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Pedestrian Protection – Assessment of the U.S. Vehicle Fleet

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16. Abstract

This study determines the current state of pedestrian protection in the U.S. vehicle fleet using established Euro NCAP pedestrian test procedures including lower legform and upper legform impacts to the front end of the vehicle and headform impacts to the hood and windshield. Nine vehicles -- passenger cars, a minivan, SUVs, and pickup trucks -- were tested. The range of scores on U.S. vehicles varied greatly. In general, global vehicles (models that include a U.S. variant and a European variant of the same vehicle) offer more pedestrian safety than vehicles marketed primarily in the United States. This observation applies to all size classes for the vehicles NHTSA tested. Tested global vehicles were markedly better. The lowest global vehicle score was higher than the highest non-global vehicle score. This was expected, as only the global vehicles are likely to contain the hood underpinnings put in place specifically for pedestrian safety.

The second objective of this study was to assess the equivalency of pedestrian protection in U.S. versus European variants of the same vehicle model, so only global vehicles were assessed. When compared to Euro NCAP results, a clear degradation in performance was observed for legform tests on U.S. variants. Those differences may have been driven by NHTSA's Part 581 bumper damageability demands on variants sold in the U.S. versus pedestrian safety demands on variants sold in Europe driven by Euro NCAP and UNECE Reg. No. 127, the pedestrian safety regulation in force in Europe. For "passenger cars" (sedans, coupes, hatchbacks) that must conform to Part 581 bumper damageability requirements, the U.S. variants performed much worse than European variants in the lower legform assessment, but no worse than (and perhaps slightly better than) non-global "passenger cars." In upper legform tests, the global "passenger cars" perform very well, with U.S. and European variants performing equally as well. Non-global vehicles did not perform well. The largest of them – the pickup and the large SUV – performed the worst of all vehicles.

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Executive Summary

This study fulfilled two objectives related to vehicle crashworthiness for pedestrian safety. The first objective of this study was to determine the current state of pedestrian protection in the U.S. vehicle fleet using established assessment methods. For this assessment, the Euro NCAP pedestrian test procedures were followed. The test procedures included lower legform and upper legform impacts to the front end of the vehicle and headform impacts to the hood and windshield. Nine vehicles -- passenger cars, a minivan, SUVs, and pickup trucks -- were tested.

The range of scores on U.S. vehicles varied greatly, from 11.02 (2016 Ford F-150) to 30.12 (2016 Toyota Prius). In general, global vehicles (models that include a U.S. variant and a European variant of the same vehicle) offer a higher level of pedestrian safety than vehicles marketed primarily in the United States. This general observation applies to all size classes for the vehicles that NHTSA tested. When comparing global versus non-global vehicles, the performance of the tested global vehicles was markedly better: The lowest global vehicle score was higher than the highest non-global vehicle score. This was expected, as only the global vehicles are likely to contain the hood underpinnings put in place specifically for pedestrian safety.

The second objective of this study was to assess the equivalency of pedestrian protection in U.S. versus European variants of the same vehicle model. Thus, only global vehicles were assessed. Although they share the same platform and underpinnings, the bumper components are not necessarily the same. When compared to Euro NCAP results, a clear degradation in performance was observed for legform tests on U.S. variants. Those differences may have been driven by NHTSA's Part 581 bumper damageability demands on variants sold in the U.S. versus pedestrian safety demands on variants sold in Europe driven by Euro NCAP and UNECE Reg. No. 127, the pedestrian safety regulation in force in Europe.

The hoods on U.S. versus European variants of global vehicles tested generally offered the same level of pedestrian safety, which was typically better than that of non-global vehicles. Exceptions include vehicles fitted with active hoods (such as the Audi A4) that appear only on European variants, which offer better protection. The headform scores for U.S. variants tabulated herein may show a slight bias; the scoring process followed by NHTSA tended to produce results that were about one point higher than scores produced by the Euro NCAP protocol. For "passenger cars" (sedans, coupes, hatchbacks) that must conform to Part 581 bumper damageability requirements, the U.S. variants performed much worse than European variants in the lower legform assessment, but no worse than (and perhaps slightly better than) non-global "passenger cars." In upper legform tests, the global "passenger cars" perform very well, with U.S. and European variants performing equally as well. Non-global vehicles did not perform well. The largest of them – the pickup and the large SUV – performed the worst of all vehicles.

In summary, this study provides (1) an assessment of the current state of pedestrian safety in the U.S. vehicle fleet, (2) a comparison of U.S. and European variants of global vehicle models, and (3) the conclusion that U.S. and European variant hoods of global vehicles perform similarly, even though testing was performed by different laboratories and the selection of impact points was done differently.

Introduction

This study fulfilled two objectives related to vehicle crashworthiness for pedestrian safety. The first objective of this study was to determine the current state of pedestrian protection in the U.S. vehicle fleet using established assessment methods. For this assessment, the Euro NCAP pedestrian test procedures were followed. The test procedures included lower legform and upper legform impacts to the front end of the vehicle and headform impacts to the hood and windshield. Nine vehicles consisting of passenger cars, a minivan, SUVs, and pickup trucks were tested in this study.

Of the nine vehicles, five were considered to be global platform vehicles that have variants sold in Europe. In our assessment, the global vehicles all performed better than the non-European vehicles that are marketed primarily in the U.S. (i.e., "U.S. market" vehicles). This trend is most likely driven by two factors. For the global vehicles, the basic vehicle platforms that underpin the hoods and front-ends may have been constructed to conform with pedestrian safety standards in force in Europe. Those underpinnings appear to have been carried over to variants sold in the U.S. However, vehicles designed mainly for the U.S. market may not have pedestrian safety underpinnings.

Also, the "U.S. market" vehicles that were tested included a large SUV and a pickup truck. Both vehicles were larger than any of the global vehicles. Their front-ends had higher ride heights, and thus had a propensity to perform poorly in the legform tests because the lower legform tended to wrap around the lower portion of the bumper and bend extensively. Also, in upper legform tests, the legform was generally directed into a "hard" portion of the grille or the upper leading edge of the front end, rather than onto the softer hood as in smaller vehicles.

The second objective of this study was to assess the equivalency of pedestrian protection in U.S. versus European variants of the same vehicle model. Thus, only global vehicles were assessed. Although they share the same platform and underpinnings, the bumper components are not necessarily the same. When compared to Euro NCAP results, a clear degradation in performance was observed for legform tests on U.S. variants. Those differences may have been driven by NHTSA's Part 581 bumper damageability demands on variants sold in the U.S. versus pedestrian safety demands on variants sold in Europe driven by Euro NCAP and UNECE Reg. No. 127, the pedestrian safety regulation in force in Europe. Part 581 is generally considered to be more rigorous than any bumper damageability requirement imposed on cars sold in Europe, while the U.S. has no safety regulation or NCAP assessment for pedestrian safety.

Since the U.S. and European variants have different performance demands, the front ends of vehicles built on global platforms are typically designed with parts that may be readily swapped out. It was observed that U.S. variants contain specialized front end parts (headlamp brackets, bumper energy absorbers, etc.) that were presumably designed to withstand Part 581 demands. In European variants, these parts may be swapped with corresponding parts that provide better protection to pedestrians. Not all U.S. variants performed poorly in legform tests, however. It is noted that Part 581 is applicable only to "passenger cars" (coupes, sedans, and hatchbacks). SUVs and other light trucks are exempt. Two global SUVs were tested. One performed just as well as the European variant, but the other performed much worse in legform tests.

The hoods, on the other hand, appear to be essentially the same for all U.S. versus European variants. Unlike the bumper area, there are no U.S. regulatory demands that might prevent a hood designed for European pedestrian safety standards from being homologated for sale in the U.S. For the most part, it was observed that pedestrian safety assessments reported by Euro NCAP for head impacts on any particular vehicle also apply to the U.S. variant of that vehicle. Exceptions include any European vehicle with an active hood (such as the Audi A4) or some other feature specific to the U.S. market (such as a hood scoop to accommodate a larger engine).

Vehicle Preparation and Markup

All vehicle preparations, markups, and tests were performed in accordance with the European New Car Assessment Programme (Euro NCAP) Pedestrian Testing Protocol (Version 8.3, December 2016), which is available on the Euro NCAP web site (www.euroncap.com). Prior to testing, vehicles were marked for setup purposes. Vehicles were prepared (additional weights, suspension settling, etc.) according to the Euro NCAP guidelines prior to markup. Markings and measurements were made and tests were performed with the vehicles in their normal ride attitude.

The vehicles tested are listed in Table 1. For the purposes of this analysis, table row entries with gray coloring were considered "global" vehicles. They have variants sold in Europe and tested by Euro NCAP. It is noted, however, that all vehicles listed are typically sold outside the U.S. market, too. For example, a variant of the 2016 Chevrolet Malibu is sold in China and South Korea. But our analysis was limited to comparing our test results for pedestrian safety to those of Euro NCAP's. Only the five vehicles highlighted below met the criteria of being tested by both.

All tests on the U.S. variants were performed at NHTSA's Vehicle Research and Test Center (VRTC). Detailed results for all tests on each vehicle can be found in the vehicle test reports in the appendices. The appendices also summarize the Euro NCAP results. Further information on the European variants can be found on the Euro NCAP web site (see www.euroncap.com).

Table 1. List and description of U.S. vehicles tested by NHTSA. Rows colored gray have European variants that have been tested by Euro NCAP.

Vehicles Tested			
Model Year (MY)	**Make**	**Model**	**Description**
2017	Audi	A4*	Midsize Passenger Car
2016	Chevrolet	Malibu	Midsize Passenger Car
2016	Chevrolet	Tahoe	Large SUV
2016	Ford	Edge	Midsize SUV
2015	Ford	F-150	Standard Pickup Truck
2016	Honda	Fit	Small Passenger Car
2016	Nissan	Rogue	Small SUV
2016	Toyota	Prius	Small Passenger Car
2015	Toyota	Sienna	Minivan

*An Audi A4 with an active hood was tested by Euro NCAP. An active hood is standard on European variants of the A4, but is not available on models sold in the U.S.

Lower Legform Tests

A certified Flex-PLI lower legform that conforms to Euro NCAP requirements was used in this study. The Euro NCAP test protocol was used. Test results were scored in accordance with the Euro NCAP Assessment Protocol - Pedestrian Protection (Version 9.0.2, November 2017).

Scoring. A maximum of 6 points are available for the lower legform tests. The total score for all tested grid points is calculated as a percentage of the maximum achievable score, which is then multiplied by the maximum (6). Each of the grid points can be awarded up to one point, resulting in a maximum achievable score equal to the number of tested grid points. For reference, the Euro NCAP performance limits for the lower legform are shown in Table 2.

Table 2. Lower and upper limits for lower legform tests.

	Tibia Bending (Nm)		**MCL Elongation (mm)**		**ACL/PCL Elongation (mm)**
	Lower	**Upper**	**Lower**	**Upper**	**Qualifying Limit**
Flex-PLI metric	282	340	19	22	10

The one point per grid point is divided into two independent assessment areas of equal weight. Tibia injury assessment (maximum 0.5 point) is based on the worst performing of the four tibia moments. Knee injury assessment (maximum 0.5 point) is based on the MCL elongation, as long as the ACL/PCL elongation is below the 10 mm injury threshold. A linear sliding scale is applied between the relevant limits of tibia bending and MCL elongation.

Test results. Lower leg scores (maximum of 6 points) from NHTSA testing are shown in Table 3. For reference, the scores obtained by Euro NCAP on European variants are also shown (global vehicles only). Overall, the U.S. variants tested by NHTSA scored poorly with an average score of 1.67 points. The Nissan Rogue and Toyota Prius (6.00 and 4.41 points, respectively) scored well and the Audi A4 and Chevrolet Malibu (2.24 and 1.99 points, respectively) scored marginally. The Chevrolet Tahoe, Ford Edge, Ford F-150, Toyota Sienna, and Honda Fit all scored poorly.

Discussion. While none of the vehicles tested by NHTSA did particularly well, the large-vehicle size class did the worst. These were non-global vehicles with higher ride heights sold primarily in the U.S. market. They had a propensity to perform poorly because the lower legform tended to wrap around the lower portion of the bumper and bend extensively. Since they were not subject to European standards, it is unlikely that their bumpers were designed for pedestrian safety.

The performance of the global passenger cars was more favorable. But, as mentioned previously, "global platform" does not necessarily mean identical as some parts and components are not necessarily the same between U.S. and Europe variants due to different standards and regulations. Focusing on the global platform vehicles, all performed well when tested by Euro NCAP as they all had high scores. However, the NHTSA scores are not consistent with the Euro NCAP scores, indicating that the bumper part differences between U.S. and European versions varied by vehicle.

Component differences between U.S. and European global platform vehicles are likely due to different regulatory demands. In the U.S., sedans must comply with Part 581 bumper standard, which is a low speed bumper damageability requirement (it does not apply to SUVs and pickups). In Europe, there is no compulsory regulation for bumper damageability. However, passenger cars must comply with UNECE Reg. No. 127, the pedestrian safety standard.

In terms of bumper design, the two standards tend to work against each other: bumpers that are compliant with Part 581 tend to be stiff, while Reg. No. 127 tends to drive a softer, energy-absorbing bumper. Table 3 includes a column to show Part 581 applicability for each vehicle. Nonetheless, the Part 581 standard does not appear to be an insurmountable obstacle to attaining good lower leg scores, as evidenced by the Toyota Prius (4.41 for the U.S. variant). This relatively high score is consistent with a study presented by Stammen and Suntay showing that a 2013 Ford Fusion had a front-end design that performed well with respect to both the Flex-PLI IARVs and the Part 581 requirements.[1]

[1] Stammen, J., & Suntay, B. (2014). *Performance of bumper systems with respect to pedestrian protection and bumper damageability requirements* (PowerPoint presentation SAE Government Industry Meeting, 2014). Washington, DC: National Highway Traffic Safety Administration. Available at https://one.nhtsa.gov/DOT/NHTSA/NVS/Public%20Meetings/SAE/2014/Stammen%20SAE%20GI%202014%20FINAL.pdf

Table 3. Lower leg scores and corresponding Part 581 applicability for U.S. vehicles.

Vehicle	Is Part 581 Applicable to U.S. Version?	Lower Leg Scores (Max 6 pts)	
		NHTSA	Euro NCAP
2017 Audi A4	Yes	2.24	5.32
2016 Chevrolet Malibu	Yes	1.99	--
2016 Chevrolet Tahoe	No	0.00	--
2016 Ford Edge	No	0.40	6.00
2015 Ford F-150	No	0.00	--
2016 Honda Fit	Yes	0.00	6.00
2016 Nissan Rogue	No	6.00	6.00
2016 Toyota Prius	Yes	4.41	6.00
2015 Toyota Sienna	No	0.00	--
Average Score (% of Max)		1.67 (28%)	5.86 (98%)

Two of the global vehicles tested were SUVs that are not required to meet Part 581: the 2016 Nissan Rogue and the 2016 Ford Edge. Both attained a perfect 6.0 score in their respective Euro NCAP assessments.

One might expect that U.S. variants of all European SUVs would perform the same in U.S. lower legform tests (since the front-end design may be carried over from the European to the U.S. variant without a part swap). However, only the Rogue carried over its perfect score to the U.S. variant, while the score for the Edge's U.S. variant barely registered above zero (0.40). In the case of the Rogue, it appears that the same front-end parts are used in both variants. On the other hand, the Edge results demonstrate that a manufacturer may elect to perform a part swap-out for reasons other than regulatory demands.

Upper Legform Testing

All upper legform tests in this study were performed with a certified upper legform impactor that conforms to Euro NCAP requirements. The Euro NCAP test protocol was used. Test results were scored in accordance with the Euro NCAP Assessment Protocol - Pedestrian Protection (V 9.0.2, November 2017).

Scoring. A maximum of 6 points are available for the upper legform tests. The total score for all tested grid points is calculated as a percentage of the maximum achievable score, which is then multiplied by the maximum (6). Each of the grid points can be awarded up to one point, resulting in a maximum achievable score equal to the number of tested grid points. A linear sliding scale is applied between the relevant limits of bending moment and sum of forces. The upper leg performance for each grid point is based on the worst performing parameter. For reference, the Euro NCAP performance limits for the upper legform are shown in Table 4.

Table 4. Lower and upper limits for upper legform tests

	Lower Limit	Upper Limit
Bending Moment	285 Nm	350 Nm
Sum of Forces	5.0 kN	6.0 kN

Test results. Upper leg scores (maximum of 6 points) from NHTSA testing on U.S. variants are shown in Table 5. For reference, the scores obtained by Euro NCAP on European variants are also shown (global vehicles only). Overall, the U.S. vehicles tested by NHTSA performed in the middle with an average score of 3.52 points. The Nissan Rogue, Honda Fit, Toyota Prius and Audi A4 (6.00, 6.00, 5.91, and 5.17 points, respectively) all performed well. The Chevrolet Malibu and Toyota Sienna (3.40 and 2.44 points, respectively) performed in the middle. The Ford F-150, Ford Edge, and Chevrolet Tahoe (1.20, 0.80, and 0.80 points, respectively) performed poorly.

Discussion. The passenger cars performed moderately well while the pickup, minivan, and, SUVs did not perform as well (except the Nissan Rogue). Focusing on the global platform vehicles, the European versions as tested by Euro NCAP performed moderately well with an average score of 4.49 points.

Column two of Table 5 indicates the approximate location on the front-end targeted by the upper legform. According to the Euro NCAP procedure, the input energy is increased if the target point is on a more vertical surface. Thus, tests into the grille area are carried out at higher energy. Tests on the hood are carried out with lower energy. Tests on the hood leading edge (or bonnet leading edge, BLE) use energy levels somewhere in between. This is reflected in the scoring, where "grille" tests are typically low scoring, especially for non-global models.

There was one vehicle where tests were carried out mostly on the hood – the 2016 Toyota Prius. Those tests produced a relatively high score (5.91). This high score is intuitive: not only is the test energy low, a hood generally provides more energy attenuation than either a grille or the leading edge of the hood. Also, an impact to the hood is probably less likely to be affected by stiffer structures in the bumper area that may be needed to comply with the U.S. Part 581 bumper standard.

The tests did demonstrate that high scores are achievable even if a test is carried out into the BLE. In comparing results on the vehicles tested on their hood leading edges (Audi A4, Chevrolet Malibu, and Honda Fit), the scores were generally high, especially for the two global vehicles (5.17 on the Audi, 6.0 on the Fit). Notably, the U.S. versions as tested by NHTSA performed about as well as (or even slightly better than) the European versions, unlike the lower legform tests in which U.S. variants performed much worse. This indicates that the BLE design of a typical global passenger car is not influenced significantly by Part 581 demands. Thus, a complete swap out of parts is apparently not needed for structures underlying the BLE on U.S. variants.

The 2016 Nissan Rogue again provides for an interesting case study. Even though the upper legform was directed into its grille, it produced a perfect score of 6.0 in the NHTSA tests and a near-perfect score of 5.4 in the Euro NCAP tests. This demonstrates that high energy attenuation

is possible for a grille design that is unencumbered by Part 581 demands and is thus acceptable (and shared) in both the U.S. and European markets.

On the other hand, the results of the 2016 Ford Edge run counter to those of the Rogue. It is also a global vehicle, the legform is directed into the grille, and it is relieved from Part 581 demands. However, the U.S. variant of the Edge performed much worse than the European variant (0.80 versus 3.56), just as it did in the lower leg tests (0.40 versus 6.0). As was seen in the lower leg tests, the upper leg tests indicate that a part swap-out on bumper and grille components has taken place between the two Edge variants.

The two largest vehicles – the Ford F-150 and the Chevrolet Tahoe – also had very low scores. With these vehicles, the test energy is at its highest and the legform is propelled directly into the grllle and bumper. Thus, the low scores associated with these non-global vehicles is not unexpected.

Table 5. Upper leg scores from NHTSA testing with corresponding Euro NCAP scores for the global platform vehicles. Maximum of 6 points.

Vehicle	Impact Location*	Is Part 581 Applicable to U.S. Version?	Upper Leg Scores (Max 6 pts)	
			NHTSA	Euro NCAP
2017 Audi A4	BLE	Yes	5.17	5.46
2016 Chevrolet Malibu	BLE	Yes	3.40	--
2016 Chevrolet Tahoe	Grille + Bumper	No	0.80	--
2016 Ford Edge	Grille	No	0.80	3.56
2015 Ford F-150	Grille + Bumper	No	1.20	--
2016 Honda Fit	BLE	Yes	6.00	3.23
2016 Nissan Rogue	Grille	No	6.00	5.40
2016 Toyota Prius	Hood	Yes	5.91	4.82
2015 Toyota Sienna	Grille	No	2.44	--
Average Score (% of Max)			3.52 (59%)	4.49 (75%)

* BLE is the bonnet (or hood) leading edge.

Headform Tests

All headform tests in this study were performed according to the procedures outlined in the Euro NCAP Pedestrian Testing Protocol. Certified child and adult headforms that conform to Euro NCAP requirements were used in this study.

Selecting grid points. In Euro NCAP, headform test points are chosen through the use of the Euro NCAP Pedestrian Headform Point Selection algorithm.[2] Before the grid points are selected by Euro NCAP, the vehicle manufacturer provides the test center with a map of the hood test area with all of the test points and their predicted severities. According to the Point Selection algorithm, a percentage of the total test points are assigned to each of the areas of different severities as reported by the manufacturer. Twenty-five percent of the test points are each assigned to the lowest severity (green) and highest severity (red) test areas. The remaining 50% of the test points are assigned to the medium severity test areas (yellow, orange, and brown).

NHTSA followed a slightly different process for selecting grid points since no manufacturer predictions were available for U.S. vehicles. NHTSA test engineers surveyed the vehicle's head test area and predicted the severity of the different areas based on their experience. Test points were selected with the aim of covering the entire severity range. A number of points corresponding to the ratios outlined in the Euro NCAP Point Selection algorithm were selected for each of the severity levels.

Scoring. NHTSA's scoring process also differed from the Euro NCAP process. In Euro NCAP, the scoring protocol makes use of the manufacturers' predictions and 10 verification tests performed by Euro NCAP test labs. The total score is based on all grid points, not just the ones tested by Euro NCAP. The total score is adjusted up or down depending on the agreement between the predictions and the outcomes of the actual tests on the verification points. The process is described fully in the Euro NCAP assessment protocol referenced earlier.

As in Euro NCAP, the NHTSA process used a maximum score is 24 for the headform tests. However, since there are no manufacturer predictions for U.S. vehicles, NHTSA calculated a total score based only on the grid points tested. For each test, a point value for that test was determined based on the HIC score and the intervals shown in Table 6. (This is the same table used in Euro NCAP. Colors are provided only for reference.) The points were then summed and divided by the number of tests. This result (having a maximum achievable value of 1) was then multiplied by 24.

Table 6. Scoring guidelines for headform impacts.

Color	Euro NCAP		Point Value
	HIC Min	HIC Max	
Green	--	<650	1
Yellow	650	<1000	0.75
Orange	1000	<1350	0.50
Brown	1350	<1700	0.25
Red	1700	--	0

Test results. Head scores (maximum of 24 points) from NHTSA testing (using NHTSA's process) are shown in Table 7, along with the actual Euro NCAP scores on European variants (global vehicles only). Overall, the U.S. vehicles tested by NHTSA performed marginally well

[2] Pedestrian Headform Point Selection, V2.1, October 2017. Accessed May 2018 from www.Euro NCAP.com

with an average score of 16.02 points and similar to the European models with an average score of 16.41 points.

Table 7. Headform scores from NHTSA testing with corresponding Euro NCAP scores for the European variants. Maximum of 24 points.

Vehicle	Head Scores (Max 24 pts)	
	NHTSA	Euro NCAP
2017 Audi A4	17.00	16.58*
2016 Chevrolet Malibu	16.36	--
2016 Chevrolet Tahoe	14.18	--
2016 Ford Edge	17.40	16.04
2015 Ford F-150	9.82	--
2016 Honda Fit	18.67	17.10
2016 Nissan Rogue	18.00	15.44
2016 Toyota Prius	19.80	16.91
2015 Toyota Sienna	16.67	--
Average Score (% of Max)	16.02 (67%)	16.41 (68%)

* Euro NCAP tests performed on an active hood.

Discussion. When comparing global versus non-global vehicles, the performance of the global vehicles is markedly better: the lowest global vehicle score is higher than the highest non-global vehicle score. This is expected, as only the global vehicles are likely to contain the hood underpinnings that were put in place specifically for pedestrian safety.

Also notable is the performance of the largest of the vehicles: The Ford F-150 and the Chevrolet Tahoe received the two lowest scores. Beside the lack of underpinnings, the overlay of the headform testing area in relationship to the windshield and front-end contributed to the low scores. For example, consider the test area of the Chevrolet Tahoe (see appendix C). The forward-most grid point lied just below the hood leading edge, a relatively "hard" impact point on a near-vertical surface. And the rearmost grid point was on the hood near the hinge – another "hard" impact point. There were no grid points on the windshield, which typically produce low HIC scores upon impact (exceptions occur near A-pillars and cowl).

For the global platform vehicles, the NHTSA scores and Euro NCAP scores were found to be relatively consistent with all NHTSA scores slightly higher/better. Note that the NHTSA score for the Audi A4 with a non-deployed hood (17.00) is actually higher that the Euro NCAP score with a deployed hood (16.58). This unexpected result is investigated further in the NHTSA report, *Assessment of Hood Designs for Pedestrian Head Protection: Active Hood Systems* (in press), where it is shown that for the case of the 2017 Audi A4, the deployed hood only provides

only a marginal improvement in head protection over the undeployed hood. For other vehicles, the improvement can be much more pronounced.

Also, the NHTSA headform scoring process tended to produce slightly higher scores than the Euro NCAP process. For the NHTSA tests, impact points were selected with the aim of covering the entire severity range, but only a few of the selected points were found to be severe. Consistency between the NHTSA and Euro NCAP scores can be further improved if additional impact points that include the more severe ones are selected. Further discussion on the equivalency of the NHTSA and Euro NCAP scoring processes is provided in the next section.

