flat Rigid Wall								
				Dummy Serial Number	32			56			032 & 056		
				Dummy Position	left & right			left & right			left & right		
Head	Max Displacement	lateral	mm	n/a	247.0	7.1	2.9	255.2	3.9	1.5	251.1	6.9	2.7
		vertical	mm	n/a	106.0	13.8	13.0	102.4	6.5	6.4	104.2	10.3	9.9
	Time of Max Displacement	n/a	ms	n/a	143.8	4.4	3.1	145.0	2.7	1.9	144.4	3.5	2.4
	Acceleration	Y	g	CFC 1000	14.1	0.4	3.1	13.1	0.2	1.2	13.6	0.6	4.6
		Z	g	CFC 1000	26.0	0.5	2.1	28.9	1.2	4.2	27.4	1.7	6.3
		Resultant	g	CFC 1000	27.5	0.5	1.9	30.0	1.2	4.1	28.8	1.6	5.5
	HIC 36	**n/a**	**n/a**	**CFC 1000**	**69.0**	**1.0**	**1.5**	**74.3**	**3.3**	**4.5**	**71.6**	**3.7**	**5.1**
Upper Neck	Force	Y	N	CFC 1000	469.1	11.6	2.5	461.3	6.9	1.5	465.2	9.9	2.1
		Z	N	CFC 1000	880.8	12.8	1.5	1038.1	28.7	2.8	959.4	85.6	8.9
	Moment	+X	N-m	CFC 600	28.2	0.8	2.9	26.0	0.4	1.5	27.1	1.3	4.9
		-X	N-m	CFC 600	-18.4	1.2	-6.6	-24.2	0.4	-1.6	-21.3	3.2	[illegible]
		Z	N-m	CFC 600	11.6	0.4	3.2	10.9	0.3	2.9	11.2	0.5	4.2
T1	Acceleration	Y	g	CFC 180	37.0	1.1	2.9	41.0	0.8	2.0	39.0	2.3	5.9
		Resultant	g	CFC 180	37.5	0.9	2.3	41.1	0.8	2.0	39.3	2.1	5.2
T12	**Acceleration**	Y	g	CFC 180	39.0	2.0	5.2	38.1	1.9	5.0	38.6	1.9	4.9
		Resultant	**g**	**CFC 180**	**39.0**	**2.0**	**5.2**	**38.4**	**1.9**	**4.9**	**38.7**	**1.9**	**4.9**
Shoulder Rib	Displacement	Y	mm	CFC 600	43.3	0.7	1.6	44.8	0.8	1.7	44.0	1.1	2.4
Thorax Rib 1	**Displacement**	**Y**	**mm**	**CFC 180**	**37.6**	**0.5**	**1.3**	**35.2**	**0.8**	**2.2**	**36.4**	**1.4**	**3.8**
Thorax Rib 2	**Displacement**	**Y**	**mm**	**CFC 180**	**41.6**	**0.6**	**1.6**	**37.8**	**0.8**	**2.1**	**39.7**	**2.1**	**5.4**
Thorax Rib 3	**Displacement**	**Y**	**mm**	**CFC 180**	**43.9**	**1.0**	**2.4**	**40.1**	**1.0**	**2.4**	**42.0**	**2.3**	**5.4**
Abdomen Rib 1	**Displacement**	**Y**	**mm**	**CFC 180**	**37.7**	**1.7**	**4.6**	**36.1**	**1.2**	**3.2**	**36.9**	**1.6**	**4.4**
Abdomen Rib 2	**Displacement**	**Y**	**mm**	**CFC 180**	**15.8**	**1.1**	**6.9**	**14.8**	**0.6**	**4.0**	**15.3**	**1.0**	**6.6**
Lumbar	Force	Y	N	CFC 1000	-840.6	17.3	-2.1	-996.7	60.9	-6.1	-918.7	92.5	[illegible]
	Moment	X	N-m	CFC 1000	-60.1	3.9	-6.4	-65.5	4.5	-6.8	-62.8	4.8	-7.7
Acetabulum	Force	Y	N	CFC 600	3388.7	152.8	4.5	3212.5	230.8	7.2	3300.6	206.6	6.3
Iliac Wing	Force	Y	N	CFC 600	-296.1	14.3	-4.8	-292.7	18.6	-6.3	-294.4	15.7	-5.3
Sum of Acetabulum and Iliac	**Force**	**Y**	**N**	**CFC 600**	**3151.4**	**147.9**	**4.7**	**3027.3**	**226.5**	**7.5**	**3089.4**	**191.8**	**6.2**
Pelvis*	Acceleration	Y	g	CFC 1000	62.0	2.2	3.6	65.8	3.6	5.4	63.9	3.4	5.4
		Resultant	g	CFC 1000	79.1	17.6	[illegible]	72.3	7.9	[illegible]	75.7	13.4	[illegible]
Sled	Acceleration	X	g	CFC 60	-11.7	0.0	-0.3	-11.7	0.0	-0.3	-11.7	0.0	-0.3
Sled	Velocity	X	m/s	CFC 60	-5.8	0.0	-0.2	-5.8	0.0	-0.2	-5.8	0.0	-0.2

%CV<=5.0 | 5.1%<CV<=10.0% | CV>10.0%

Bold type indicates proposed injury criteria measures

*For Pelvis Y Acceleration, second peak is shown in table.