Equivalency of U.S. Versus European Hoods for Pedestrian Safety

As mentioned earlier, the second portion of this study investigated the equivalency of U.S. versus European variants of the same models for their pedestrian safety. This portion of the study is therefore limited to the five global vehicles that were tested. For the hood, there are no regulatory trade-offs like there are for the bumper. While there are no pedestrian standards for U.S. hoods, there are no other U.S. standards that would preclude the use of a hood on a U.S. variant that is compliant with Reg. No. 127.

Table 3, presented earlier, generally shows that U.S. hoods score slightly better than European hoods on the same model. This is non-intuitive: if any real difference in hoods did exist, one would expect the European hood to outperform the U.S. hood, since the European variant is the one that must comply with the safety standard. Thus, the difference in scores is likely related to differences in the grid points tested. This is investigated below. It could also be related to the NHTSA versus Euro NCAP scoring process. This is investigated later.

Case studies: Toyota Prius and Ford Edge

NHTSA chose two global vehicles to investigate hood equivalency more directly. Head impacts were performed on two U.S. variants for which the Euro NCAP impact points were known prior to testing and results were compared with their European counterparts. The vehicles evaluated in this portion of the study are listed in Table 8.

Table 8. Vehicles evaluated for consistency between U.S. versus European variants.

Vehicles Evaluated			
Model Year (MY)	**Make**	**Model**	**Description**
2016	Toyota	Prius	Passenger Car
2016	Ford	Edge	Midsize SUV

Case 1: 2016 Toyota Prius: NHTSA and Euro NCAP test results. Initially, NHTSA checked to assure that the WAD lines that were drawn on our U.S. variant were consistent with the WAD lines drawn by the Euro NCAP lab on the European variant. Figure 1 shows the mark-ups of the 2016 Toyota Prius. The NHTSA vehicle mark-up is shown on the left and the Euro NCAP vehicle mark-up is shown on the right. Although difficult to see, the WAD marks along the centerline of the NHTSA and Euro NCAP vehicles match up well. Thus, a grid point-by-grid

point comparison of HIC scores may be made to assess the equivalency of the U.S. variant versus the European variant.

Six grid points were tested that were common with those tested by Euro NCAP. (NHTSA also tested another four points; Euro NCAP tested another five points). The common headform impact locations are shown in Figure 2. The results are shown in Table 9 along with the Euro NCAP results and the manufacturers' predictions for the common points. (Results for all other points are given in the appendix).

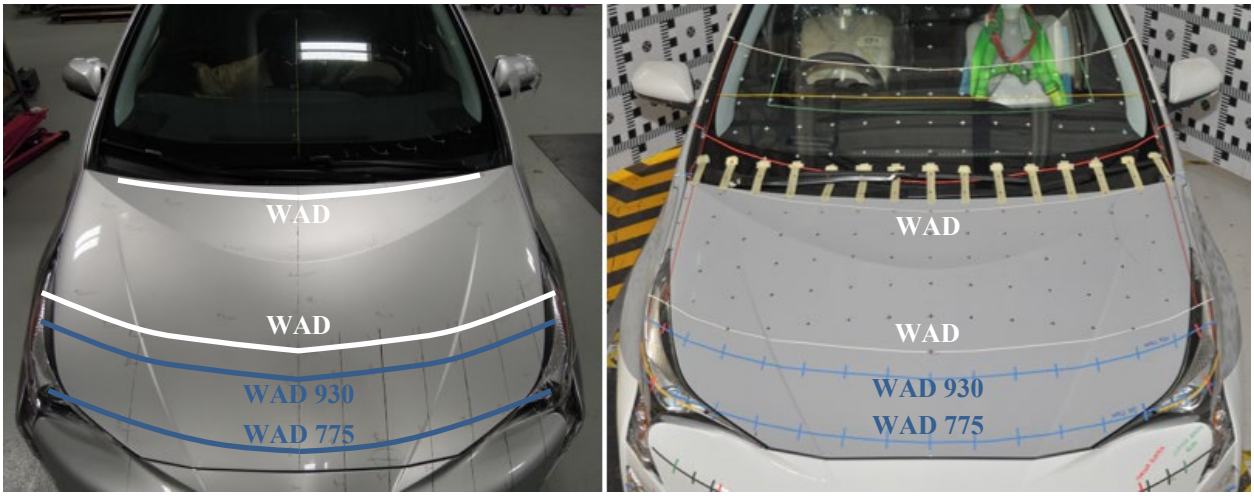


Figure 1. 2016 Toyota Prius NHTSA (left) and Euro NCAP (right) hood mark-up.

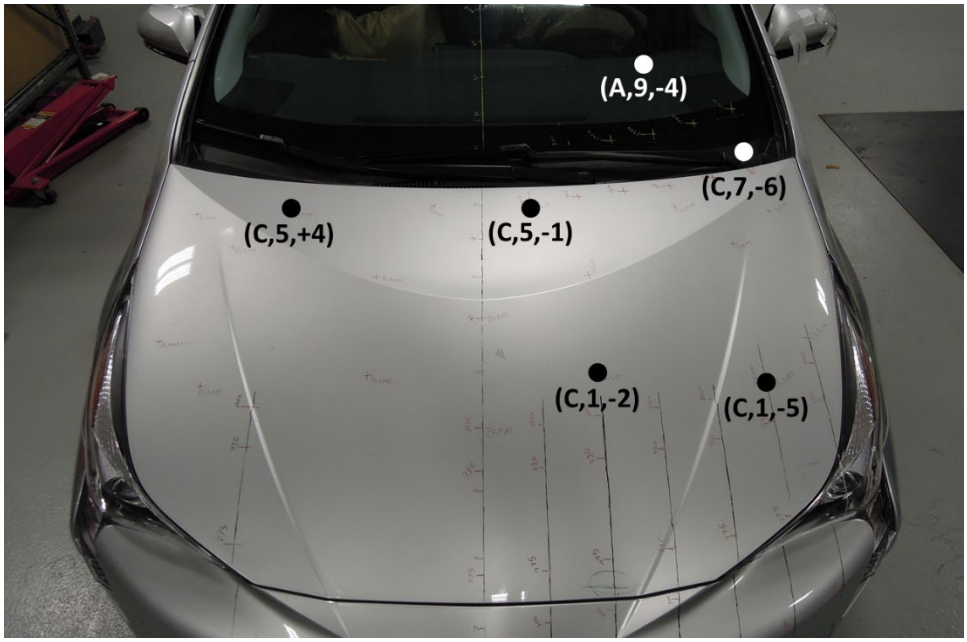


Figure 2. 2016 Toyota Prius headform impact locations of common NHTSA and Euro NCAP grid points.

The only common grid point that produced a significantly different score was the one on the windshield (A,9,-4), where NHTSA observed an HIC of 722 while Euro NCAP observed an HIC of 1017. Given the unpredictability of glazing fracture, however, this result is not necessarily indicative of a fundamental design difference between U.S. and European variants.

For the common points on the hood itself, the NHTSA HIC results were mostly consistent with the Euro NCAP HIC results. The largest difference is seen for grid point (C,5,+4). NHTSA observed a HIC of 366 while Euro NCAP observed a HIC of 605. Although different, both HICs are relatively low and both fall within the manufacturer prediction of less than HIC 650.

There was one grid point (C,1,-5) where both NHTSA's and Euro NCAP's results were consistent with each other but both were below the manufacturer's prediction. It should also be noted that Euro NCAP tested a point over the cowl and near the windshield wiper motors (C,7,+6) and upon further review, it was discovered that the Toyota Prius that was tested by Euro NCAP was a right-hand drive vehicle where the steering column and windshield wiper motors were on the opposite side of the U.S. vehicle. Therefore, in order to test the same structures, the driver side of the U.S. Prius (C,7,-6) was tested, resulting in similar HIC values to Euro NCAP.

Table 9. 2016 Toyota Prius headform impact HIC scores in tests run by NHTSA and Euro NCAP.

Grid point	HIC SCORES		
	NHTSA	Euro NCAP	Toyota Predicted
C 1,-2	495	595	< 650
C 1,-5	999	1043	1350 - 1700
C 4,5	659	720	< 650
C 5,4	366	605	< 650
C 7,-6	918	909	1000 - 1350
A 9,-4	722	1017	650 - 1000

Case 2: *2016 Ford Edge: NHTSA and Euro NCAP test results.* As with the Toyota Prius, we first checked the WAD lines to assure that they were consistent between variants. Figure 3 shows the mark-up of the 2016 Ford Edge variants. The NHTSA vehicle mark-up is shown on the left and the Euro NCAP vehicle mark-up is shown on the right. Again, the WAD lines match up well and justify a grid point-by-grid point comparison of HIC scores between the two variants.

Seven grid points were tested that were common with those tested by Euro NCAP: two on the windshield and five on the actual hood. (NHTSA tested another 10 points; Euro NCAP tested another three points). The common impact locations are shown in Figure 4. The test results are shown in Table 10 along with the Euro NCAP results and the manufacturers' predictions. (Results for all other points are given in the appendix.)

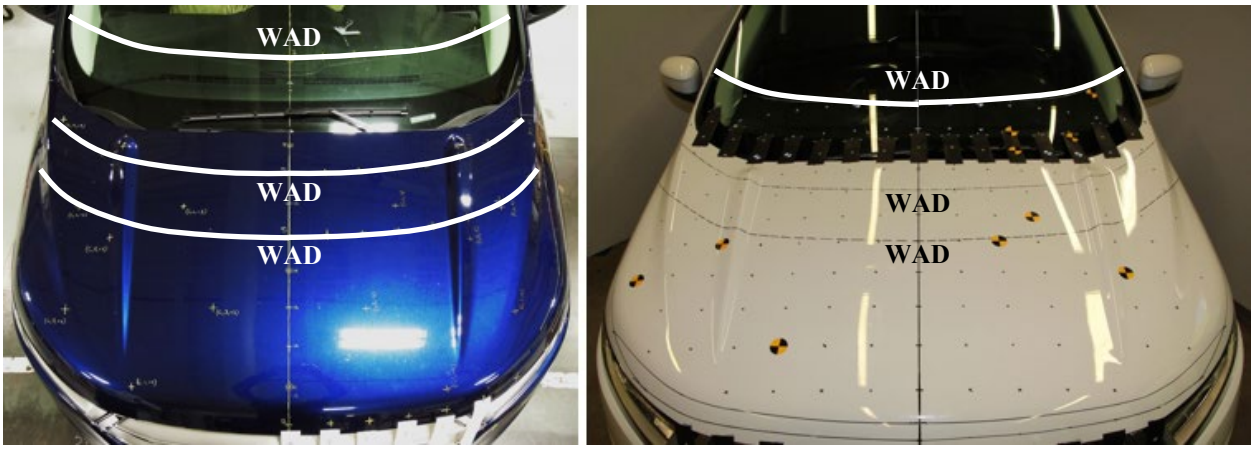


Figure 3. 2016 Ford Edge NHTSA (left) and Euro NCAP (right) hood mark-up.

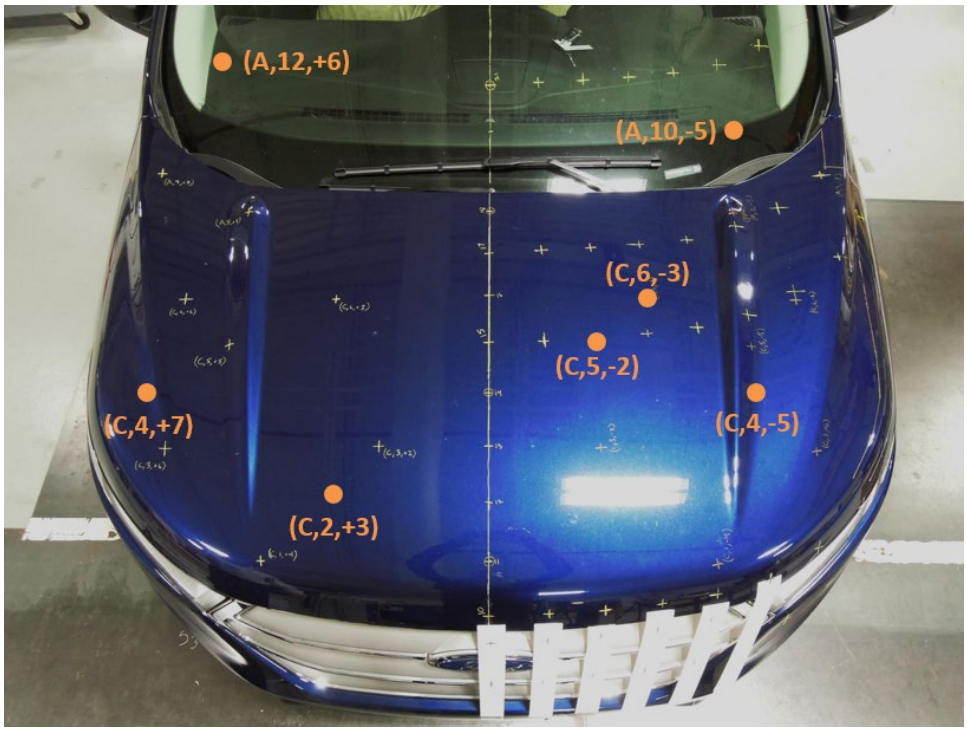


Figure 4. 2016 Ford Edge headform impact locations of common NHTSA and Euro NCAP grid points.

For the 2016 Ford Edge, the NHTSA HIC results were mostly consistent with the Euro NCAP HIC results. There were some slight discrepancies (C,4,+7), but all of NHTSA's and Euro NCAP's HIC results followed the manufacturer's prediction with the exception of one impact point (C,4,-5) where both NHTSA and Euro NCAP actually observed a lower than predicted HIC.

Table 10. 2016 Ford Edge headform impact HIC scores in tests run by NHTSA and Euro NCAP.

Grid point		HIC SCORES		
		NHTSA	Euro NCAP	Ford Predicted
C	2,3	915	767	650-1000
C	4,-5	569	642	650-1000
C	4,7	1127	1332	1000 - 1350
C	5,-2	496	573	< 650
C	6,-3	496	594	< 650
A	10,-5	1827	1904	> 1700
A	12,-6	449	503	< 650

Further analysis on hood equivalency

To assess the equivalency of the hoods even further, NHTSA's U.S.-only data was compared with Euro NCAP's European-only data using the same scoring system under the hypothesis that the hoods are equivalent (and thus, the two datasets should not produce significantly different scores). For this exercise, the Euro NCAP scoring system was used by assuming that the manufacturer predictions for the European variants are also valid for the U.S. variants.

The results are tabulated in Table 11. Also shown in Table 11 are scores computed using NHTSA's averaging method. This is discussed in the next section when comparing the equivalency of the scoring methods themselves.

A summary table, derived from Table 11, is given in Table 12. It shows the differences in scores between the U.S. variants and the European variants for each of the five global vehicles.

Table 11. Headform impact results: simplified NHTSA scoring versus Euro NCAP scoring.

Vehicle	Scoring Method	Total Headform Score (24 max.)			
		U.S. Data Only	**European Data Only**	**Combined U.S. and European**	
2016 Toyota Prius	NHTSA averaging method	20.40	16.91	18.80	
	Euro NCAP protocol (inc. use of Toyota predictions)	18.36	16.91	17.59	
2016 Ford Edge	NHTSA averaging method	17.65	18.00	17.70	
	Euro NCAP protocol (inc. use of Ford predictions)	16.35	16.04	16.31	
2016 Nissan Rogue	NHTSA averaging method	18.00	16.20	17.10	
	Euro NCAP protocol (inc. use of Nissan predictions)	17.56	15.44	16.92	
2016 Honda Fit	NHTSA averaging method	18.67	17.40	18.00	
	Euro NCAP protocol (inc. use of Honda predictions)	17.68	17.10	17.38	***U.S. Data Only for Audi A4***
2017 Audi A4		*Deployed Hood*			*Undeployed*
	NHTSA averaging method	19.00	19.80	19.20	17.00
	Euro NCAP protocol (inc. use of Audi predictions)	16.32	16.58	16.48	Not applicable

Table 12. Summary Table: differences in headform scoring: U.S. data versus European data.
(All scores are based on the Euro NCAP scoring process.)

Vehicle	Difference in scores [US variant – European variant]
2016 Ford Edge	+0.31
2016 Toyota Prius	+1.45
2016 Nissan Rogue	+2.12
2016 Honda Fit	+0.58
2017 Audi A4*	-0.26
Average	*+0.84*

*For Audi A4, only tests using an active hood are compared.

Of the comparisons shown in the summary table, the Ford Edge provided the best dataset to compare the equivalency of the U.S. versus European variants. Here, NHTSA tested the greatest number of grid points (seventeen) of any of the vehicles, and seven of those points were common with those tested by Euro NCAP. The Toyota Prius also provided a good comparative dataset (10 grid points tested, with seven common points).

For the Ford Edge, the U.S. headform score of 16.35 was essentially identical to the Euro NCAP score of 16.04. Similarly, comparison of the Prius variants indicates that the hoods are the same since the headform scores are within 1.45 points. No statistical procedures to quantify the source of the variability in the scores were attempted.

For the Honda Fit, the Nissan Rogue, and the Audi A4, NHTSA did not have the Euro NCAP test information prior to running the tests, and hence there were very few common grid points tested. Furthermore, the equivalency of the WAD lines between the European and U.S. variants was not verified. The front-end contour of the bumpers may not have been identical, which may have resulted in slightly different WAD lines such that the grid points may not have corresponded exactly.

Nonetheless, the results for the Fit, Rogue, and A4 are compiled in the tables above as they were for the Prius and Edge. When all vehicles are considered, the U.S. variants produced scores within about 2 points of those produced on European variants.

As an aside, the comparison of the Audi A4 variants was made only for active hoods since Euro NCAP did not test the Audi with the hood undeployed. A full assessment of the active hood versus the non-deployable hood is provided in a separate report (cited earlier).

In the summary table, it is notable that NHTSA's data on U.S. variants produced slightly higher scores than Euro NCAP's data on European variants for four of the five global vehicles (the Audi A4 was the exception). If there were truly any difference between the hood systems, it would be expected that the European variant would outperform the U.S. variant (and not the other way around) since Europe is where the pedestrian assessments are imposed.

In reviewing the data, NHTSA's head impacts more often produced HIC values that were just below the range specified by the manufacturer for the European variant. This is most likely attributed to randomness within the grid point selection process and the limited number of grid points tested, not a real difference in hoods.

In summary, it does appear that hood systems on U.S. and European variants are essentially the same. This implies that, for the most part, pedestrian safety assessments reported by Euro NCAP for head impacts on any particular vehicle (and not just the ones NHTSA tested) may also apply to the U.S. variant of that vehicle. Exceptions include any European vehicle with an active hood (such as the Audi A4) or some other feature specific to the U.S. (such as a hood scoop to accommodate a larger engine).

Headform Scoring Protocol: NHTSA Method Versus Euro NCAP Method

As stated earlier, NHTSA's headform assessment made use of a simplified scoring process in which only the points tested were factored into the overall score. This was necessitated because NHTSA did not have the manufacturer-supplied predictions for each grid point, which are needed to apply the Euro NCAP assessment protocol.

To examine the equivalency of the NHTSA versus Euro NCAP scoring methodologies, data from the global vehicles was again examined. For this assessment, NHTSA's data on U.S. variants with the Euro NCAP data on European variants were combined. In doing so, it is assumed that both sets of data were obtained from tests on equivalent hoods, and that the larger (pooled) data provides a better dataset upon which to draw comparisons between the two methods. From this pooled data two scores were computed: a score using NHTSA's methodology and a score using the Euro NCAP protocol.

The results are summarized in Table 13, which shows that the NHTSA scoring methodology generally results in a score that is about 1 point higher than the Euro NCAP protocol. There were no instances where the NHTSA method produced lower scores. The greatest difference was with the 2017 Audi A4 (2.72 points higher with NHTSA method). It is noted again that the Audi results are based on tests with an active hood and that Audi's manufacturer predictions applied to the Euro NCAP method are valid only when the hood is deployed. Since NHTSA installed the actuators on the U.S. version (they are not otherwise available on U.S. variants), additional complications related to the deployment of the hood may have been introduced.

As before, the difference in scoring methods may be related to the limited number of grid points tested. Also, the Euro NCAP procedure includes a ten-percent tolerance rule wherein HIC values within 10% of the upper or lower limit of the prediction range are assigned a point value associated with the predicted range. NHTSA did not employ such a rule because no predictions were available for the U.S. variants. Since NHTSA's tests produced more HIC values that were just above the Euro NCAP predicted range, overall scores tended to be slightly higher than those of Euro NCAP.

Thus, the headform scores for U.S. variants presented earlier may be biased towards slightly elevated for all vehicles. In other words, if manufacturer predictions for each grid point were available to NHTSA and the Euro NCAP protocol was followed, slightly lower scores might be expected.

Table 13. Summary of NHTSA versus Euro NCAP scoring methods. (Scores computed from data pooled from NHTSA and Euro NCAP tests combined).

Vehicle	Difference in scores
	[NHTSA method – Euro NCAP protocol]
2016 Ford Edge	+1.39
2016 Toyota Prius	+1.21
2016 Nissan Rogue	+0.18
2016 Honda Fit	+0.62
2017 Audi A4*	+2.72
Average	*+1.22*

*For Audi A4, only tests using an active hood are included.

Summary of U.S. Vehicle Fleet Assessment

A summary of the total vehicle scores (summation of lower legform, upper legform, and headform scores) for the U.S. vehicles tested by NHTSA and the European vehicles tested by Euro NCAP are shown in Table 14. The maximum score possible is 36 points.

Table 14. Total vehicle scores from NHTSA testing with corresponding Euro NCAP scores for the global platform vehicles. Maximum of 36 points.

Vehicle	Total Vehicle Scores (Max 36 pts)	
	NHTSA	Euro NCAP
2017 Audi A4	24.41	27.35*
2016 Chevrolet Malibu	21.75	--
2016 Chevrolet Tahoe	14.98	--
2016 Ford Edge	18.60	25.60
2015 Ford F-150	11.02	--
2016 Honda Fit	24.67	26.33
2016 Nissan Rogue	30.00	27.44
2016 Toyota Prius	30.12	27.73
2015 Toyota Sienna	19.10	--
Average Score (% of Max)	21.22 (59%)	26.78 (74%)

* Includes headform score in tests performed on an active hood.

As seen in the table, the range of scores on U.S. vehicles varied greatly – from 11.02 (2016 Ford F-150) to 30.12 (2016 Toyota Prius). Other observations, discussed previously, include the following:

• In general, global vehicles (i.e., those models that include a U.S. variant and a European variant of the same vehicle) offer a higher level of pedestrian safety than vehicles marketed primarily in the U.S. This general observation applies to all size classes for the vehicles that NHTSA tested.

• When comparing global versus non-global vehicles, the performance of the global vehicles that were tested was markedly better: the lowest global vehicle score was higher than the highest non-global vehicle score. This was expected, as only the global vehicles are likely to contain the hood underpinnings put in place specifically for pedestrian safety.

• When reviewing each of the three component tests, the two largest vehicles tested – a Ford F-150 pickup and a Chevrolet Tahoe large SUV – always had the lowest scores for each type of test. These non-global vehicles are not subject to European pedestrian safety regulations, and they have rigid bumpers with high ground clearance that caused extensive tibia bending in the lower leg tests and high femur forces in the upper leg tests. Their poor headform scores were partially affected by the overlay of their headform testing areas wherein the forward-most grid points lied just below the hood leading edge, a relatively "hard" impact point.

• The hoods on U.S. versus European variants of global vehicles tested generally offered the same level of pedestrian safety, which was typically better than that of non-global vehicles. Exceptions include vehicles fitted with active hoods (such as the Audi A4) that appear only on European variants, which offer better protection.

• The headform scores for U.S. variants tabulated herein may show a slight bias; the scoring process followed by NHTSA tended to produce results that were about one point higher than scores produced by the Euro NCAP protocol.

• For "passenger cars" (sedans, coupes, hatchbacks) that must conform to Part 581 bumper damageability requirements, the U.S. variants performed much worse than European variants in the lower legform assessment, but no worse than (and perhaps slightly better than) non-global "passenger cars."

• In upper legform tests, the global "passenger cars" perform very well, with U.S. and European variants performing equally as well. Non-global vehicles did not perform well. The largest of them – the pickup and the large SUV – performed the worst of all vehicles.

Appendix A: 2017 Audi A4

Overview

A 2017 Audi A4 was tested.

Exemplar 2017 Audi A4.

Vehicle Information

Pertinent vehicle information is listed in Table A-1 below. Descriptions for the lateral hood width and front-end width can be found in Appendix J.

Table A-1. Vehicle information

Make	Audi
Model	A4
Year	2017
VIN	WAUFNAF42HN010973
Type	Passenger Car
GVWR	2175 kg
Lateral Hood Width	1690 mm
Front End Width	1810 mm

Headform Testing

For the 2017 Audi A4, 6 points were chosen and are shown in Figure A-1 below.

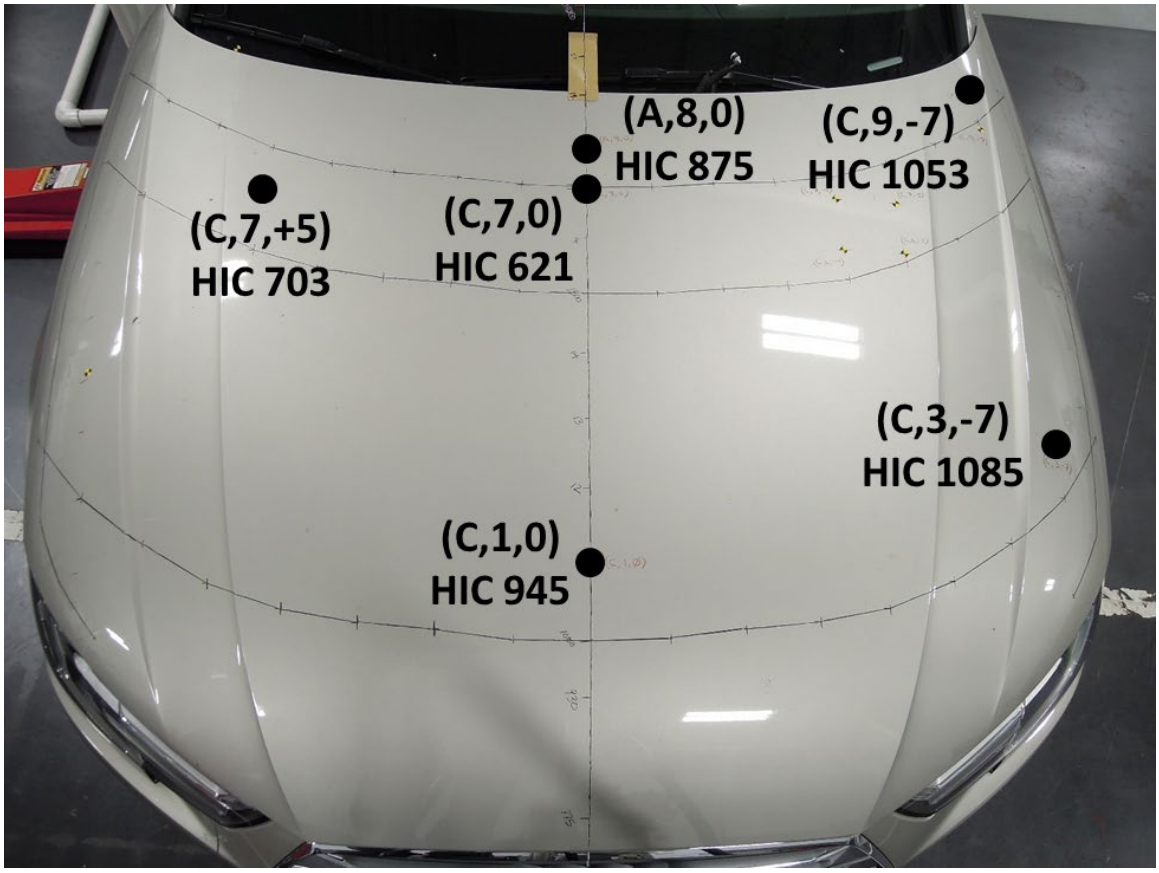


Figure A-1. 2017 Audi A4 selected headform impact points, their corresponding grid coordinates, and HIC results.

HIC results and corresponding points for the selected impact points are shown in Table A-2. The 2017 Audi A4 earned 4.25 points out of a possible 6 points, resulting in a score of 17.0 for the undeployed hood. Results for an active hood are also shown for the U.S. variant (active hood installed by NHTSA) and for the European variant with the standard active hood as tested by Euro NCAP. The active hood is not available to consumers on U.S. variants.

Table A-2. 2017 Audi A4 headform impact locations, HIC results, and resulting score.

			HIC SCORES				
			Non-active hood		Active hood – deployed		
Test No.	**Grid point**		**NHTSA (pts)**		***NHTSA (for ref only)***	***Euro NCAP (for ref only)***	***Audi Predicted (for ref only)***
1730	C	1,0	**945**	**0.75**	***795***	**---**	***1000 - 1350***
1731	C	7,0	**621**	**1**	***698***	**---**	***< 650***
1732	C	9,-7	**1053**	**0.5**	***1153***	**---**	***1000 - 1350***
1733	C	7,5	**703**	**0.75**	***556***	***568***	***< 650***
1734	C	3,-7	**1085**	**0.5**	***766***	**---**	***650 - 1000***
1735	A	8,0	**875**	**0.75**	***450***	**---**	***< 650***
---	A	9,-3	**---**	**---**	---	***398***	***< 650***
---	A	11,-2	**---**	**---**	---	***1055***	***> 1700***
---	C	4,4	**---**	**---**	---	***628***	***650 - 1000***
---	A	8,7	**---**	**---**	---	***773***	***650 - 1000***
---	C	7,-2	**---**	**---**	---	***589***	***<650***
---	A	10,-7	**---**	**---**	---	***1048***	***650 - 1000***
---	C	3,-4	**---**	**---**	---	***670***	***650 - 1000***
---	C	2,-1	**---**	**---**	---	***649***	***650 - 1000***
Total Points (6 max)			4.25		*4.50*		
Score			**17.00**		***18.00***	***16.58***	

Lower Legform Testing

The bumper test zone is defined as either the area limited by the bumper corners or the outermost ends of the underlying bumper beam, whichever is larger. The distance from the bumper corner of the fascia to the centerline was measured to be 509 mm. The distance from the outermost ends of the underlying bumper beam to the centerline of the 2017 Audi A4 was measured to be 582 mm. The bumper test zone is the larger of the two distances, and for the 2017 Audi A4, is 582 mm from the centerline. Grid points are located every 100 mm from the centerline in both lateral directions resulting in 13 grid points for the 2017 Audi A4. Non-tested grid points are awarded the worst result from one of the adjacent points. In addition, symmetry will be applied to all grid points. Given these conditions, three test points were tested and are shown in Figure A-2 below.

Figure A-2. 2017 Audi A4 selected lower legform impact points

Lower legform results for the selected impact points are shown in Table A-3 and the corresponding score is shown in Table A-4. Results that fall below the lower limit are highlighted in green, above the upper limit are in red, and between the lower and upper limits are in orange. Following the Euro NCAP guidelines, the 2017 Audi A4 earned 4.86 points out of a possible 13 points, resulting in a score of 2.2.

Table A-3. 2017 Audi A4 lower legform impact locations and corresponding results.

		Tibia Bending Limits				*Ligament Elongation Limits*		
		282-340 Nm				*19-22 mm*	*10 mm*	
Test #	**Location**	**Tibia 1**	**Tibia 2**	**Tibia 3**	**Tibia 4**	**MCL**	**ACL**	**PCL**
LL 1710	L+1	320	274	229	139	23.9	12.4	6.7
LL 1711	L-3	253	253	212	136	22.4	13.9	6.3
LL 1712	L+5	206	188	165	152	17.9	11.2	7.3
European Variant (ref only)	*L +6*	*220*	*213*	*155*	*105*	*19.9*	*6.3*	*7.1*
	L +2	*210*	*213*	*208*	*178*	*20.6*	*7.6*	*5.6*
	L 0	*207*	*245*	*238*	*176*	*17.2*	*6.5*	*5.2*
	L -1	*229*	*229*	*208*	*171*	*20.0*	*7.2*	*5.5*
	L -3	*172*	*186*	*214*	*169*	*18.8*	*6.6*	*5.1*
	L -4	*163*	*124*	*174*	*185*	*15.6*	*5.7*	*5.9*

Table A-4. 2017 Audi A4 lower legform grid points and score.

Location	**Points on U.S. variant**			***Points on Euro. variant (for ref. only)***
	Bending	**Elongation**	**Total**	
L+6	0.5	0	0.5	*0.850*
L+5	0.5	0	0.5	*0.850*
L+4	0.5	0	0.5	*1.000*
L+3	0.5	0	0.5	*1.000*
L+2	0.172	0	0.172	*0.733*
L+1	0.172	0	0.172	*0.833*
L0	0.172	0	0.172	*1.000*
L-1	0.172	0	0.172	*0.833*
L-2	0.172	0	0.172	*0.733*
L-3	0.5	0	0.5	*1.000*
L-4	0.5	0	0.5	*1.000*
L-5	0.5	0	0.5	*0.850*
L-6	0.5	0	0.5	*0.850*
Points Total (Out of Max Possible 13 Points)	**4.86**			***11.53***
Score	**2.24**			***5.46***

Upper Legform Testing

Since the lower bumper reference line is less than 425 mm, upper legform impacts were performed at the wrap around distance (WAD) 775 mm. Starting at the vehicle's centerline, grid points are marked every 100 mm in both lateral directions along the WAD 775 mm line up to the corner reference points. Grid points less than 50 mm from the corner reference points are deleted. As with lower leg testing, non-tested grid points are awarded the worst result from one of the adjacent points. In addition, symmetry will be applied to all grid points. Given these conditions, four test points were tested and are shown in Figure A-3 below.

Figure A-3. 2017 Audi A4 selected upper legform impact points

Upper legform results for the selected impact points are shown in Table A-5 below. Results that fall below the lower limit are highlighted in green, above the upper limit are in red, and between the lower and upper limits are in orange. The possible number of points awarded for each injury measure is shown in Table A-6 below. The 2017 Audi A4 earned 11.2 points out of a possible 13 points, resulting in a score of 5.2.

Table A-5. 2017 Audi A4 upper legform impact locations and corresponding results

Test #	Location	Angle (°)	Energy (J)	Femur Bending Moment Limits: 285 – 350 Nm			Sum Femur Loads (N) Limits: 5-6 kN
				Upper	Middle	Lower	
UL 1708	U0	41.9	186	115	146	137	2675
UL 1711	U+2	42.5	181	152	188	169	3164
UL 1710	U+4	42.0	186	189	250	239	3986
UL 1709	U-6	43.3	173	261	314	274	4460
European Variant (ref only)	*U +7*	---	---	*263*	*298*	*235*	*4660*
	U +4	---	---	*201*	*280*	*280*	*4460*
	U +2	---	---	*173*	*209*	*188*	*3390*
	U 0	---	---	*126*	*170*	*176*	*3350*
	U -3	---	---	*184*	*238*	*225*	*3800*
	U -5	---	---	*200*	*249*	*231*	*3780*
	U -6	---	---	*264*	*316*	*284*	*4420*

Table A-6. Points awarded for each injury measure and resulting score for the upper legform tests. Upper leg performance for each grid point is based on the worst performing parameter.

Location	Points on U.S. variant			*Points on Euro. variant (ref only)*
	Bending	Force	Total	
U+7				*0.79*
U+6	0.55	1	0.55	*0.53*
U+5	0.55	1	0.55	*1.00*
U+4	1	1	1	*1.00*
U+3	1	1	1	*1.00*
U+2	1	1	1	*1.00*
U+1	1	1	1	*1.00*
U0	1	1	1	*1.00*
U-1	1	1	1	*1.00*
U-2	1	1	1	*1.00*
U-3	1	1	1	*1.00*
U-4	1	1	1	*1.00*
U-5	0.55	1	0.55	*1.00*
U-6	0.55	1	0.55	*0.53*
U-7				*0.79*
Points Total (Out of Max Possible 13 Points)	**11.2**			***13.64***
Score	**5.17**			***5.24***

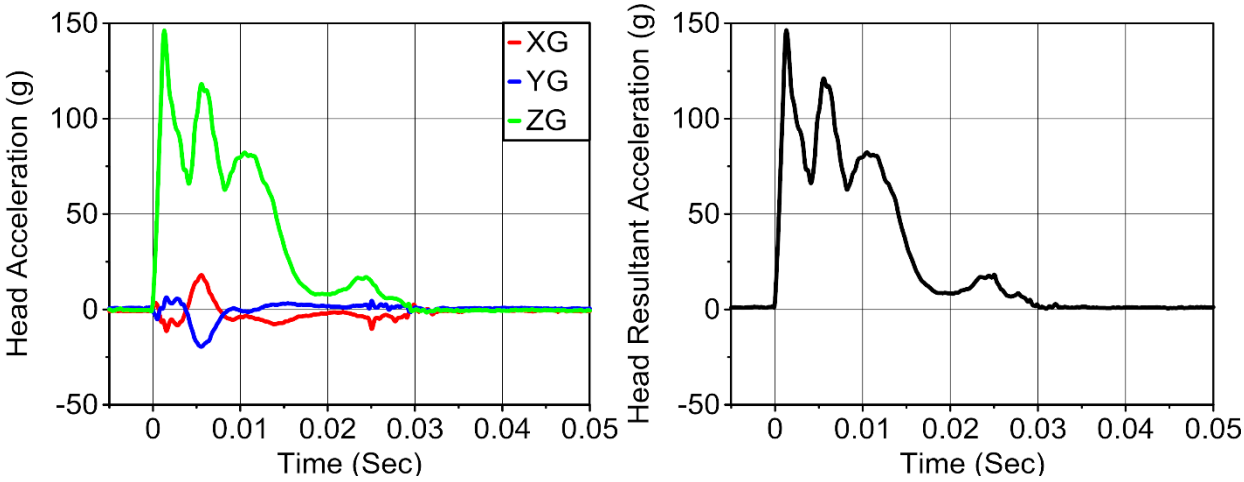
Summary

Table A-7. Summary of results for the 2017 Audi A4.

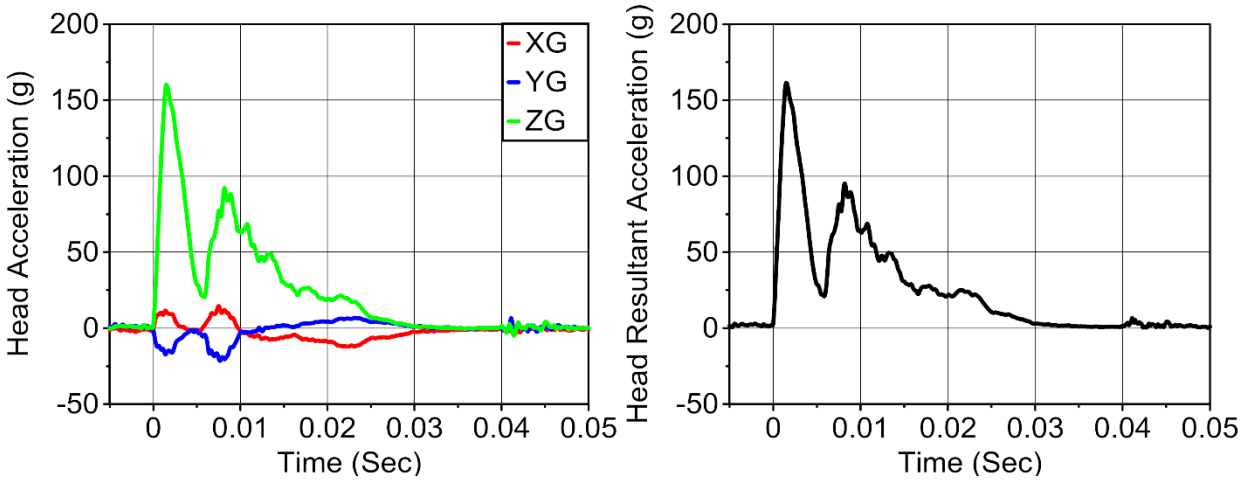
2017 Audi A4	Head	Lower Leg	Upper Leg	Total	% of Max
Score (Out of 36)	17.0	2.24	5.17	24.4	67.8%