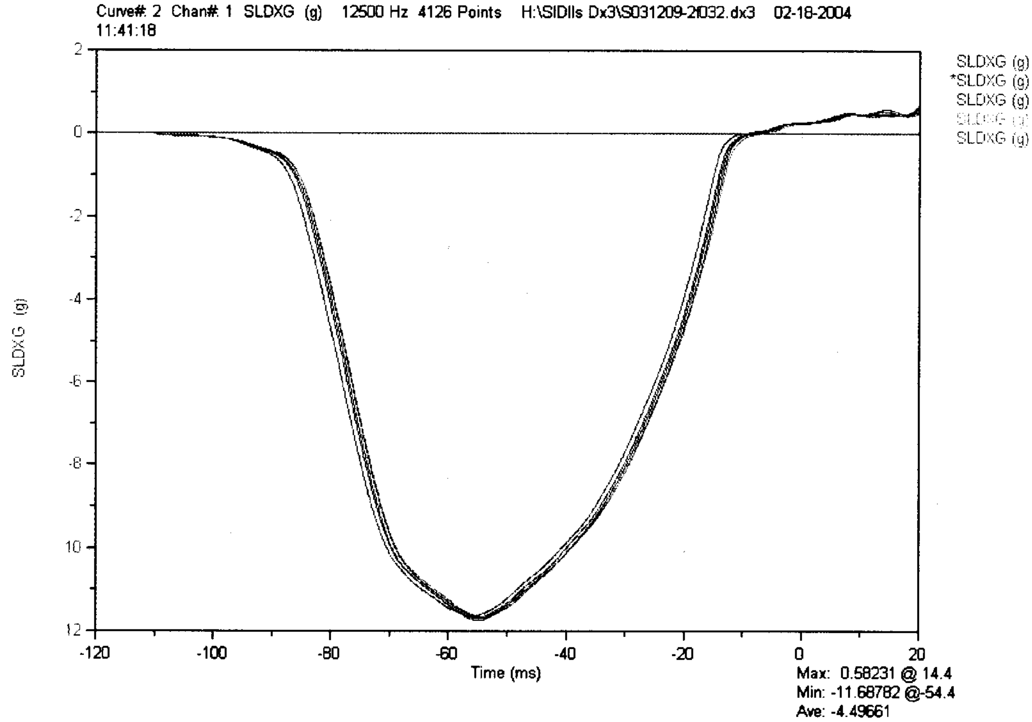

Figure B.1. Sled Acceleration Pulse

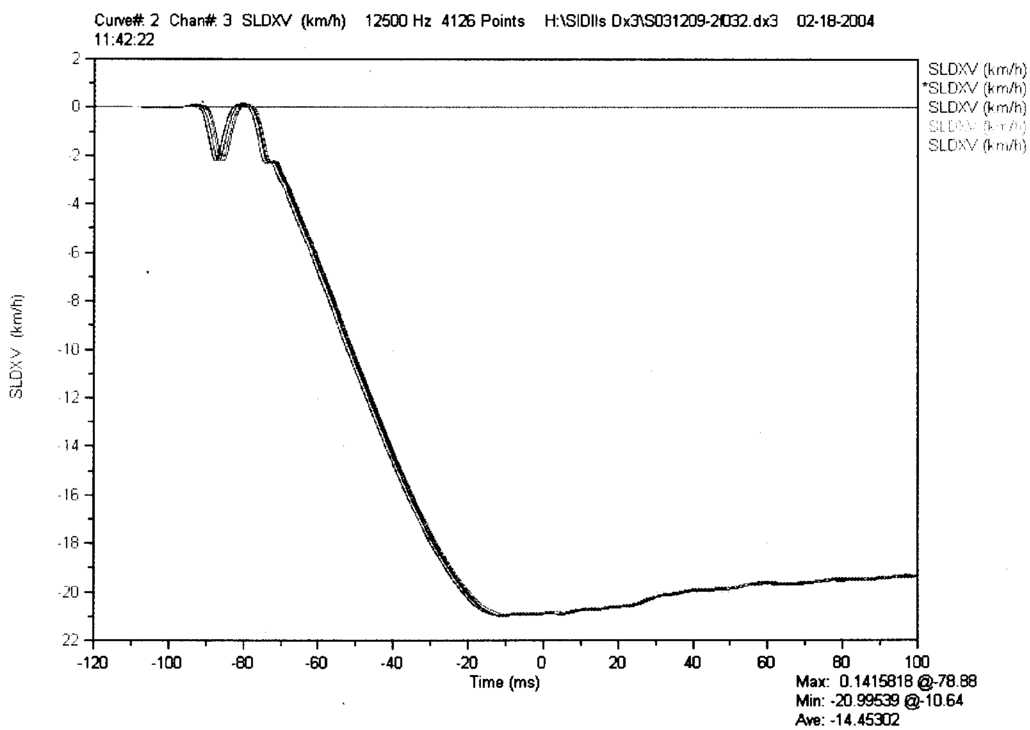

Figure B.2. Sled Velocity

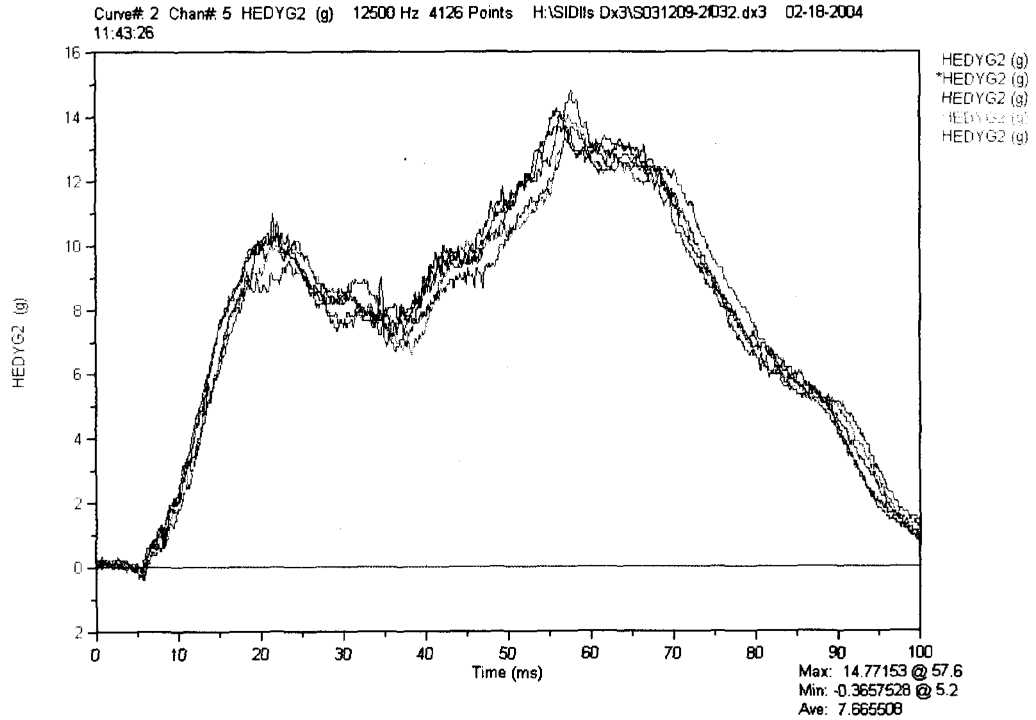

Figure B.3.a. Lateral Head Acceleration – Dummy 032

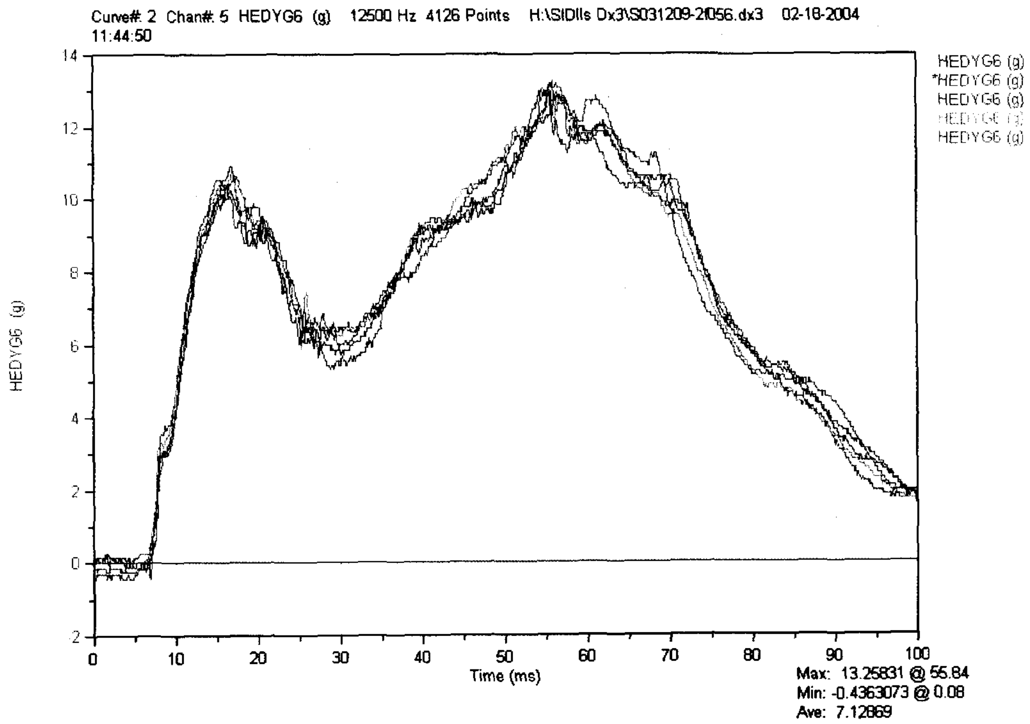

Figure B.3.b. Lateral Head Acceleration – Dummy 056

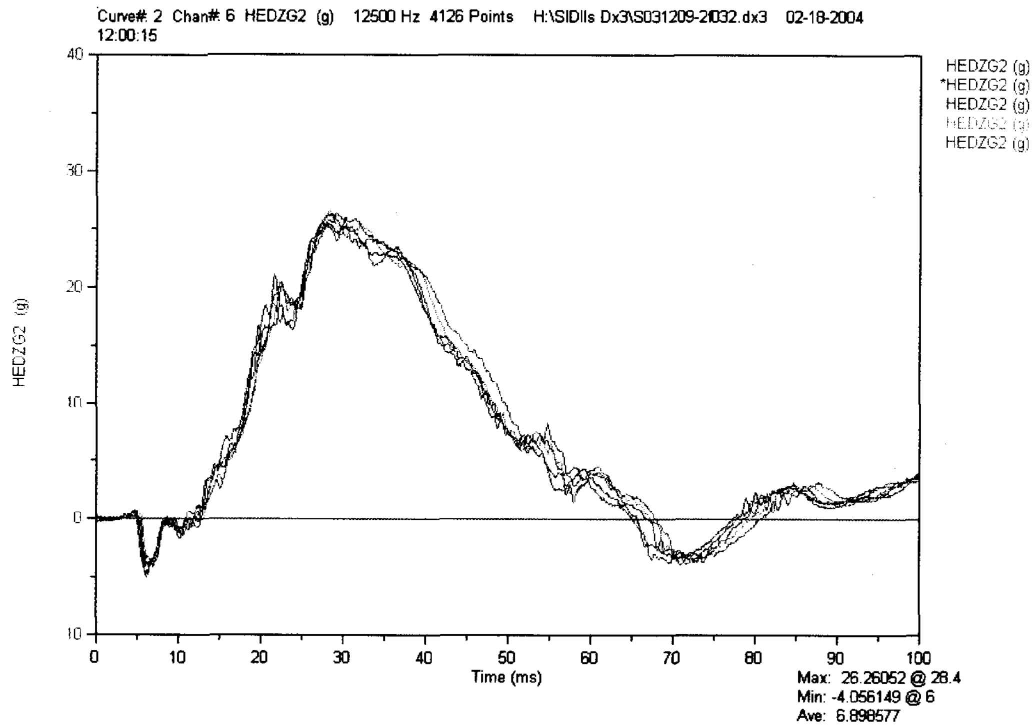

Figure B.4.a. Vertical Head Acceleration – Dummy 032

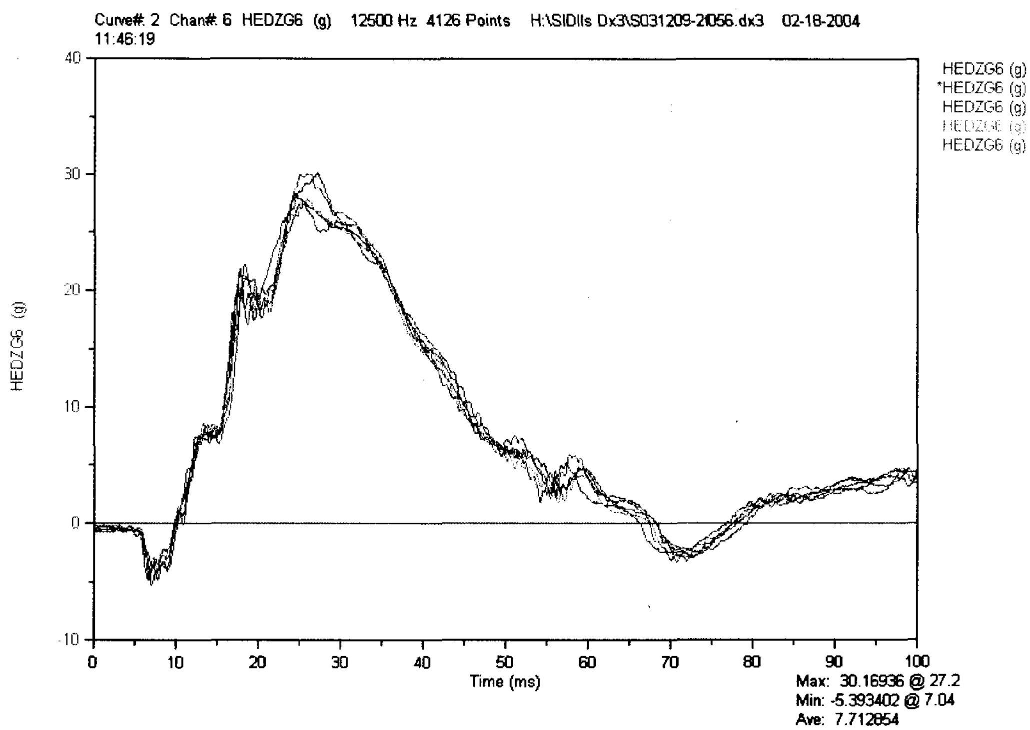

Figure B.4.b. Vertical Head Acceleration – Dummy 056

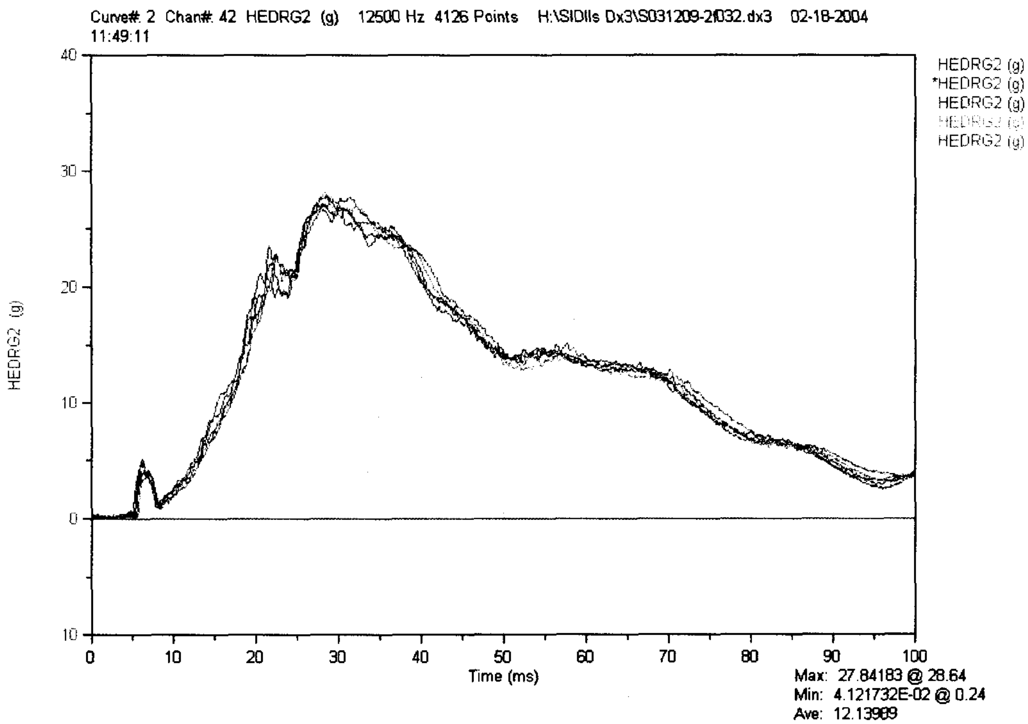

Figure B.5.a. Resultant Head Acceleration – Dummy 032

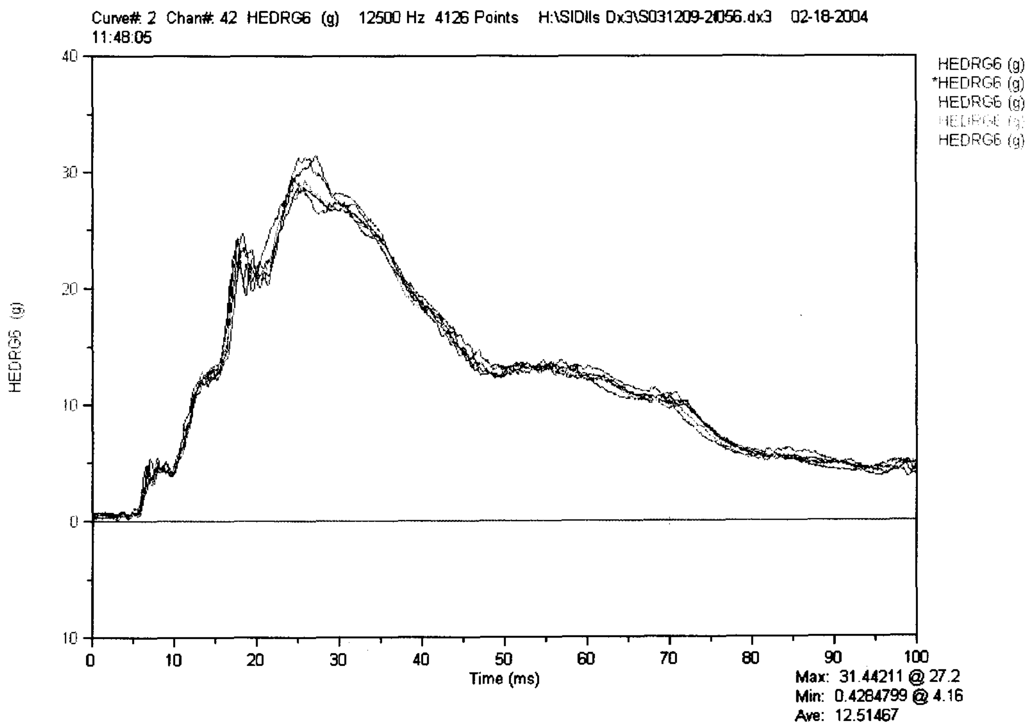

Figure B.5.b. Resultant Head Acceleration – Dummy 056

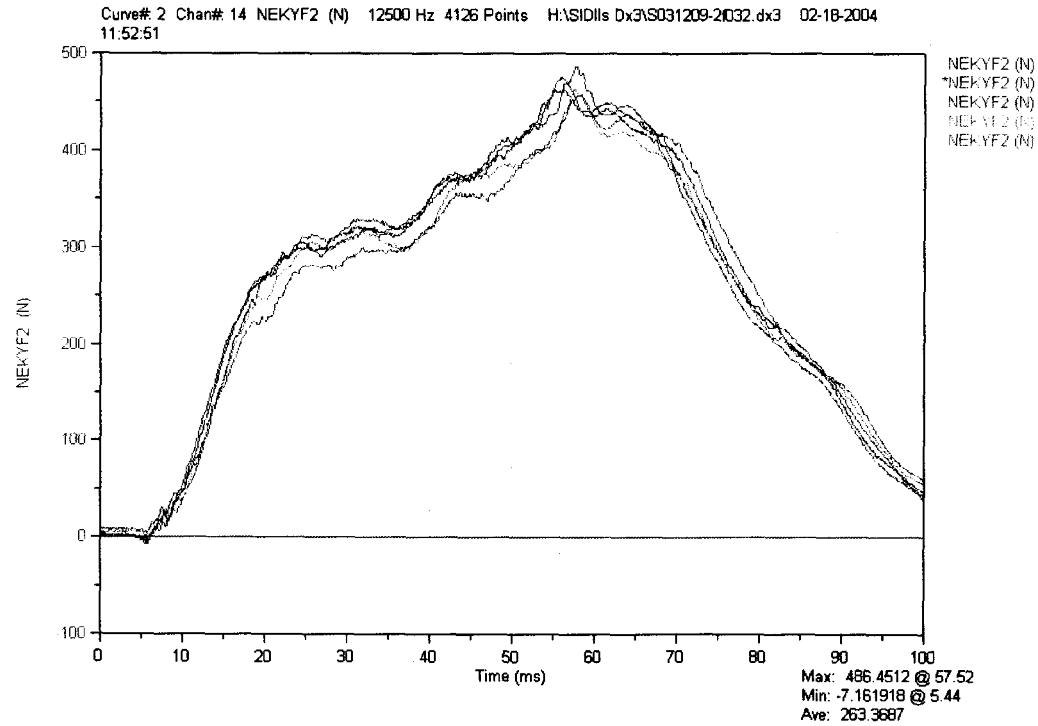

Figure B.6.a. Upper Neck Lateral Shear Force – Dummy 032

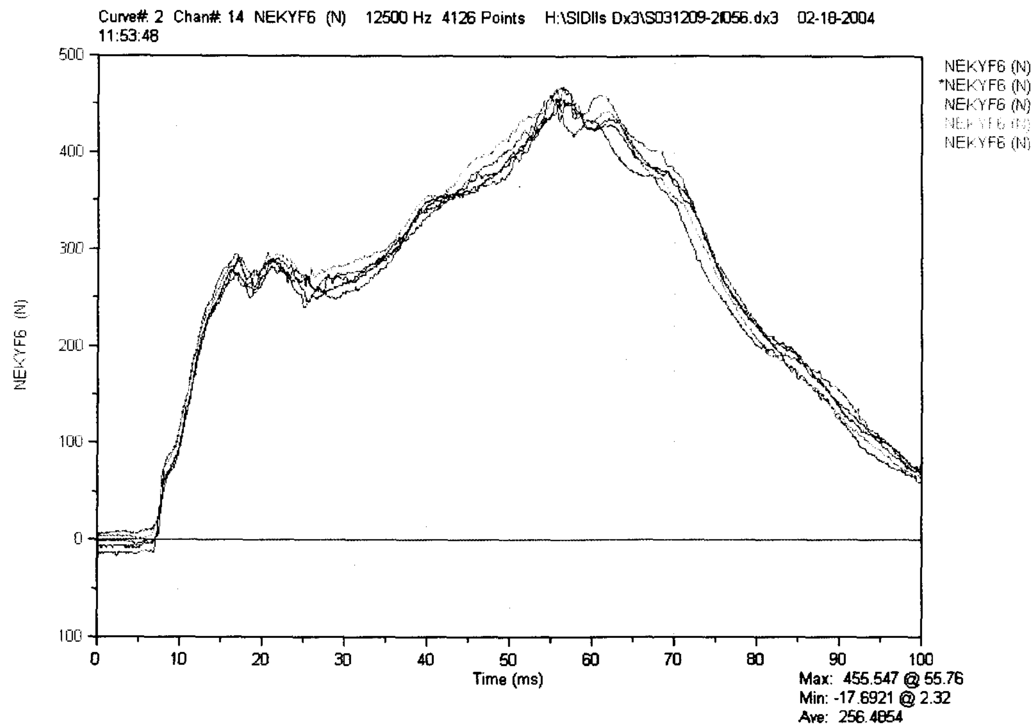

Figure B.6.b. Upper Neck Lateral Shear Force – Dummy 56

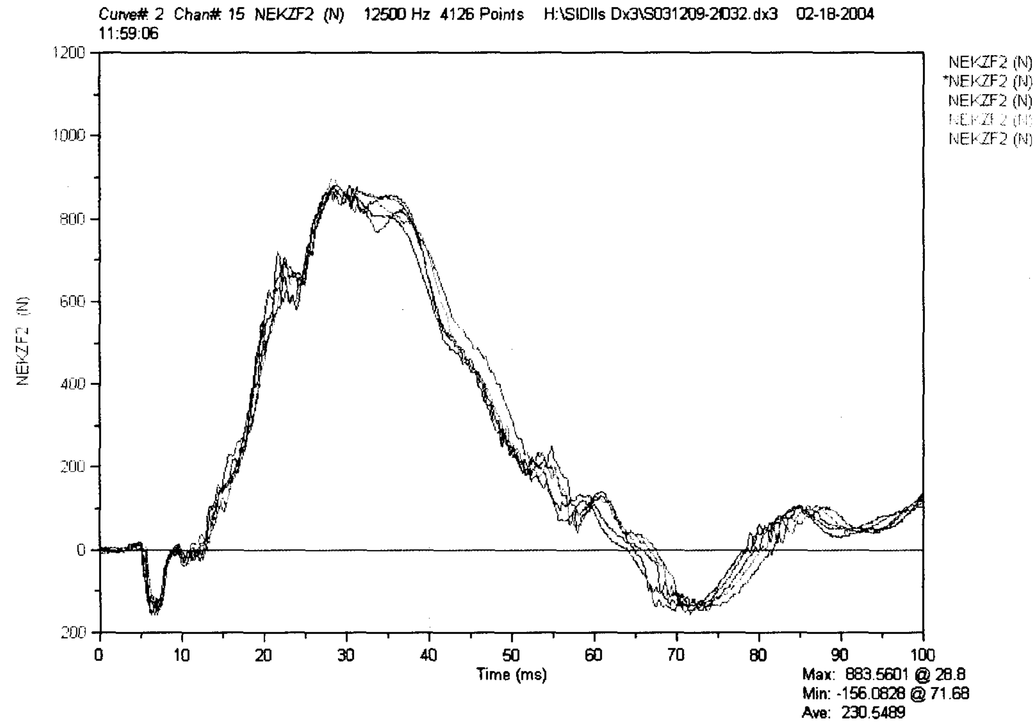

Figure B.7.a. Upper Neck Axial Force – Dummy 032

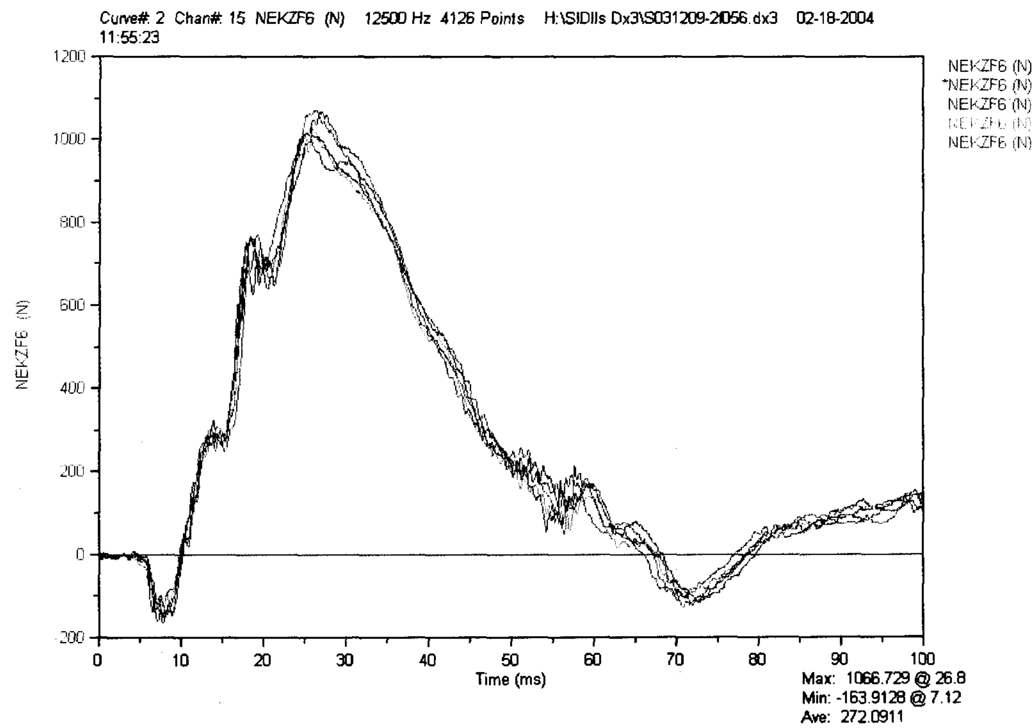

Figure B.7.b. Upper Neck Axial Force – Dummy 056

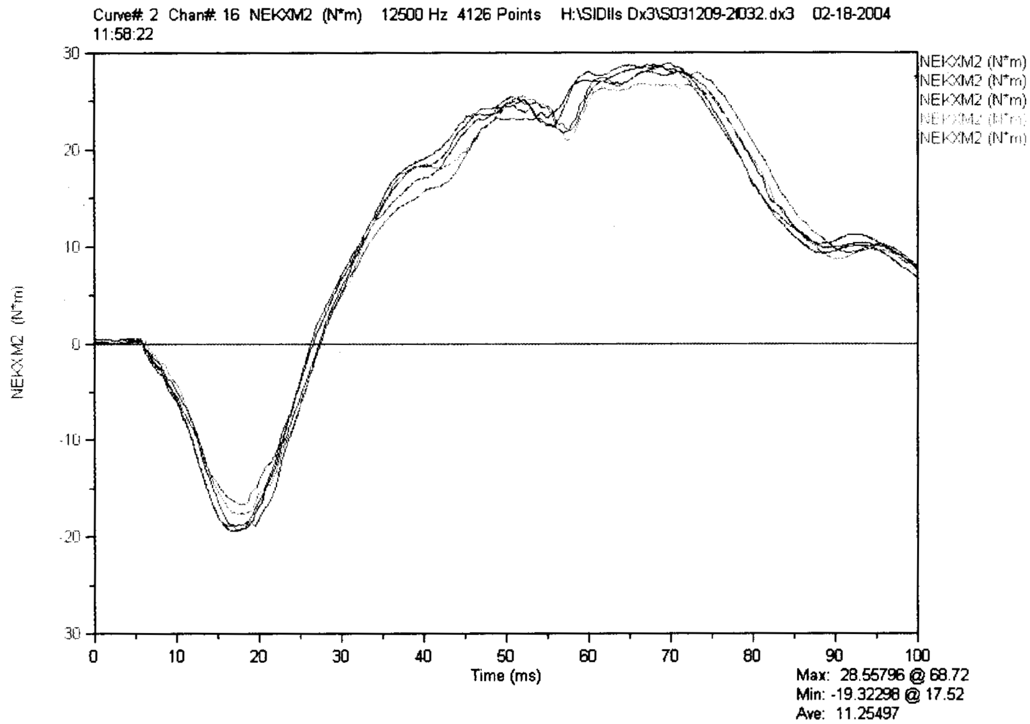

Figure B.8.a. Upper Neck Lateral Bending Moment – Dummy 032

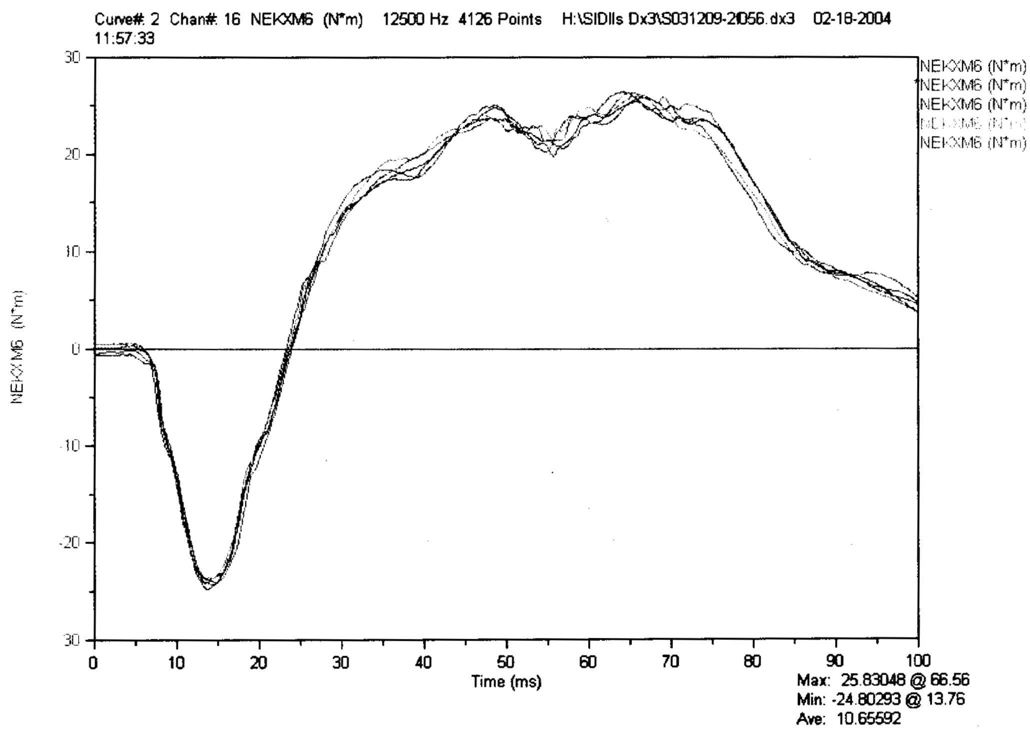

Figure B.8.b. Upper Neck Lateral Bending Moment – Dummy 056

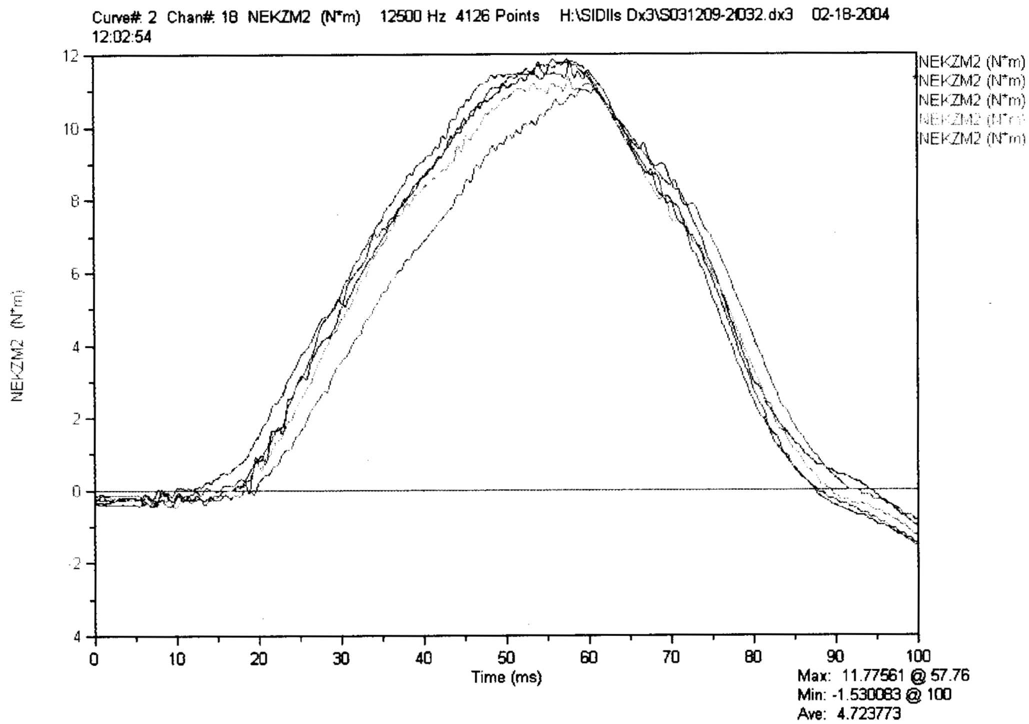

Figure B.9.a. Upper Neck Axial Moment – Dummy 032

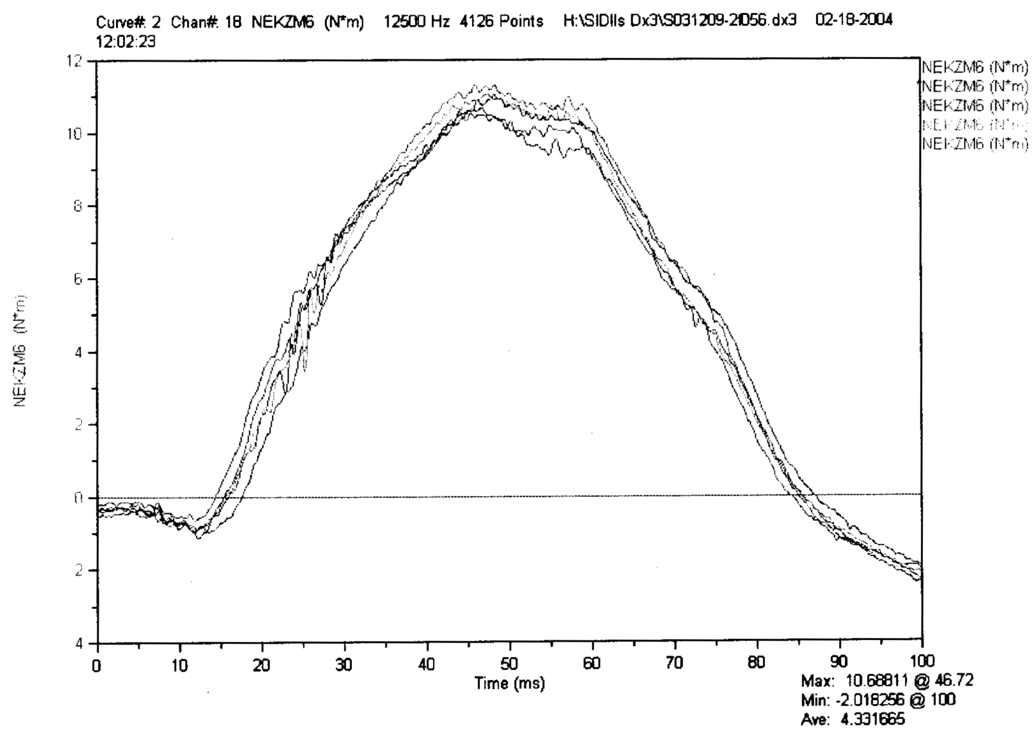

Figure B.9.b. Upper Neck Axial Moment – Dummy 056

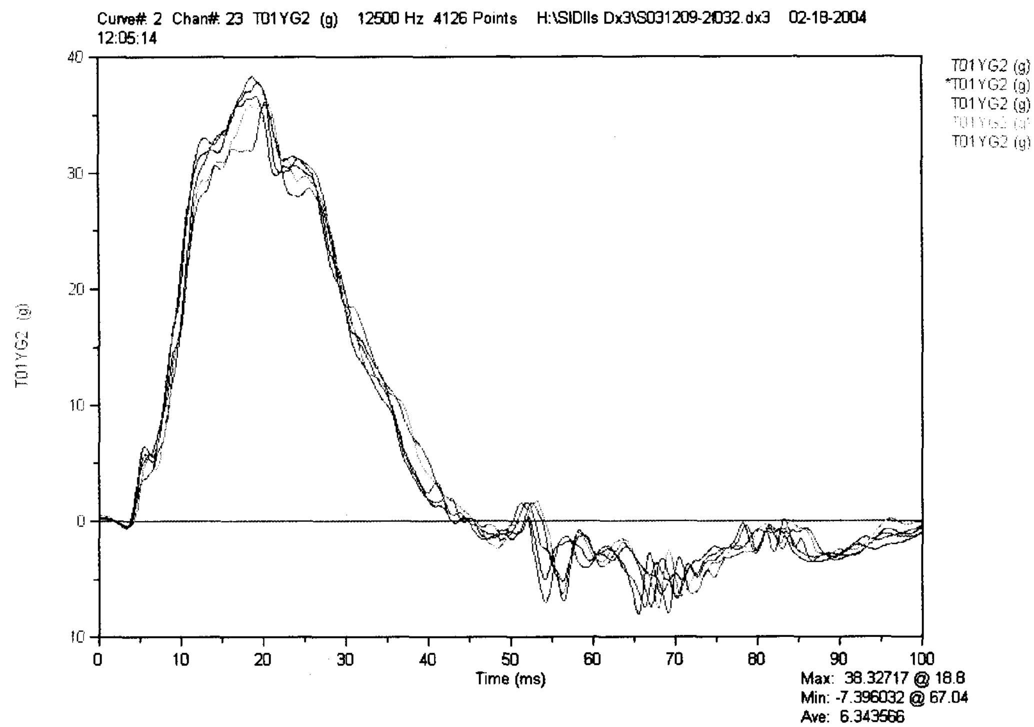

Figure B.10.a. Upper Spine (T1) Lateral Acceleration – Dummy 032

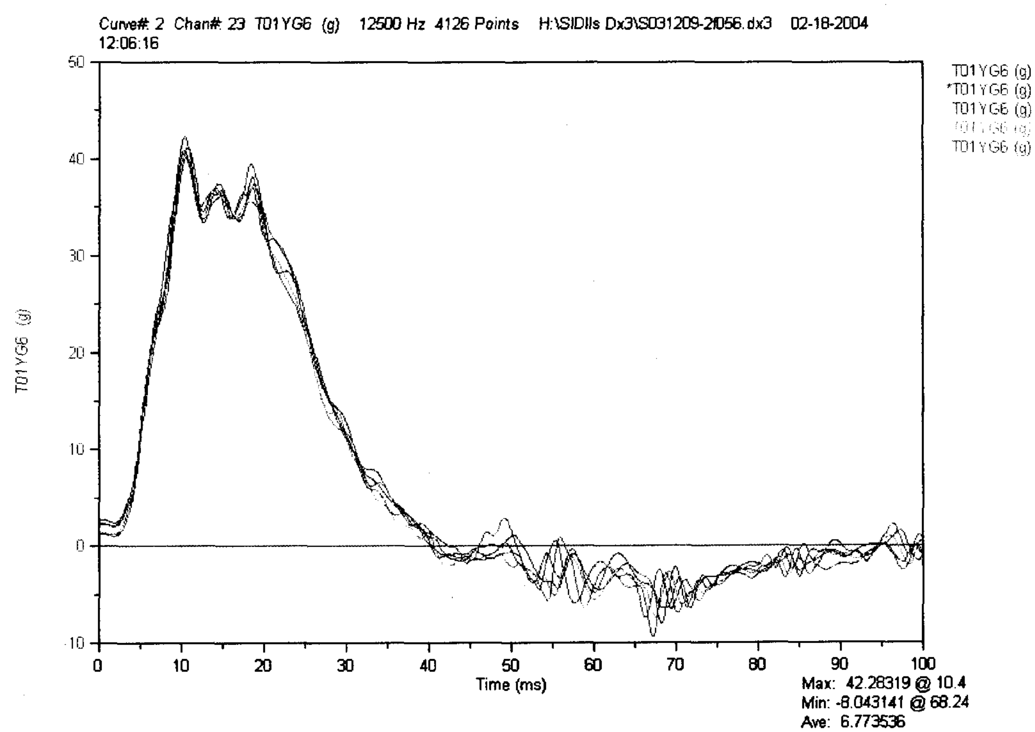

Figure B.10.b. Upper Spine (T1) Lateral Acceleration – Dummy 056

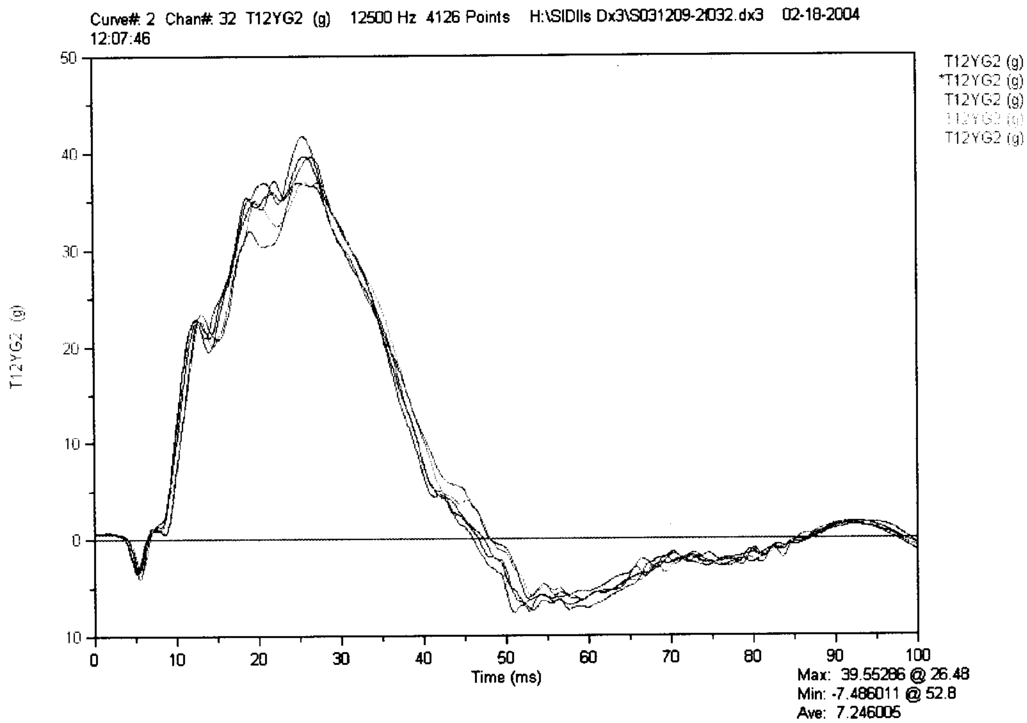

Figure B.11.a. Lower Spine (T12) Lateral Acceleration – Dummy 032

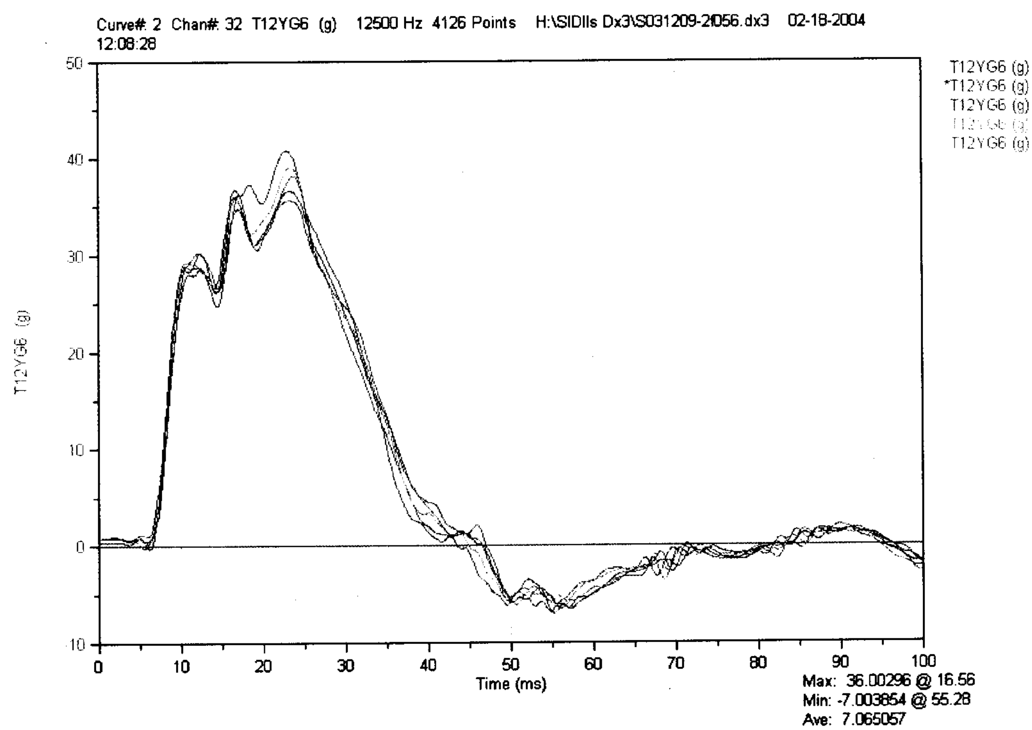

Figure B.11.b. Lower Spine (T12) Lateral Acceleration – Dummy 056

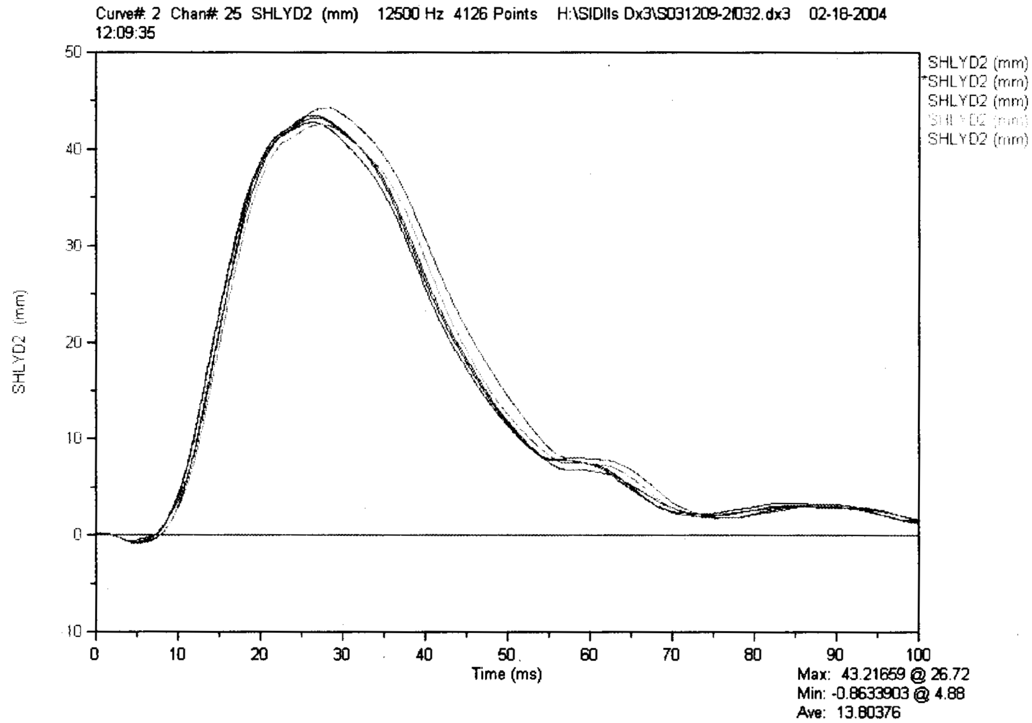

Figure B.12.a. Shoulder Rib Deflection – Dummy 032

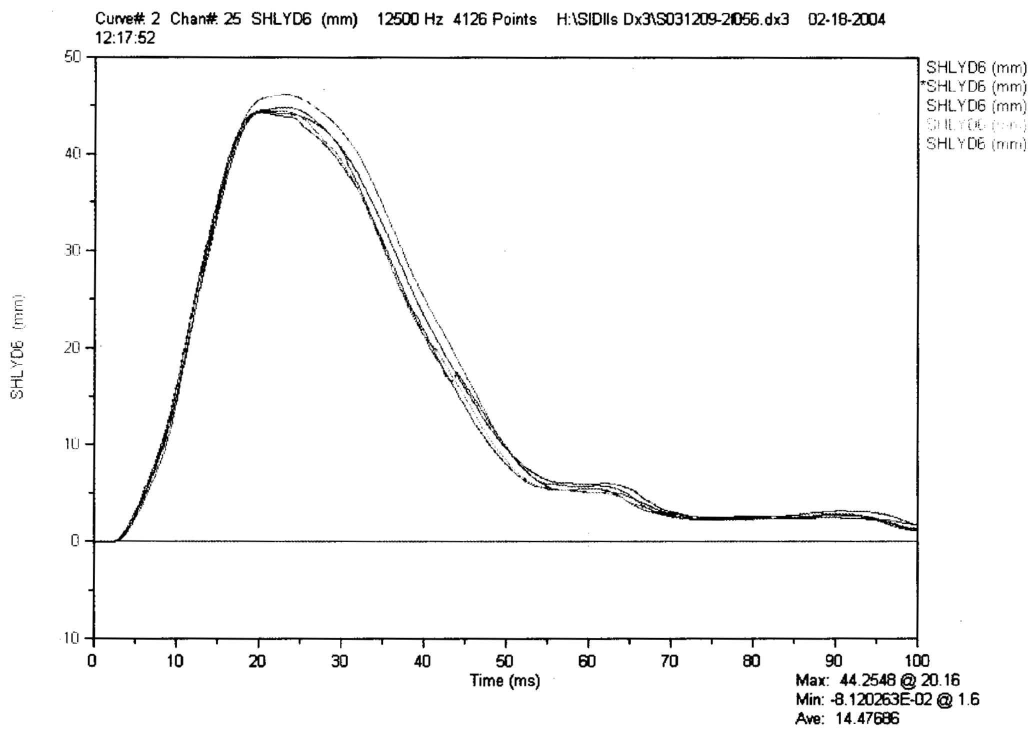

Figure B.12.b. Shoulder Rib Deflection – Dummy 056

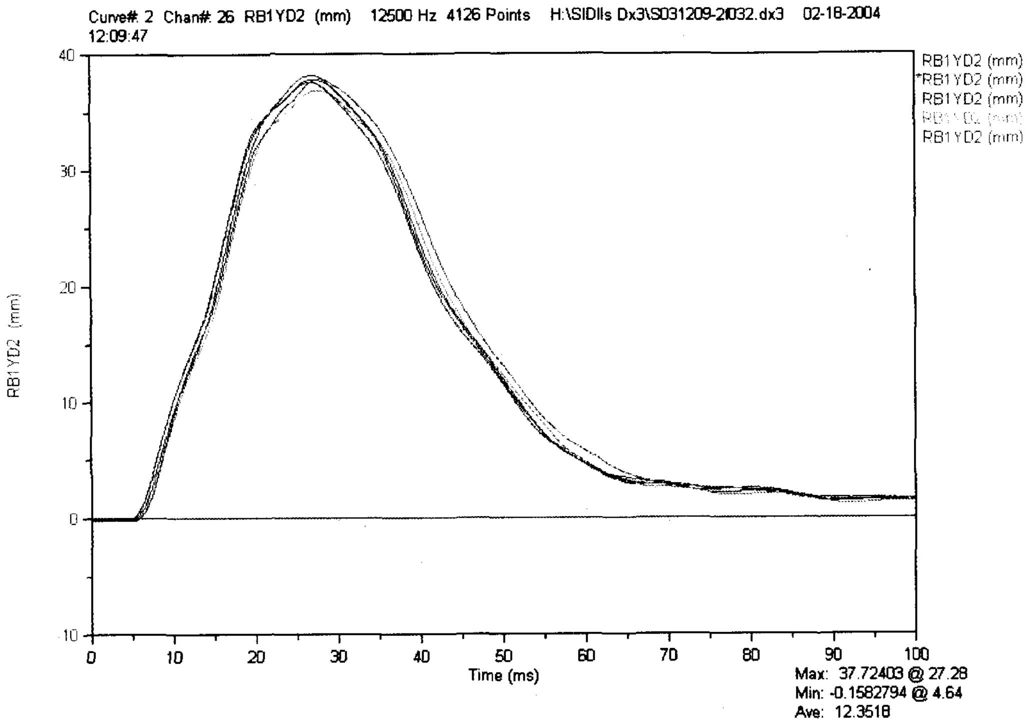

Figure B.13.a. Upper Thoracic Rib Deflection – Dummy 032

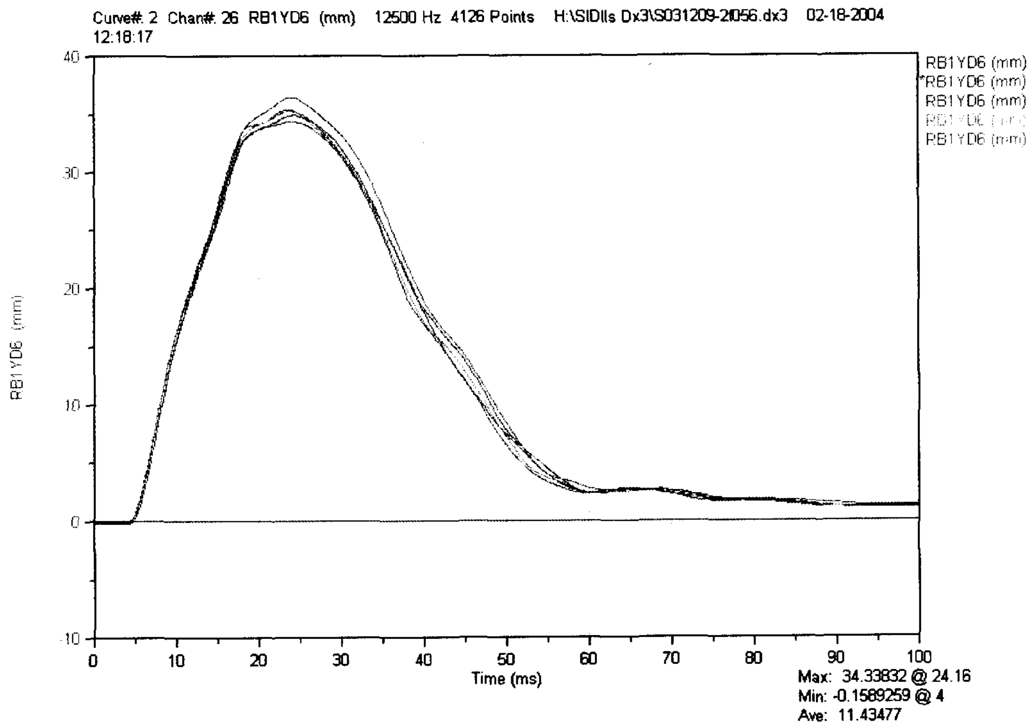

Figure B.13.b. Upper Thoracic Rib Deflection – Dummy 056

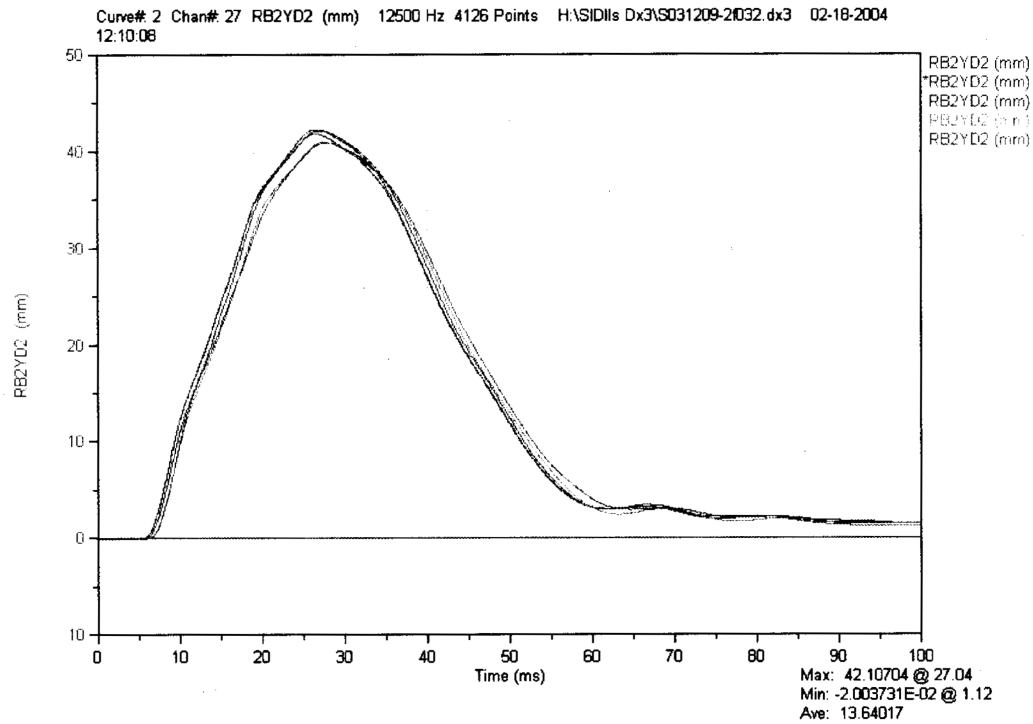

Figure B.14.a. Middle Thoracic Rib Deflection – Dummy 032

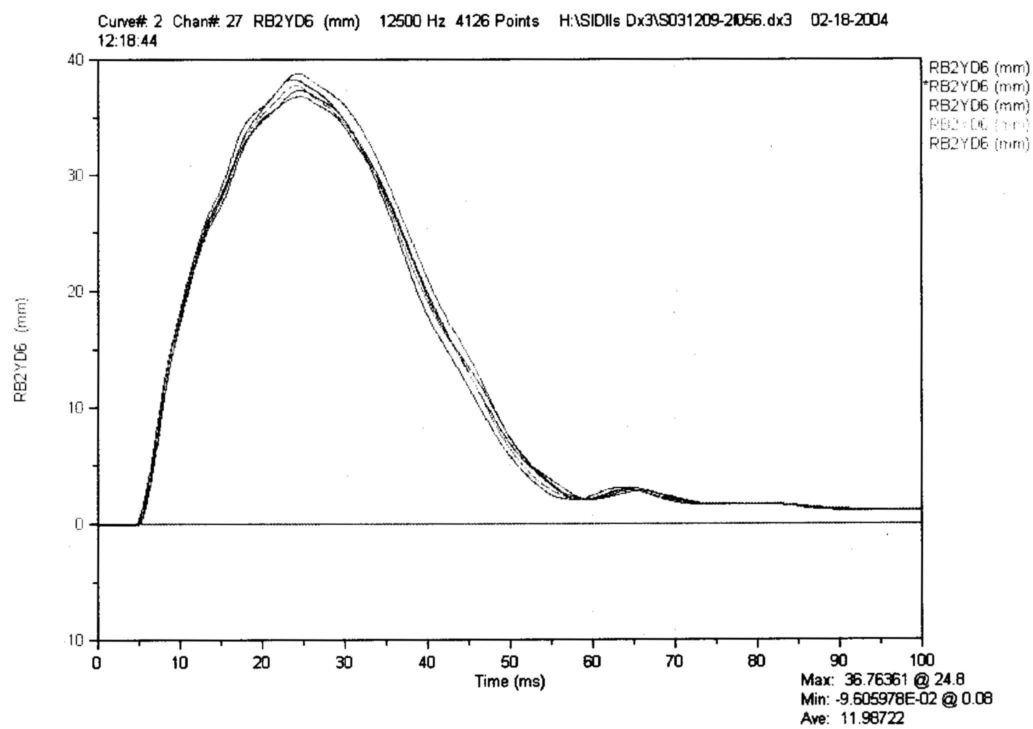

Figure B.14.b. Middle Thoracic Rib Deflection – Dummy 056

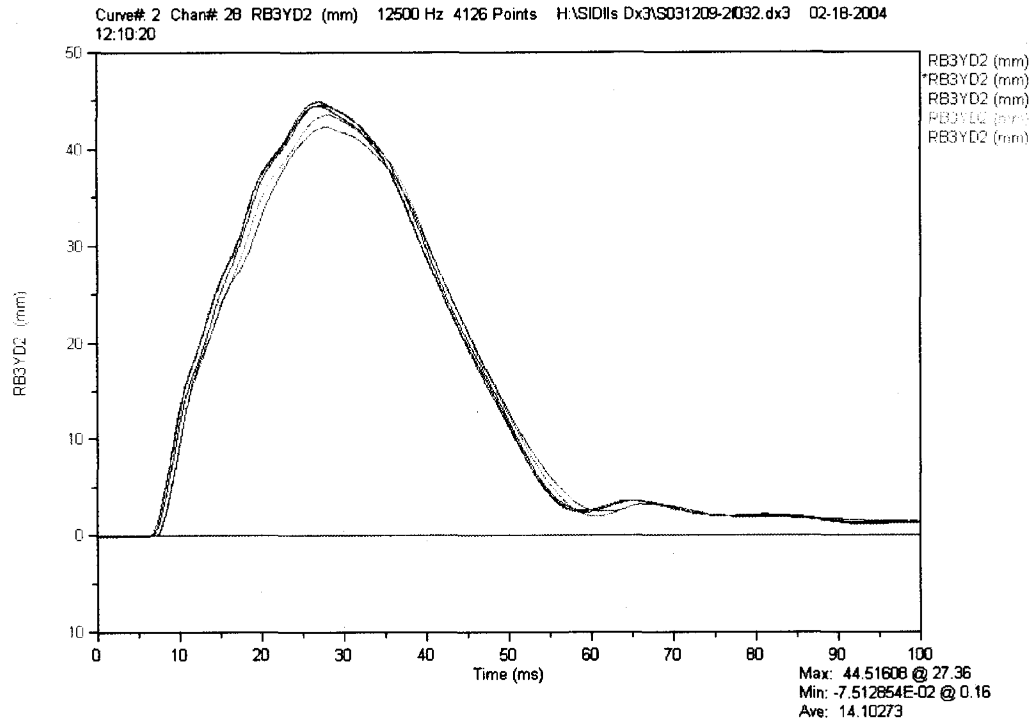

Figure B.15.a. Lower Thoracic Rib Deflection – Dummy 032

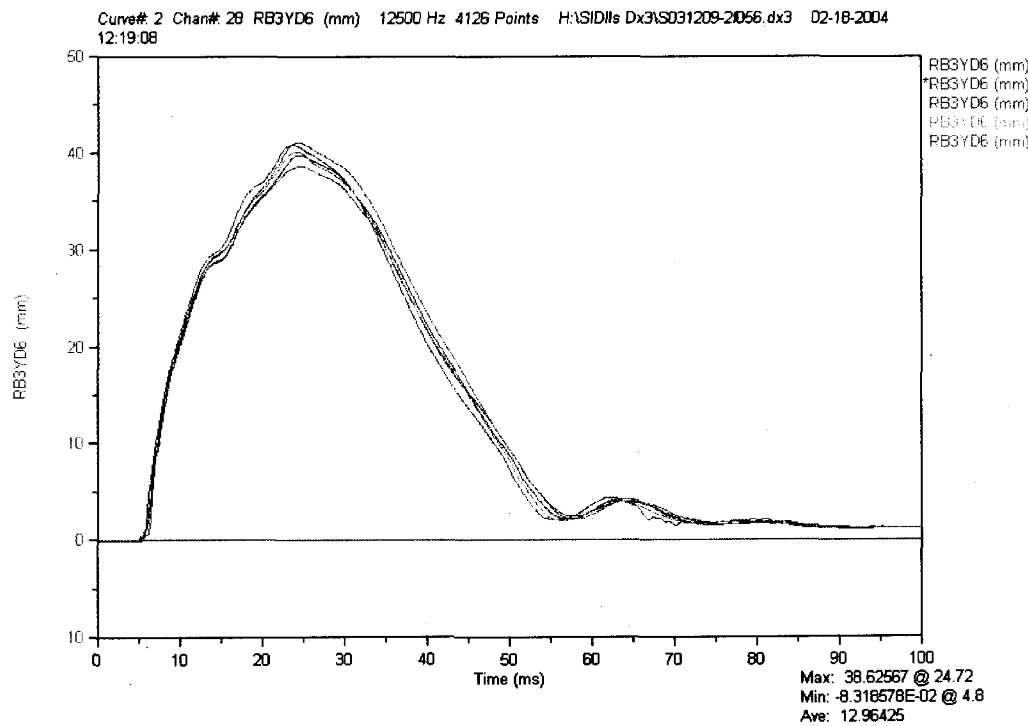

Figure B.15.b. Lower Thoracic Rib Deflection – Dummy 056