Headform Impact Data Traces

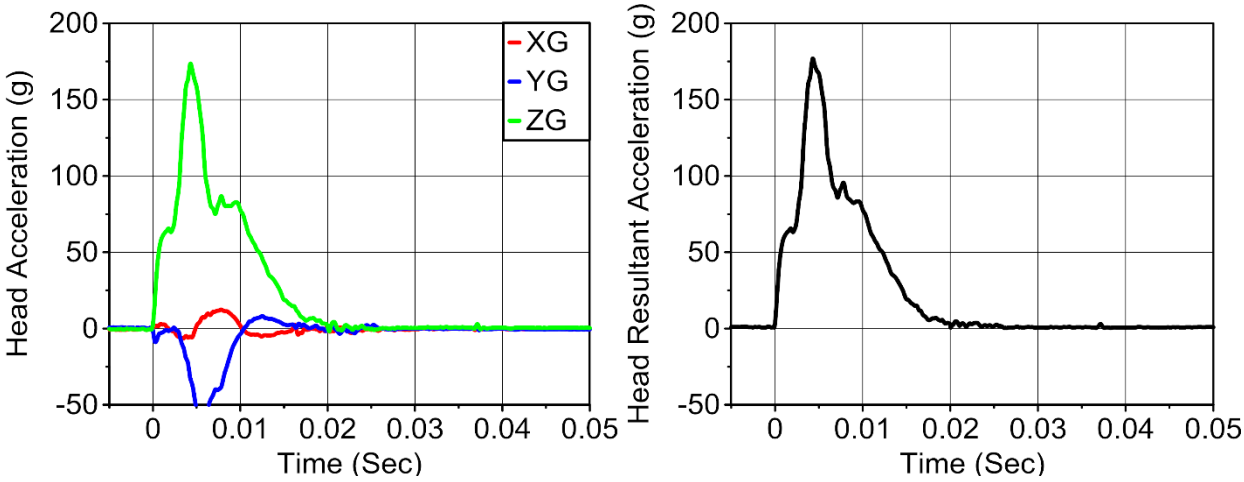
ChildHead 1730



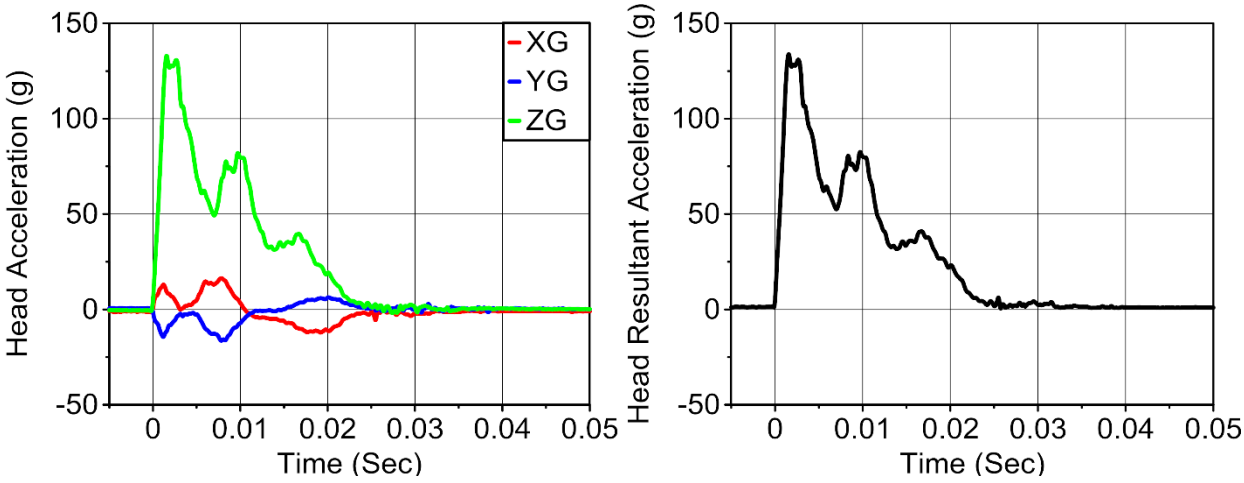
ChildHead 1731



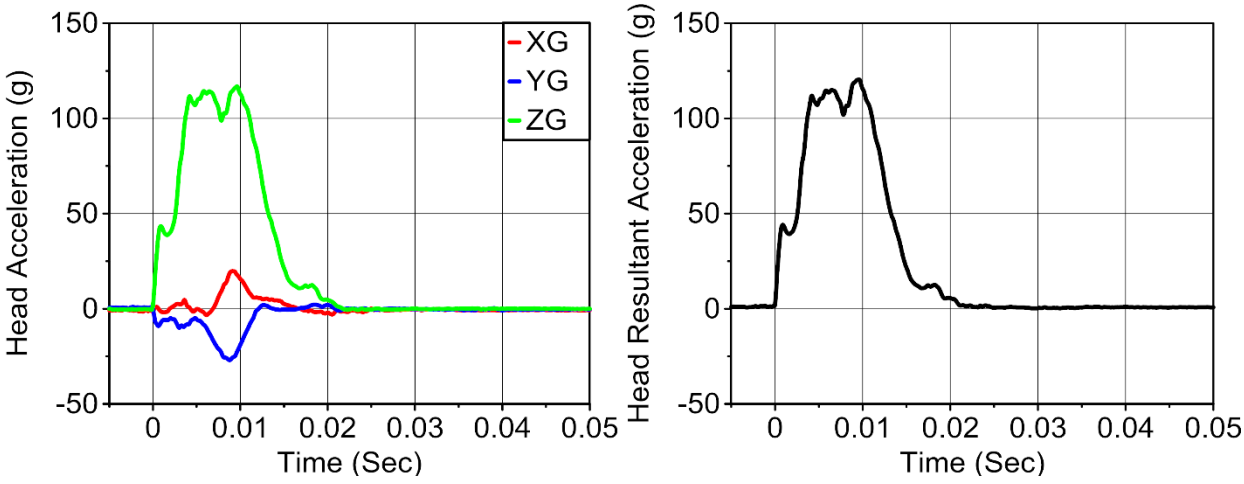
ChildHead 1732



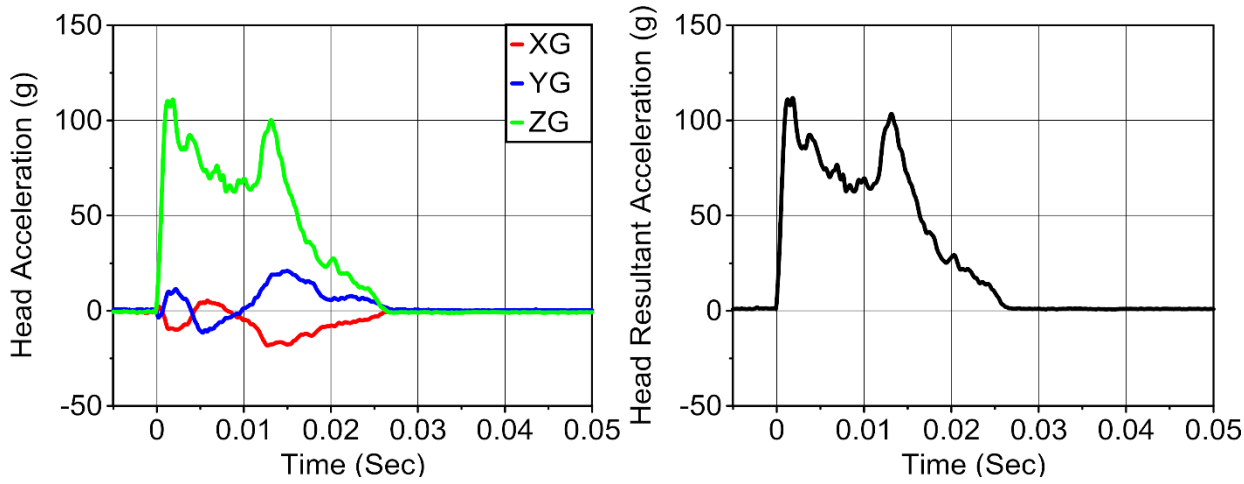
ChildHead 1733



ChildHead 1734

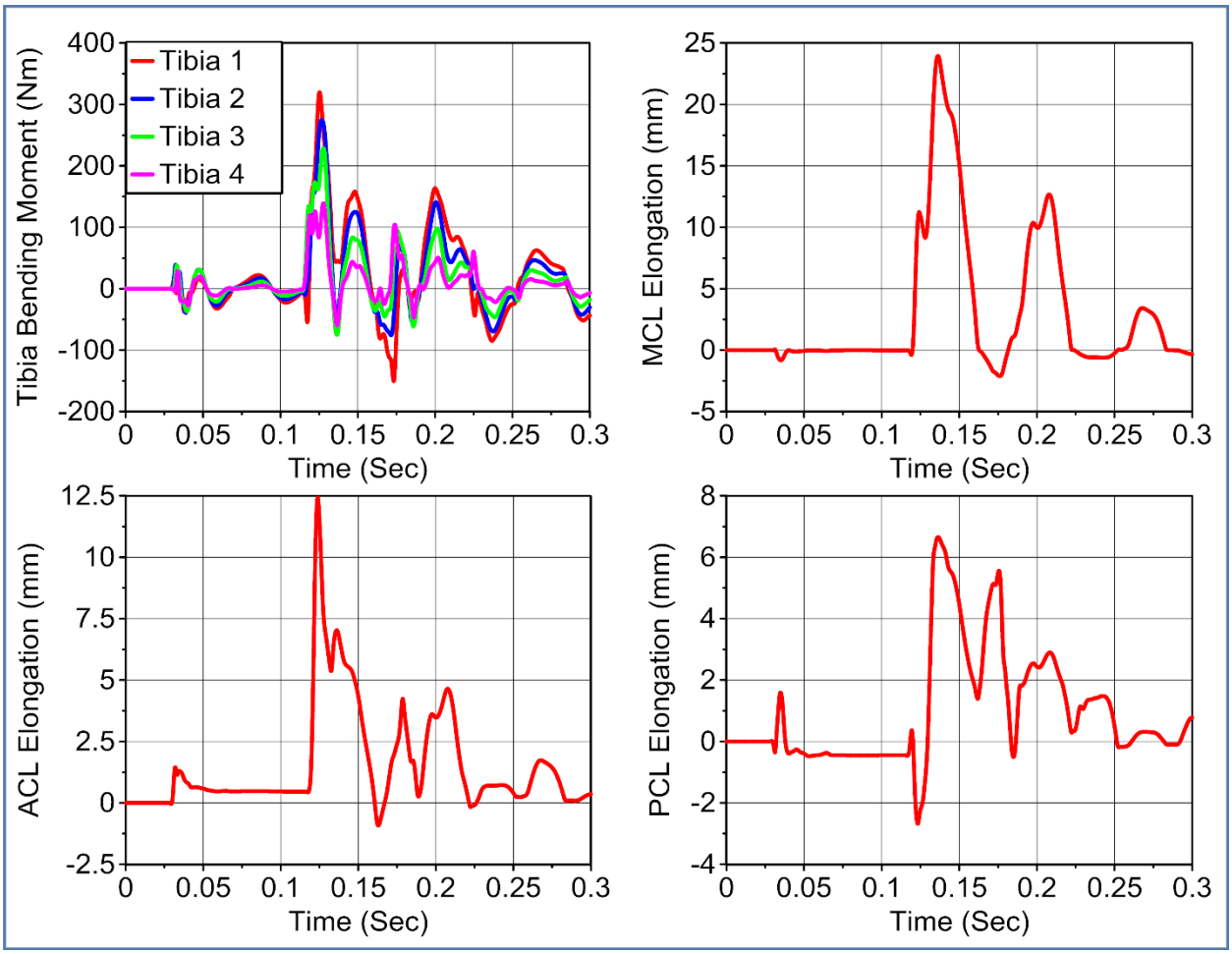


AdultHead 1735

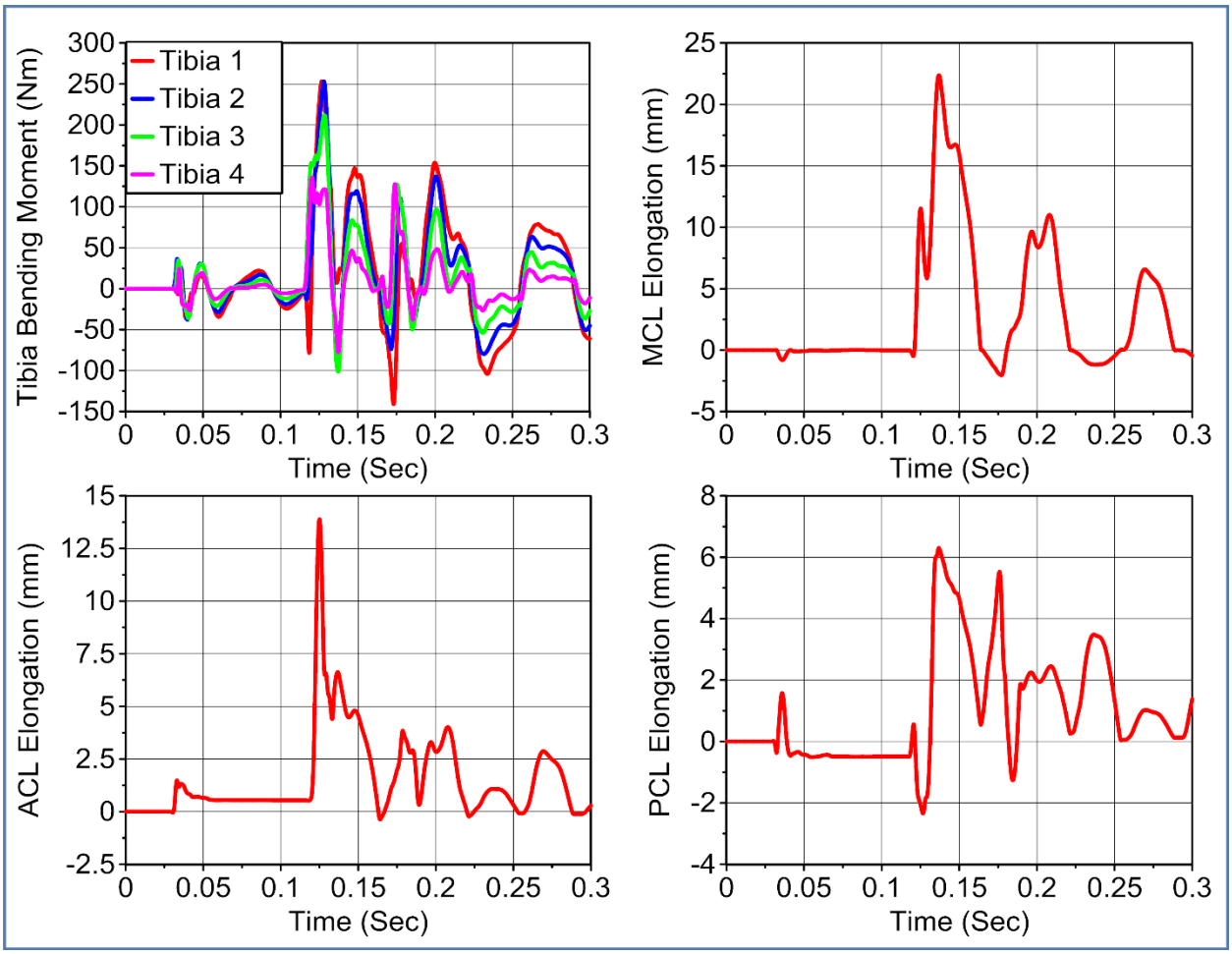


Lower Legform Impact Data Traces

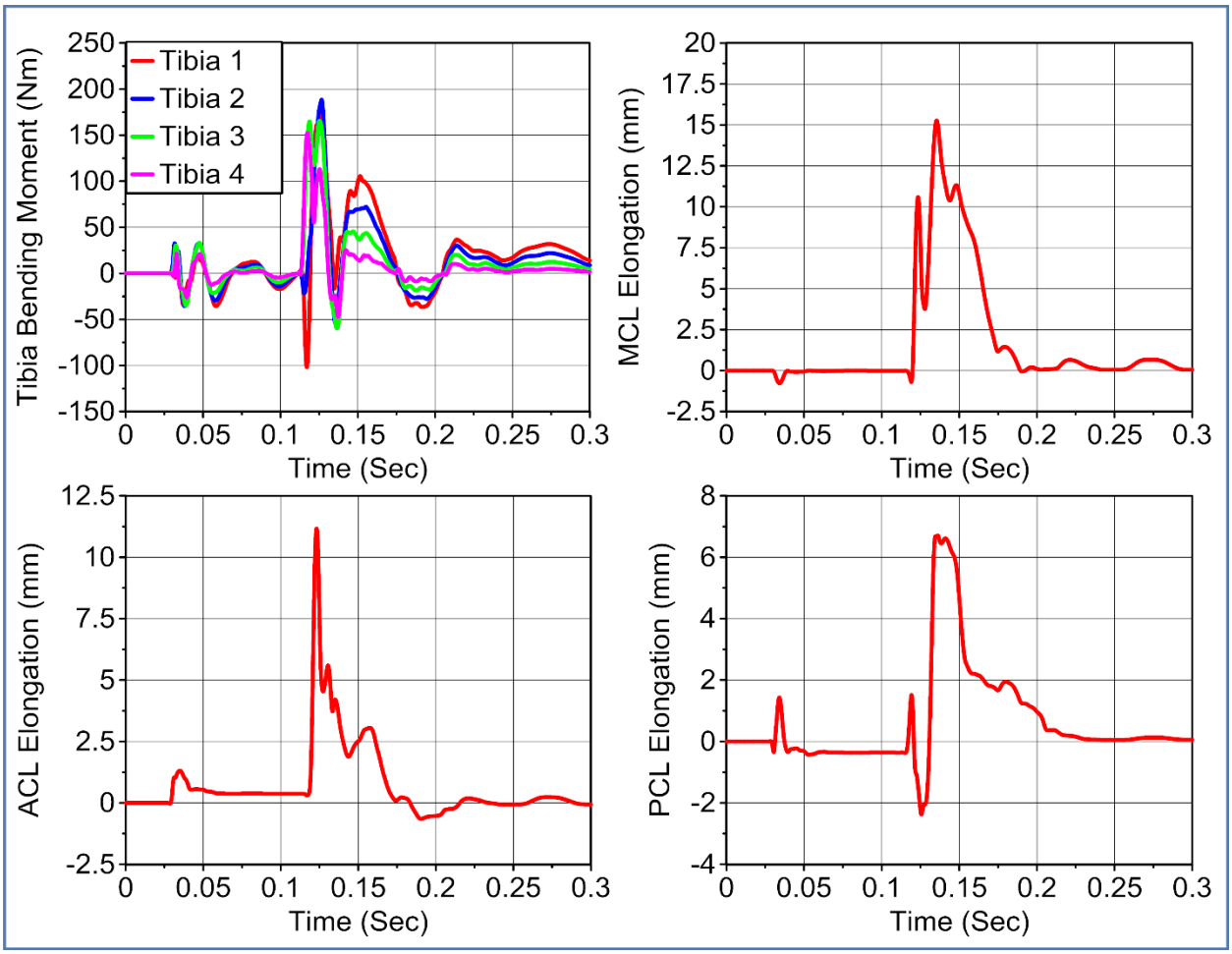
LL 1710



LL 1711

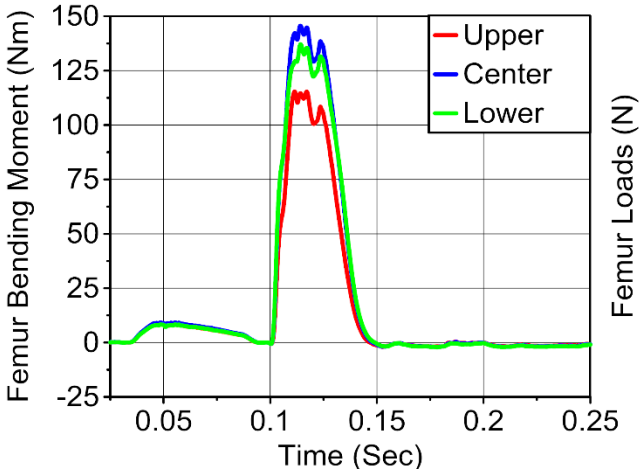

Tibia Bending Moment (Nm)
Tibia 1
Tibia 2
Tibia 3
Tibia 4
Time (Sec)
MCL Elongation (mm)
Time (Sec)
ACL Elongation (mm)
Time (Sec)
PCL Elongation (mm)
Time (Sec)

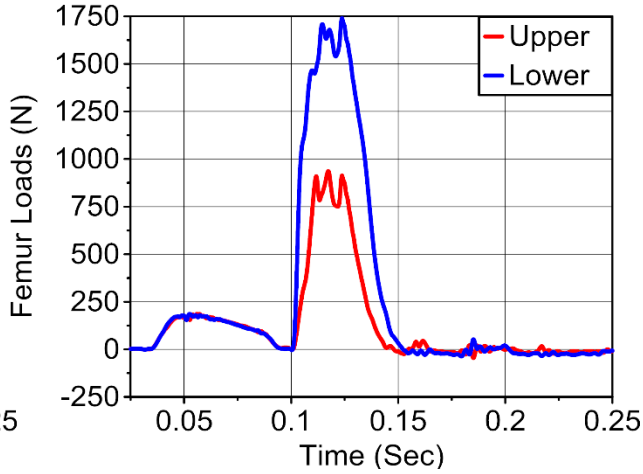
LL 1712


Tibia Bending Moment (Nm)
Tibia 1
Tibia 2
Tibia 3
Tibia 4
Time (Sec)
MCL Elongation (mm)
Time (Sec)
ACL Elongation (mm)
Time (Sec)
PCL Elongation (mm)
Time (Sec)

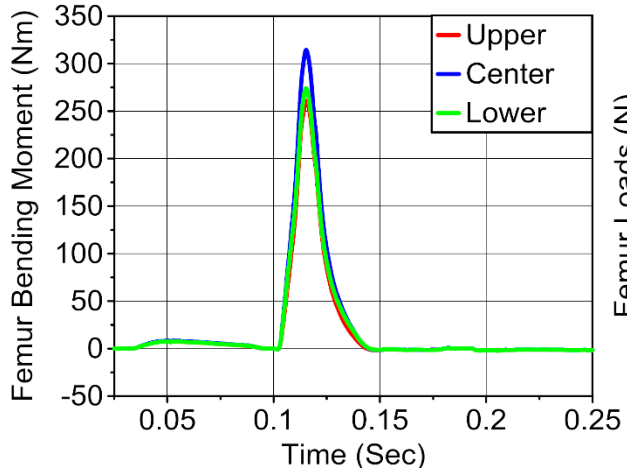
Upper Legform Impact Data Traces

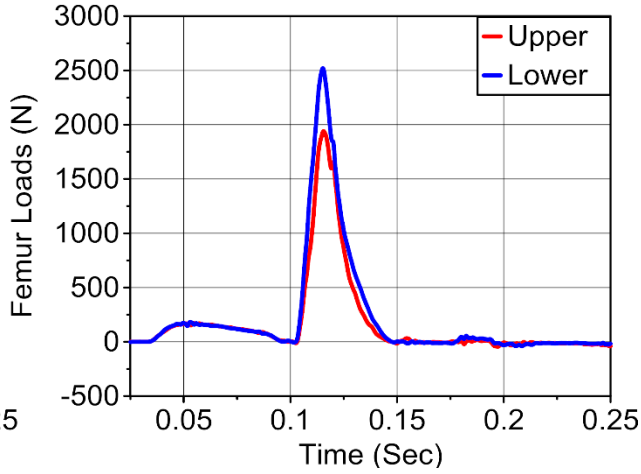
UL 1708



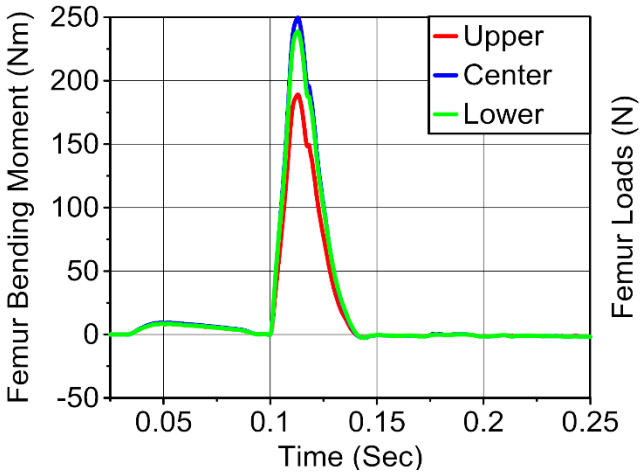


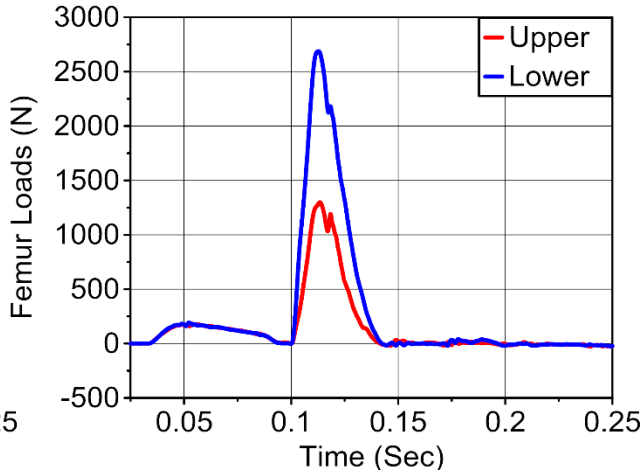
UL 1709



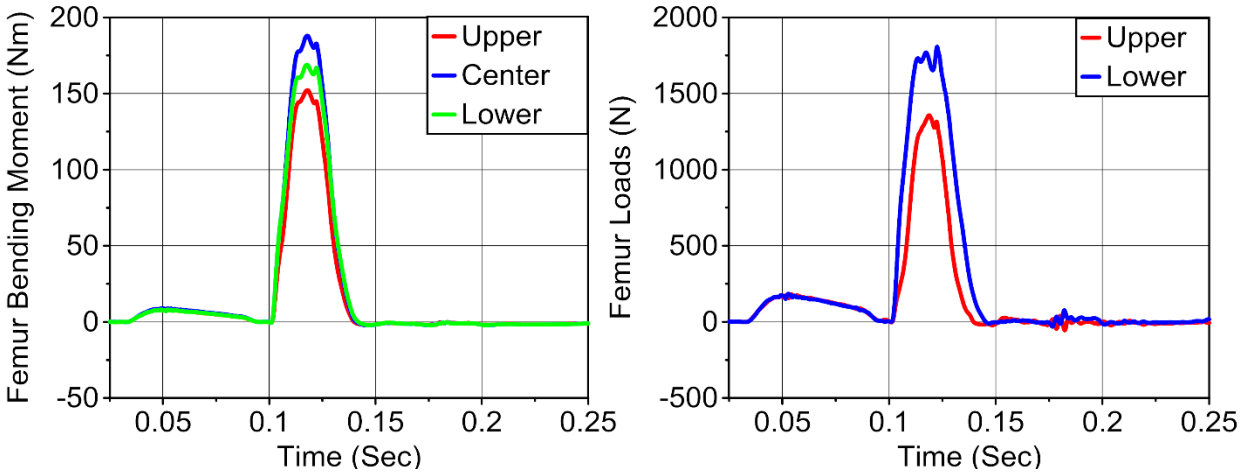


UL 1710





UL 1711



Examples of Post-Test Vehicle Damage

ChildHead 1732

ChildHead 1734

Appendix B: 2016 Chevrolet Malibu

Overview

A 2016 Chevrolet Malibu was tested.

Exemplar 2016 Chevrolet Malibu

Vehicle Information

Pertinent vehicle information is listed in Table B-1 below. Descriptions for the lateral hood width and front-end width can be found in Appendix J.

Table B-1. Vehicle information

Make	Chevrolet
Model	Malibu
Year	2016
VIN	1G11B5SA0GF123475
Type	Passenger Car
GVWR	2006 kg
Lateral Hood Width	1586 mm
Front End Width	1830 mm

Headform Testing

For the 2016 Chevrolet Malibu, 11 points were chosen and are shown in Figure B-1 below.

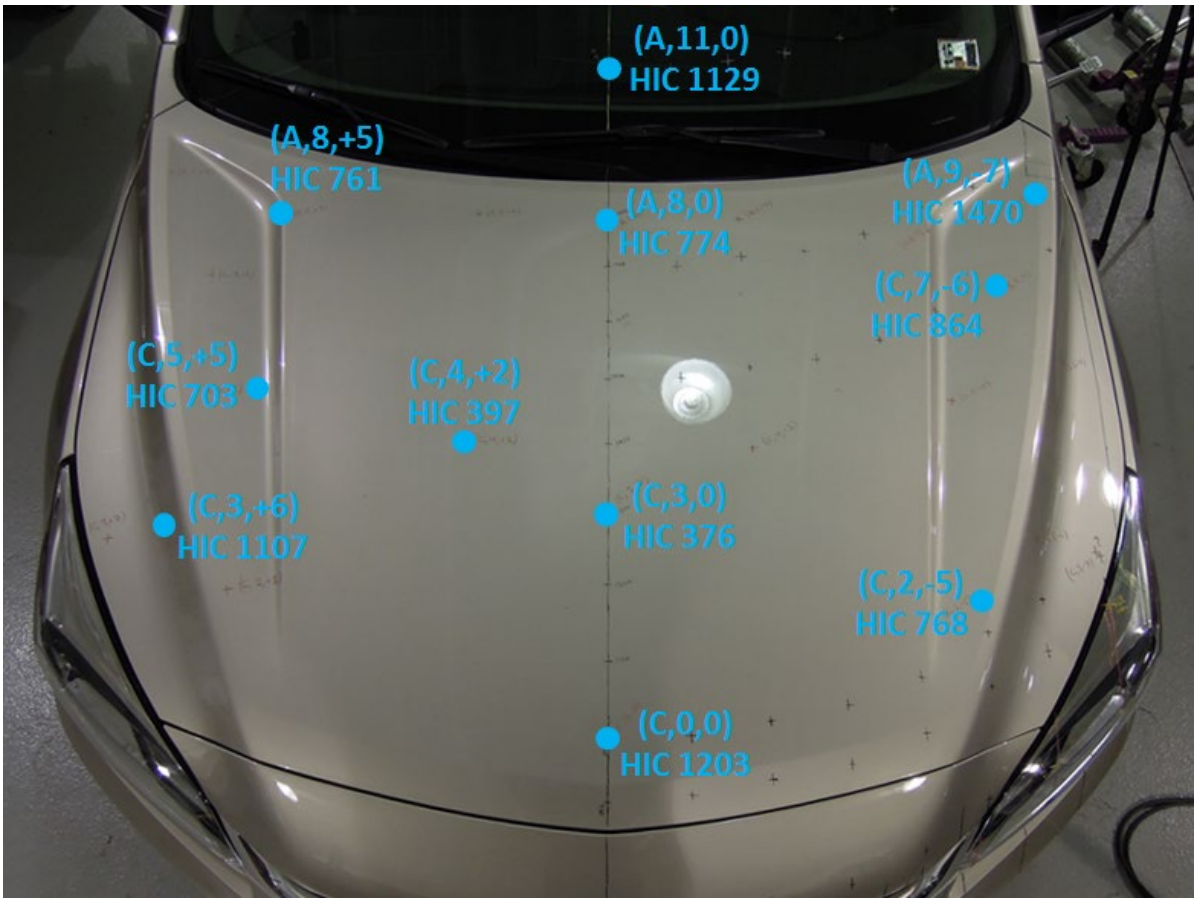


Figure B-1. 2016 Chevrolet Malibu selected headform impact points, their corresponding grid coordinates, and HIC results.

HIC results and corresponding points for the selected impact points are shown in Table B-2 below. The 2016 Chevrolet Malibu earned 7.5 points out of a possible 11 points, resulting in a score of 16.4. There is no Euro NCAP score for a European variant of this vehicle.

Table B-2. 2016 Chevrolet Malibu headform impact locations, HIC results, and resulting score.

			HIC SCORES			
Test No.	**Grid point**		**NHTSA (pts)**		**Euro NCAP (for ref only)**	**G.M Predicted (for ref only)**
1612	A	11,1	**1129**	**0.50**	**---**	**---**
1613	A	8,0	**774**	**0.75**	**---**	**---**
1614	A	8,5	**761**	**0.75**	**---**	**---**
1615	A	9,-7	**1470**	**0.25**	**---**	**---**
1616	C	0,0	**1203**	**0.50**	**---**	**---**
1624	C	3,0	**376**	**1.0**	**---**	**---**
1625	C	7,-6	**864**	**0.75**	**---**	**---**
1626	C	2,-5	**768**	**0.75**	**---**	**---**
1627	C	5,5	**703**	**0.75**	**---**	**---**
1628	C	4,2	**397**	**1.0**	**---**	**---**
1629	C	3,6	**1107**	**0.50**	**---**	**---**
Total Points (11 max)			7.5		*n/a*	
Score			**16.4**			

Lower Legform Testing

The bumper test zone is defined as either the area limited by the bumper corners or the outermost ends of the underlying bumper beam, whichever is larger. The distance from the bumper corner of the fascia to the centerline was measured to be 462 mm. The distance from the outermost ends of the underlying bumper beam to the centerline of the 2016 Chevrolet Malibu was measured to be 604 mm. The bumper test zone is the larger of the two distances, and for the 2016 Chevrolet Malibu, is 708 mm from the centerline. Grid points are located every 100 mm from the centerline in both lateral directions resulting in 15 grid points for the 2016 Chevrolet Malibu. Non-tested grid points are awarded the worst result from one of the adjacent points. In addition, symmetry will be applied to all grid points. Given these conditions, four test points were tested and are shown in Figure B-2 below.

Figure B-2. 2016 Chevrolet Malibu selected lower legform impact points

Lower legform results for the selected impact points are shown in Table B-3 and the corresponding score is shown in Table B-4. Results that fall below the lower limit are highlighted in green, above the upper limit are in red, and between the lower and upper limits are in orange. Following Euro NCAP guidelines, the 2016 Chevrolet Malibu earned 5.0 points out of a possible 15 points, resulting in a score of 2.0.

Table B-3. 2016 Chevrolet Malibu lower legform impact locations and corresponding results

		Tibia Bending Limits				*Ligament Elongation Limits*		
		282-340 Nm				*19-22 mm*	*10 mm*	
Test #	**Location**	**Tibia 1**	**Tibia 2**	**Tibia 3**	**Tibia 4**	**MCL**	**ACL**	**PCL**
LL 1607	L+1	302	411	258	126	14.1	6.9	5.2
LL 1608	L+5	376	296	185	105	20.9	9.6	9.6
LL 1609	L-7	403	351	239	121	25.1	9.4	8.1
LL 1610	L-3	319	346	215	116	13.6	6.1	4.4

No European Variant

Table B-4. 2016 Chevrolet Malibu lower legform grid points and score

Location	Points on U.S. variant			*No Euro variant*
	Bending	Elongation	Total	
L+6	0	0	0	---
L+6	0	0	0	---
L+5	0	0.37	0.37	---
L+4	0	0.37	0.37	---
L+3	0	0.5	0.5	---
L+2	0	0.5	0.5	---
L+1	0	0.5	0.5	---
L0	0	0.5	0.5	---
L-1	0	0.5	0.5	---
L-2	0	0.5	0.5	---
L-3	0	0.5	0.5	---
L-4	0	0.37	0.37	---
L-5	0	0.37	0.37	---
L-6	0	0	0	---
L-7	0	0	0	---
Points Total (Out of Max Possible 15 Points)	5.0			
Score	2.0			*n/a*

Upper Legform Testing

Since the lower bumper reference line is less than 425 mm, upper legform impacts were performed at the wrap around distance (WAD) 775 mm. Starting at the vehicle's centerline, grid points are marked every 100 mm in both lateral directions along the WAD 775 mm line up to the corner reference points. Grid points less than 50 mm from the corner reference points are deleted. As with lower leg testing, non-tested grid points are awarded the worst result from one of the adjacent points. In addition, symmetry will be applied to all grid points. Given these conditions, four test points were tested and are shown in Figure B-3.

Figure B-3. 2016 Chevrolet Malibu selected upper legform impact points

Upper legform results for the selected impact points are shown in Table B-5 below. Results that fall below the lower limit are highlighted in green, above the upper limit are in red, and between the lower and upper limit are in orange. The possible number of points awarded for each injury measure is shown in Table B-6 below. The 2016 Chevrolet Malibu earned 8.5 points out of a possible 15 points, resulting in a score of 3.4.

Table B-5. 2016 Chevrolet Malibu upper legform impact locations and corresponding results

Test #	Location	Angle (°)	Energy (J)	Femur Bending Moment Limits: 285 – 350 Nm			Sum Femur Loads (N) Limits: 5-6 kN
				Upper	Middle	Lower	
UL 1605	U+1	28.5	312	249	220	153	5663
UL 1606	U-3	31.2	288	220	212	166	5304
UL 1607	U+5	38.1	223	275	313	269	5066
UL 1608	U-7	36.2	241	210	225	174	3777

No European Variant

Table B-6. Points awarded for each injury measure and resulting score for the upper legform tests. Upper leg performance for each grid point is based on the worst performing parameter.