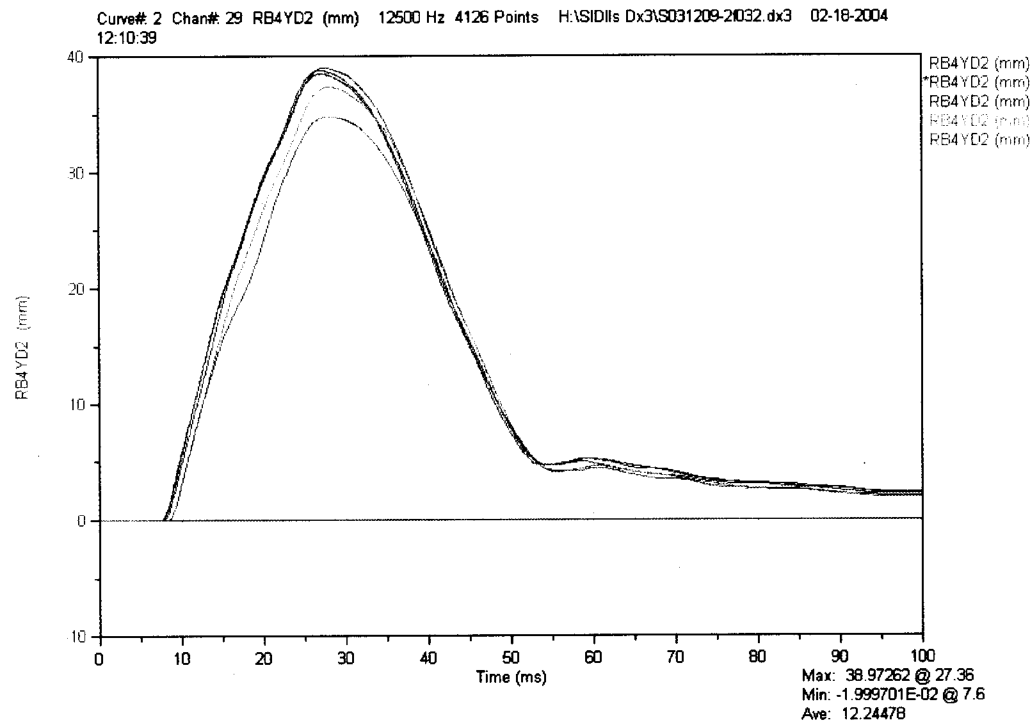

Figure B.16.a. Upper Abdominal Rib Deflection – Dummy 032

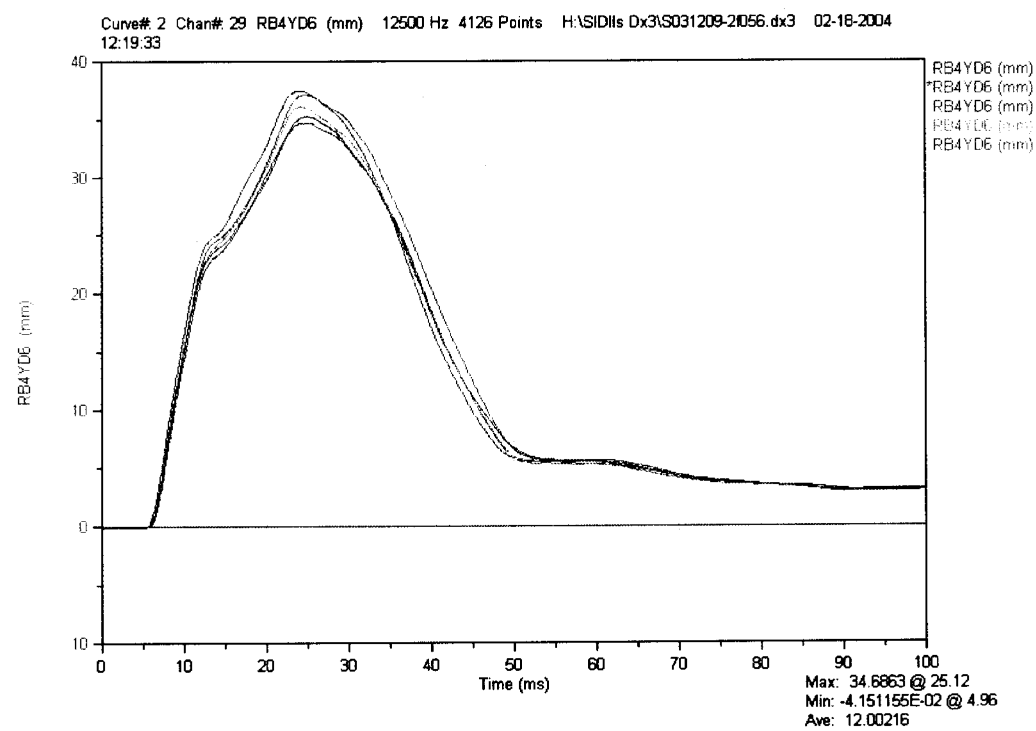

Figure B.16.b. Upper Abdominal Rib Deflection – Dummy 056

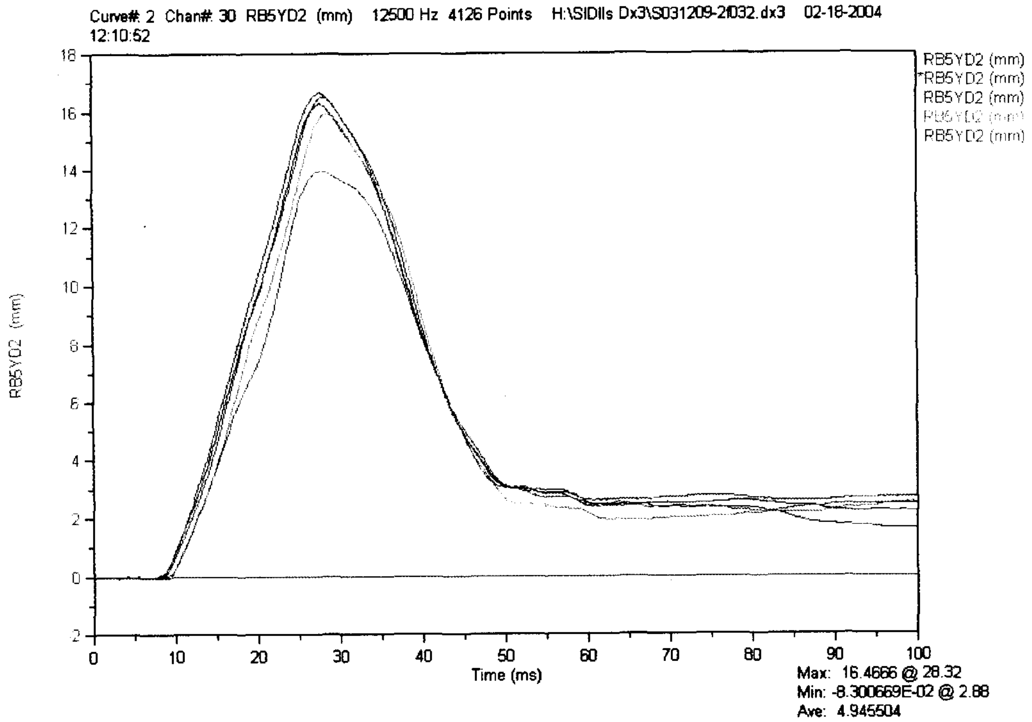

Figure B.17.a. Lower Abdominal Rib Deflection – Dummy 032

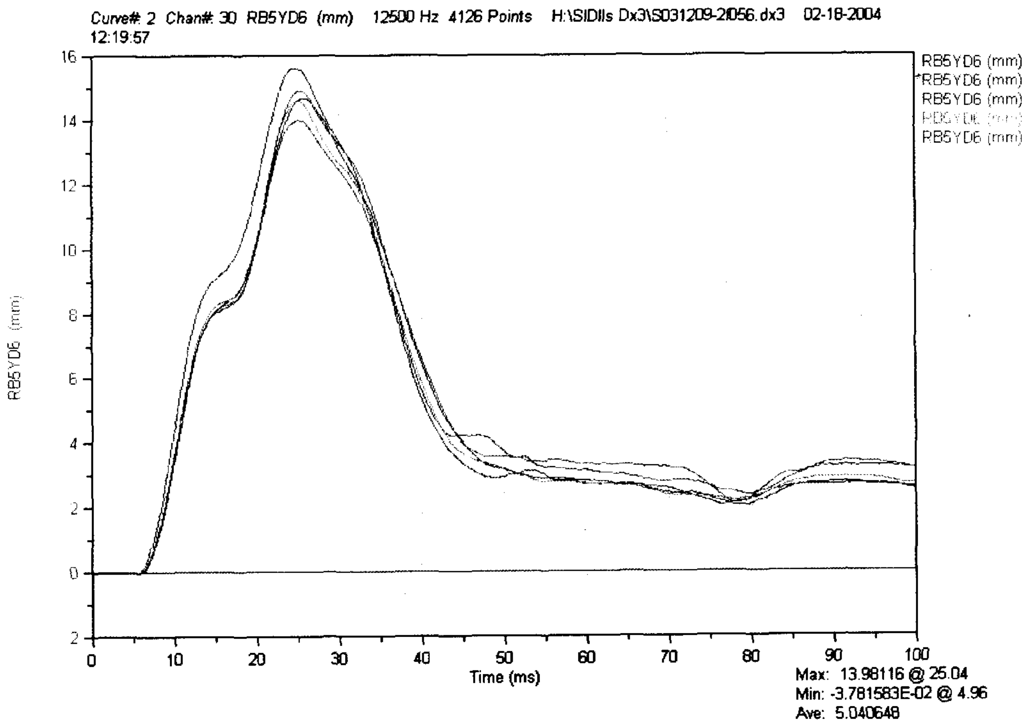

Figure B.17.b. Lower Abdominal Rib Deflection – Dummy 056

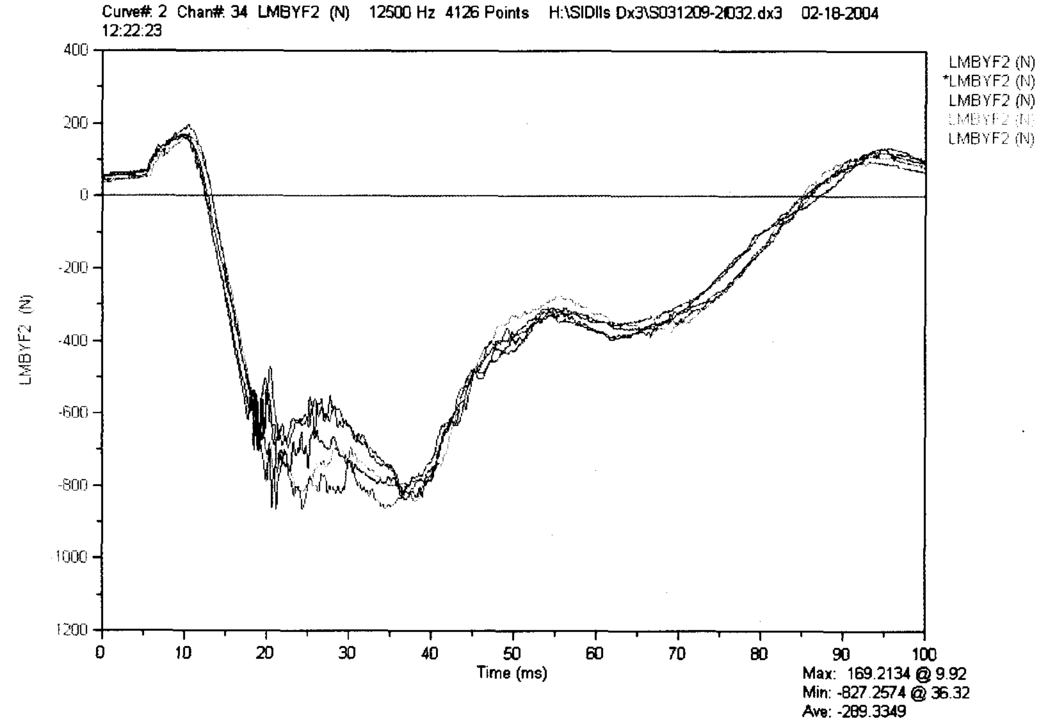

Figure B.18.a. Lumbar Lateral Shear Force – Dummy 032

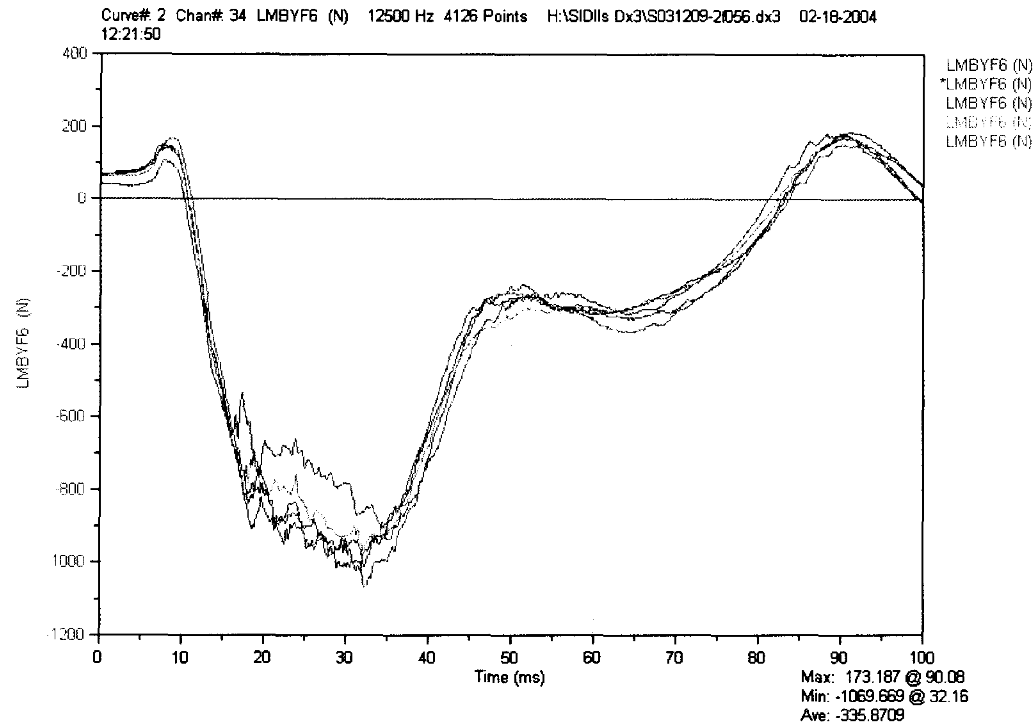

Figure B.18.b. Lumbar Lateral Shear Force – Dummy 056

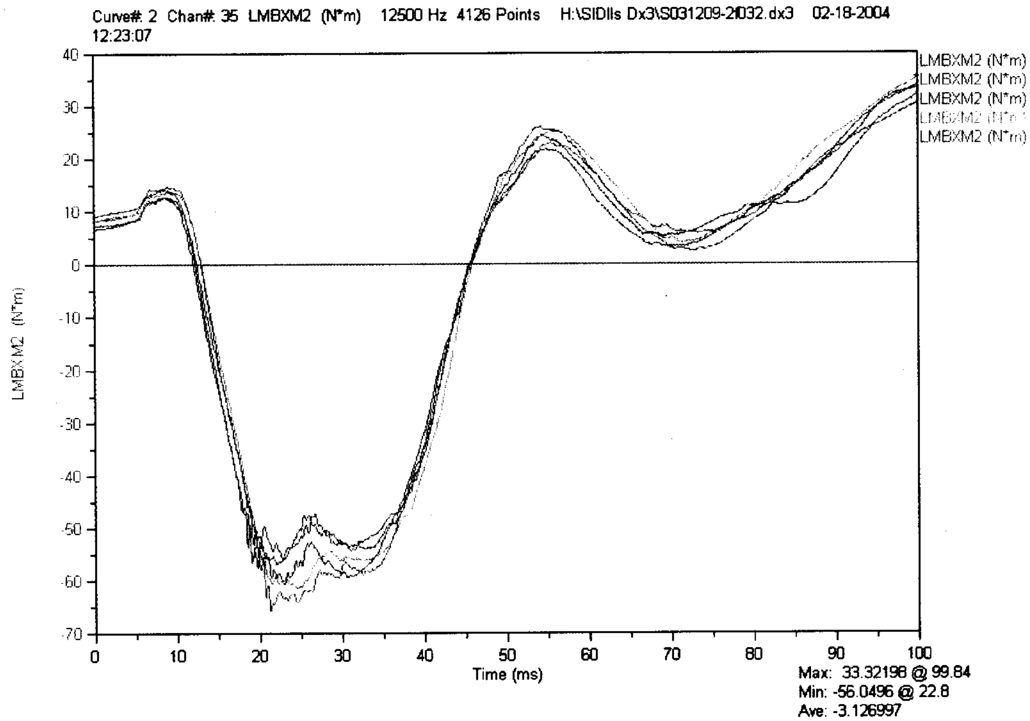

Figure B.19.a. Lumbar Lateral Bending Moment – Dummy 032

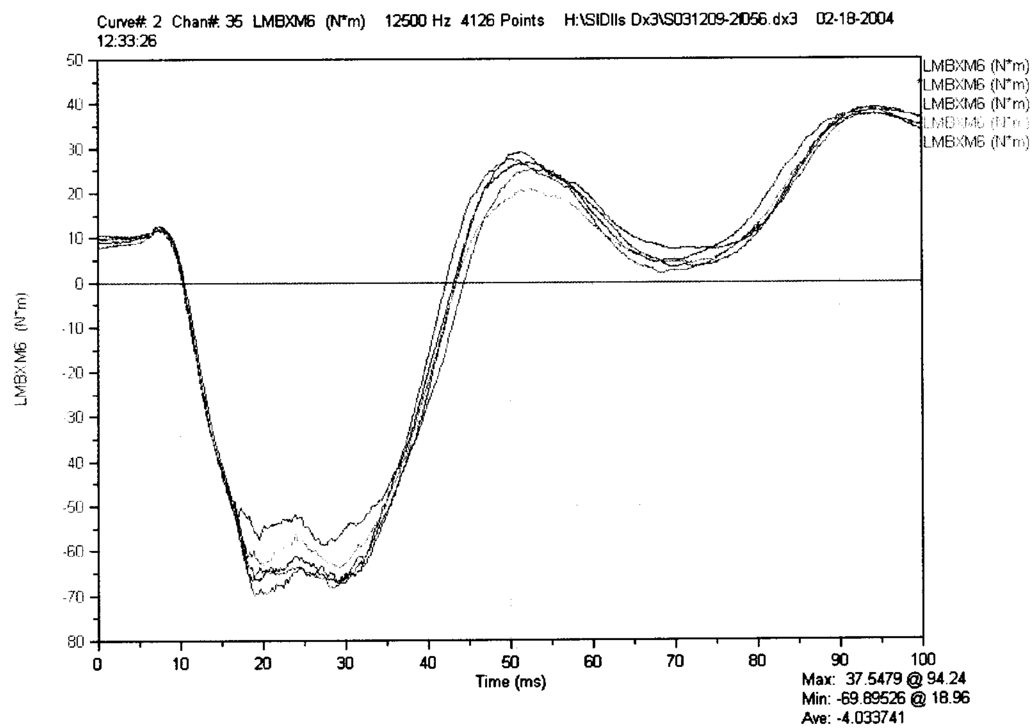

Figure B.19.b. Lumbar Lateral Bending Moment – Dummy 056

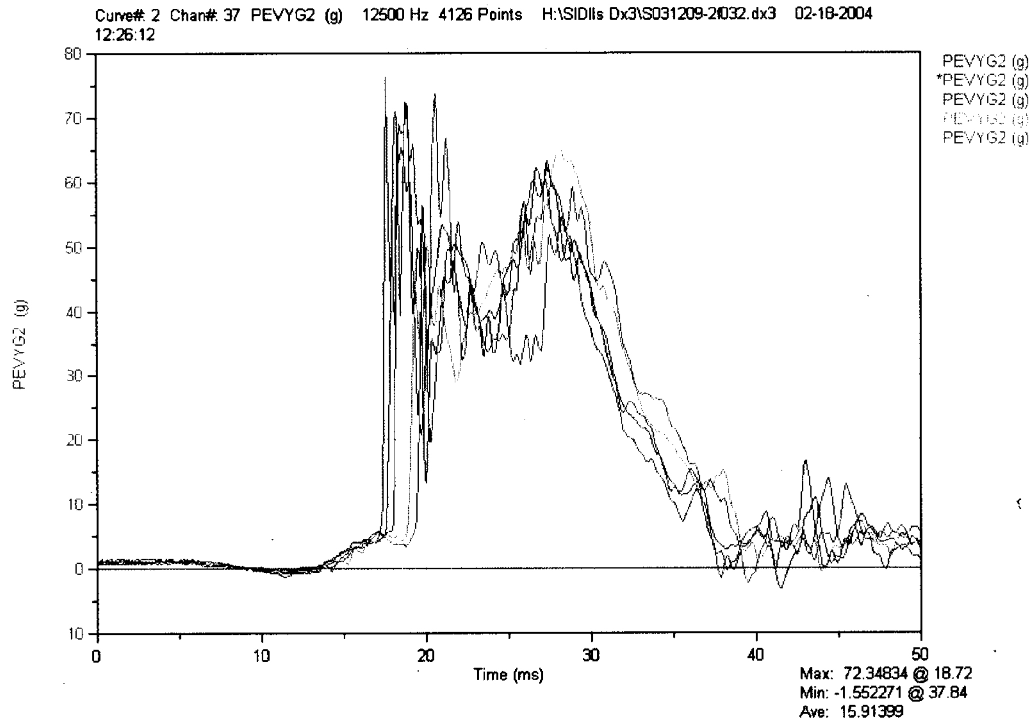

Figure B.20.a. Pelvis Lateral Acceleration – Dummy 032

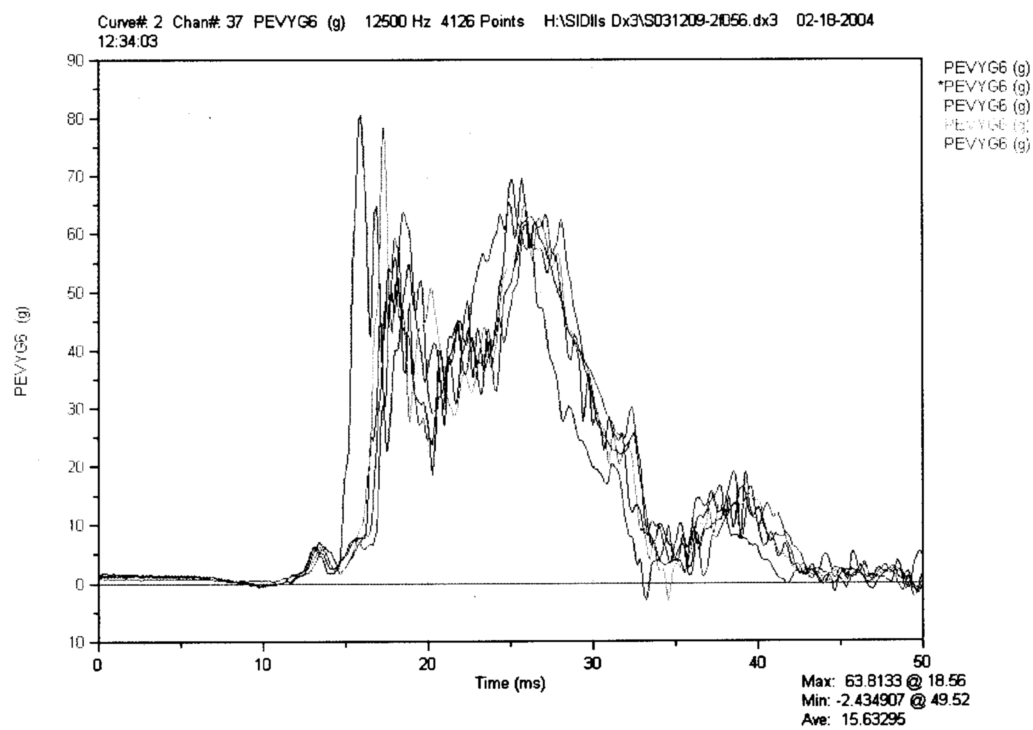

Figure B.20.b. Pelvis Lateral Acceleration – Dummy 056

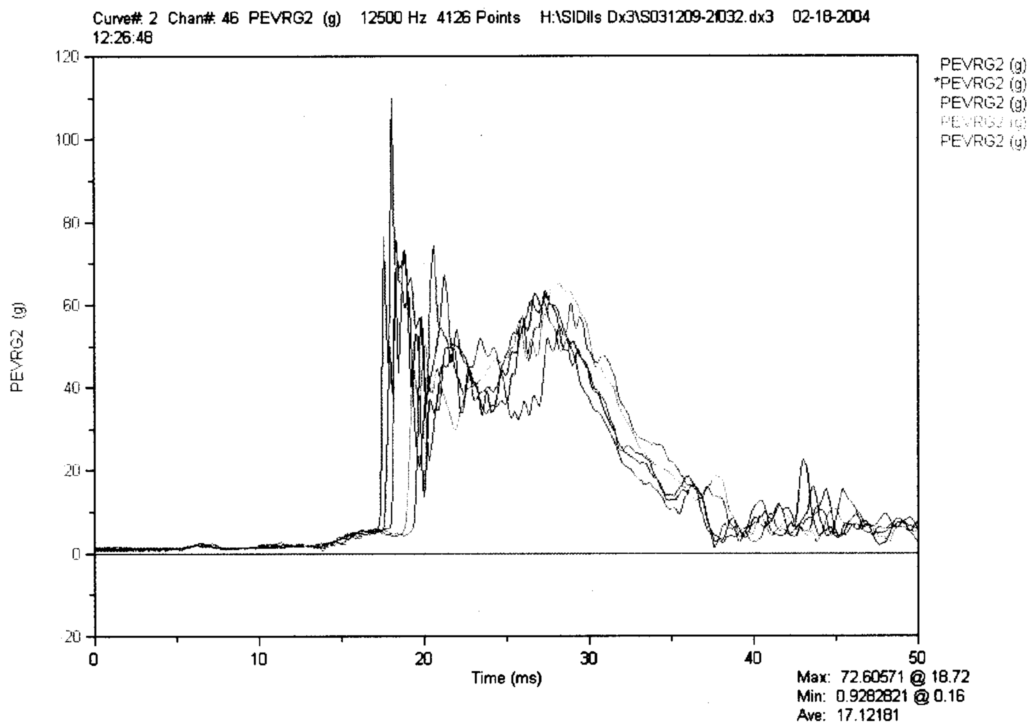

Figure B.21.a. Pelvis Resultant Acceleration – Dummy 032

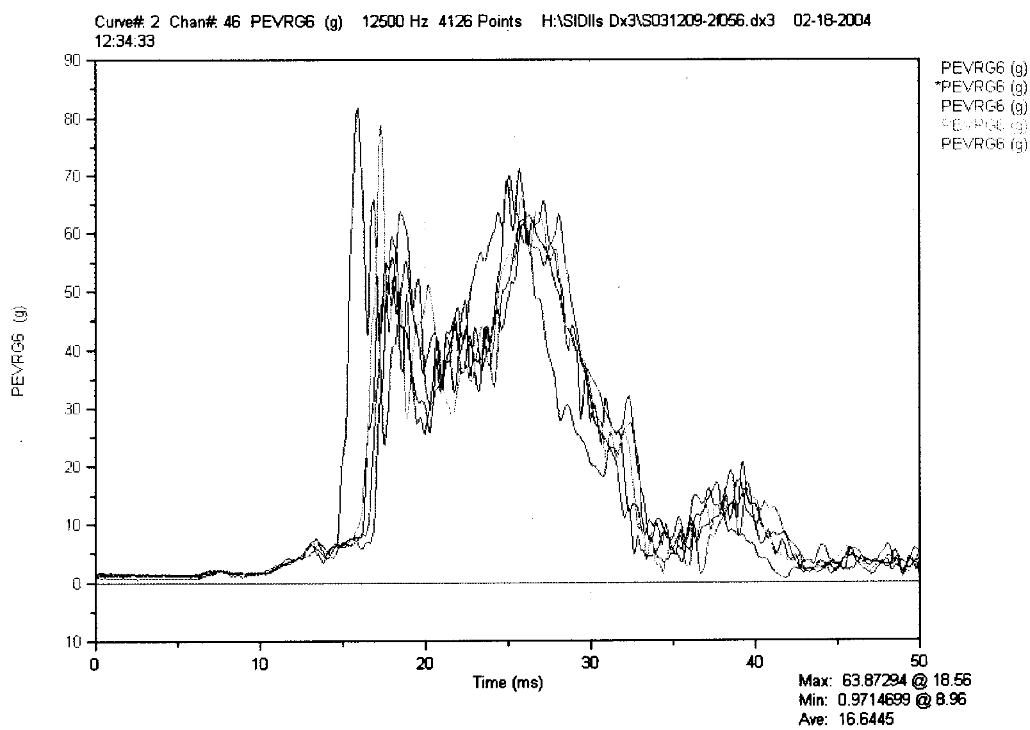

Figure B.21.b. Pelvis Resultant Acceleration – Dummy 056

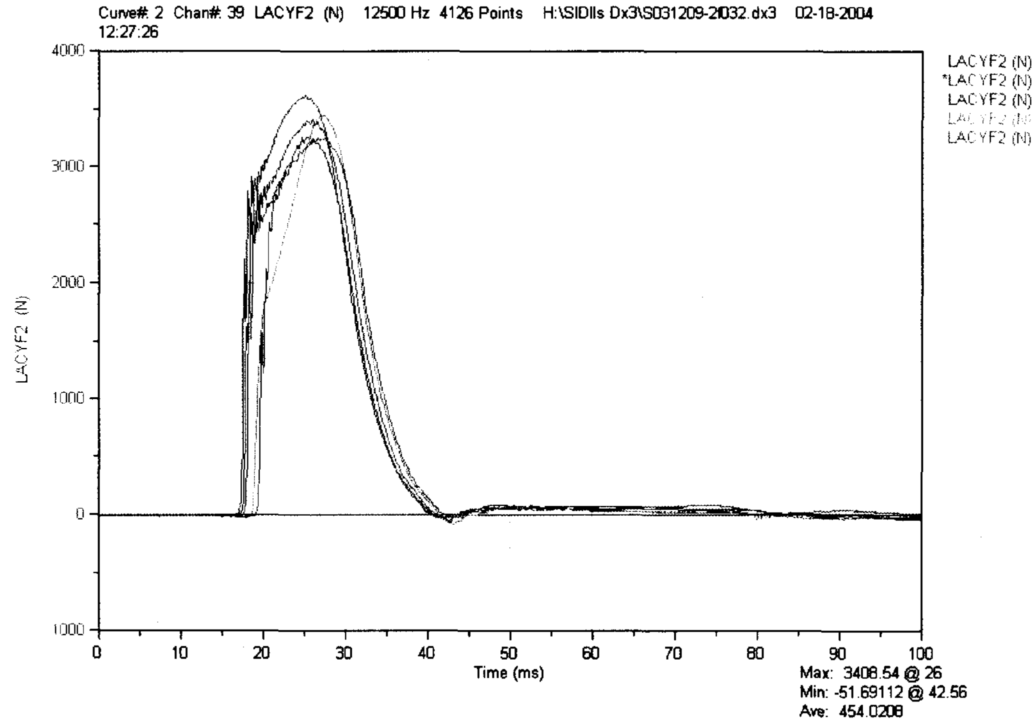

Figure B.22.a. Left Acetabulum Lateral Force – Dummy 032

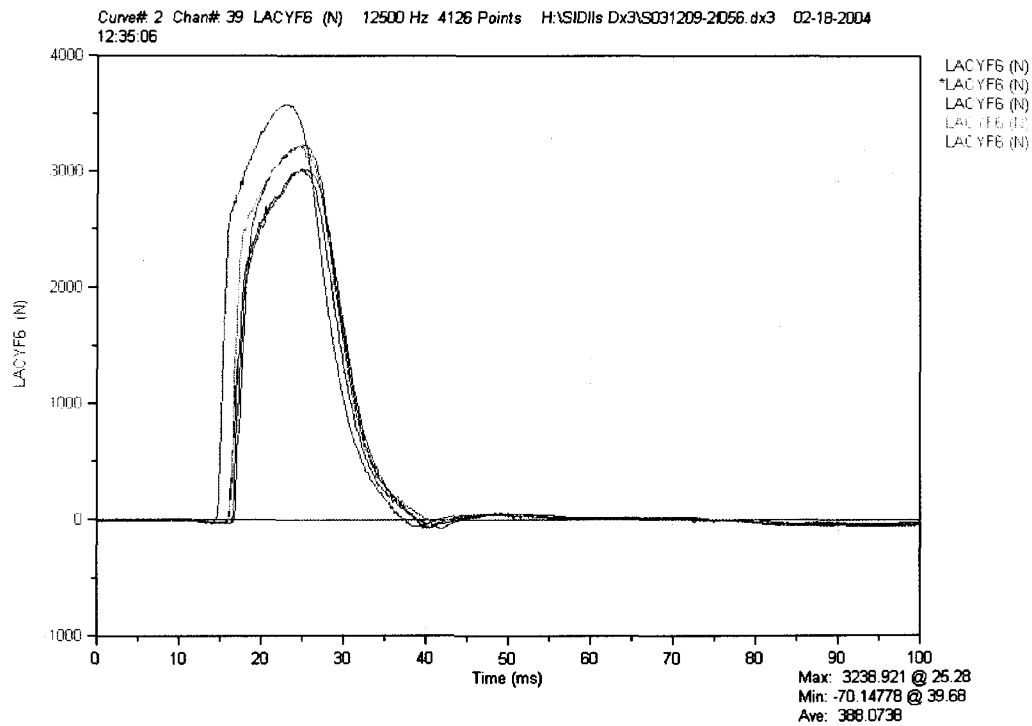

Figure B.22.b. Left Acetabulum Lateral Force – Dummy 056

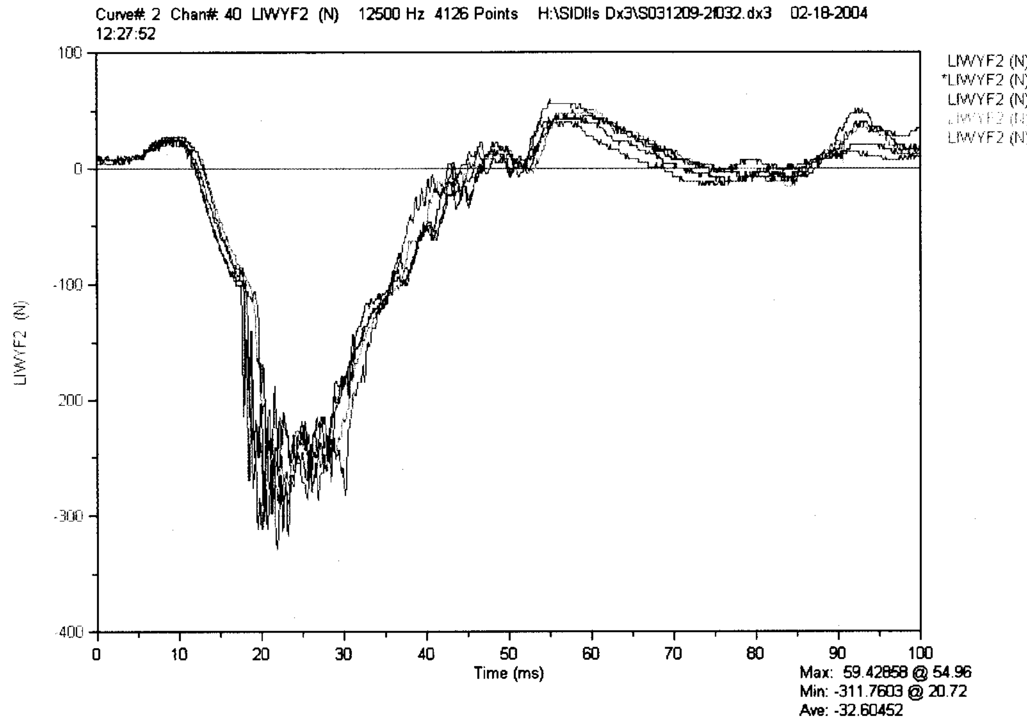

Figure B.23.a. Left Iliac Wing Lateral Force – Dummy 032

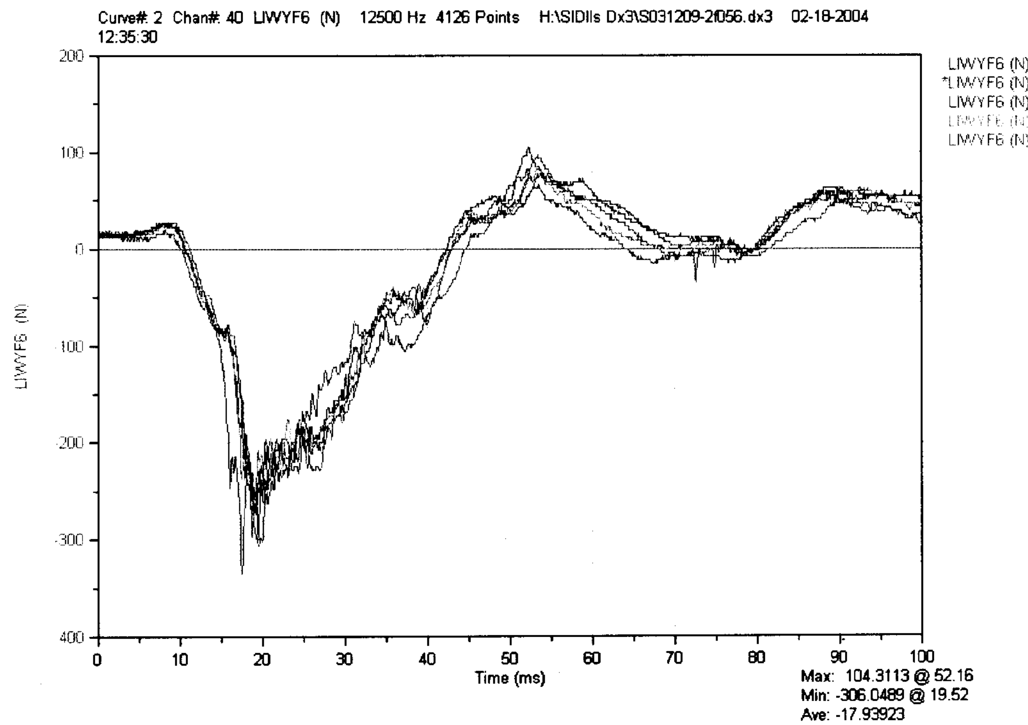

Figure B.23.b. Left Iliac Wing Lateral Force – Dummy 056

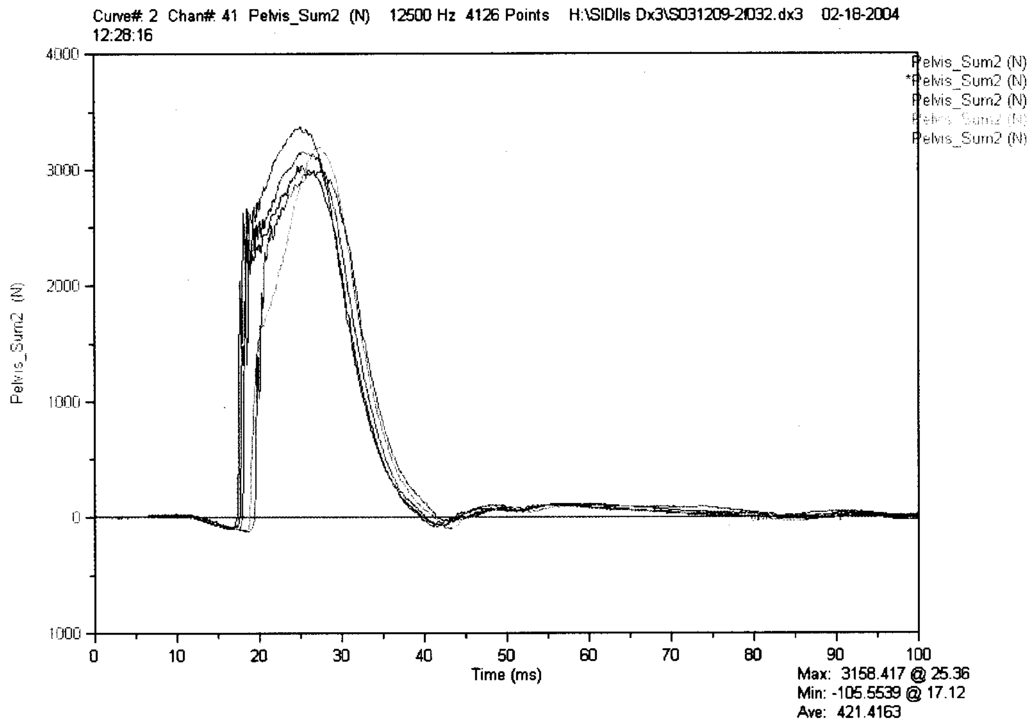

Figure B.24.a. Sum of Iliac Wing and Acetabulum Lateral Forces – Dummy 032

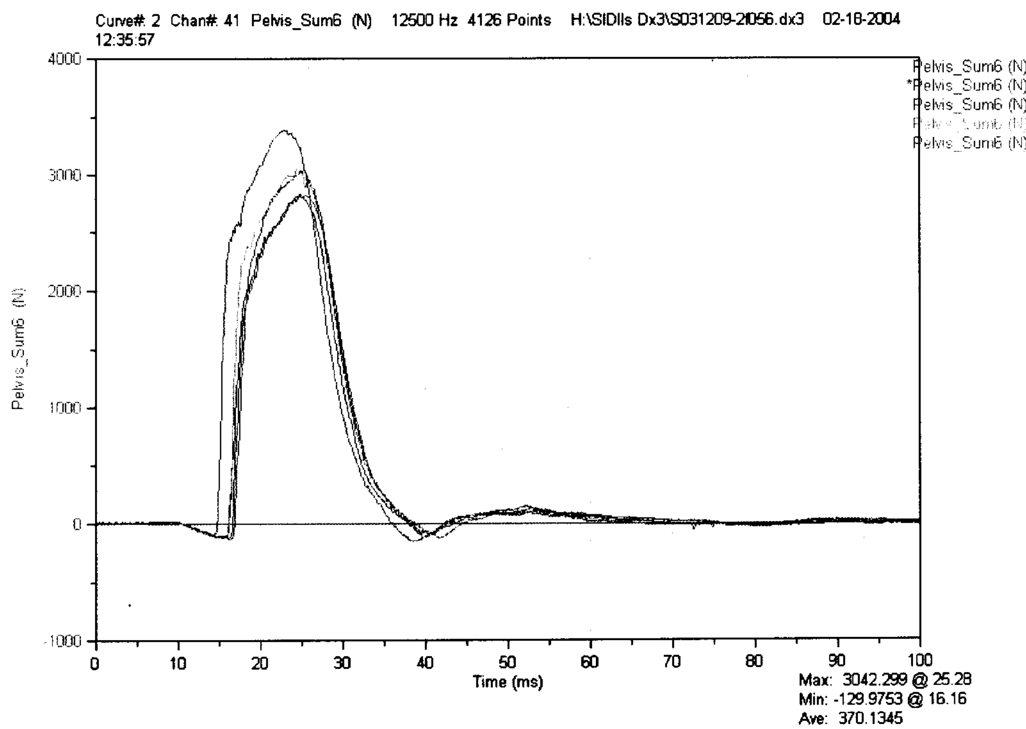

Figure B.24.b. Sum of Iliac Wing and Acetabulum Lateral Forces – Dummy 056

Appendix C.
6.0 m/s Rigid Abdomen Offset Sled Test Responses

Table C.1. Peak Responses During 6.0 m/s Rigid Abdomen Offset Sled Tests

				Test Condition	6.0 m/s Rigid Abdomen Offset									
				Dummy Serial Number	32					56				
				Dummy Position	right	right	right	right	right	left	left	left	left	left
Location	**Measurement**	**Direction**	**Units**	**Filter Class / Test # S0312----**	17-1	17-2	18-1	18-2	18-3	17-1	17-2	18-1	18-2	18-3
Head	Max Displacement	lateral	mm	n/a	235	235	237	239	238	240	238	240	242	242
		vertical	mm	n/a	127	114	129	136	136	107	113	116	117	121
	Time of Max Displacement	n/a	ms	n/a	134	129	136	135	136	130	133	134	133	135
	Acceleration	Y	g	CFC 1000	14.7	14.6	14.3	15.0	14.6	14.2	13.7	13.6	13.7	13.7
		Z	g	CFC 1000	31.6	32.1	32.0	32.4	33.8	33.8	32.8	33.5	33.2	34.1
		Resultant	g	CFC 1000	33.5	34.2	34.1	34.1	35.6	35.5	34.5	35.3	34.9	36.1