Location	Points on U.S. Variant			*No Euro Variant*
	Bending	Force	Total	
U+7	1	1	1	---
U+6	0.57	0.93	0.57	---
U+5	0.57	0.93	0.57	---
U+4	0.57	0.93	0.57	---
U+3	1	0.7	0.7	---
U+2	1	0.34	**0.34**	---
U+1	1	0.34	**0.34**	---
U0	1	0.34	**0.34**	---
U-1	1	0.34	**0.34**	---
U-2	1	0.34	**0.34**	---
U-3	1	0.7	0.7	---
U-4	0.57	0.93	0.57	---
U-5	0.57	0.93	0.57	---
U-6	0.57	0.93	0.57	---
U-7	1	1	1	---
Points Total (Out of Max Possible 15 Points)	**8.5**			
Score	**3.4**			**n/a**

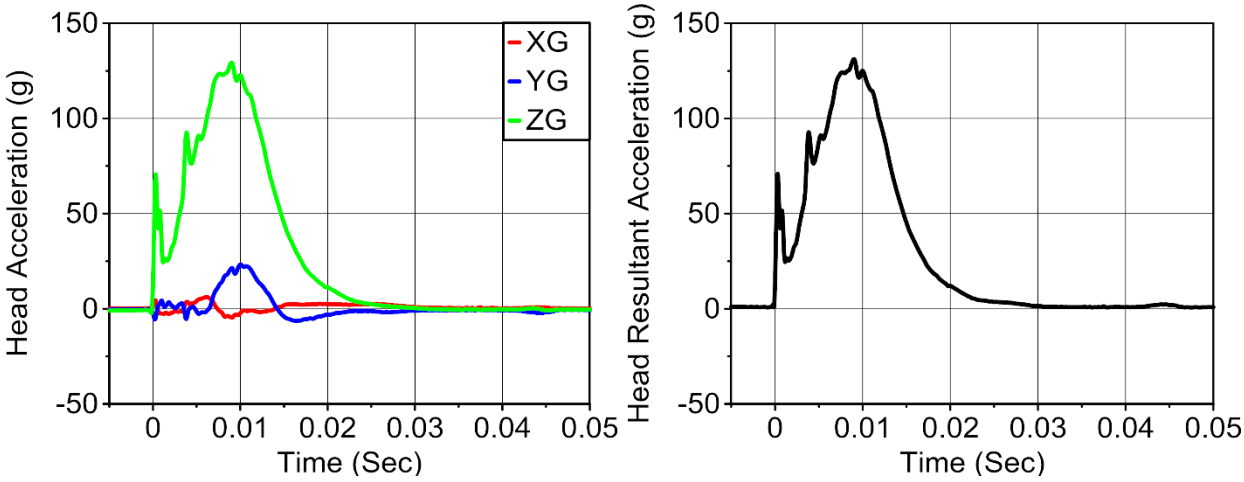
Summary

Table B-7. Summary of results for the 2016 Chevrolet Malibu

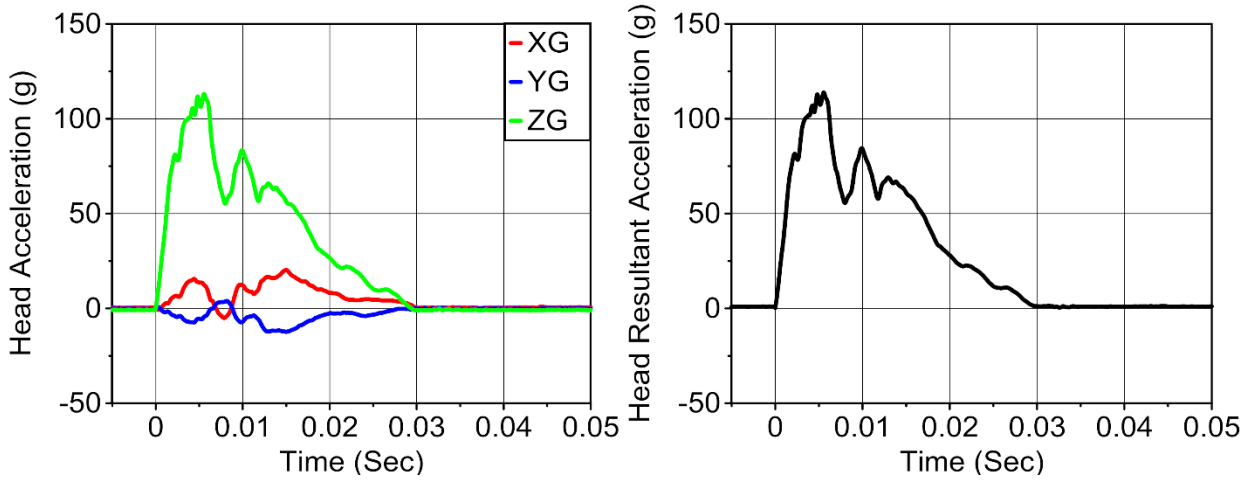
2016 Chevrolet Malibu	Head	Lower Leg	Upper Leg	Total	% of Max
Score (Out of 36)	16.4	2.0	3.4	**21.8**	**60.5%**