	HIC 36	**n/a**	**n/a**	**CFC 1000**	**76.7**	**75.7**	**75.3**	**81.4**	**79.3**	**81.2**	**78.8**	**80.5**	**78.7**	**83.7**
Upper Neck	Force	Y	N	CFC 1000	486.8	482.2	476.7	491.1	478.9	502.3	484.2	486.4	485.0	492.7
		Z	N	CFC 1000	1129.5	1129.5	1127.3	1135.2	1172.5	1238.8	1193.0	1191.7	1195.3	1230.0
	Moment	+X	N-m	CFC 600	30.7	30.4	30.8	30.8	30.5	32.4	30.9	30.5	29.6	30.5
		-X	N-m	CFC 600	-26.1	-25.8	-25.5	-25.5	-25.9	-27.7	-27.5	-27.6	-27.1	-25.3
		Z	N-m	CFC 600	12.2	12.0	12.0	12.3	12.3	12.9	13.0	12.8	13.0	13.6
T1	Acceleration	Y	g	CFC 180	44.2	44.3	43.4	43.2	44.6	53.6	48.5	46.7	47.0	46.4
		Resultant	g	CFC 180	44.5	44.5	43.8	43.4	45.0	53.8	48.9	47.1	47.4	46.7
T12	**Acceleration**	Y	g	CFC 180	41.0	41.2	41.0	39.8	39.9	44.7	43.2	43.5	43.5	43.1
		Resultant	**g**	**CFC 180**	**41.6**	**42.1**	**41.5**	**40.4**	**40.3**	**45.1**	**43.8**	**43.5**	**43.6**	**43.2**
Shoulder Rib	Displacement	Y	mm	CFC 600	36.5	35.9	35.7	36.6	36.3	39.1	39.8	39.4	40.3	41.5
Thorax Rib 1	**Displacement**	**Y**	**mm**	**CFC 180**	**24.7**	**24.3**	**24.0**	**25.2**	**24.3**	**24.9**	**23.9**	**23.0**	**22.0**	**22.3**
Thorax Rib 2	**Displacement**	**Y**	**mm**	**CFC 180**	**28.0**	**26.8**	**26.0**	**27.6**	**26.3**	**25.4**	**24.5**	**23.7**	**23.1**	**23.1**
Thorax Rib 3	**Displacement**	**Y**	**mm**	**CFC 180**	**49.9**	**49.0**	**48.2**	**48.8**	**48.0**	**49.2**	**48.9**	**48.2**	**47.7**	**47.4**
Abdomen Rib 1	**Displacement**	**Y**	**mm**	**CFC 180**	**48.0**	**47.7**	**47.4**	**46.2**	**46.4**	**48.0**	**48.3**	**47.5**	**47.3**	**47.0**
Abdomen Rib 2	**Displacement**	**Y**	**mm**	**CFC 180**	**41.1**	**41.4**	**41.1**	**39.3**	**40.0**	**41.6**	**42.1**	**41.2**	**40.9**	**40.5**
Lumbar	Force	Y	N	CFC 1000	-1610.0	-1599.9	-1543.6	-1545.0	-1555.1	-1707.7	-1594.8	-1581.6	-1545.3	-1598.2
	Moment	X	N-m	CFC 1000	-81.9	-82.2	-79.7	-77.9	-79.1	-90.9	-85.8	-86.9	-85.9	-87.6
Acetabulum	Force	Y	N	CFC 600	2810.1	2759.8	2557.6	2742.7	2470.6	2763.7	2886.7	2993.7	2883.1	2650.8
Iliac Wing	Force	Y	N	CFC 600	-339.5	-303.5	-288.6	-328.7	-302.9	-267.3	-286.8	-275.0	-278.2	-274.5
Sum of Acetabulum and Iliac	**Force**	**Y**	**N**	**CFC 600**	**2625.7**	**2506.8**	**2309.0**	**2474.3**	**2213.5**	**2577.7**	**2722.2**	**2821.4**	**2715.0**	**2468.2**
Pelvis*	Acceleration	Y	g	CFC 1000	55.7	53.8	53.3	53.6	54.8	67.3	64.2	67.9	61.6	64.0
		Resultant	g	CFC 1000	79.8	72.7	70.2	74.6	76.3	77.9	93.9	81.0	82.5	70.4
Sled	Acceleration	X	g	CFC 60	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7
Sled	Velocity	X	m/s	CFC 60	-5.9	-5.8	-5.8	-5.9	-5.8	-5.9	-5.8	-5.8	-5.9	-5.8

Bold type indicates proposed injury criteria measures

*For Pelvis Y Acceleration, second peak is shown in table.