Headform Impact Data Traces

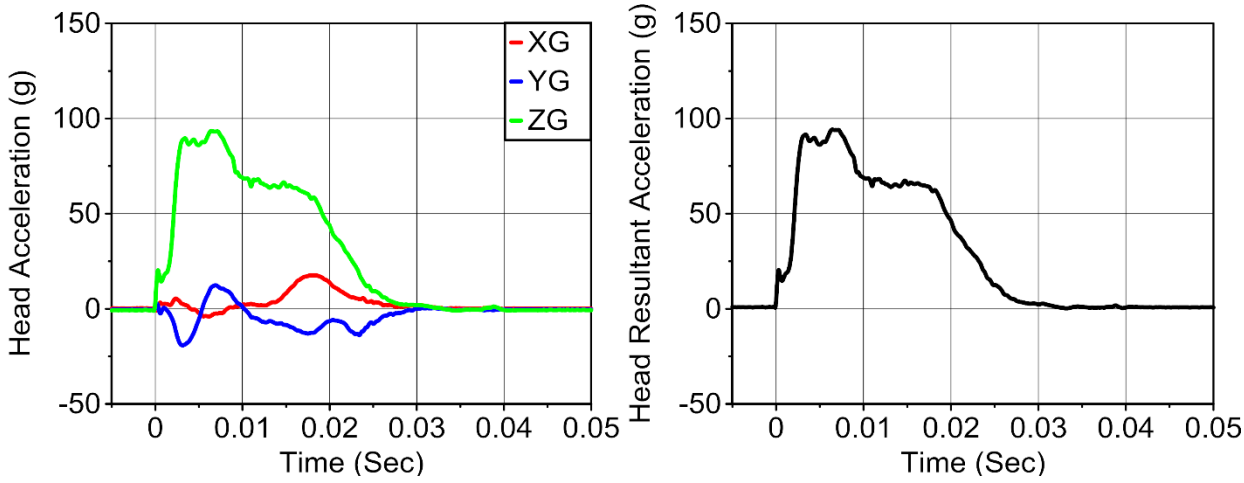
AdultHead 1612



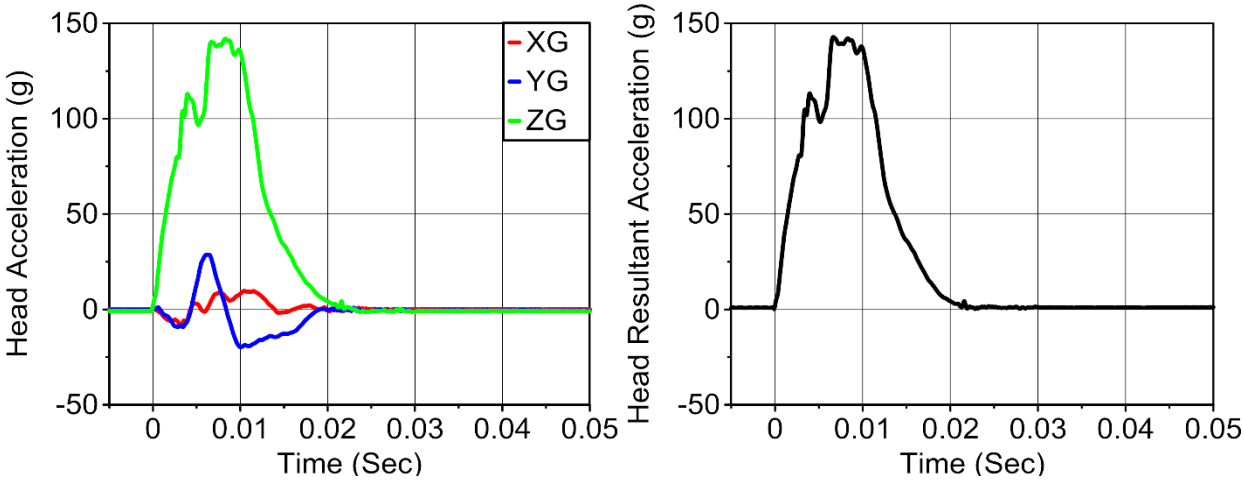
AdultHead 1613



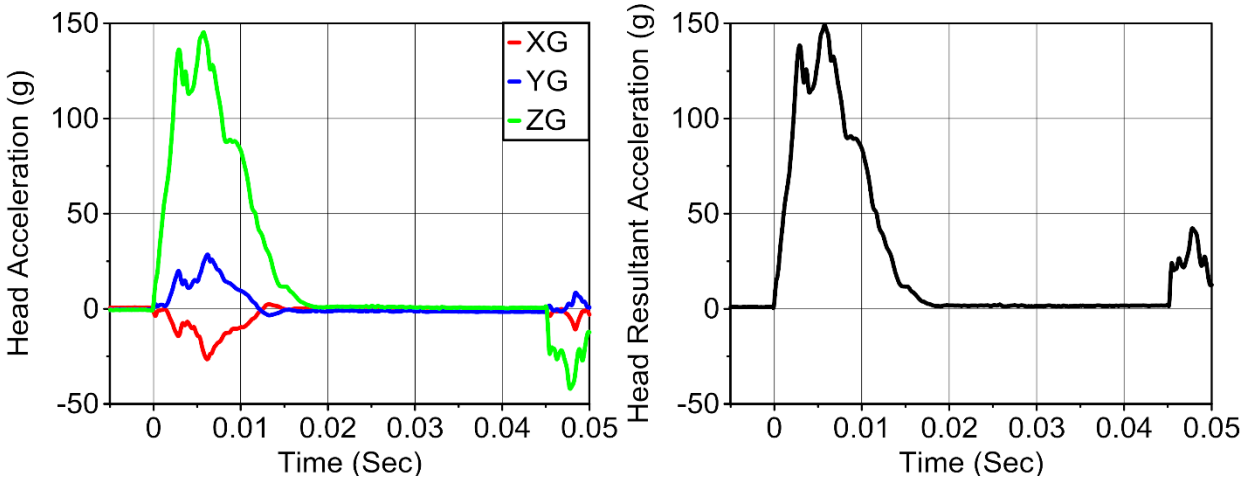
AdultHead 1614



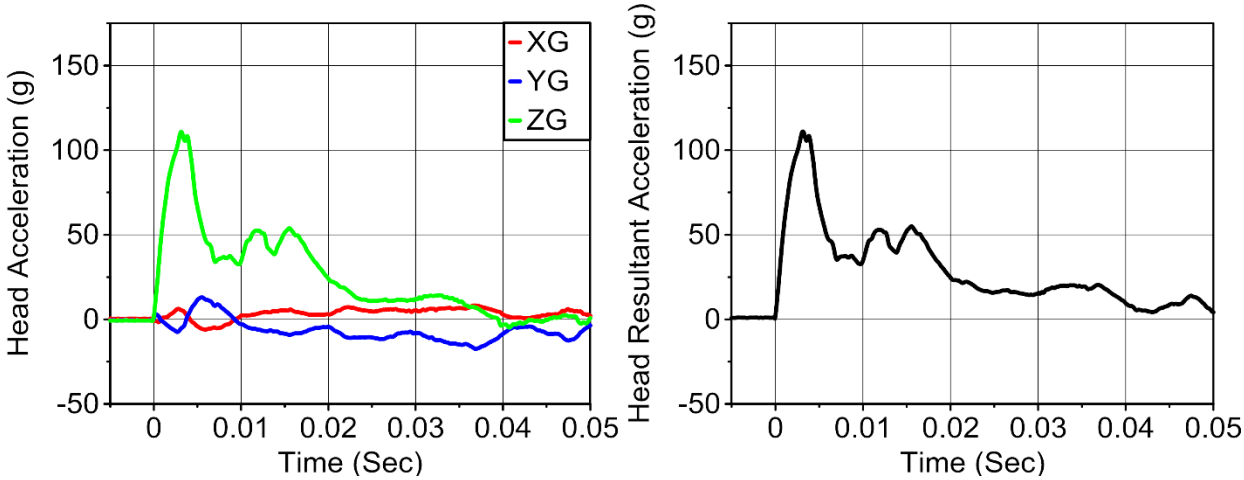
AdultHead 1615



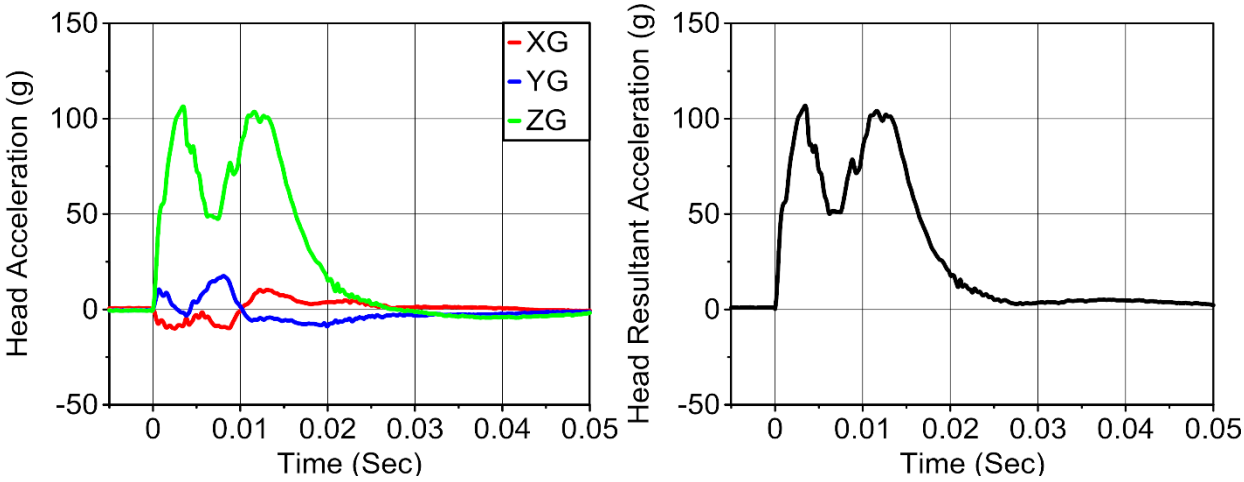
ChildHead 1616



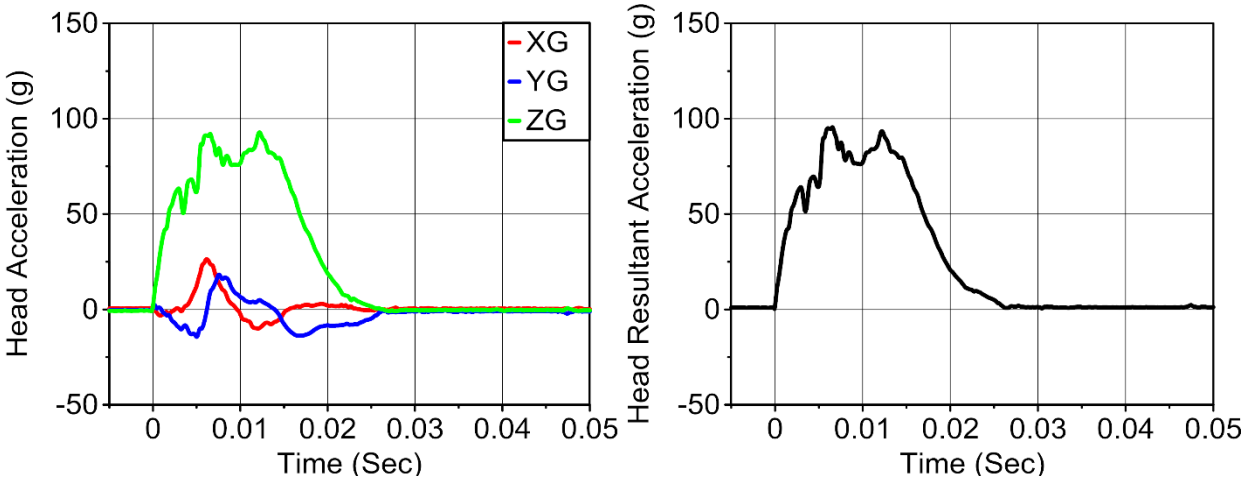
ChildHead 1624



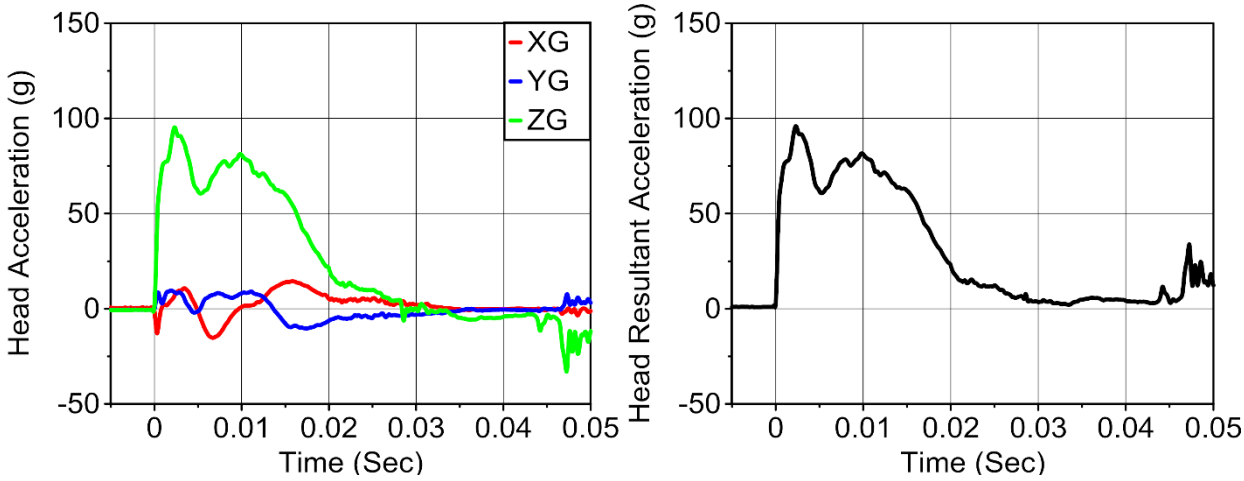
ChildHead 1625



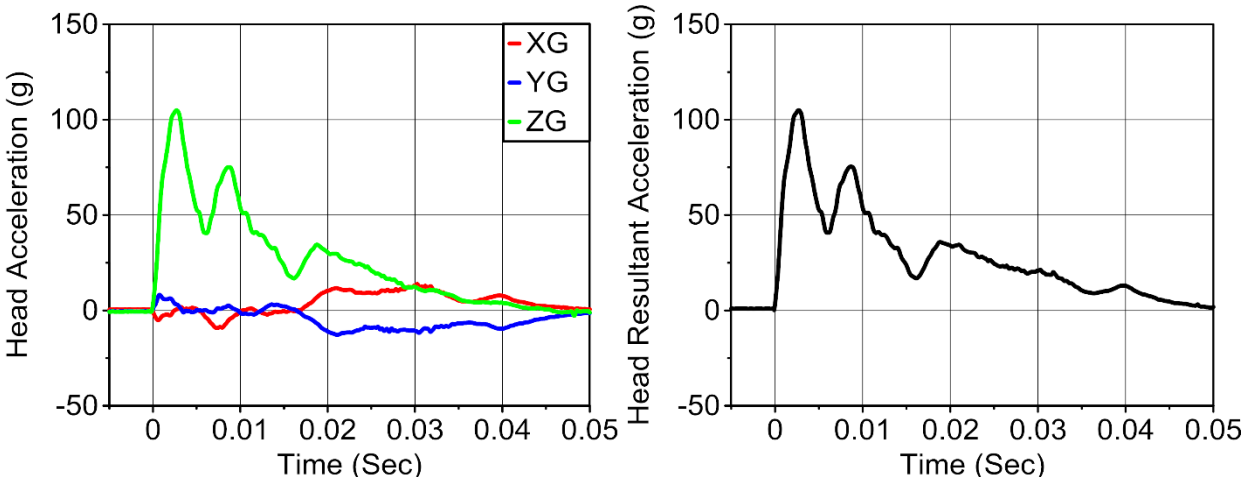
ChildHead 1626



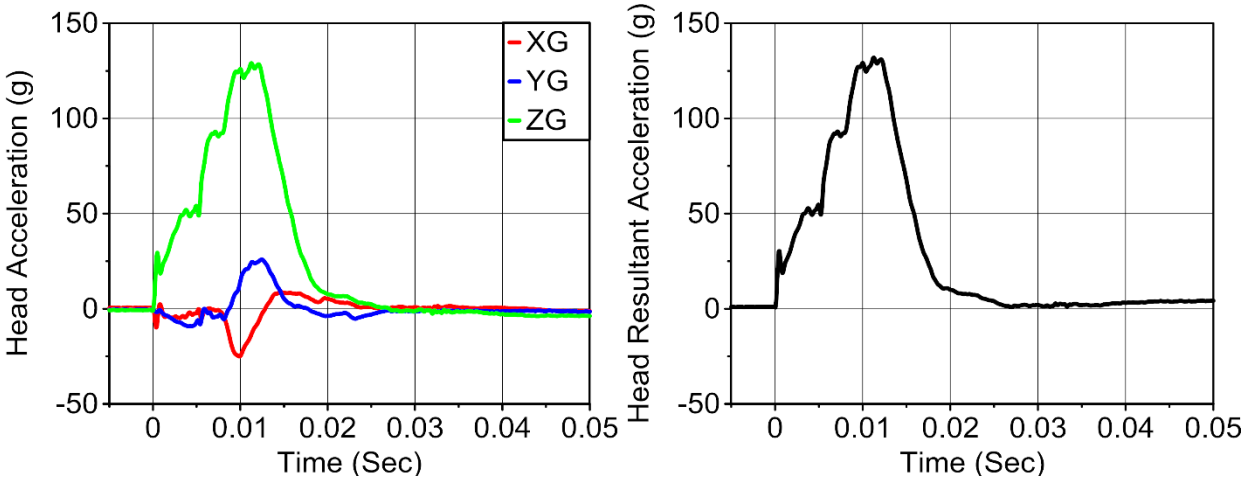
ChildHead 1627



ChildHead 1628

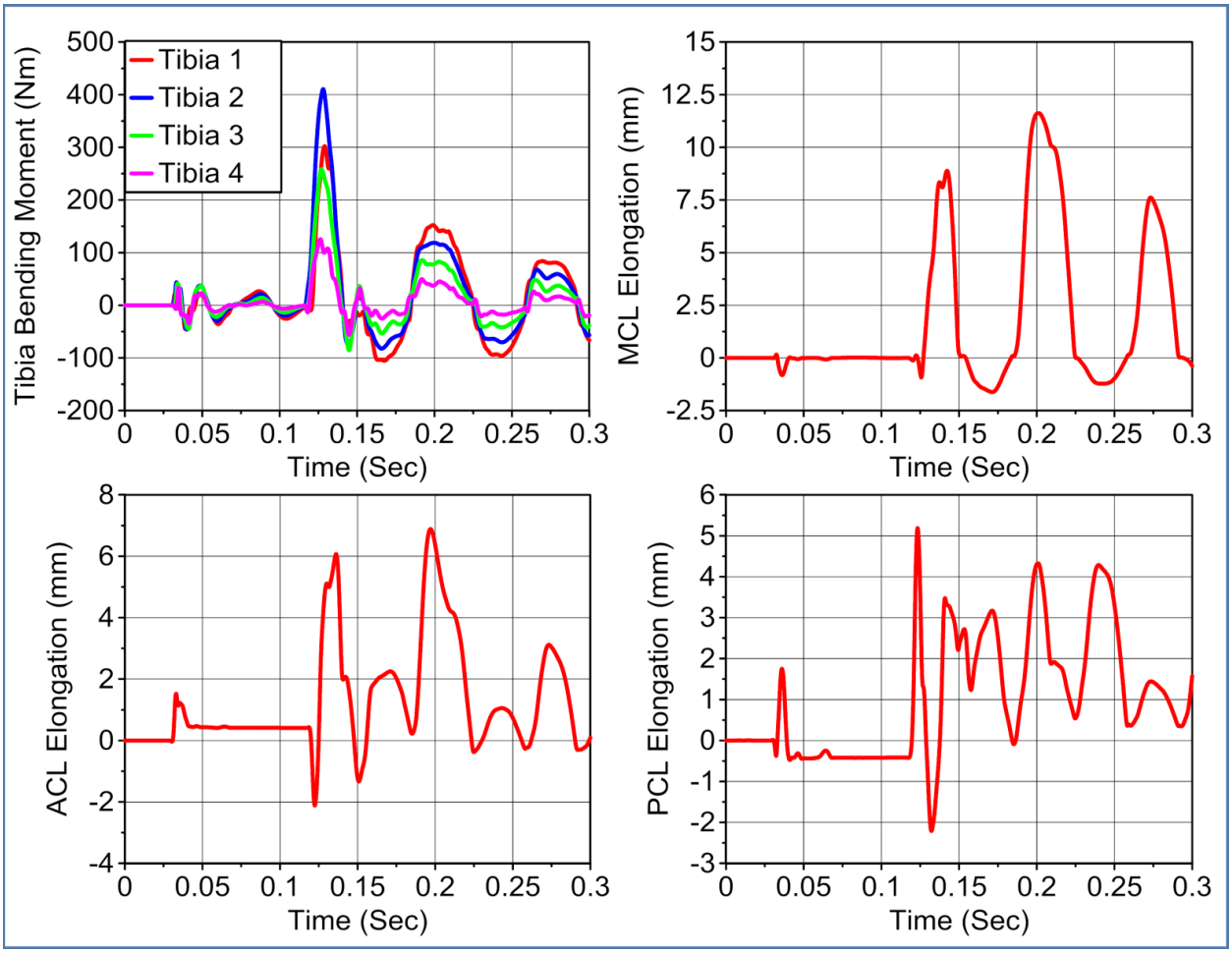


ChildHead 1629

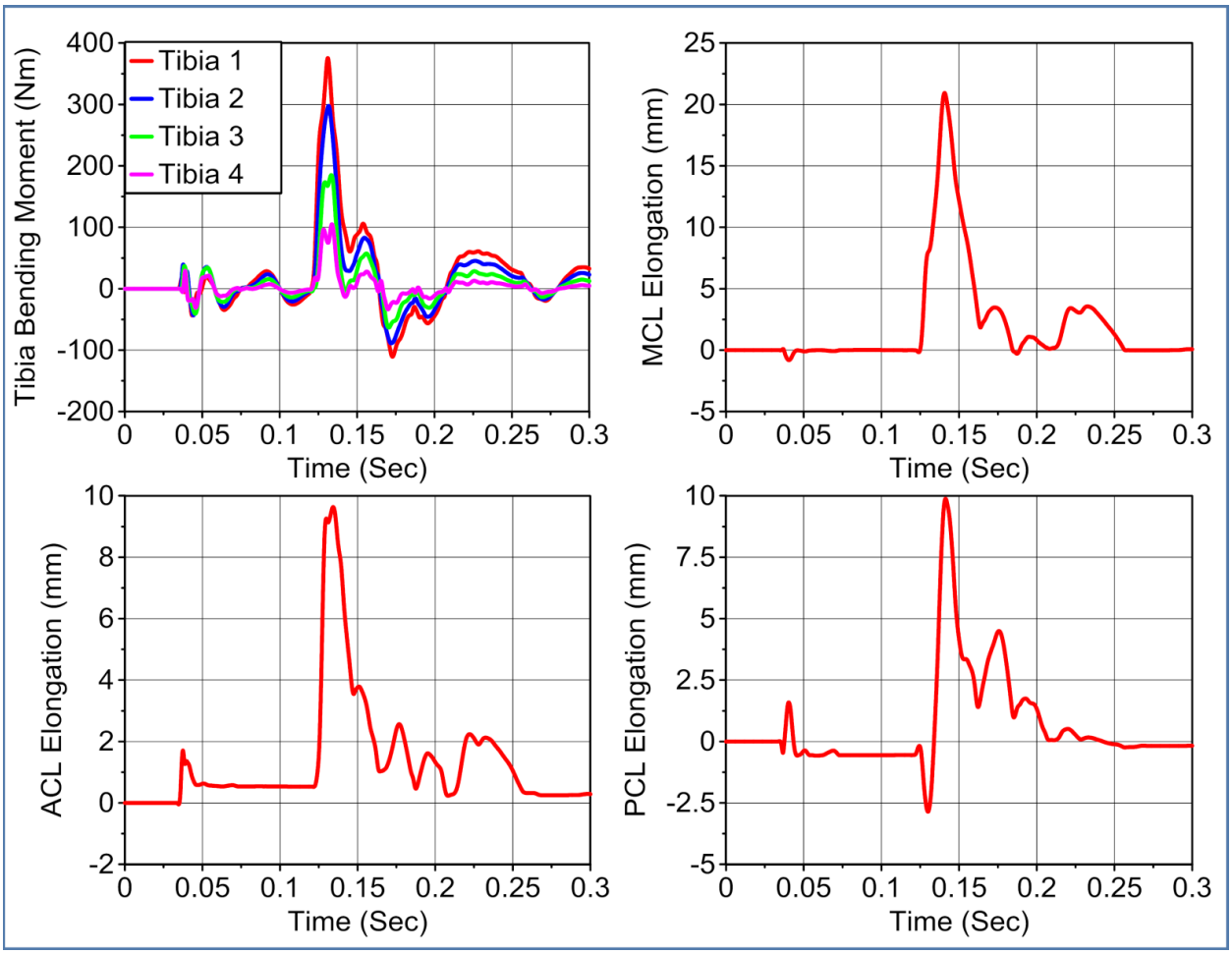


Lower Legform Impact Data Traces

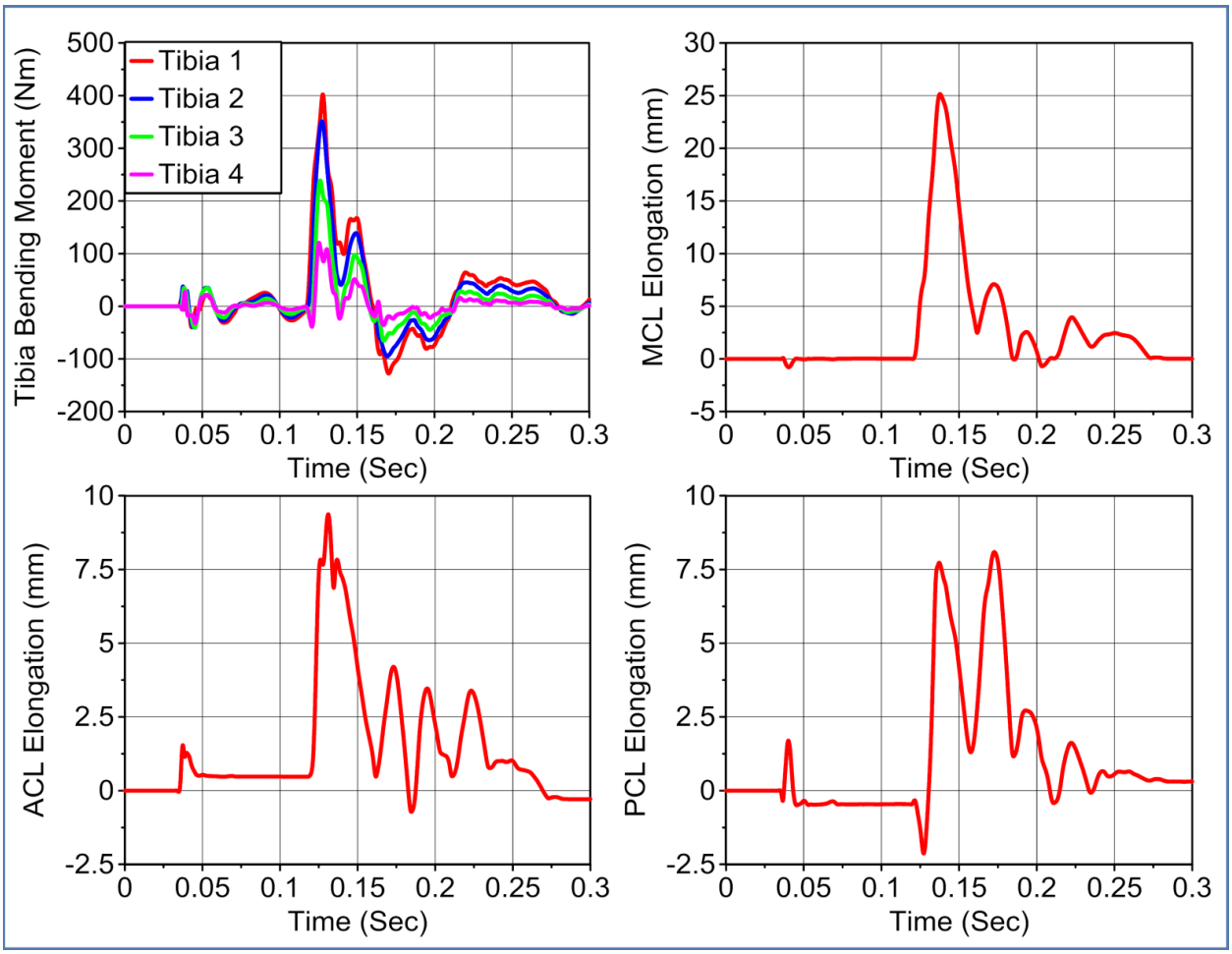
LL 1607



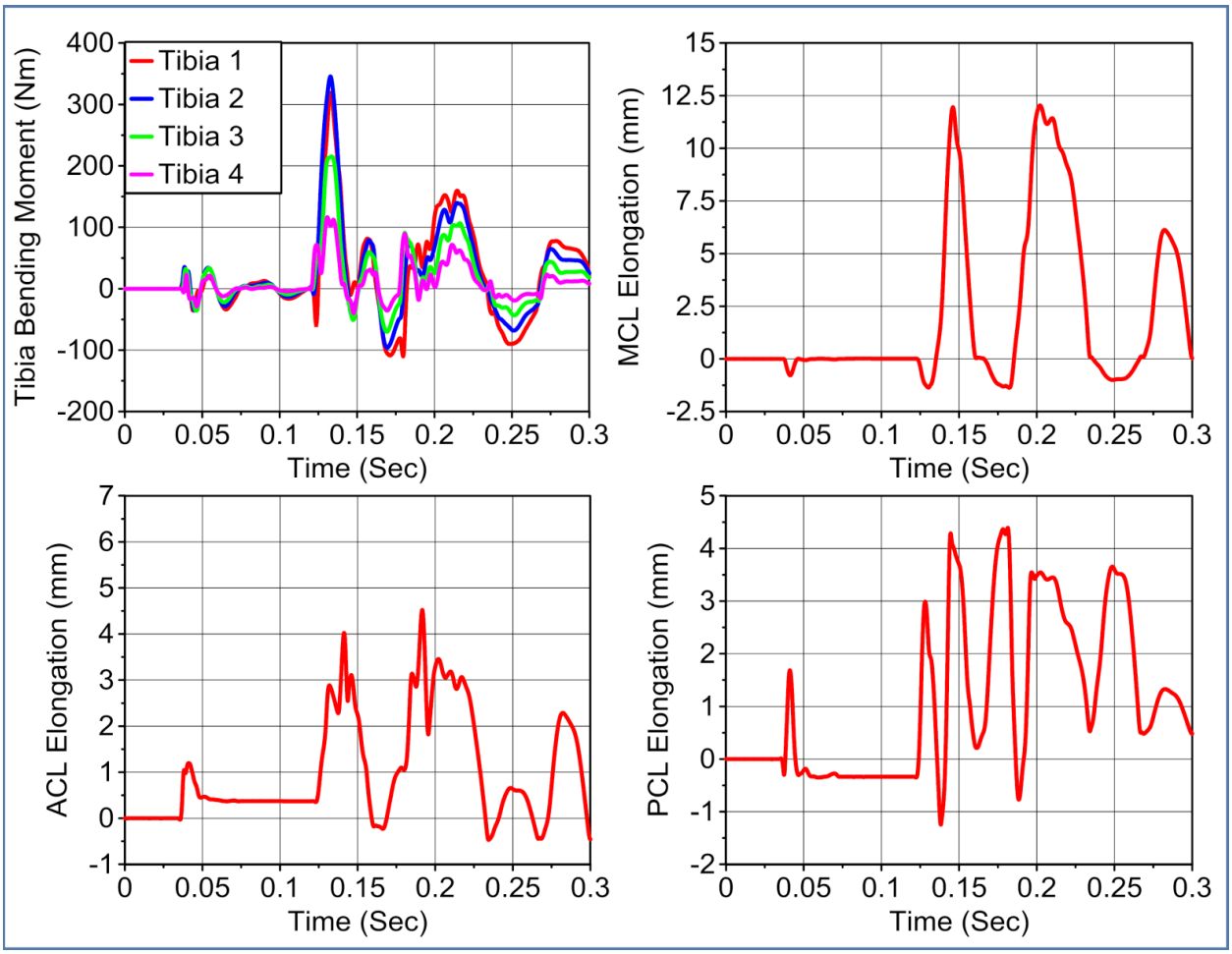
LL 1608


Tibia Bending Moment (Nm)
Tibia 1
Tibia 2
Tibia 3
Tibia 4
Time (Sec)
MCL Elongation (mm)
Time (Sec)
ACL Elongation (mm)
Time (Sec)
PCL Elongation (mm)
Time (Sec)

LL 1609

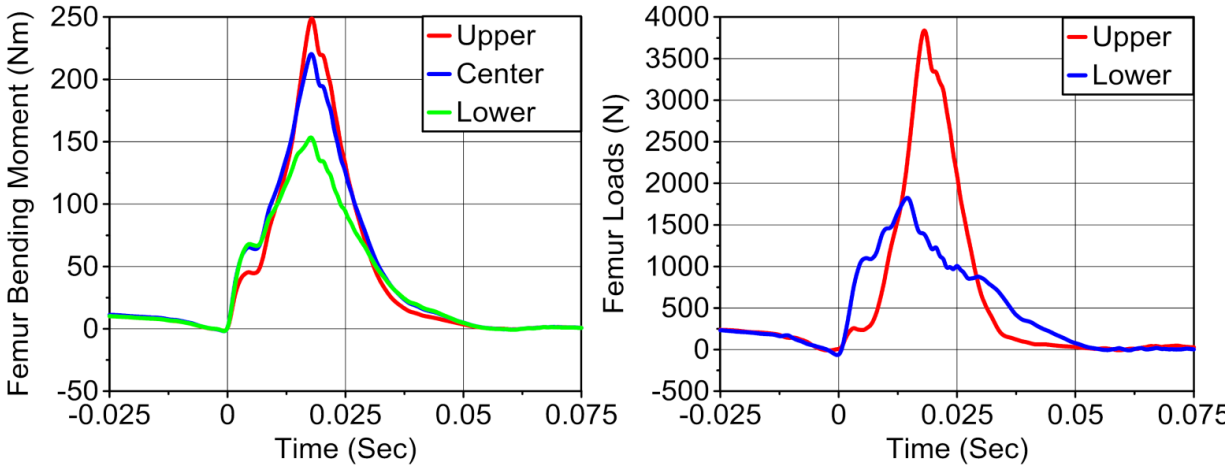

Tibia Bending Moment (Nm)
Tibia 1
Tibia 2
Tibia 3
Tibia 4
Time (Sec)
MCL Elongation (mm)
Time (Sec)
ACL Elongation (mm)
Time (Sec)
PCL Elongation (mm)
Time (Sec)

LL 1610

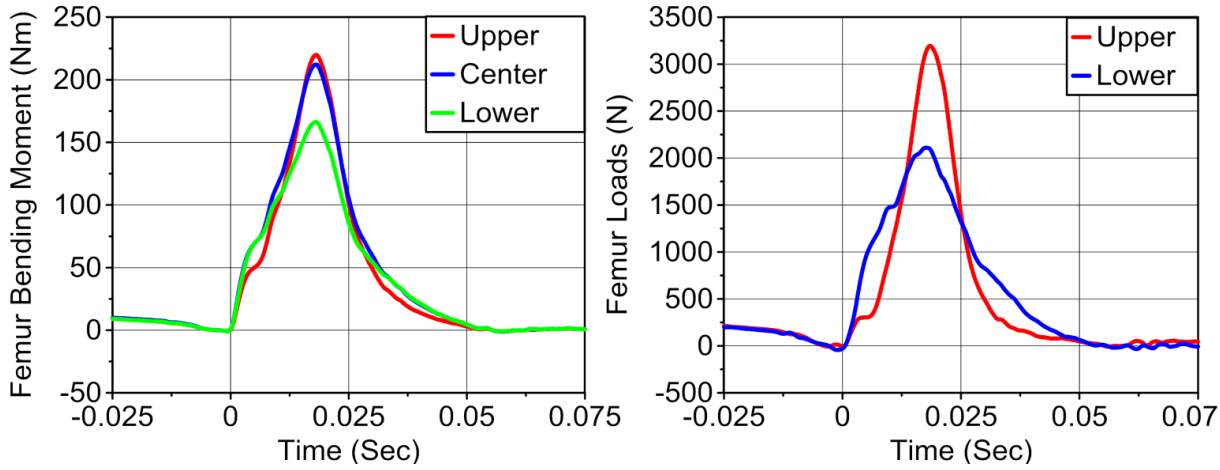

Tibia Bending Moment (Nm)
Tibia 1
Tibia 2
Tibia 3
Tibia 4
Time (Sec)
MCL Elongation (mm)
Time (Sec)
ACL Elongation (mm)
Time (Sec)
PCL Elongation (mm)
Time (Sec)

Upper Legform Impact Data Traces

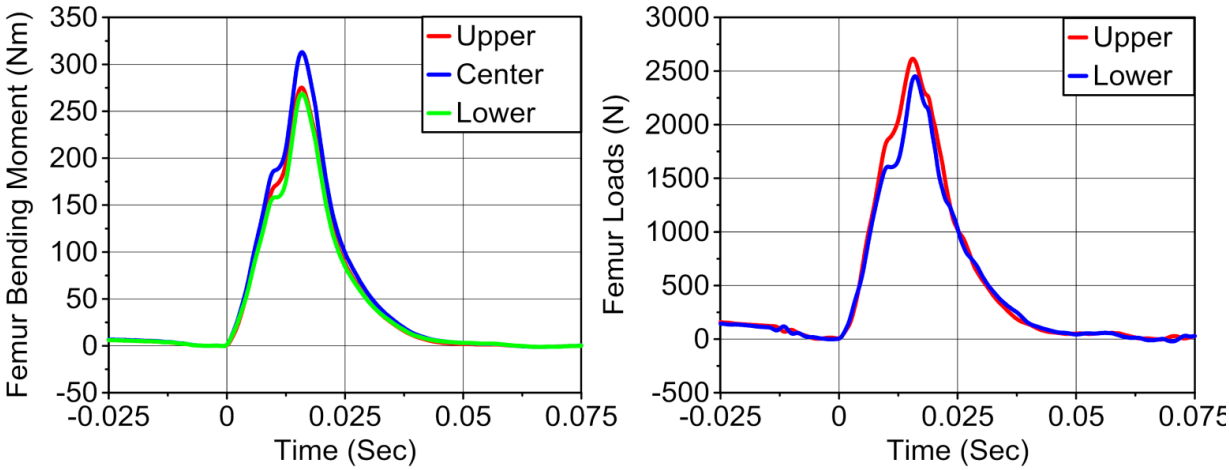
UL 1605



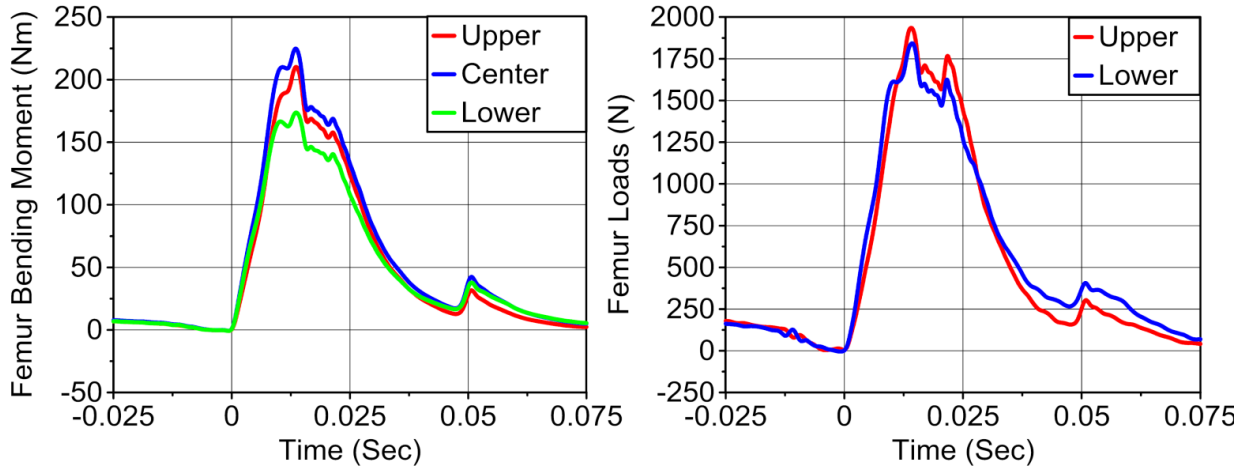
UL 1606



UL 1607



UL 1608



Examples of Post-Test Vehicle Damage

AdultHead 1612

ChildHead 1625

LL 1608

UL 1605

Appendix C: 2016 Chevrolet Tahoe

Overview

A 2016 Chevrolet Tahoe was tested.

Exemplar 2016 Chevrolet Tahoe

Vehicle Information

Pertinent vehicle information is listed in Table C-1 below. Descriptions for the lateral hood width and front-end width can be found in Appendix J.

Table C-1. Vehicle information

Make	Chevrolet
Model	Tahoe
Year	2016
VIN	1GNSCAKC2GR172637
Type	Standard SUV
GVWR	3221 kg
Lateral Hood Width	1760 mm
Front End Width	2020 mm

Headform Testing

For the 2016 Chevrolet Tahoe, 11 points were chosen and are shown in Figure C-1 below.

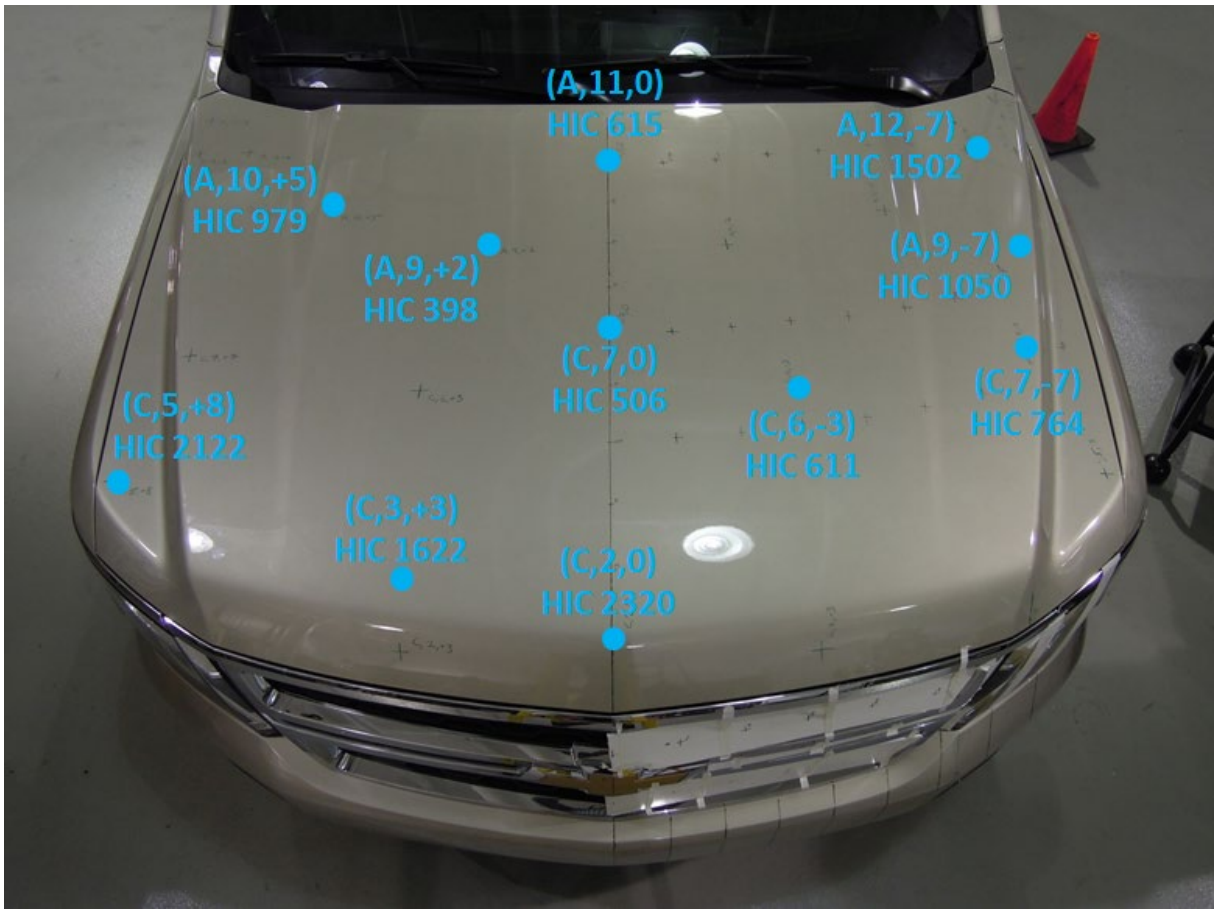


Figure C-1. 2016 Chevrolet Tahoe selected headform impact points, their corresponding grid coordinates, and HIC results.

HIC results and corresponding points for the selected impact points are shown in Table C-2 below. The 2016 Chevrolet Tahoe earned 6.5 points out of a possible 11 points, resulting in a score of 14.2. There is no Euro NCAP score for a European variant of this vehicle.

Table C-2. 2016 Chevrolet Tahoe headform impact locations, HIC results, and resulting score.

			HIC SCORES			
Test No.	**Grid point**		**NHTSA (pts)**		**Euro NCAP (for ref only)**	**G.M. Predicted (for ref only)**
1632	C	7,0	506	1	---	---
1633	C	7,-7	764	0.75	---	---
1634	C	2,0	2320	0	---	---
1635	A	10,5	979	0.75	---	---
1636	A	11,0	615	1	---	---
1637	A	9,2	398	1	---	---
1638	A	12,-7	1502	0.25	---	---
1639	C	6,-3	611	1	---	---
1640	C	3,3	1622	0.25	---	---
1641	C	5,8	2122	0	---	---
1642	A	9,-7	1050	0.5	---	---
Total Points (11 max)			6.50		*n/a*	
Score			**14.2**			

Lower Legform Testing

The bumper test zone is defined as either the area limited by the bumper corners or the outermost ends of the underlying bumper beam, whichever is larger. The distance from the bumper corner of the fascia to the centerline was measured to be 630 mm. The distance from the outermost ends of the underlying bumper beam to the centerline of the 2016 Chevrolet Tahoe was measured to be 583 mm. The bumper test zone is the larger of the two distances, and for the 2016 Chevrolet Tahoe, is 630 mm from the centerline. Grid points are located every 100 mm from the centerline in both lateral directions resulting in 13 grid points for the 2016 Chevrolet Tahoe. Non-tested grid points are awarded the worst result from one of the adjacent points. In addition, symmetry will be applied to all grid points. Given these conditions, three test points were tested and are shown in Figure C-2 below.

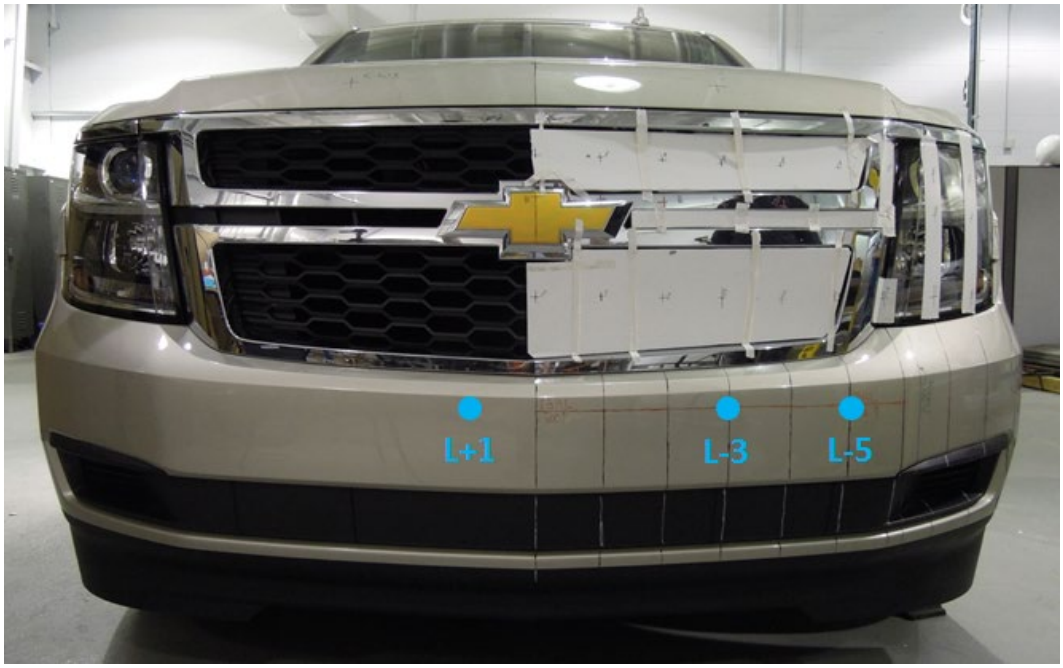


Figure C-2. 2016 Chevrolet Tahoe selected lower legform impact points

Lower legform results for the selected impact points are shown in Table C-3 and the corresponding score is shown in Table C-4. Results that fall below the lower limit are highlighted in green, above the upper limit are in red, and between the lower and upper limits are in orange. Following Euro NCAP guidelines, the 2016 Chevrolet Tahoe earned 0.0 points out of a possible 13 points, resulting in a score of 0.0.

Table C-3. 2016 Chevrolet Tahoe lower legform impact locations and corresponding results

		Tibia Bending Limits				*Ligament Elongation Limits*		
		282-340 Nm				*19-22 mm*	*10 mm*	
Test #	**Location**	**Tibia 1**	**Tibia 2**	**Tibia 3**	**Tibia 4**	**MCL**	**ACL**	**PCL**
LL 1616	L+1	383	367	272	115	29.7	10.3	13.7
LL 1617	L-5	354	360	275	119	26.1	8.3	3.8
LL 1618	L-3	374	358	255	109	29	10.2	16.1

No European Variant

Table C-4. 2016 Chevrolet Tahoe lower legform grid points and score

Location	Points on U.S. variant			*No Euro variant*
	Bending	Elongation	Total	
L+7	0	0	0	---
L+6	0	0	0	---
L+5	0	0	0	---
L+4	0	0	0	---
L+3	0	0	0	---
L+2	0	0	0	---
L+1	0	0	0	---
L0	0	0	0	---
L-1	0	0	0	---
L-2	0	0	0	---
L-3	0	0	0	---
L-4	0	0	0	---
L-5	0	0	0	---
L-6	0	0	0	---
L-7	0	0	0	---
Points Total (Out of Max Possible 15 Points)	0.0			
Score	0.0			*n/a*

Upper Legform Testing

Since the lower bumper reference line is less than 425 mm, upper legform impacts were performed at the wrap around distance (WAD) 775 mm. Starting at the vehicle's centerline, grid points are marked every 100 mm in both lateral directions along the WAD 775 mm line up to the corner reference points. Grid points less than 50 mm from the corner reference points are deleted. As with lower leg testing, non-tested grid points are awarded the worst result from one of the adjacent points. In addition, symmetry will be applied to all grid points. Given these conditions, four test points were tested and are shown in Figure C-3.

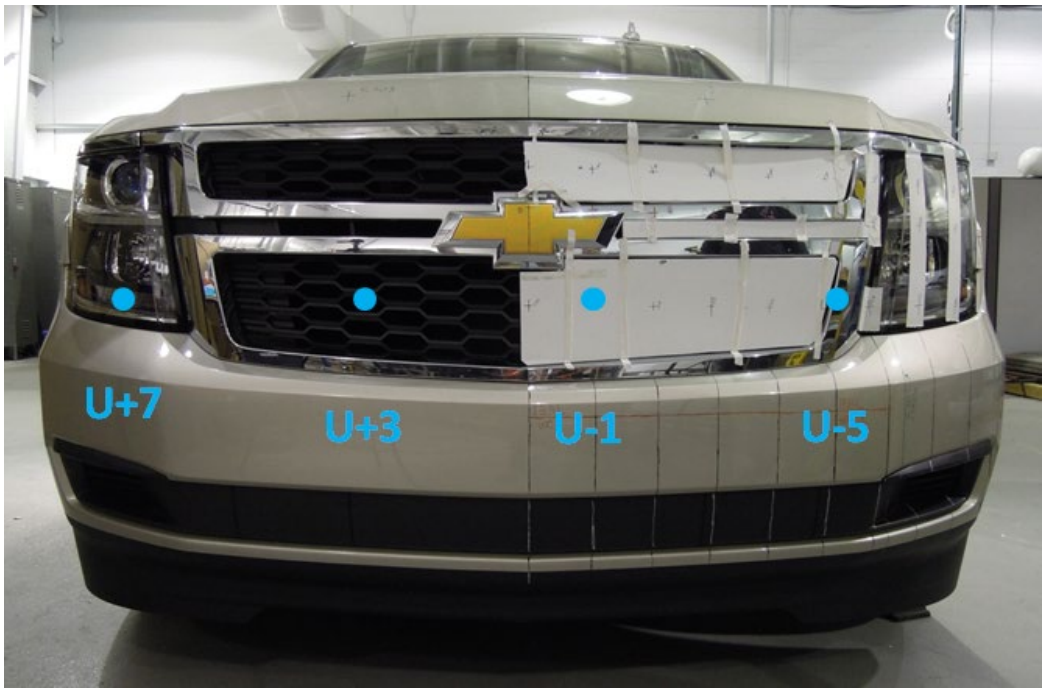


Figure C-3. 2016 Chevrolet Tahoe selected upper legform impact points

Upper legform results for the selected impact points are shown in Table C-5 below. Results that fall below the lower limit are highlighted in green, above the upper limit are in red, and between the lower and upper limits are in orange. The possible number of points awarded for each injury measure is shown in Table C-6 below. The 2016 Chevrolet Tahoe earned 2.0 points out of a possible 15 points, resulting in a score of 0.8.

Table C-5. 2016 Chevrolet Tahoe upper legform impact locations and corresponding results.

Test #	Location	Angle (°)	Energy (J)	Femur Bending Moment Limits: 285 – 350 Nm			Sum Femur Loads (N) Limits: 5-6 kN
				Upper	Middle	Lower	
UL 1651	U+3	8.5	442	88	118	145	8739
UL 1652	U-1	8.4	443	71	83	96	7341
UL 1653	U-5	9.4	439	131	173	202	10479
UL 1654	U+7	10.9	433	201	216	178	3765

No European Variant

Table C-6. Points awarded for each injury measure and resulting score for the upper legform tests. Upper leg performance for each grid point is based on the worst performing parameter.

Location	Points on U.S. Variant			*No Euro Variant*
	Bending	Force	Total	
U+7	1	1	1	---
U+6	1	0	**0**	---
U+5	1	0	**0**	---
U+4	1	0	**0**	---
U+3	1	0	**0**	---
U+2	1	0	**0**	---
U+1	1	0	**0**	---
U0	1	0	**0**	---
U-1	1	0	**0**	---
U-2	1	0	**0**	---
U-3	1	0	**0**	---
U-4	1	0	**0**	---
U-5	1	0	**0**	---
U-6	1	0	**0**	---
U-7	1	1	1	---
Points Total (Out of Max Possible 15 Points)	**2.0**			
Score	**0.8**			**n/a**

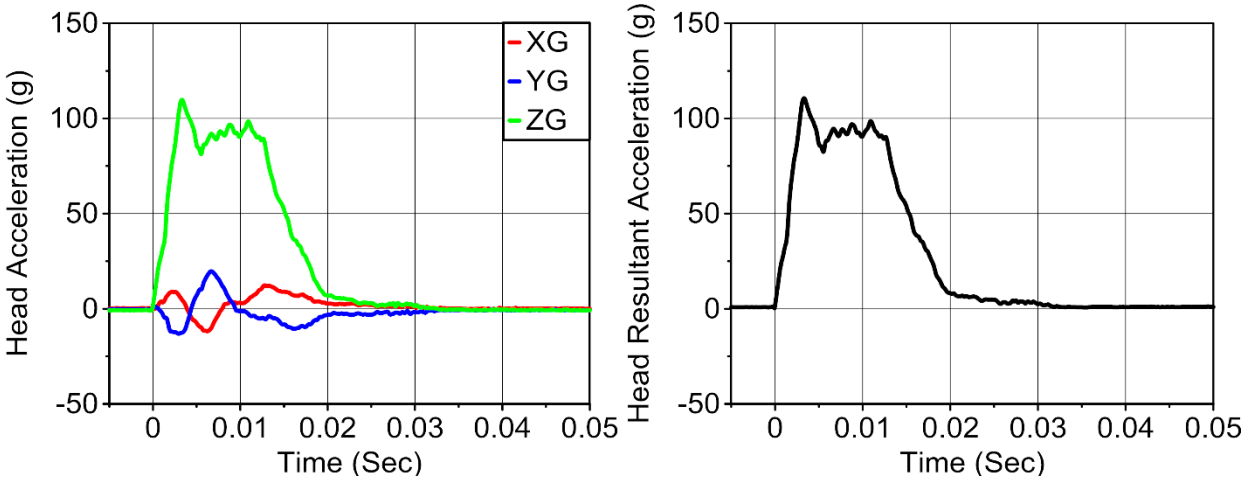
Summary

Table C-7. Summary of results for the 2016 Chevrolet Tahoe

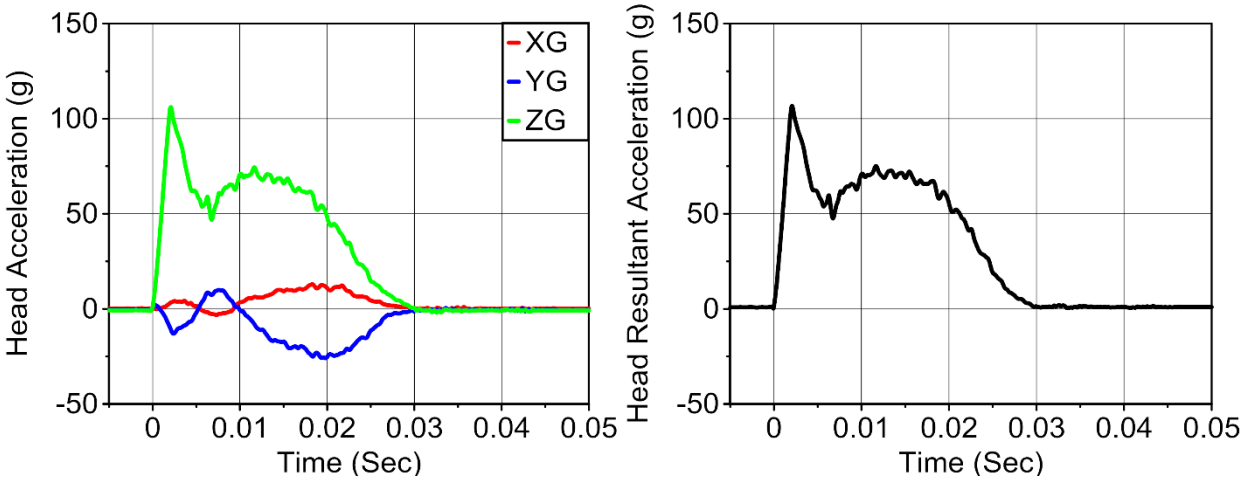
2016 Chevrolet Tahoe	Head	Lower Leg	Upper Leg	Total	% of Max
Score (Out of 36)	14.2	0.0	0.8	**15.0**	**41.7%**