Table C.2. Statistical Analysis for 6.0 m/s Rigid Abdomen Offset Sled Tests

				Test Condition	6.0 m/s Rigid Abdomen Offset								
				Dummy Serial Number	032			056			032 & 056		
				Dummy Position	left & right			left & right			left & right		
Location	**Measurement**	**Direction**	**Units**	**Filter Class / Statistical Parameters**	AVG	SD	%CV	AVG	SD	%CV	AVG	SD	% CV
Head	Max Displacement	lateral	mm	n/a	236.8	1.8	0.8	240.4	1.7	0.7	238.6	2.5	1.0
		vertical	mm	n/a	128.4	9.0	7.0	114.8	5.2	4.5	121.6	10.0	8.2
	Time of Max Displacement	n/a	ms	n/a	134.0	2.9	2.2	133.0	1.9	1.4	133.5	2.4	1.8
	Acceleration	Y	g	CFC 1000	14.6	0.2	1.6	13.8	0.2	1.7	14.2	0.5	3.6
		Z	g	CFC 1000	32.4	0.8	2.6	33.5	0.5	1.5	32.9	0.9	2.7
		Resultant	g	CFC 1000	34.3	0.8	2.3	35.3	0.6	1.7	34.8	0.8	2.4
	HIC 36	**n/a**	**n/a**	**CFC 1000**	**77.7**	**2.6**	**3.4**	**80.6**	**2.1**	**2.6**	**79.1**	**2.7**	**3.4**
Upper Neck	Force	Y	N	CFC 1000	483.1	5.8	1.2	490.1	7.6	1.6	486.6	7.4	1.5
		Z	N	CFC 1000	1138.8	19.1	1.7	1209.8	22.7	1.9	1174.3	42.3	3.6
	Moment	+X	N-m	CFC 600	30.7	0.2	0.7	30.8	1.0	3.3	30.7	0.7	2.2
		-X	N-m	CFC 600	-25.8	0.3	-1.0	-27.1	1.0	-3.7	-26.4	1.0	-3.7
		Z	N-m	CFC 600	12.2	0.2	1.3	13.0	0.3	2.6	12.6	0.5	4.2
T1	Acceleration	Y	g	CFC 180	43.9	0.6	1.4	48.5	3.0	6.2	46.2	3.1	6.8
		Resultant	g	CFC 180	44.2	0.6	1.4	48.8	2.9	6.0	46.5	3.1	6.7
T12	**Acceleration**	Y	g	CFC 180	40.6	0.6	1.6	43.6	0.6	1.4	42.1	1.7	4.0
		Resultant	**g**	**CFC 180**	**41.2**	**0.8**	**1.9**	**43.8**	**0.7**	**1.7**	**42.5**	**1.6**	**3.7**
Shoulder Rib	Displacement	Y	mm	CFC 600	36.2	0.4	1.0	40.0	1.0	2.4	38.1	2.1	5.6
Thorax Rib 1	**Displacement**	**Y**	**mm**	**CFC 180**	**24.5**	**0.5**	**1.9**	**23.2**	**1.2**	**5.2**	**23.9**	**1.1**	**4.6**
Thorax Rib 2	**Displacement**	**Y**	**mm**	**CFC 180**	**26.9**	**0.8**	**3.1**	**24.0**	**1.0**	**4.1**	**25.5**	**1.8**	**7.0**
Thorax Rib 3	**Displacement**	**Y**	**mm**	**CFC 180**	**48.8**	**0.7**	**1.5**	**48.3**	**0.8**	**1.6**	**48.5**	**0.8**	**1.6**
Abdomen Rib 1	**Displacement**	**Y**	**mm**	**CFC 180**	**47.1**	**0.8**	**1.7**	**47.6**	**0.5**	**1.1**	**47.4**	**0.7**	**1.4**
Abdomen Rib 2	**Displacement**	**Y**	**mm**	**CFC 180**	**40.6**	**0.9**	**2.3**	**41.3**	**0.6**	**1.5**	**40.9**	**0.8**	**2.0**
Lumbar	Force	Y	N	CFC 1000	-1570.7	31.8	-2.0	-1605.5	60.8	-3.8	-1588.1	49.3	-3.1
	Moment	X	N-m	CFC 1000	-80.1	1.8	-2.3	-87.4	2.1	-2.4	-83.8	4.3	-5.1
Acetabulum	Force	Y	N	CFC 600	2668.2	146.1	5.5	2835.6	131.5	4.6	2751.9	158.0	5.7
Iliac Wing	Force	Y	N	CFC 600	-312.6	20.8	-6.7	-276.4	7.1	-2.6	-294.5	24.1	-8.2
***Sum of* Acetabulum and Iliac**	**Force**	**Y**	**N**	**CFC 600**	**2425.9**	**164.0**	**6.8**	**2660.9**	**138.3**	**5.2**	**2543.4**	**189.2**	**7.4**
Pelvis*	Acceleration	Y	g	CFC 1000	54.2	1.0	1.8	65.0	2.6	4.0	59.6	6.0	10.0
		Resultant	g	CFC 1000	74.7	3.6	4.9	81.2	8.5	10.5	77.9	7.0	9.0
Sled	Acceleration	X	g	CFC 60	-11.7	0.0	-0.3	-11.7	0.0	-0.3	-11.7	0.0	-0.3
Sled	Velocity	X	m/s	CFC 60	-5.8	0.0	-0.3	-5.8	0.0	-0.3	-5.8	0.0	-0.3

Bold type indicates proposed injury criteria measures

%CV<=5.0 | 5.1%<CV<=10.0% | CV>10.0%

*For Pelvis Y Acceleration, second peak is shown in table.

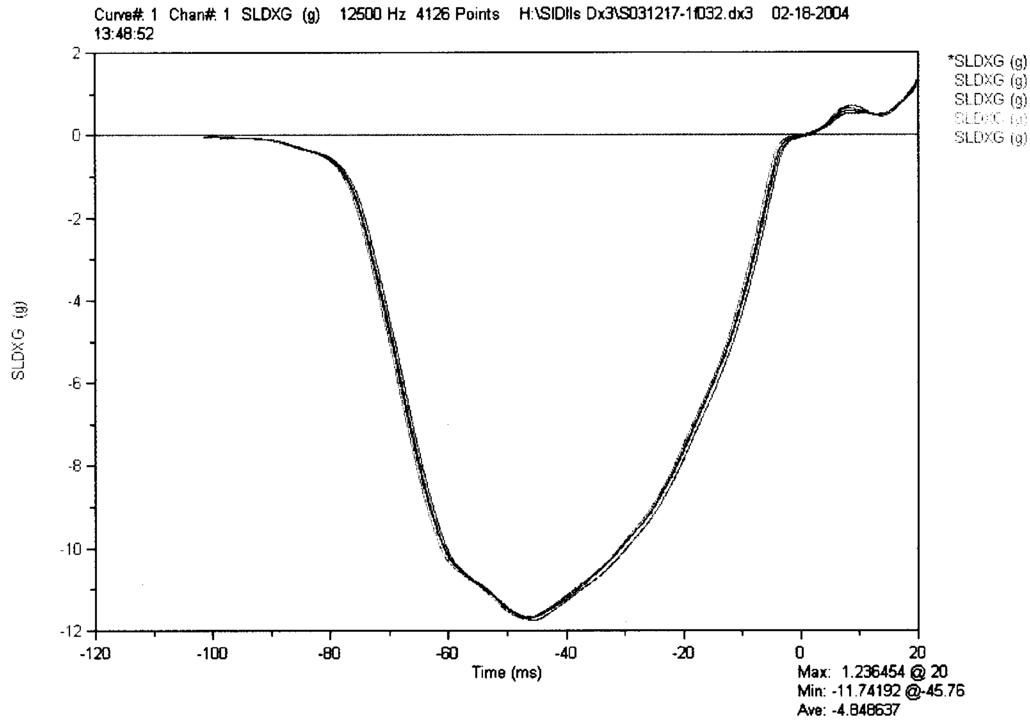

Figure C.1. Sled Acceleration Pulse

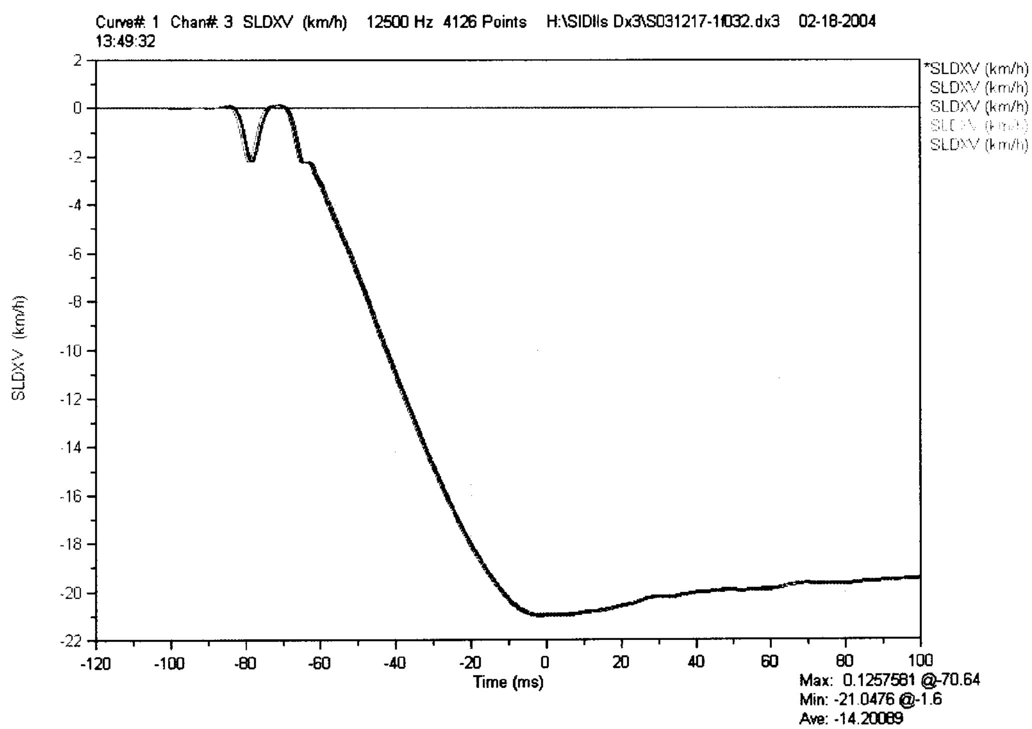

Figure C.2. Sled Velocity

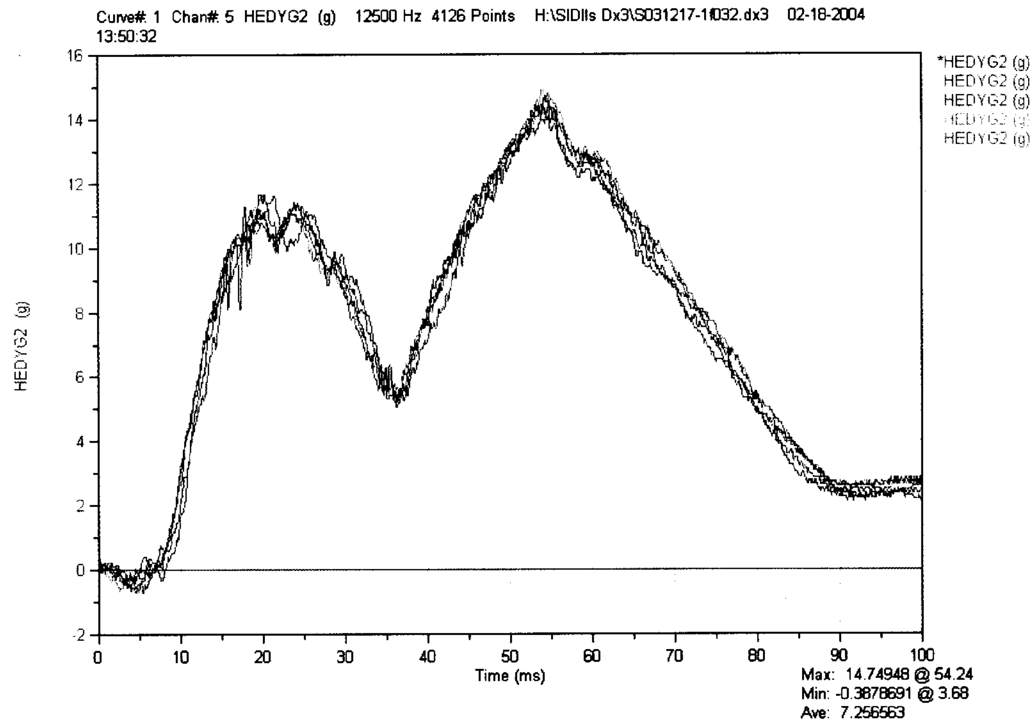

Figure C.3.a. Head Lateral Acceleration – Dummy 032

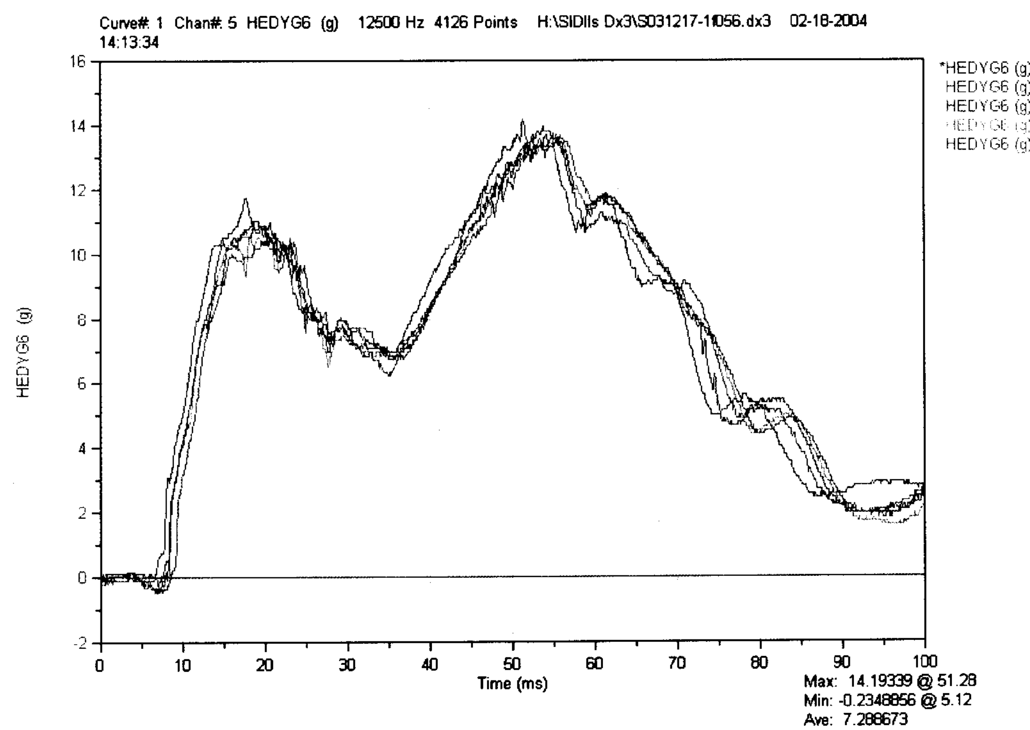

Figure C.3.b. Head Lateral Acceleration – Dummy 056

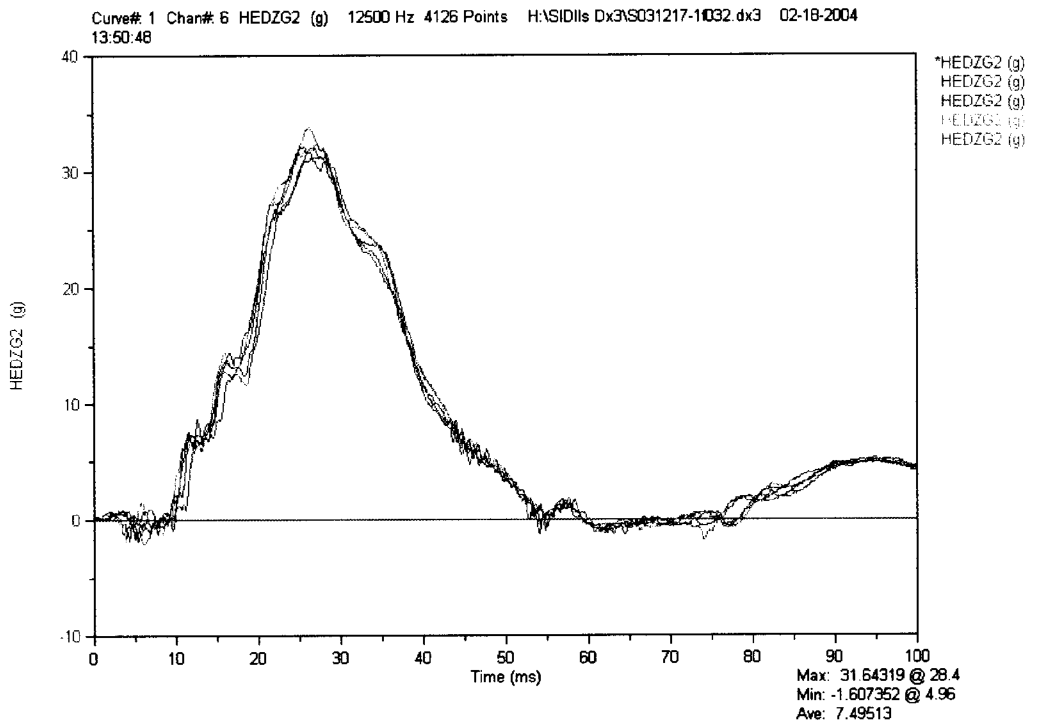

Figure C.4.a. Head Vertical Acceleration – Dummy 032

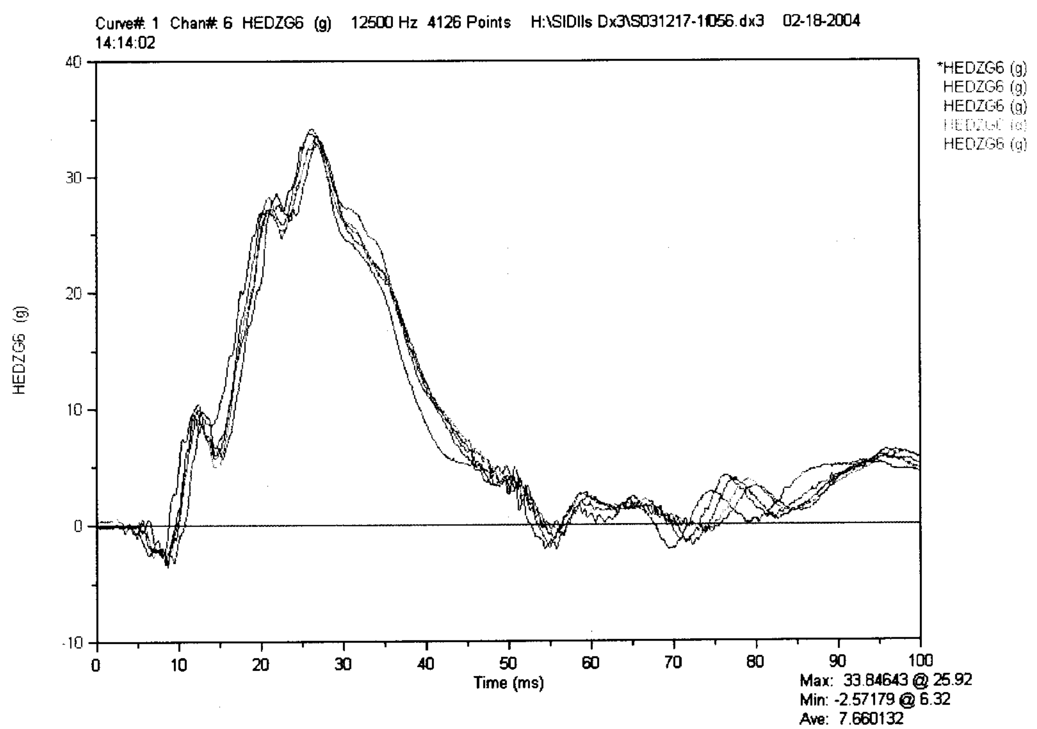

Figure C.4.b. Head Vertical Acceleration – Dummy 056

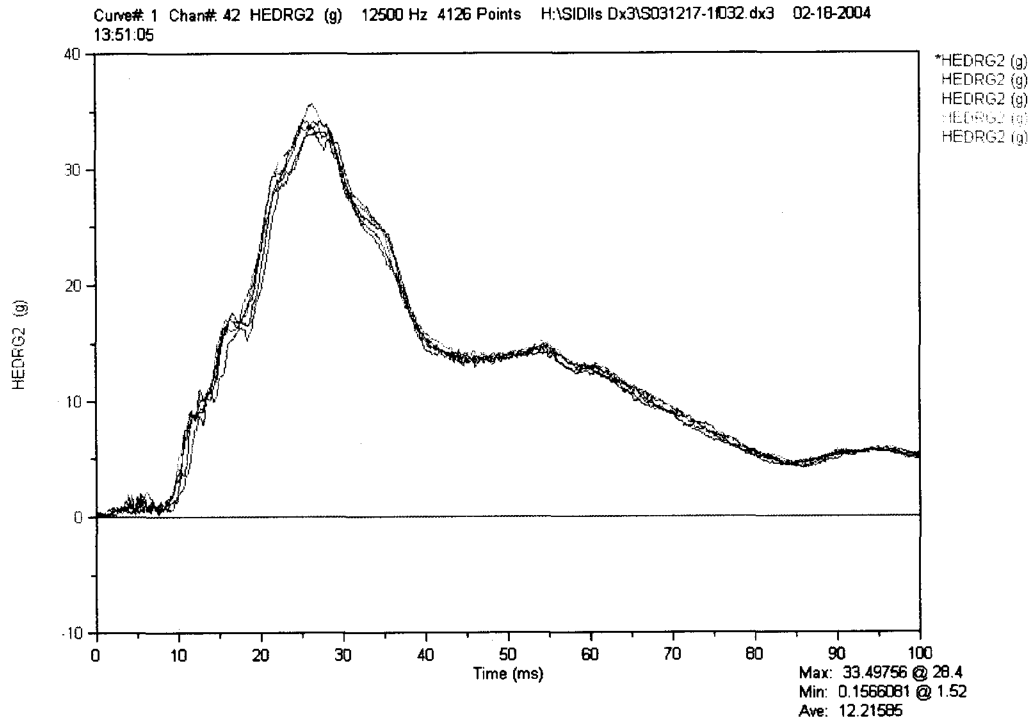

Figure C.5.a. Head Resultant Acceleration – Dummy 032

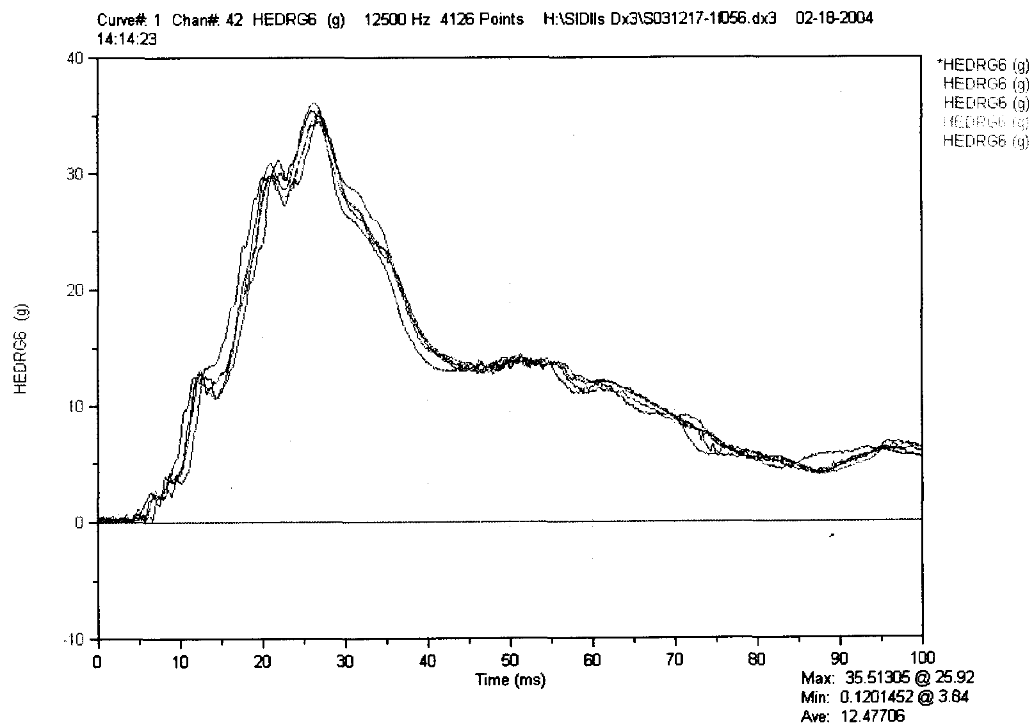

Figure C.5.b. Head Resultant Acceleration – Dummy 056

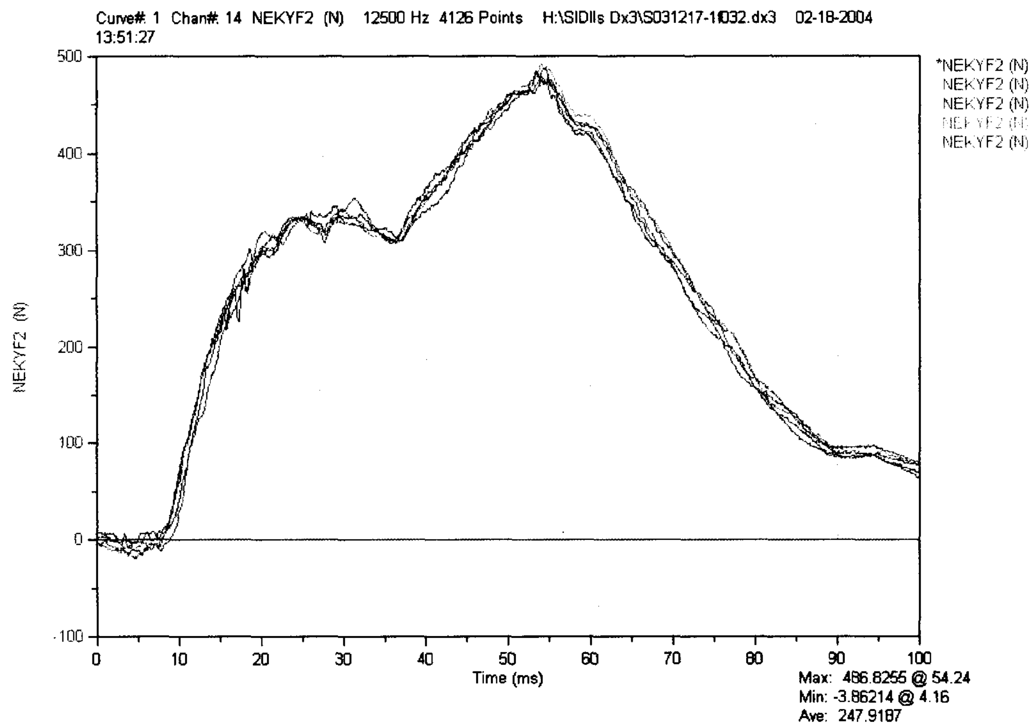

Figure C.6.a. Upper Neck Lateral Shear Force – Dummy 032

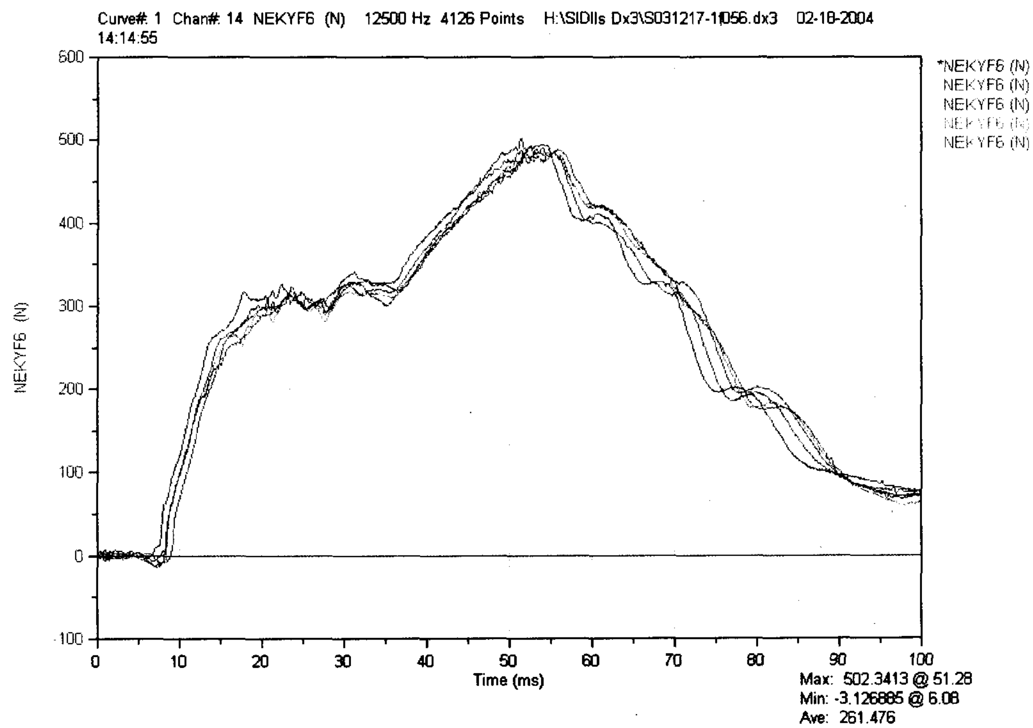

Figure C.6.b. Upper Neck Lateral Shear Force – Dummy 056

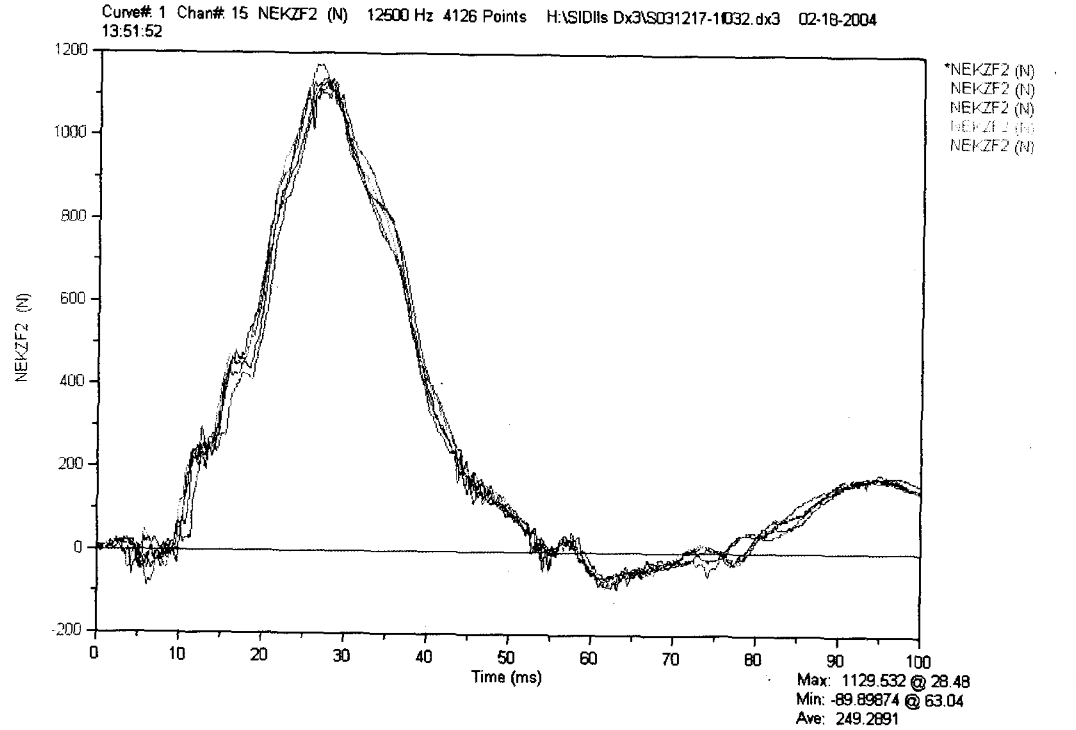

Figure C.7.a. Upper Neck Axial Force – Dummy 032

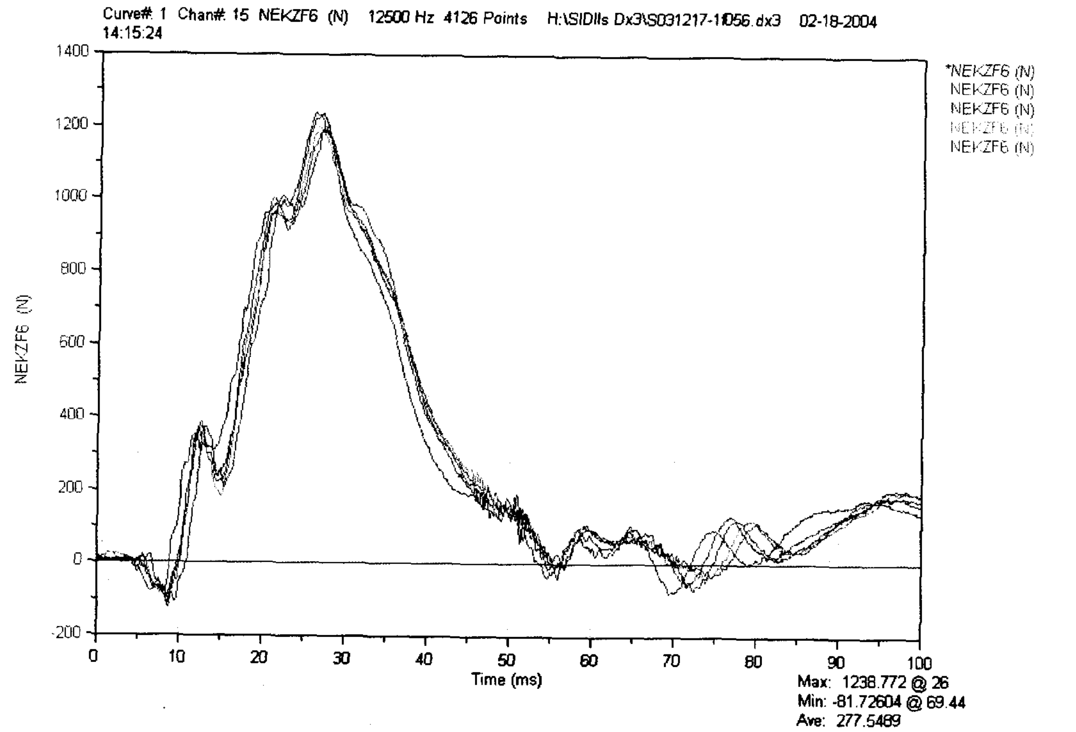

Figure C.7.b. Upper Neck Axial Force – Dummy 056

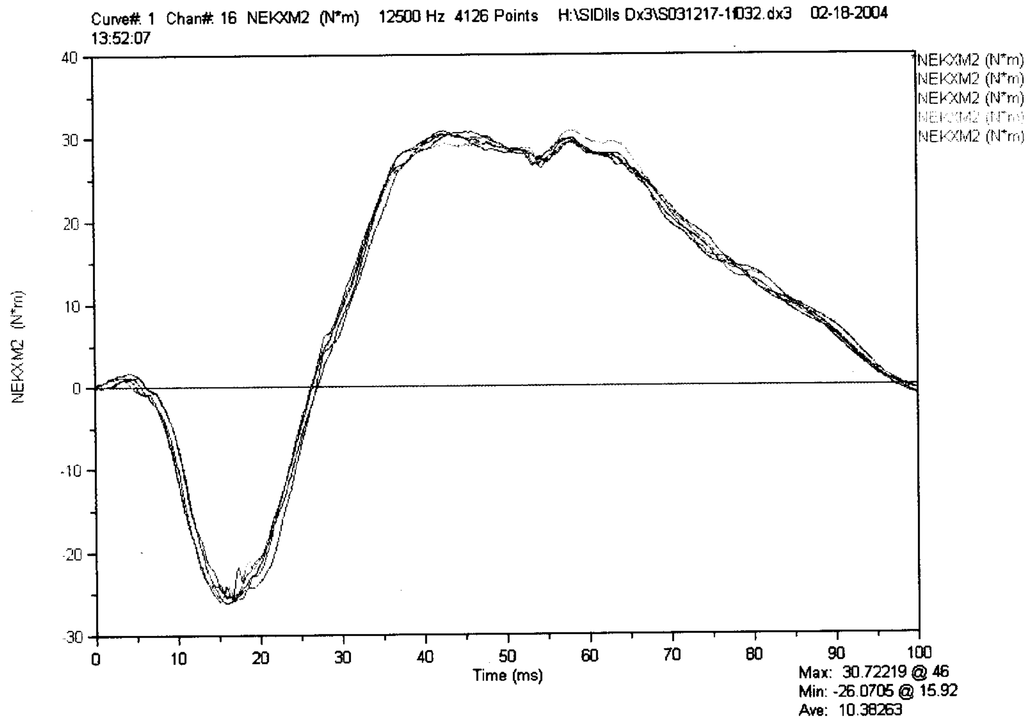

Figure C.8.a. Upper Neck Lateral Bending Moment – Dummy 032

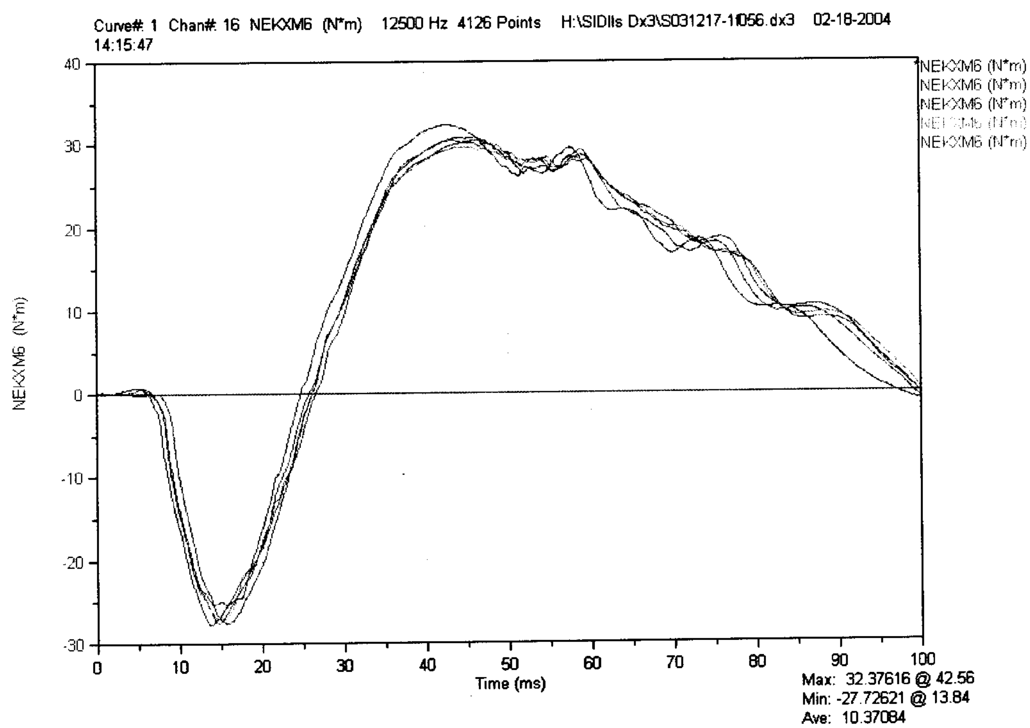

Figure C.8.b. Upper Neck Lateral Bending Moment – Dummy 056

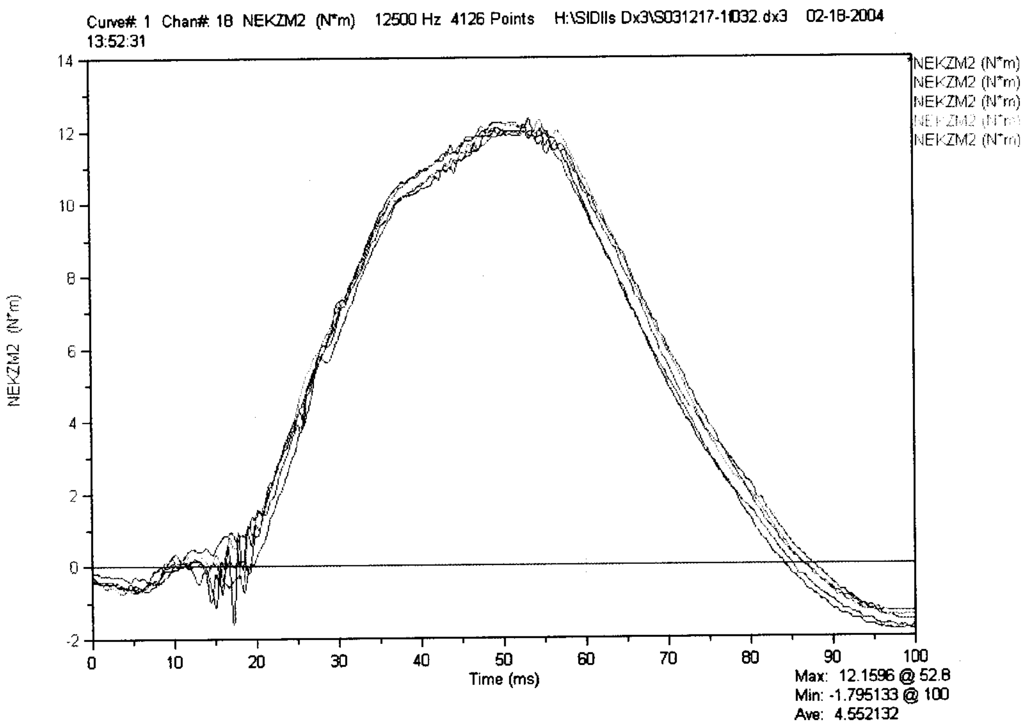

Figure C.9.a. Upper Neck Axial Moment – Dummy 032

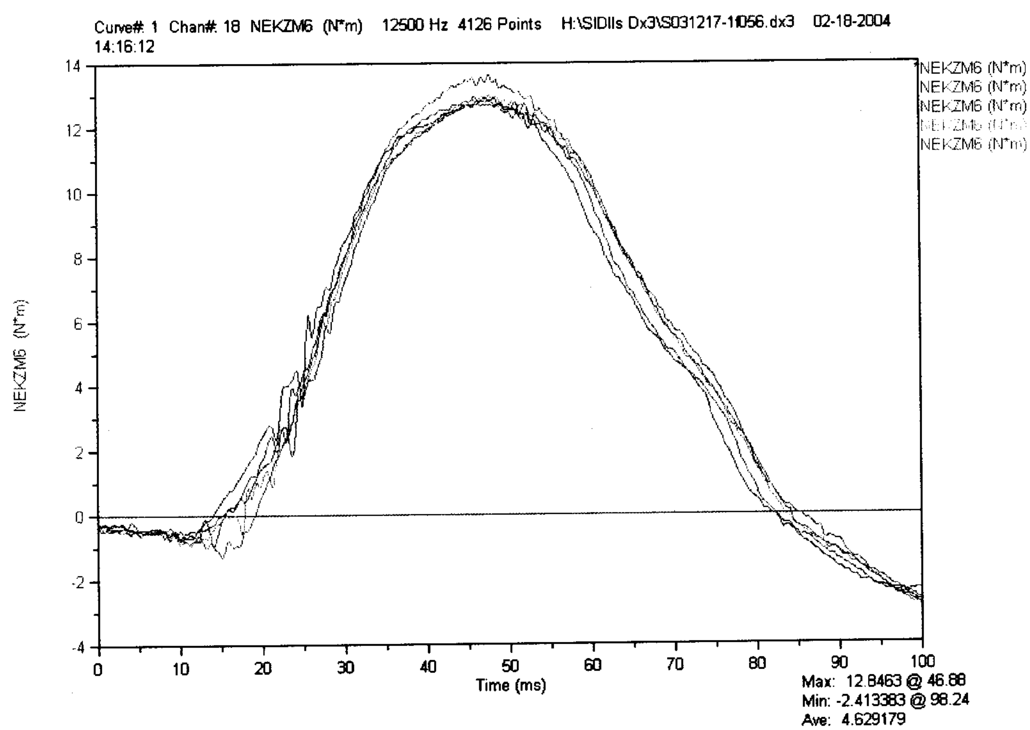

Figure C.9.b. Upper Neck Axial Moment – Dummy 056

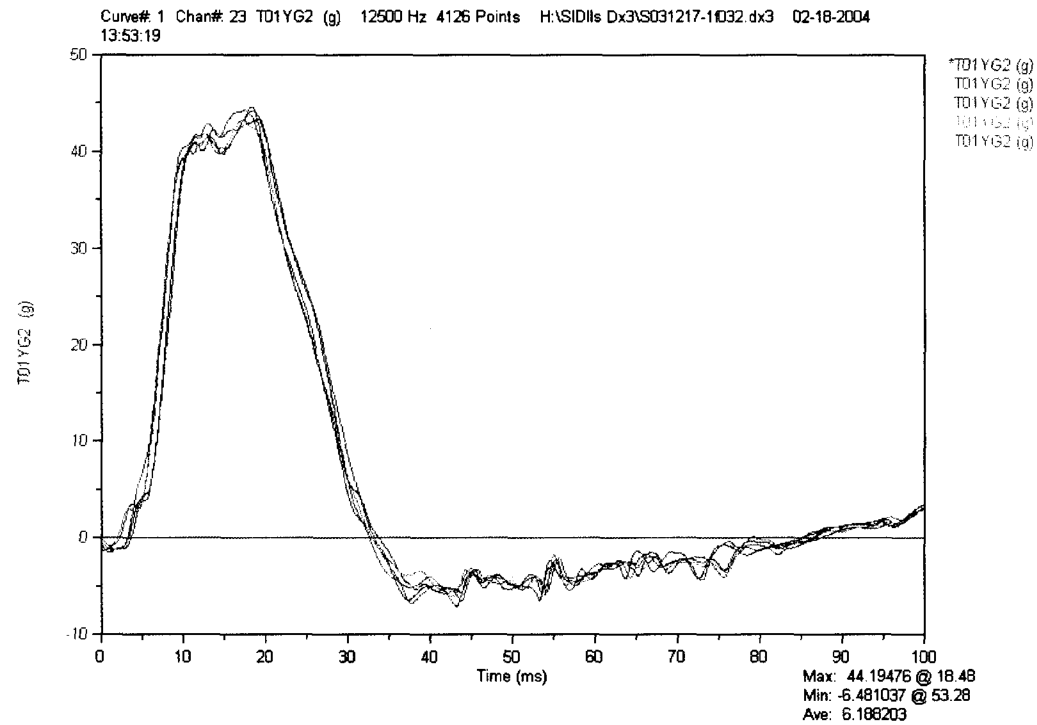

Figure C.10.a. Upper Spine (T1) Lateral Acceleration – Dummy 032

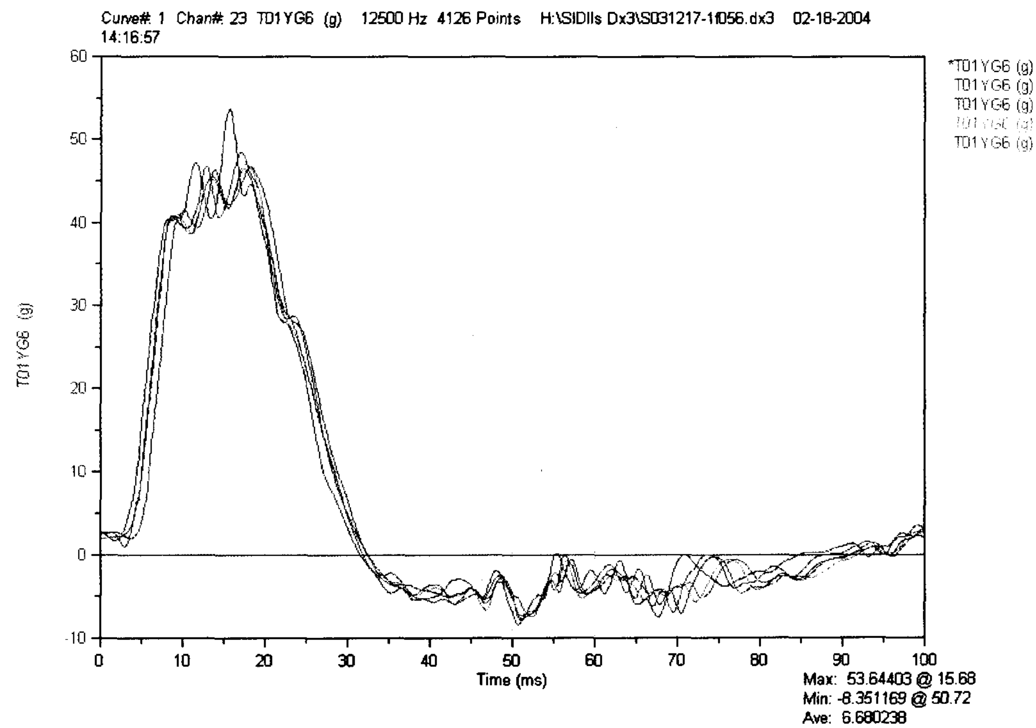

Figure C.10.b. Upper Spine (T1) Lateral Acceleration – Dummy 056

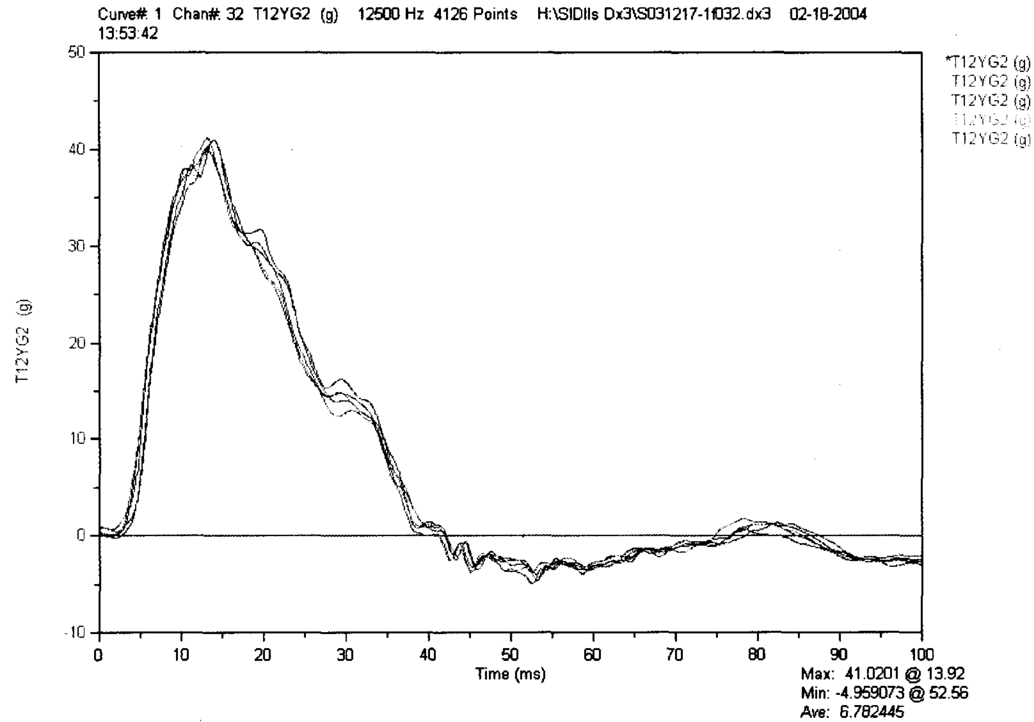

Figure C.11.a. Lower Spine (T12) Lateral Acceleration – Dummy 032

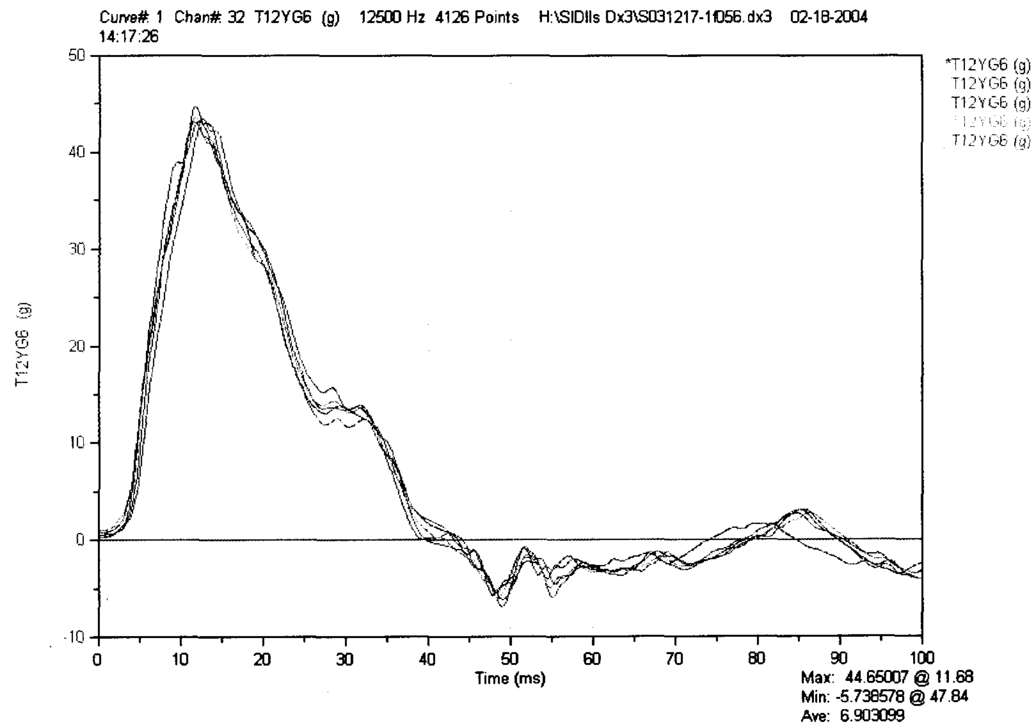

Figure C.11.b. Lower Spine (T12) Lateral Acceleration – Dummy 056

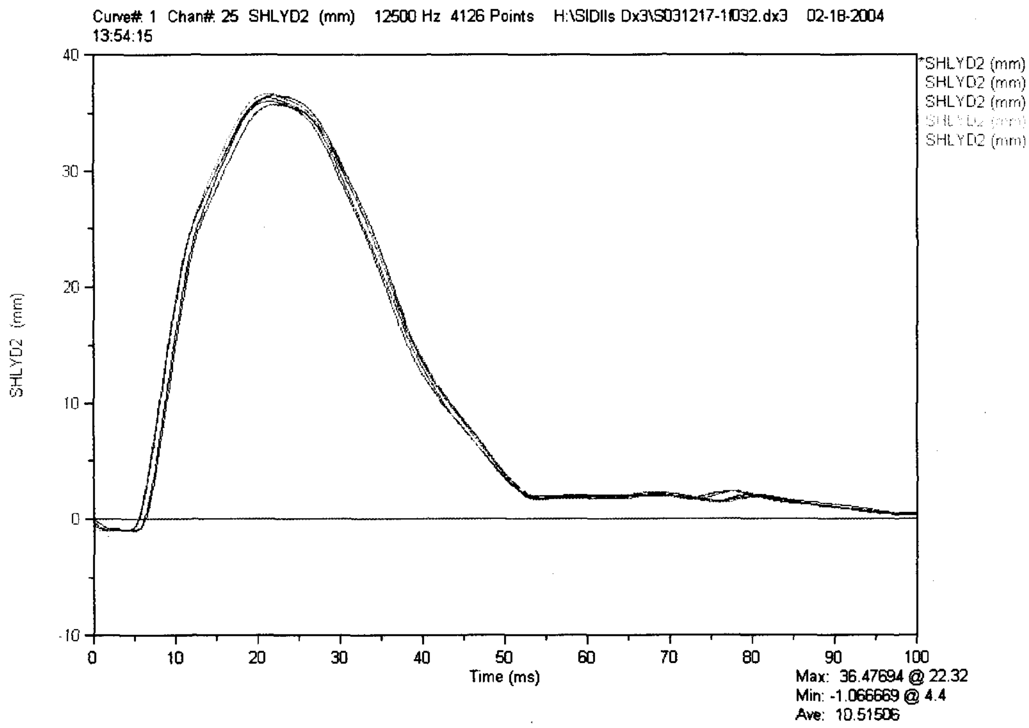

Figure C.12.a. Shoulder Rib Deflection – Dummy 032

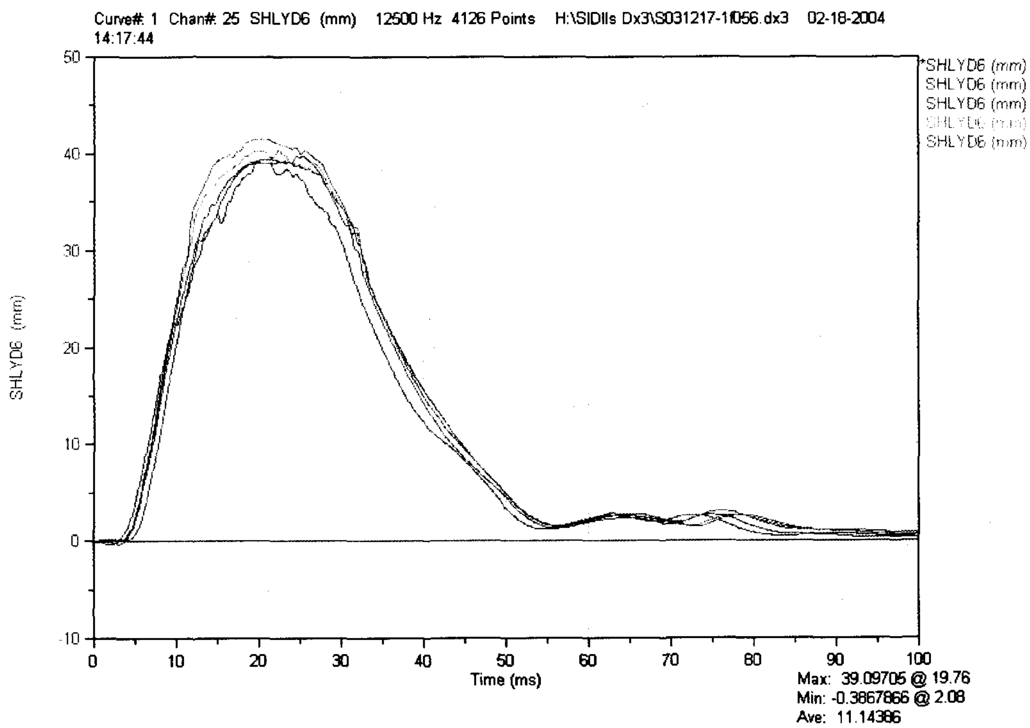

Figure C.12.b. Shoulder Rib Deflection – Dummy 056

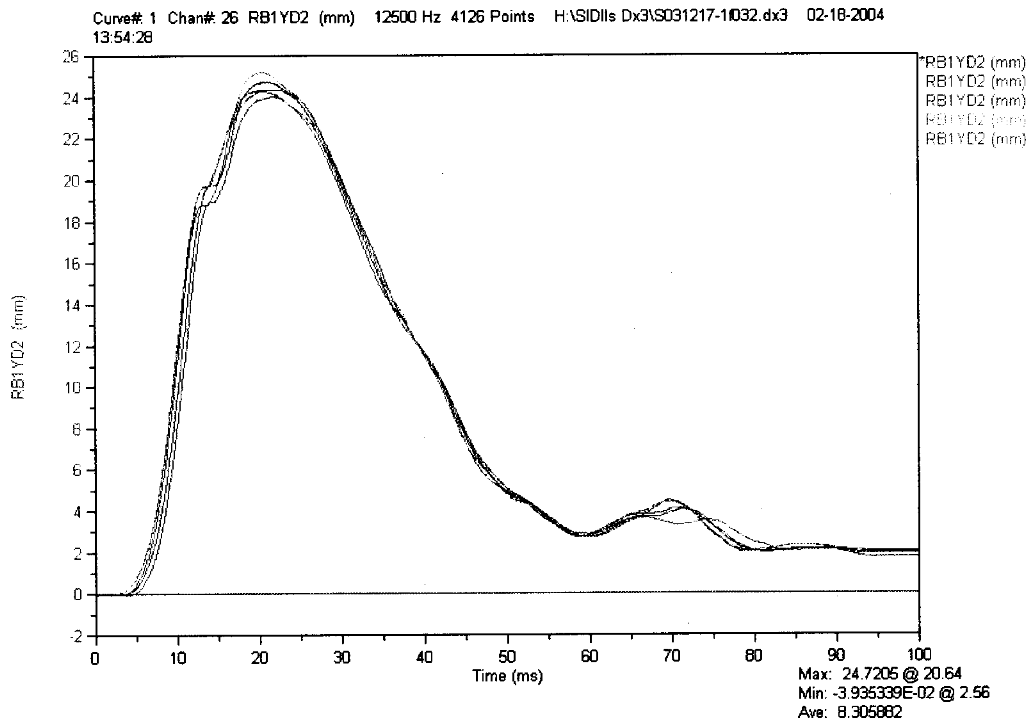

Figure C.13.a. Upper Thoracic Rib Deflection – Dummy 032

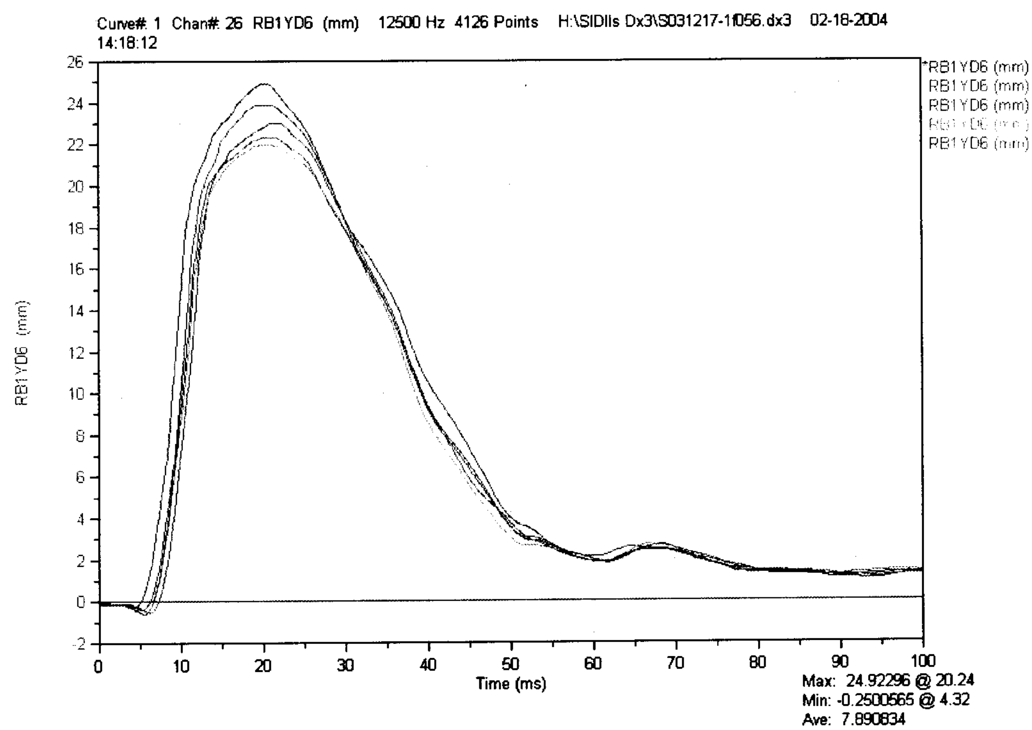

Figure C.13.b. Upper Thoracic Rib Deflection – Dummy 056

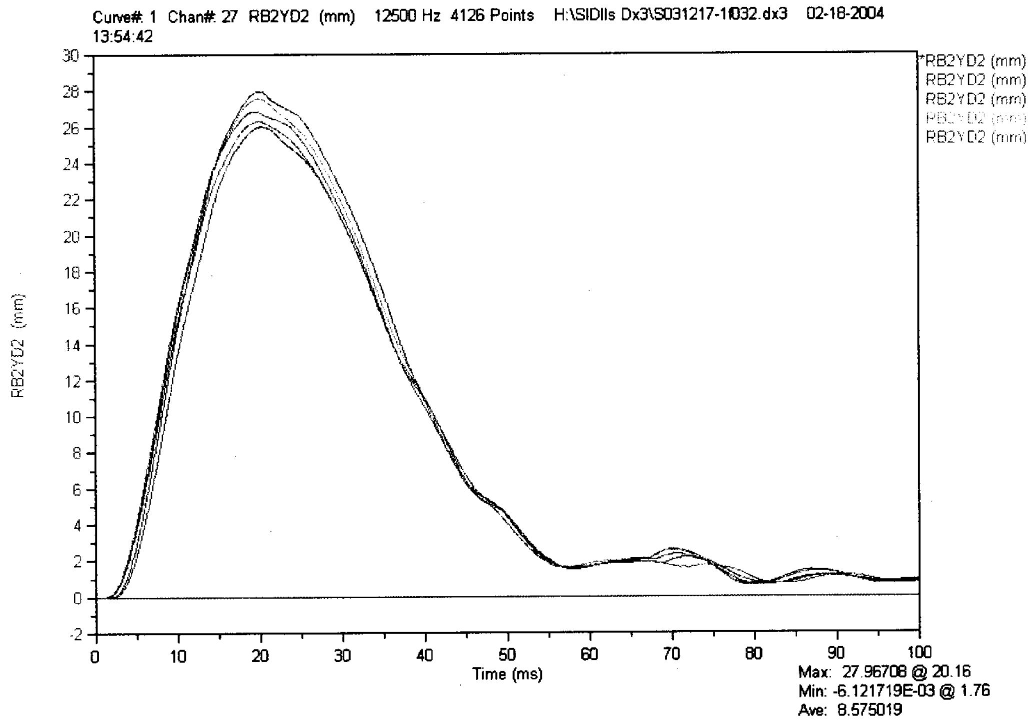

Figure C.14.a. Middle Thoracic Rib Deflection – Dummy 032

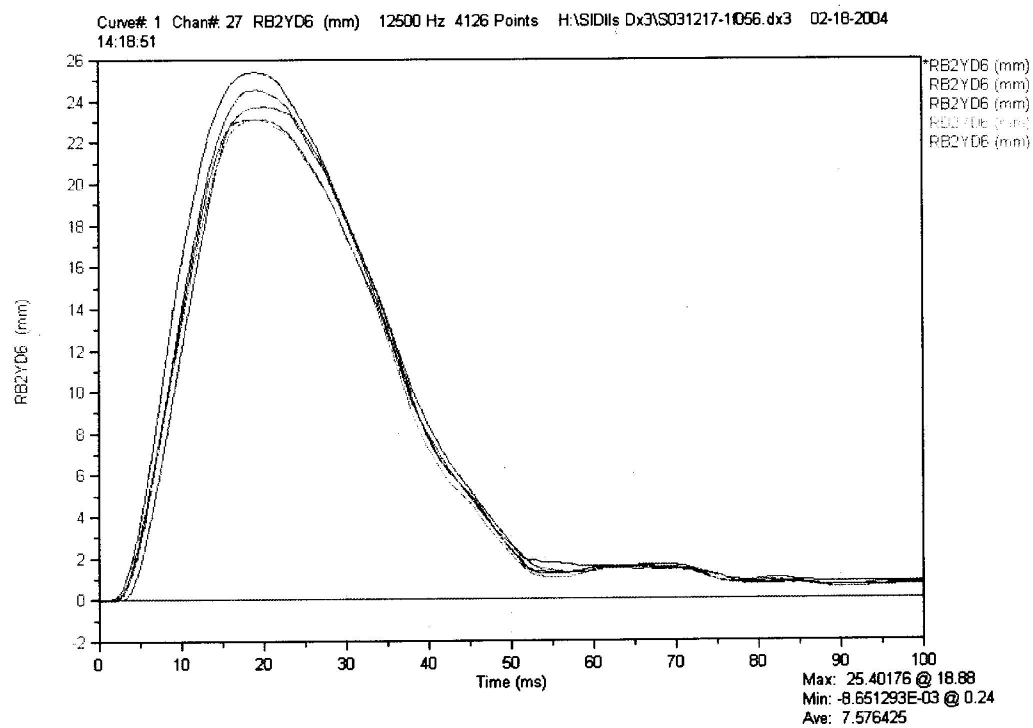

Figure C.14.b. Middle Thoracic Rib Deflection – Dummy 056

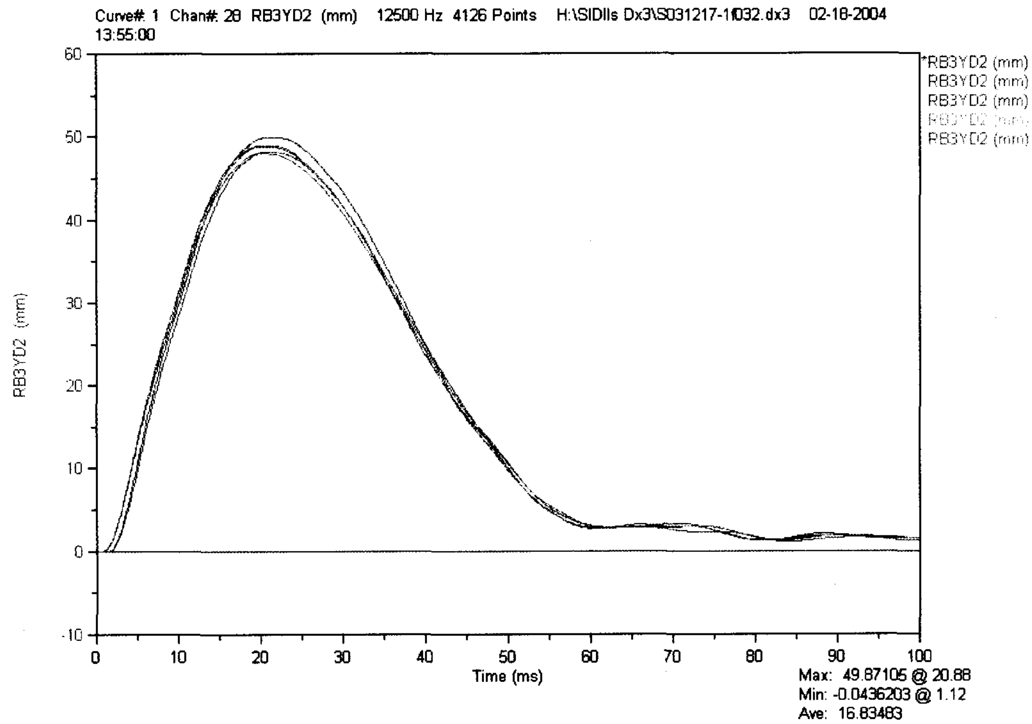

Figure C.15.a. Lower Thoracic Rib Deflection – Dummy 032

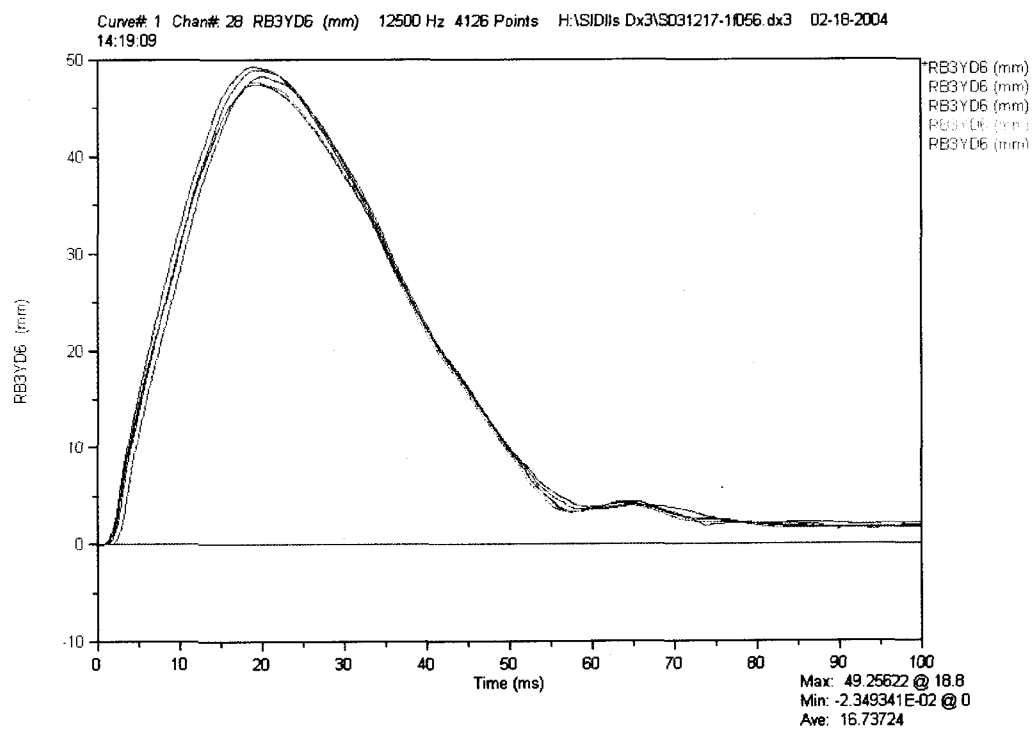

Figure C.15.b. Lower Thoracic Rib Deflection – Dummy 056

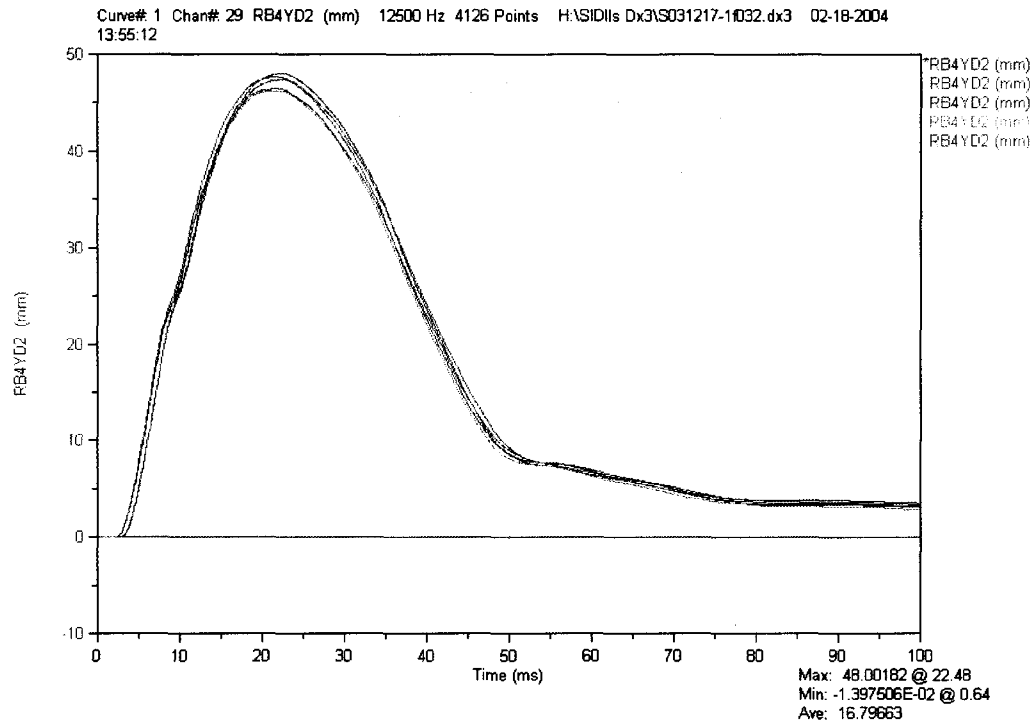

Figure C.16.a. Upper Abdominal Rib Deflection – Dummy 032

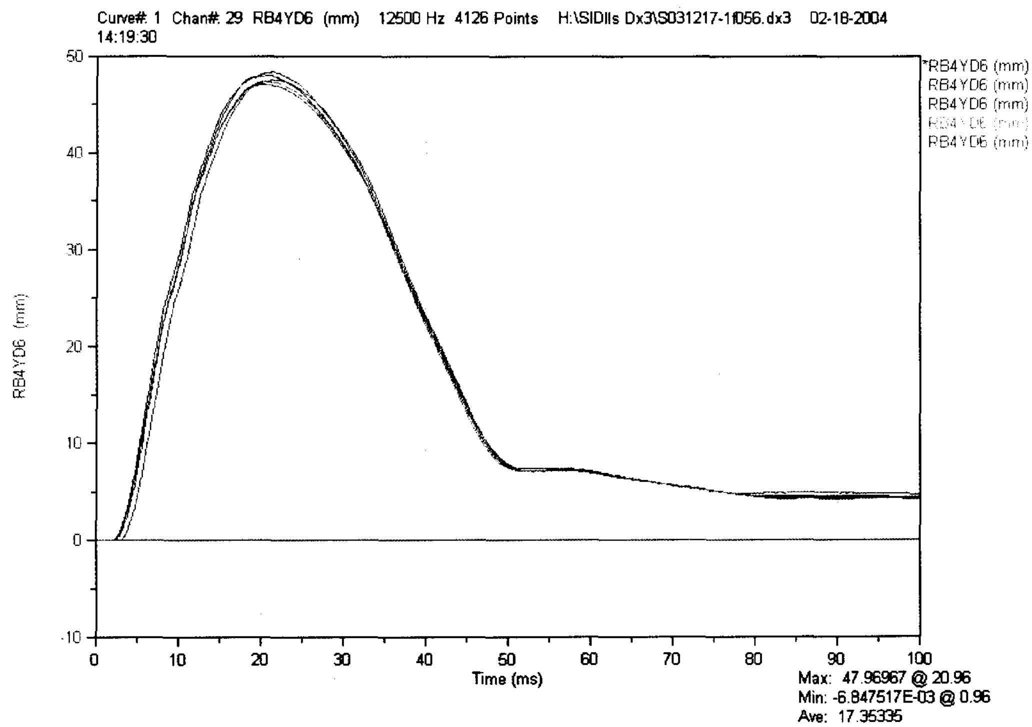

Figure C.16.b. Upper Abdominal Rib Deflection – Dummy 056

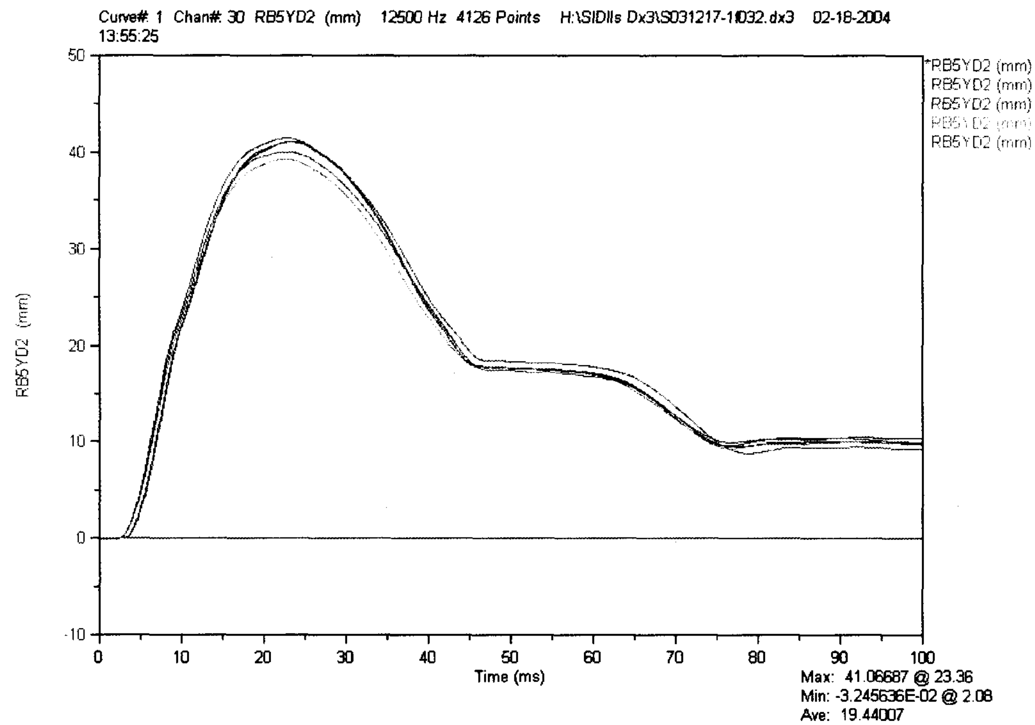

Figure C.17.a. Lower Abdominal Rib Deflection – Dummy 032

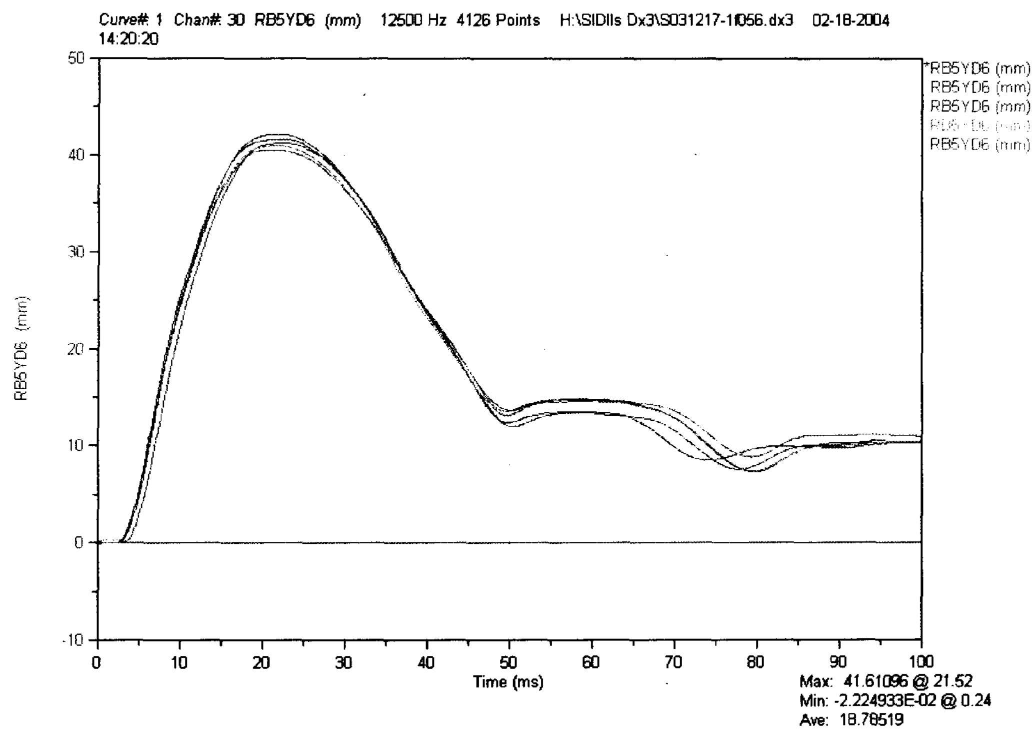

Figure C.17.b. Lower Abdominal Rib Deflection – Dummy 056

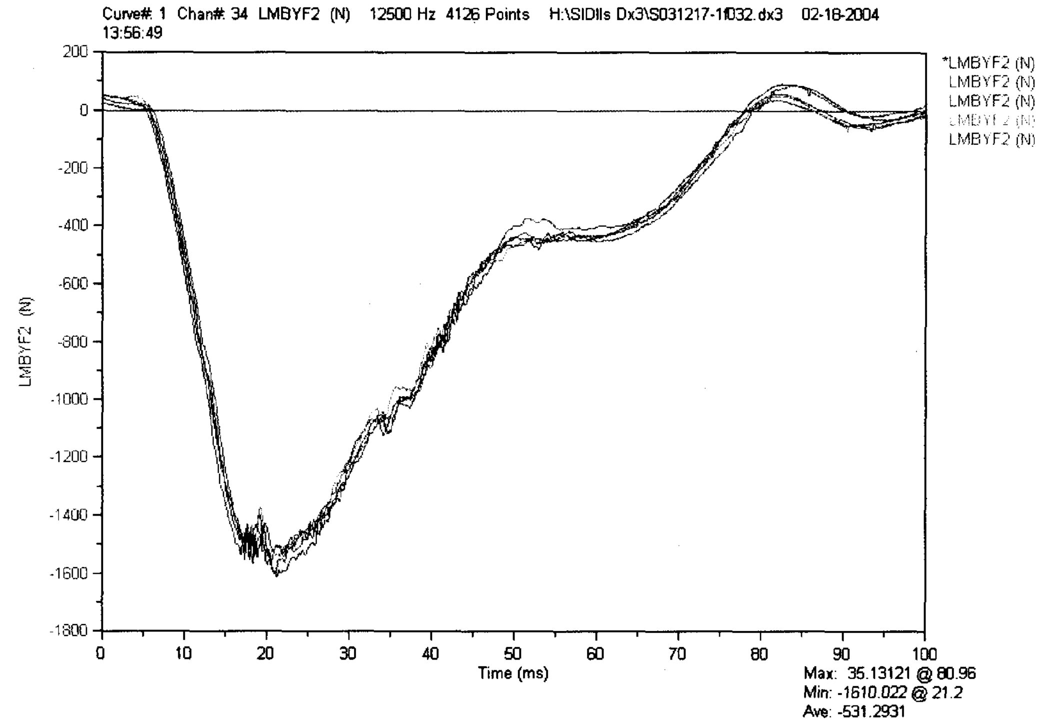

Figure C.18.a. Lumbar Lateral Shear Force – Dummy 032

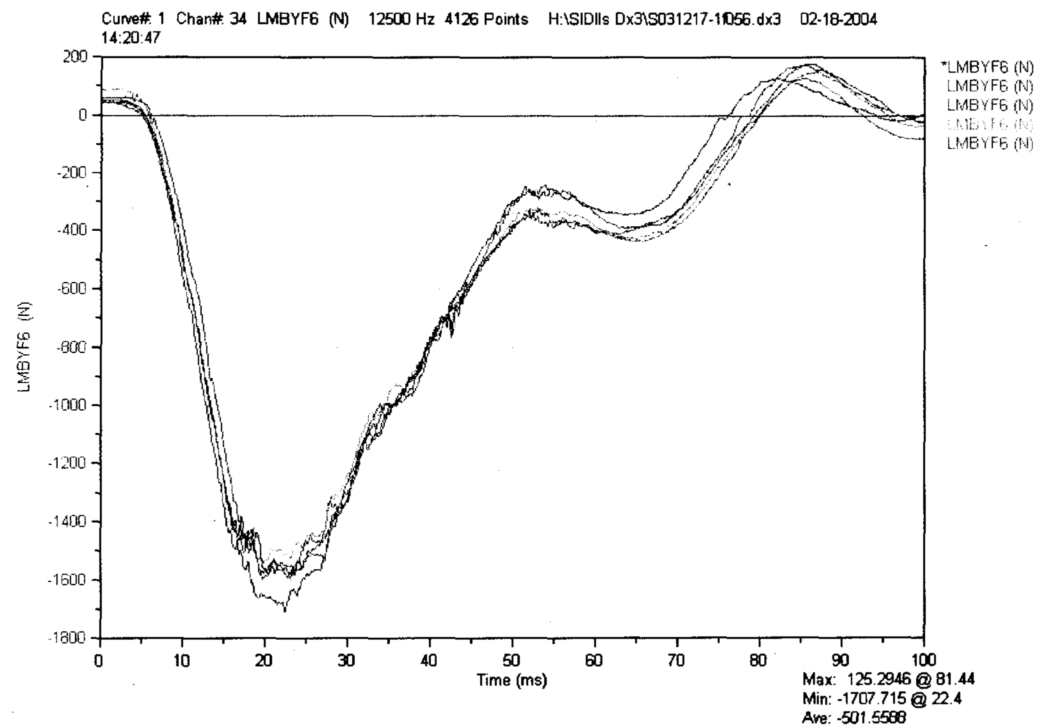

Figure C.18.b. Lumbar Lateral Shear Force – Dummy 056

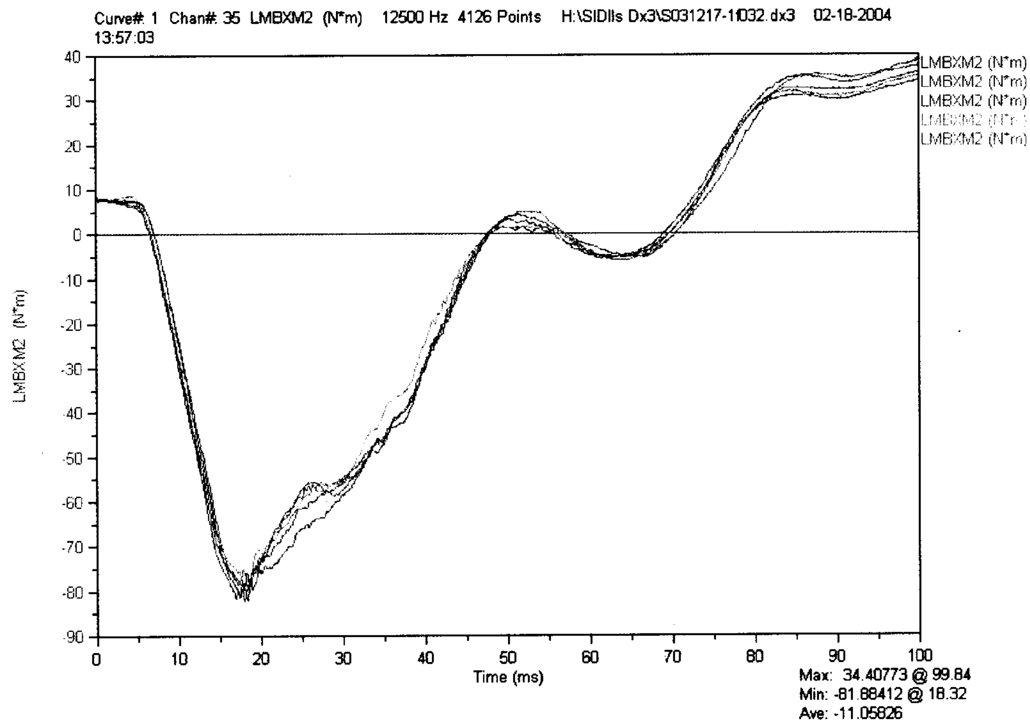

Figure C.19.a. Lumbar Lateral Bending Moment – Dummy 032

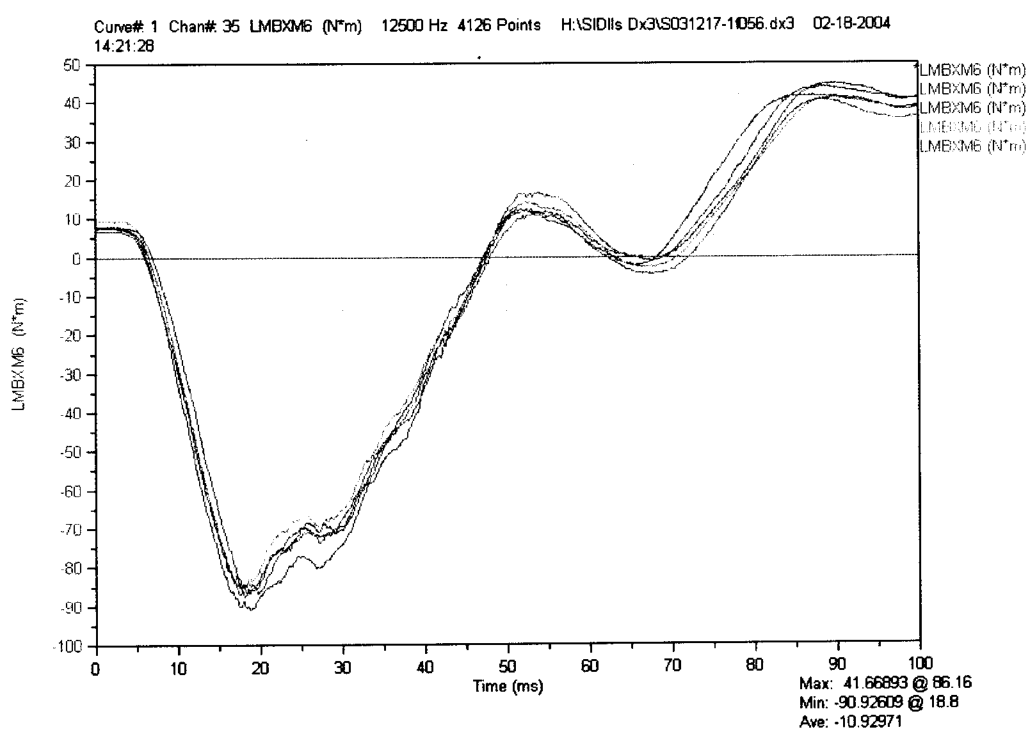

Figure C.19.b. Lumbar Lateral Bending Moment – Dummy 056

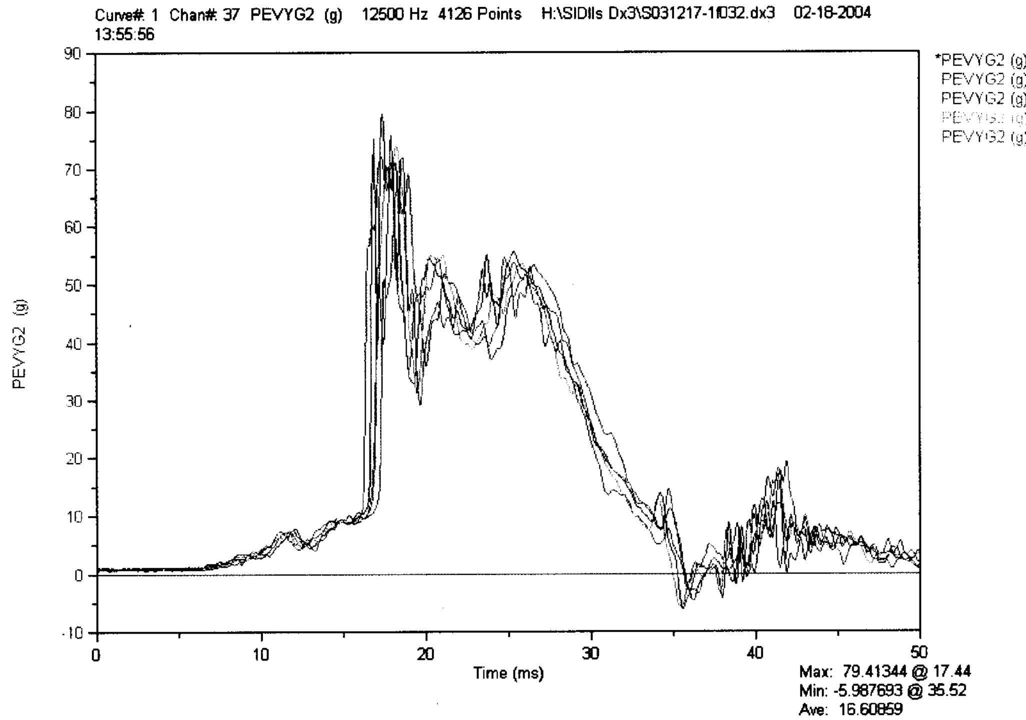

Figure C.20.a. Pelvis Lateral Acceleration – Dummy 032

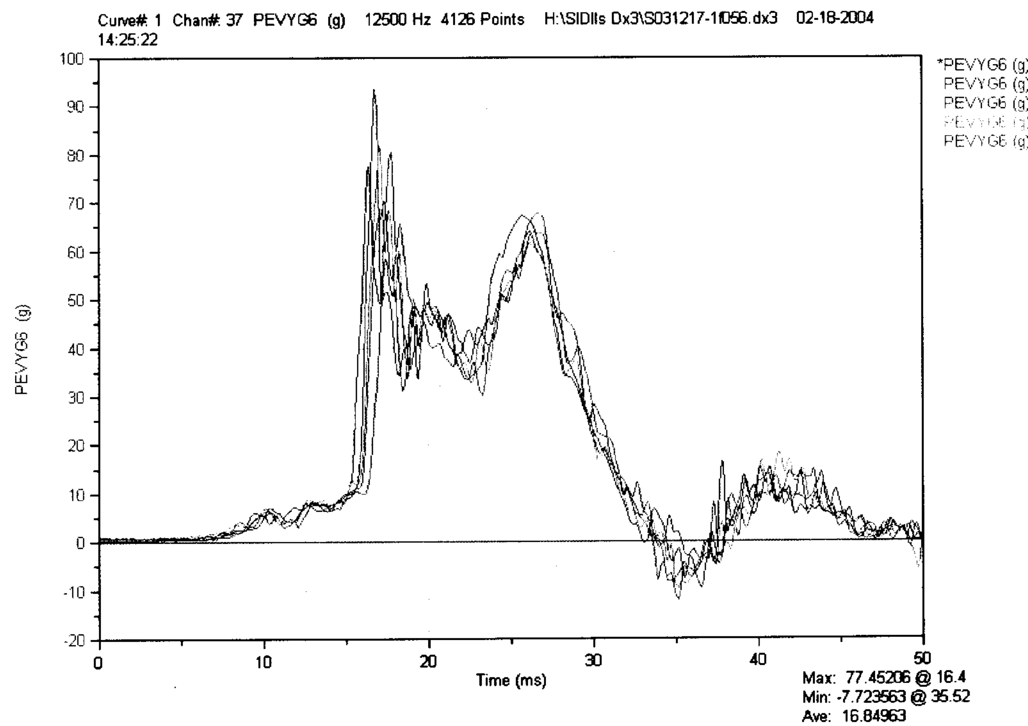

Figure C.20.b. Pelvis Lateral Acceleration – Dummy 056

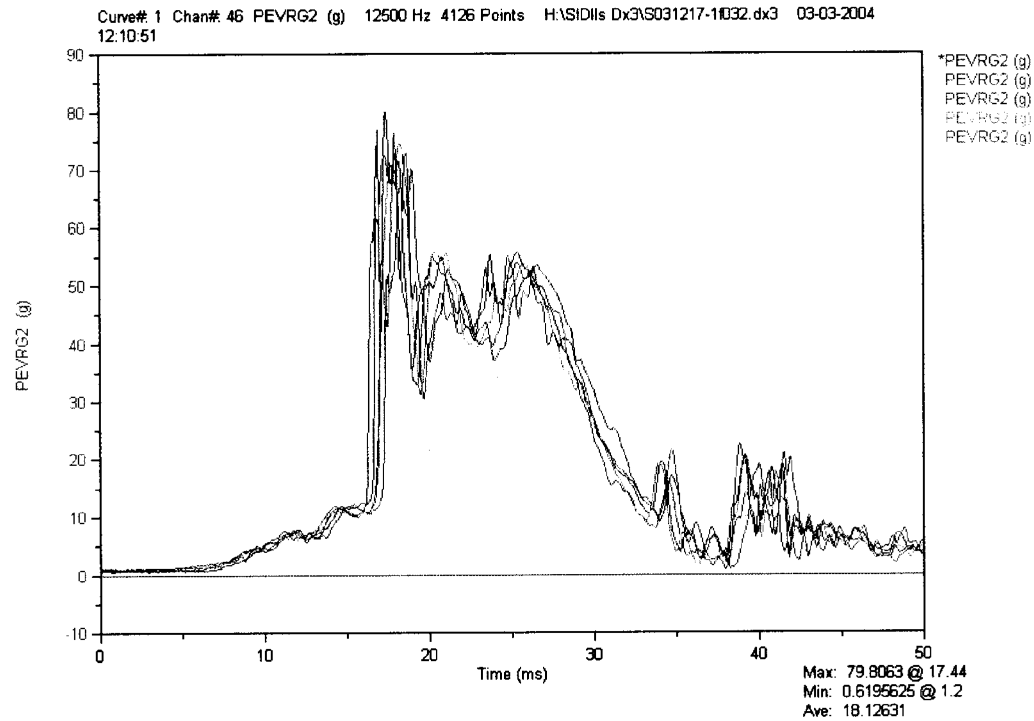

Figure C.21.a. Pelvis Resultant Acceleration – Dummy 032

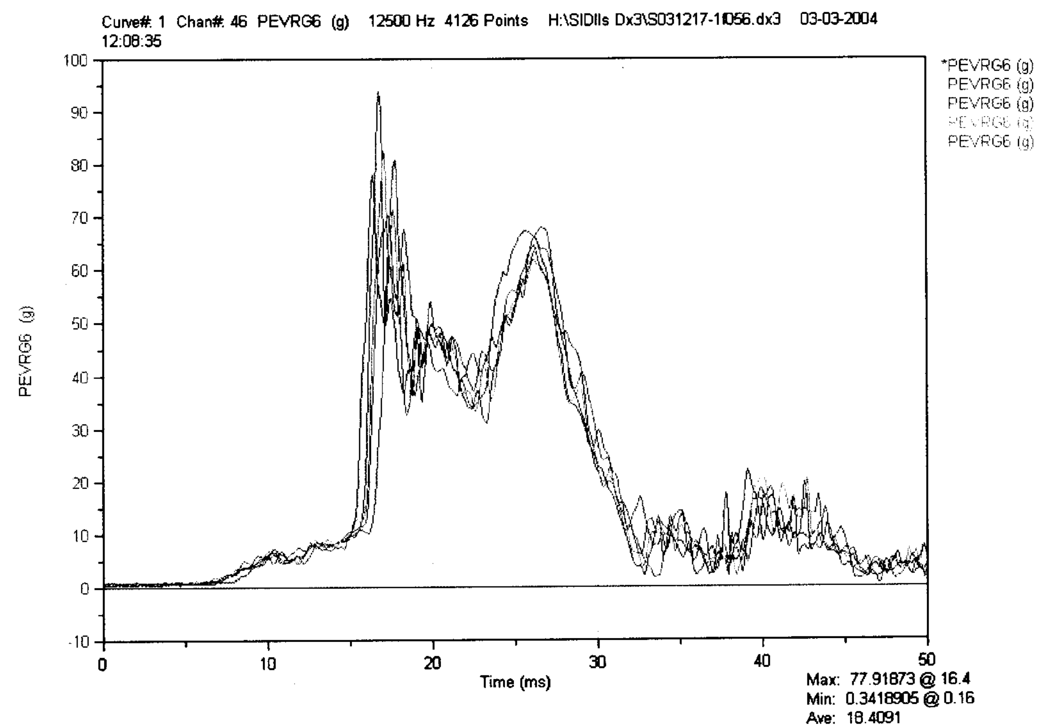

Figure C.21.b. Pelvis Resultant Acceleration – Dummy 056

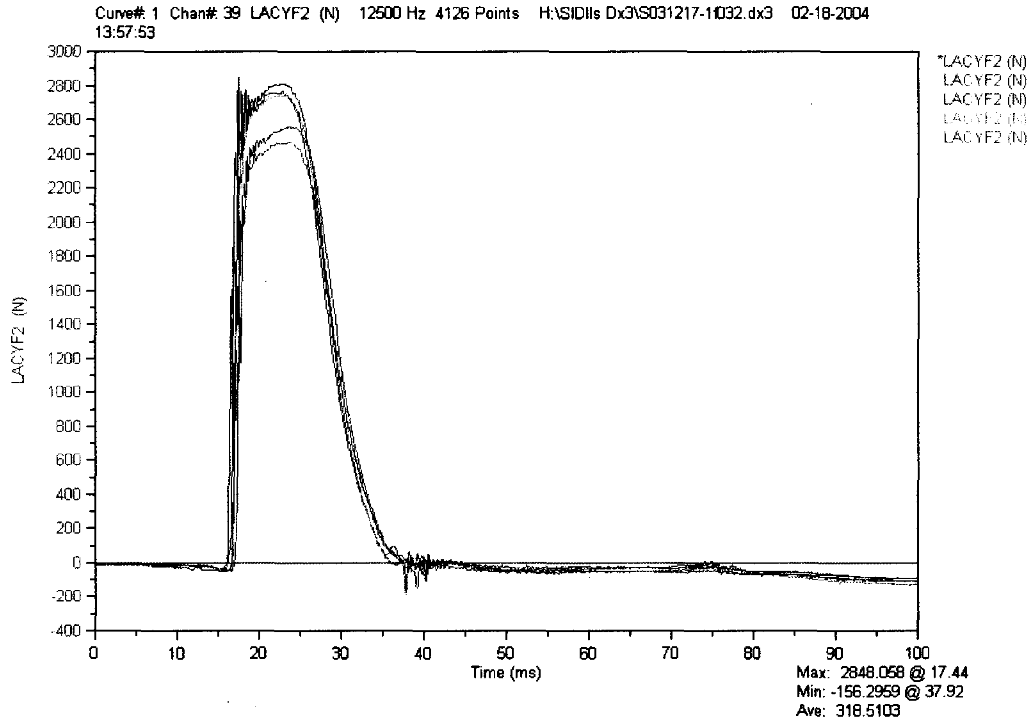

Figure C.22.a. Left Acetabulum Lateral Force – Dummy 032

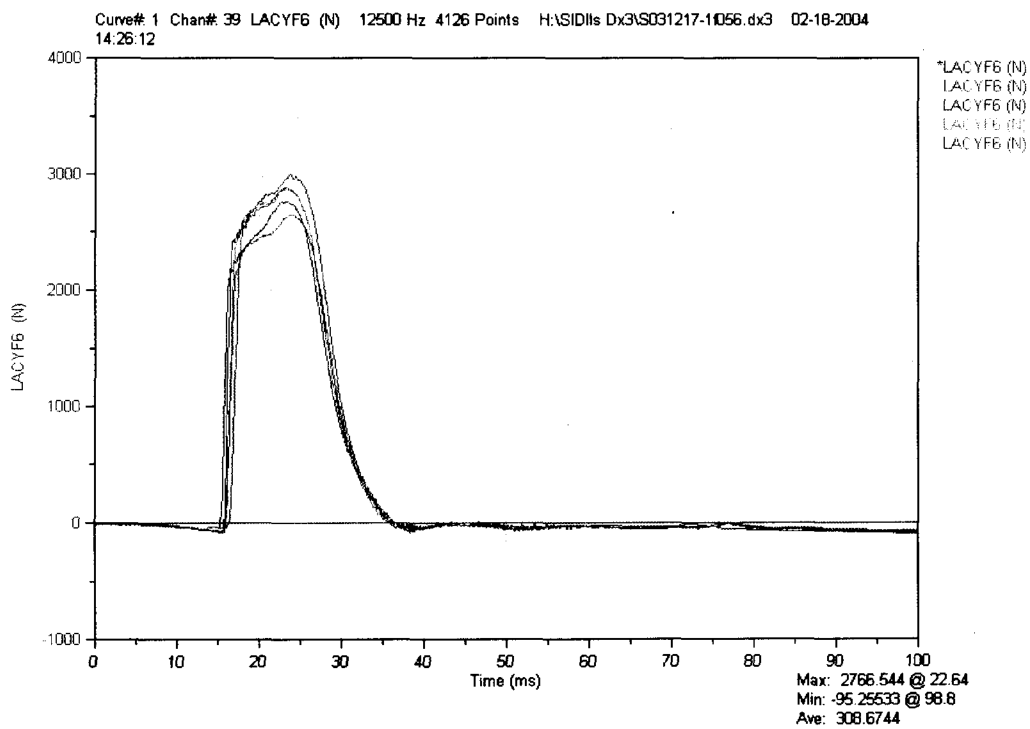

Figure C.22.b. Left Acetabulum Lateral Force – Dummy 056

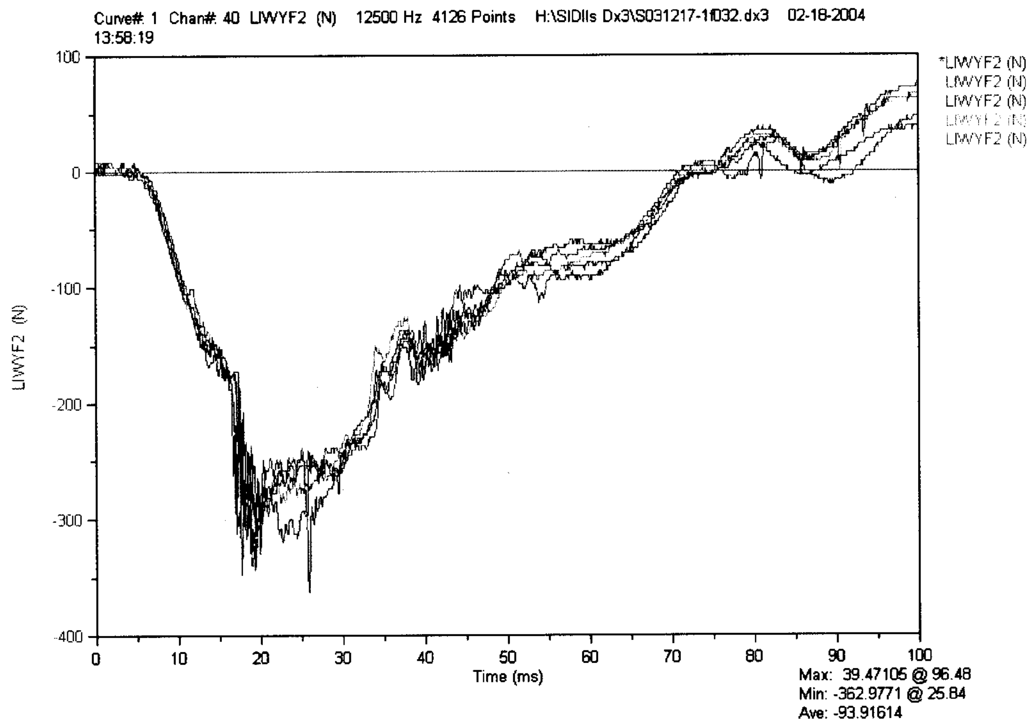

Figure C.23.a. Left Iliac Wing Lateral Force – Dummy 032

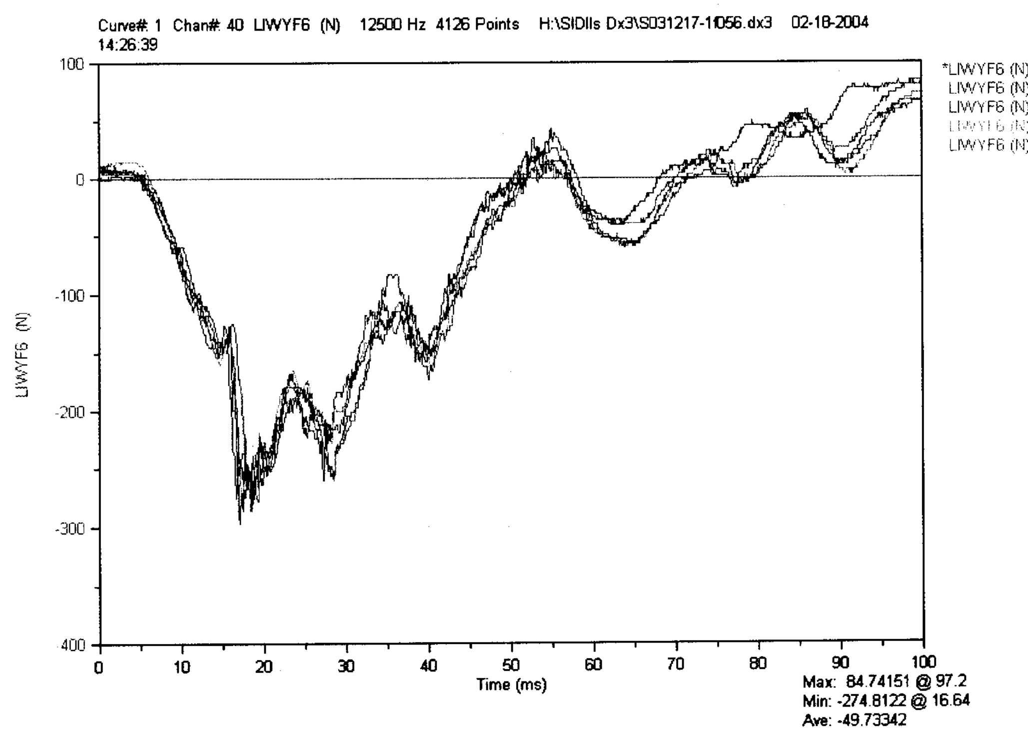

Figure C.23.b. Left Iliac Wing Lateral Force – Dummy 056

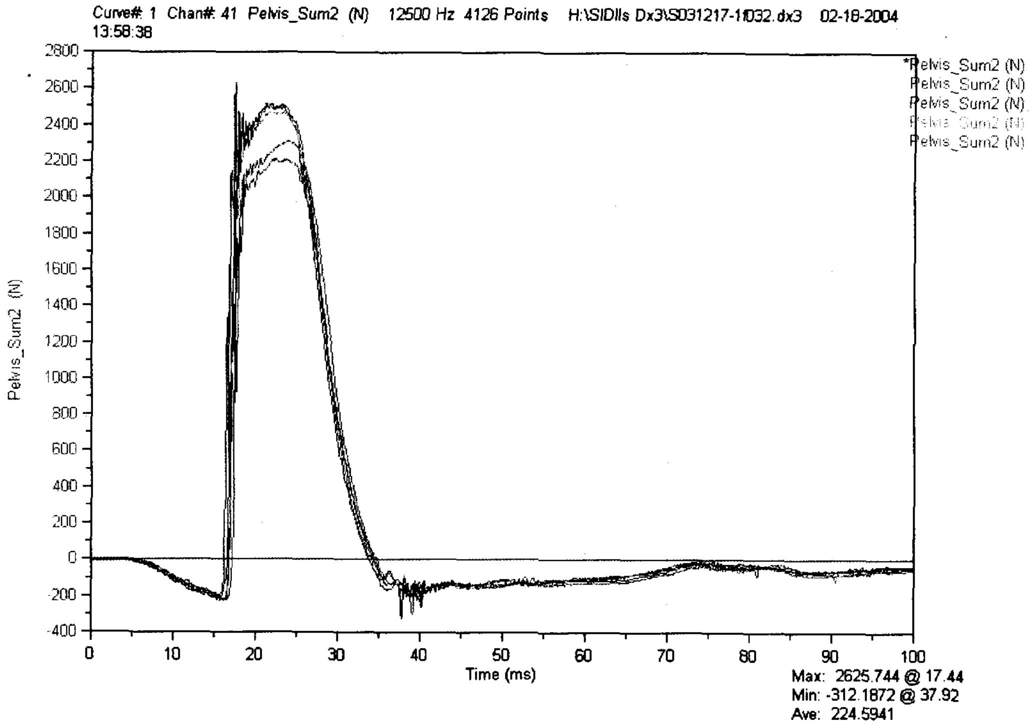

Figure C.24.a. Sum of Acetabulum and Iliac Wing Lateral Forces – Dummy 032

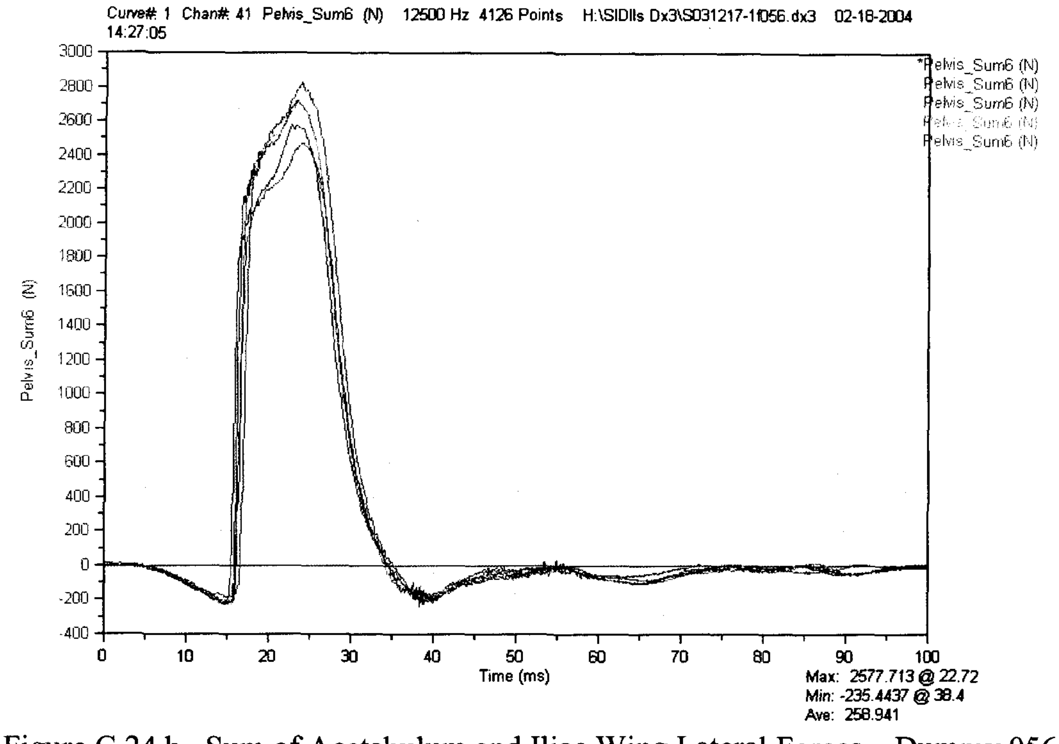

Figure C.24.b. Sum of Acetabulum and Iliac Wing Lateral Forces – Dummy 056