Headform Impact Data Traces

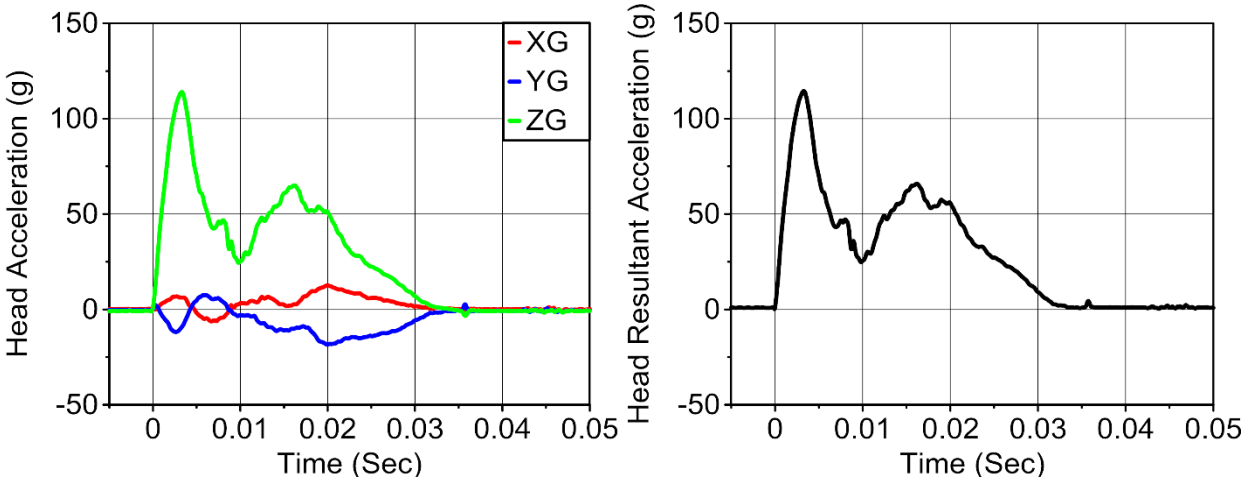
AdultHead 1635



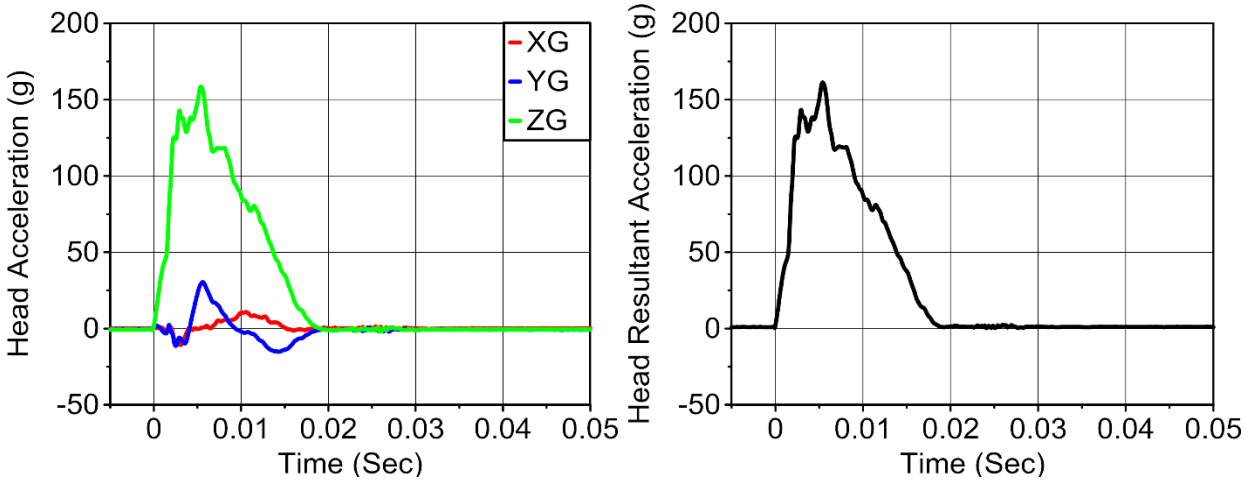
AdultHead 1636



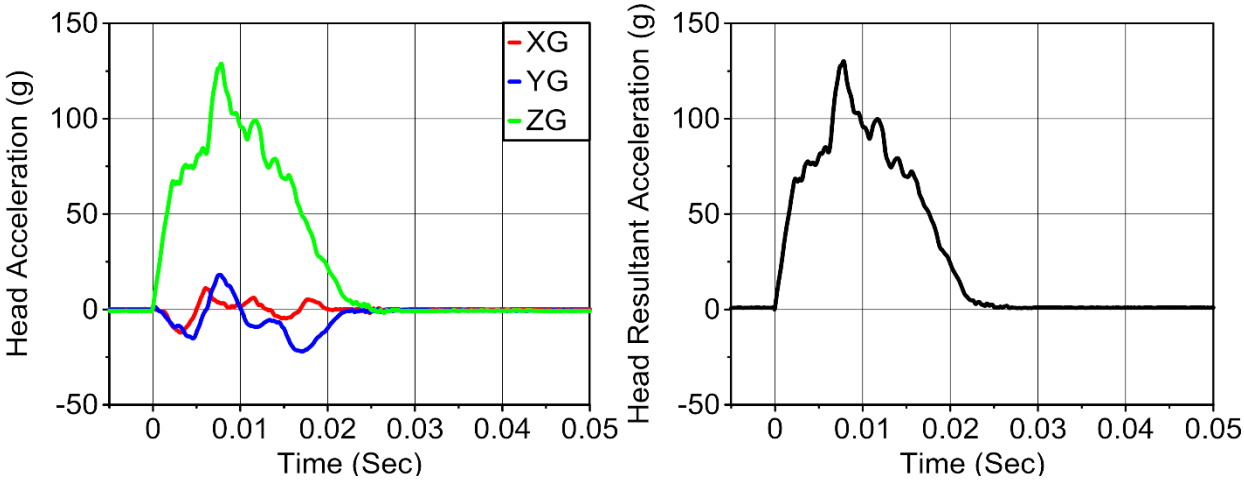
AdultHead 1637



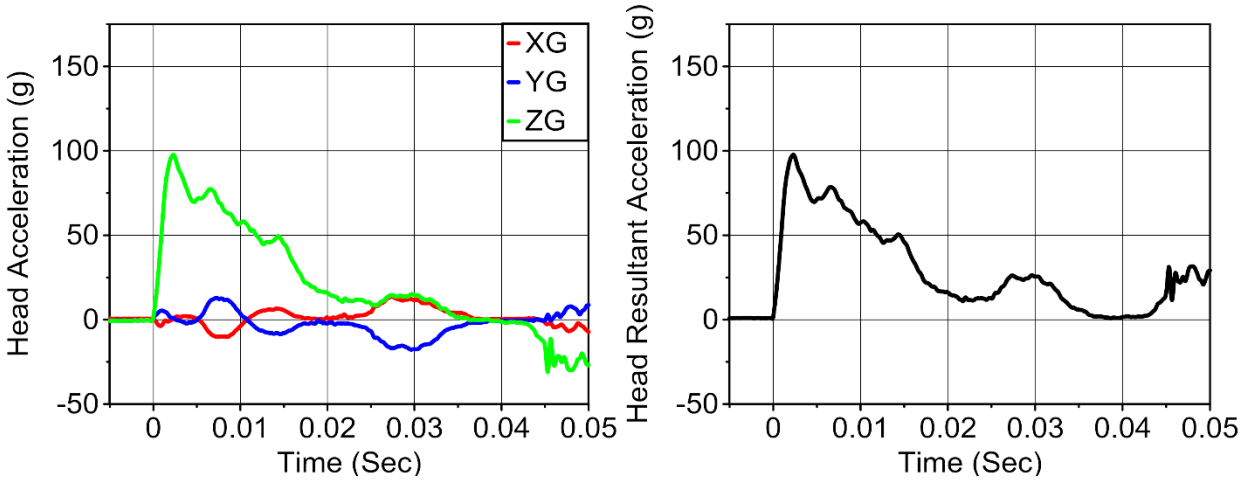
AdultHead 1638



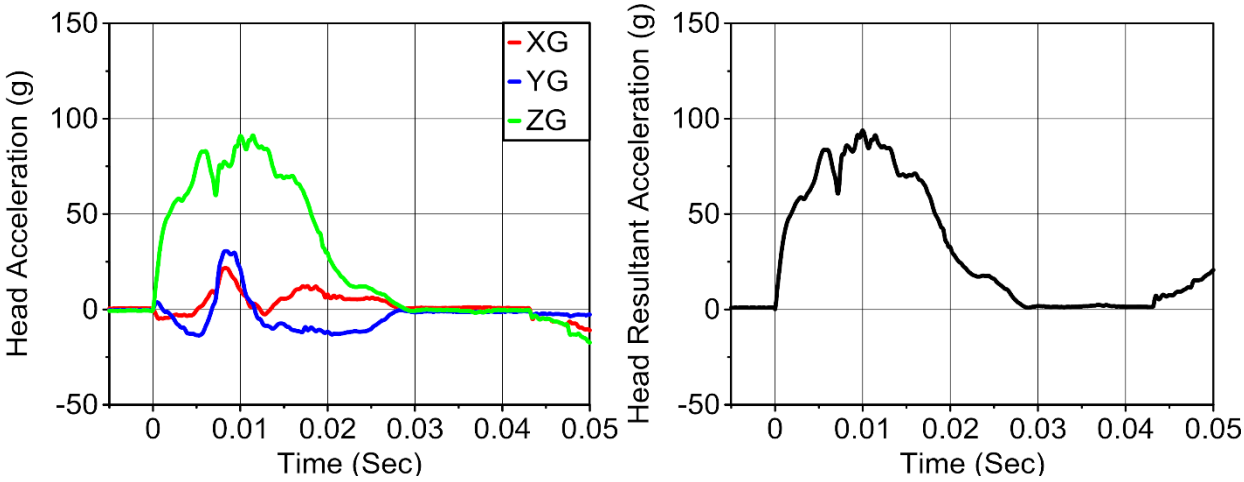
AdultHead 1642



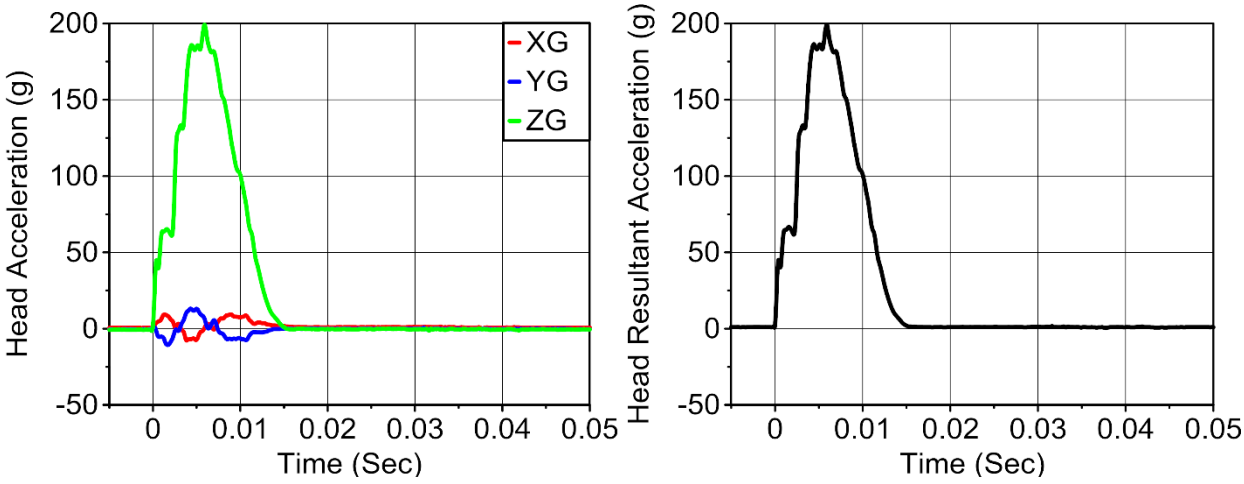
ChildHead 1632



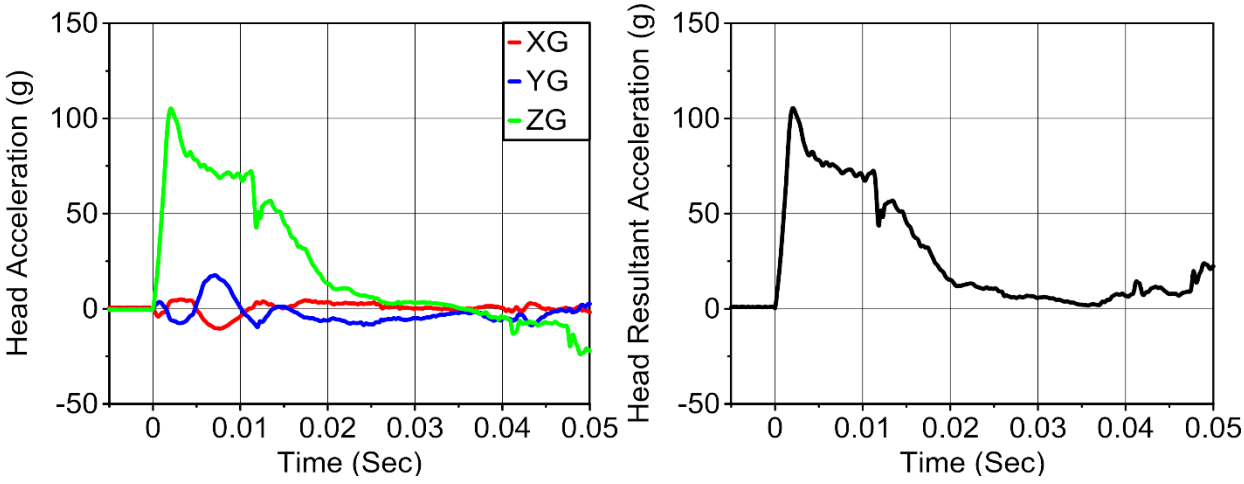
ChildHead 1633



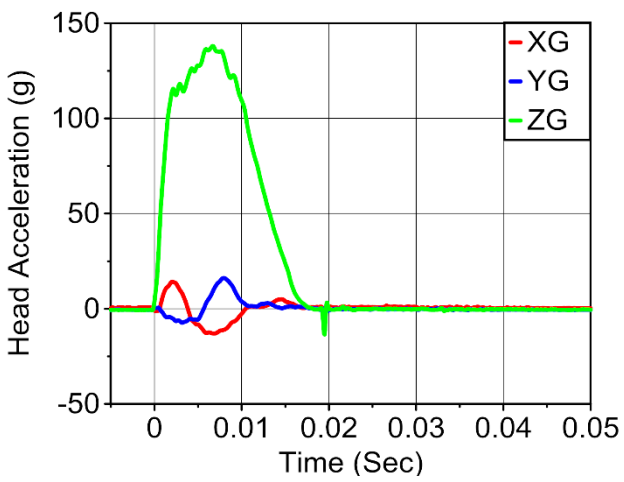
ChildHead 1634

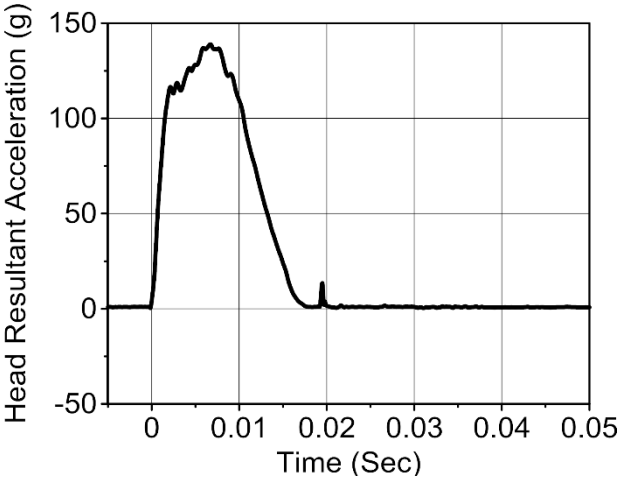


ChildHead 1639

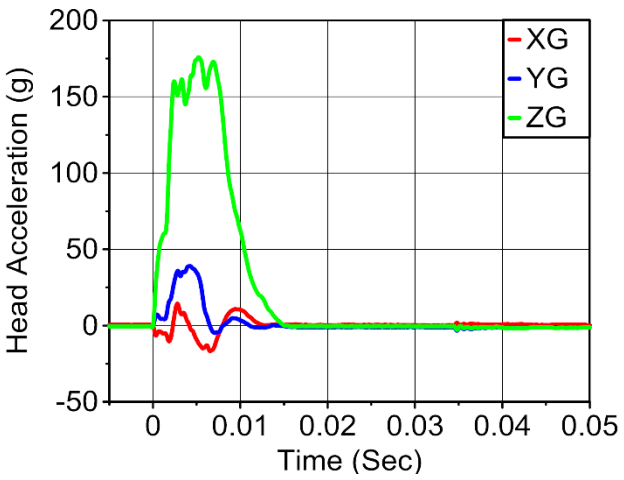


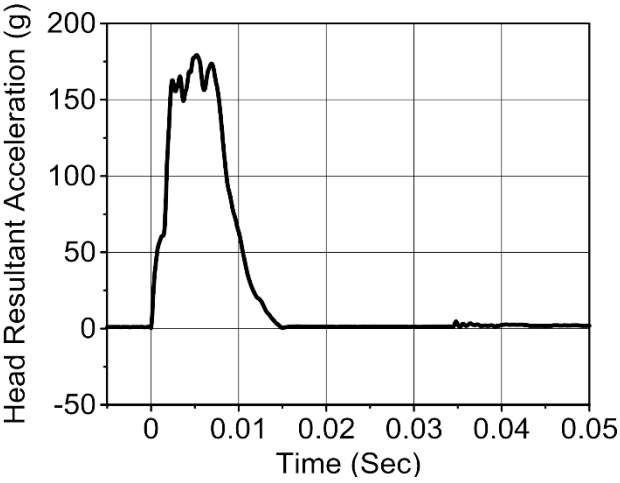
ChildHead 1640





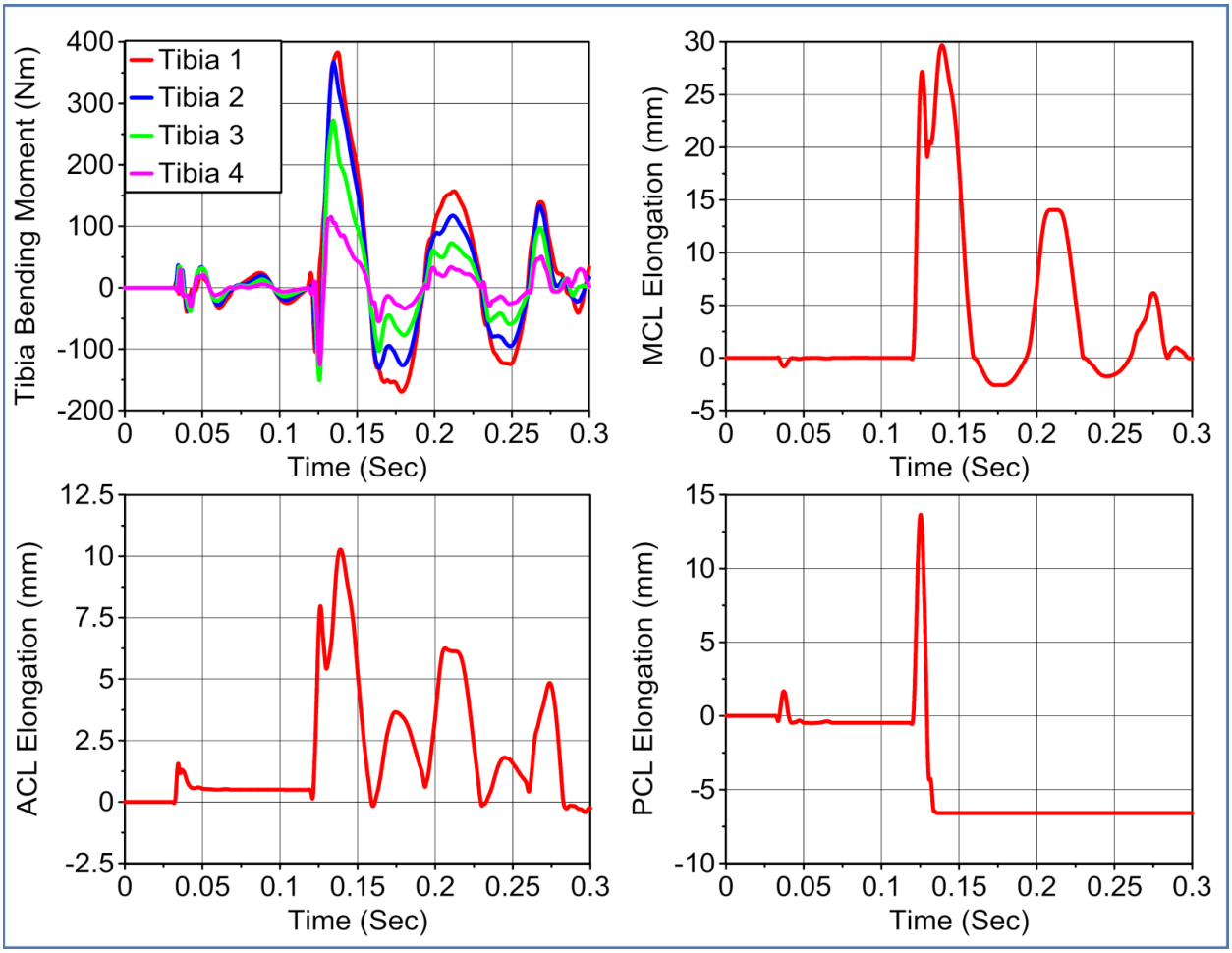
ChildHead 1641



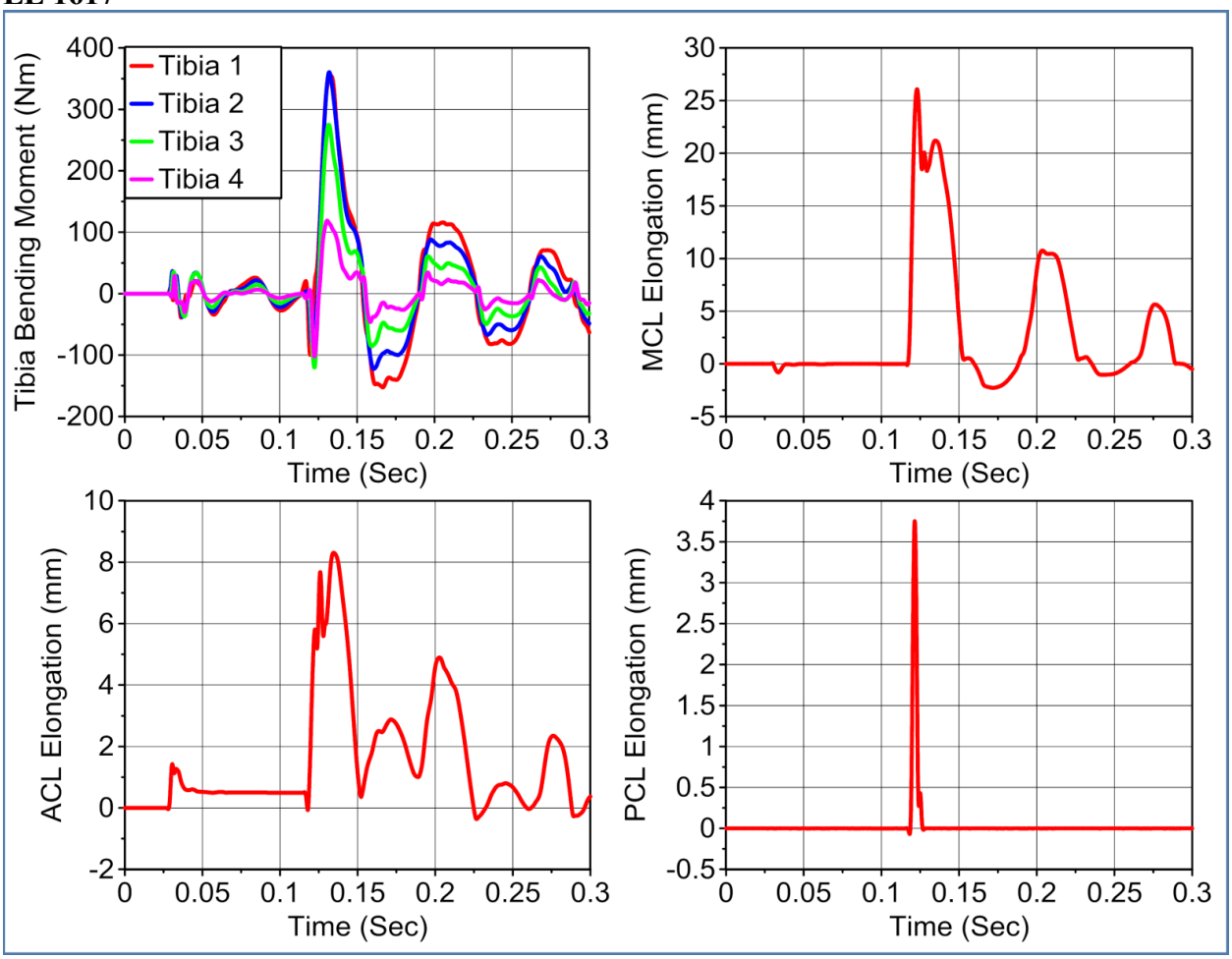


Lower Legform Impact Data Traces

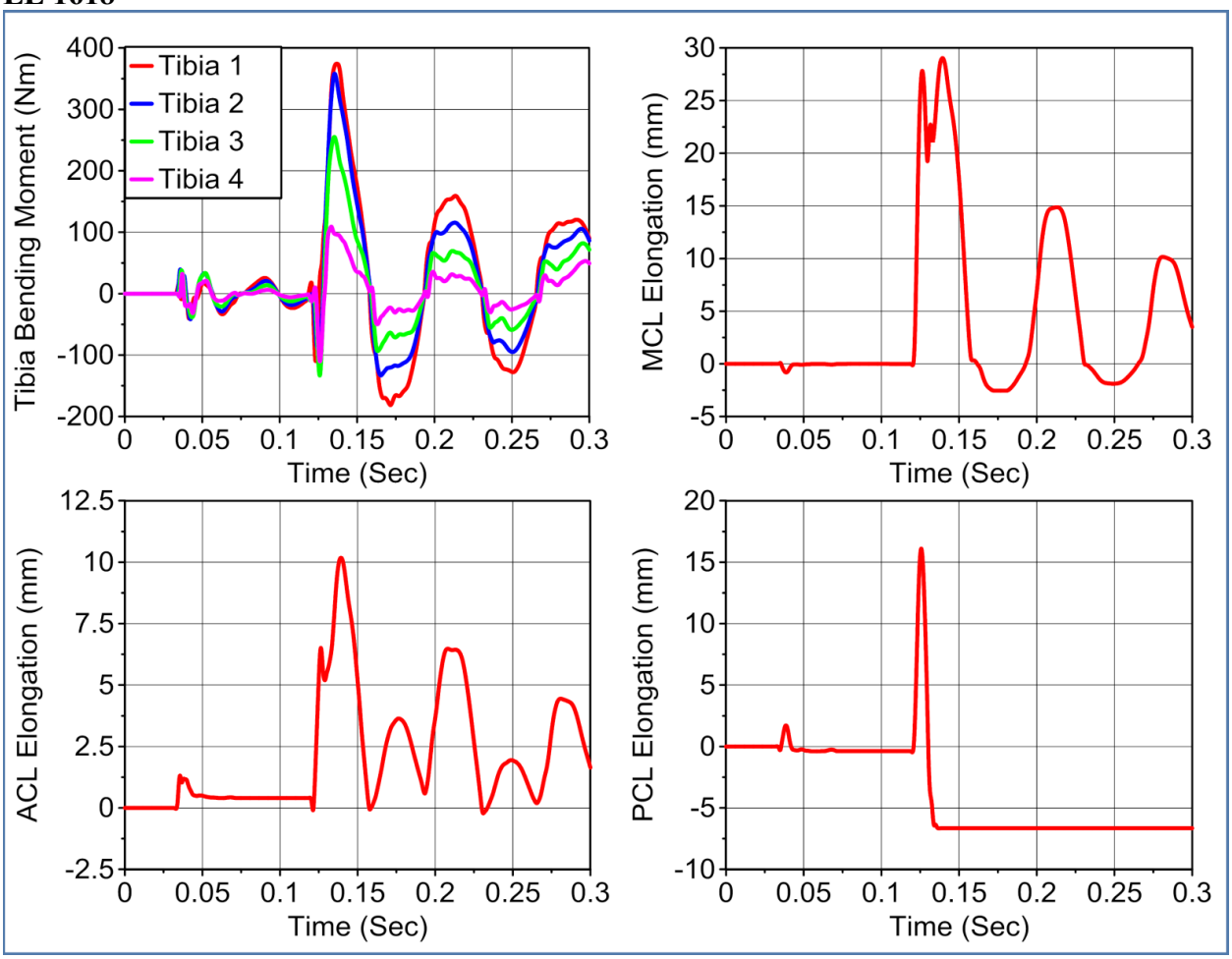
LL 1616



LL 1617

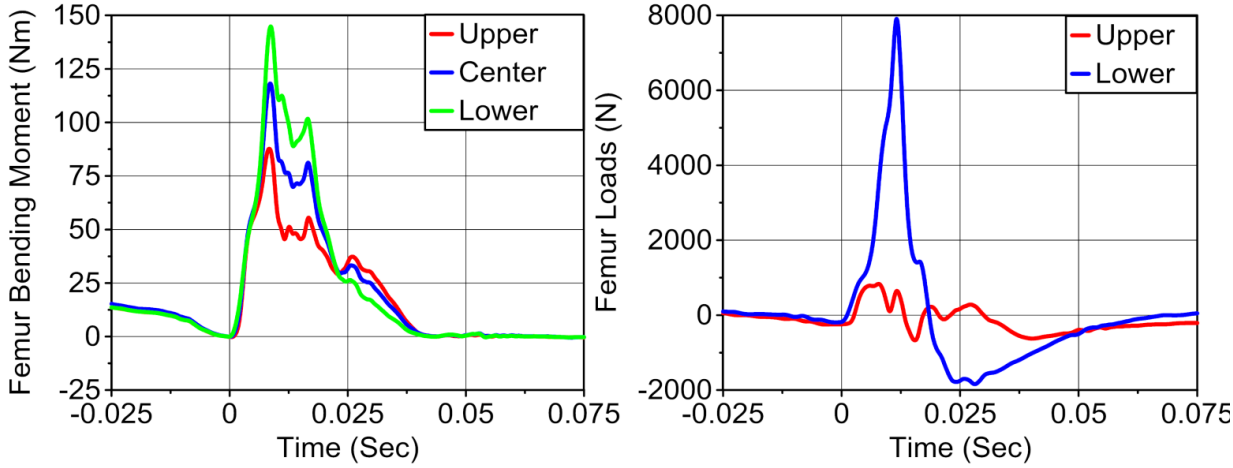

Tibia 1
Tibia 2
Tibia 3
Tibia 4
Tibia Bending Moment (Nm)
400
300
200
100
0
-100
-200
0
0.05
0.1
0.15
0.2
0.25
0.3
Time (Sec)
MCL Elongation (mm)
30
25
20
15
10
5
0
-5
Time (Sec)
ACL Elongation (mm)
10
8
6
4
2
0
-2
Time (Sec)
PCL Elongation (mm)
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
Time (Sec)

LL 1618

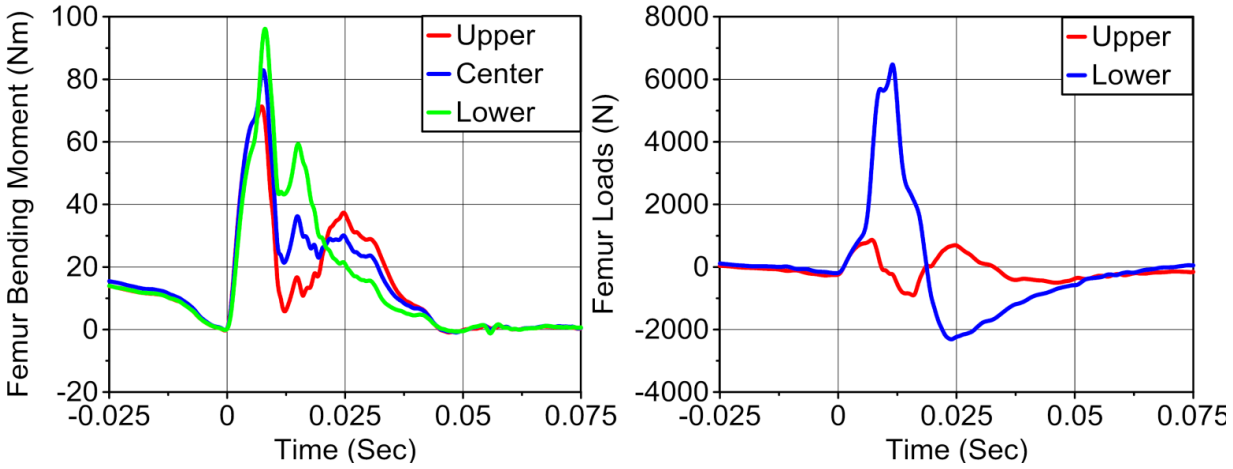

Tibia Bending Moment (Nm)
Tibia 1
Tibia 2
Tibia 3
Tibia 4
Time (Sec)
MCL Elongation (mm)
Time (Sec)
ACL Elongation (mm)
Time (Sec)
PCL Elongation (mm)
Time (Sec)

Upper Legform Impact Data Traces

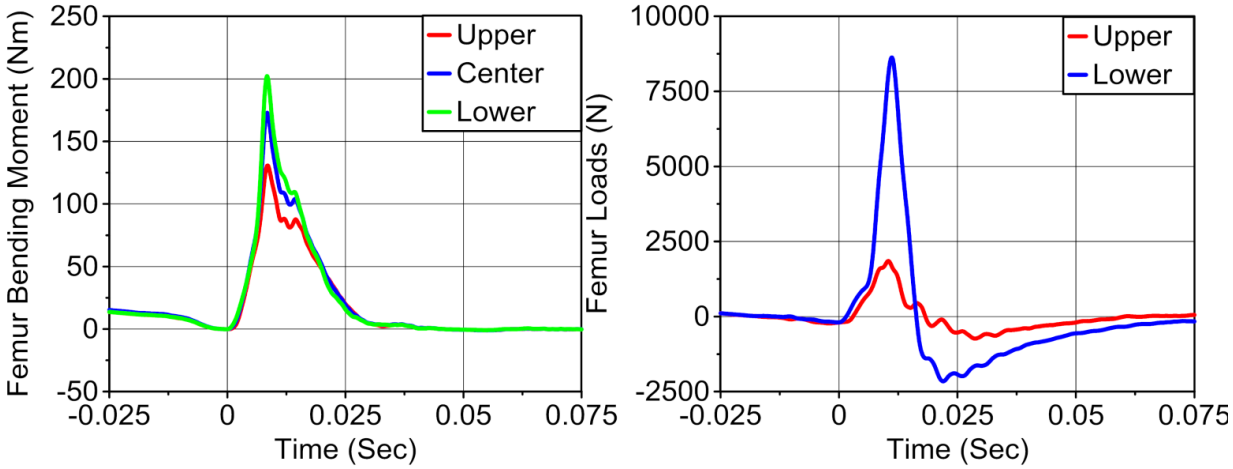
UL 1651



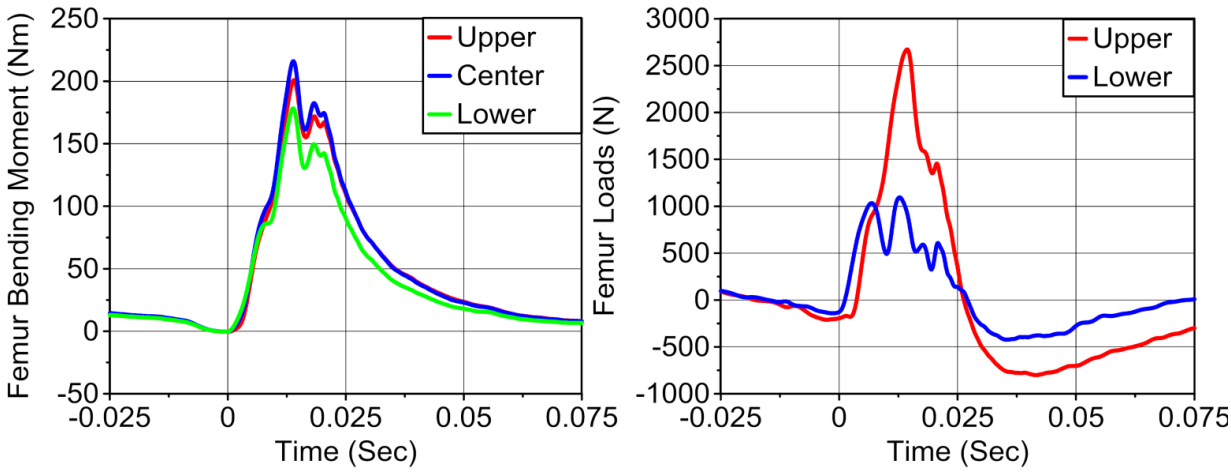
UL 1652



UL 1653



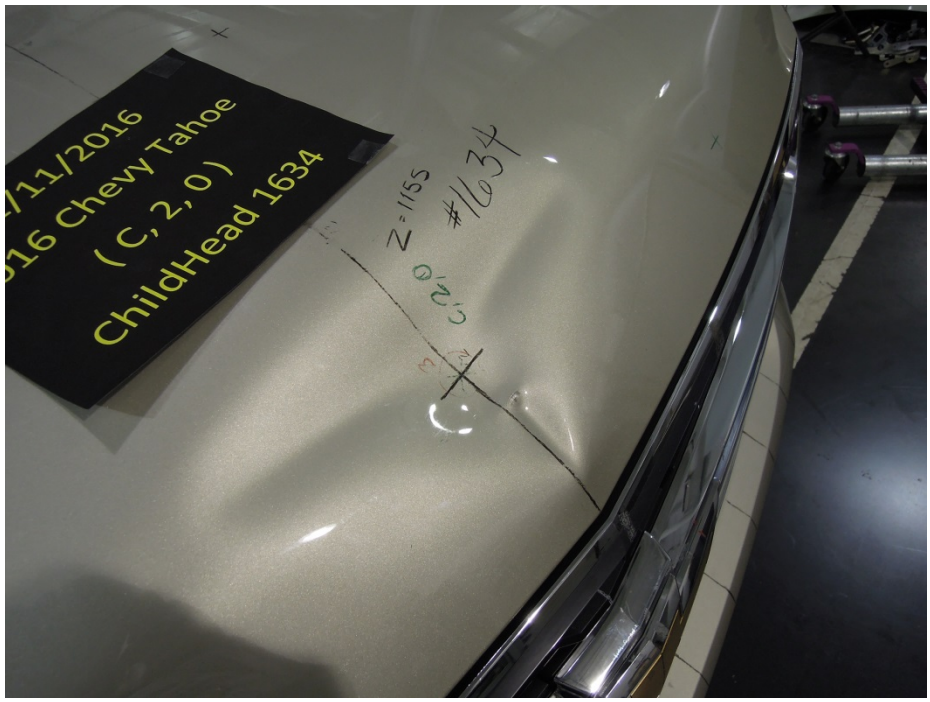
UL 1654



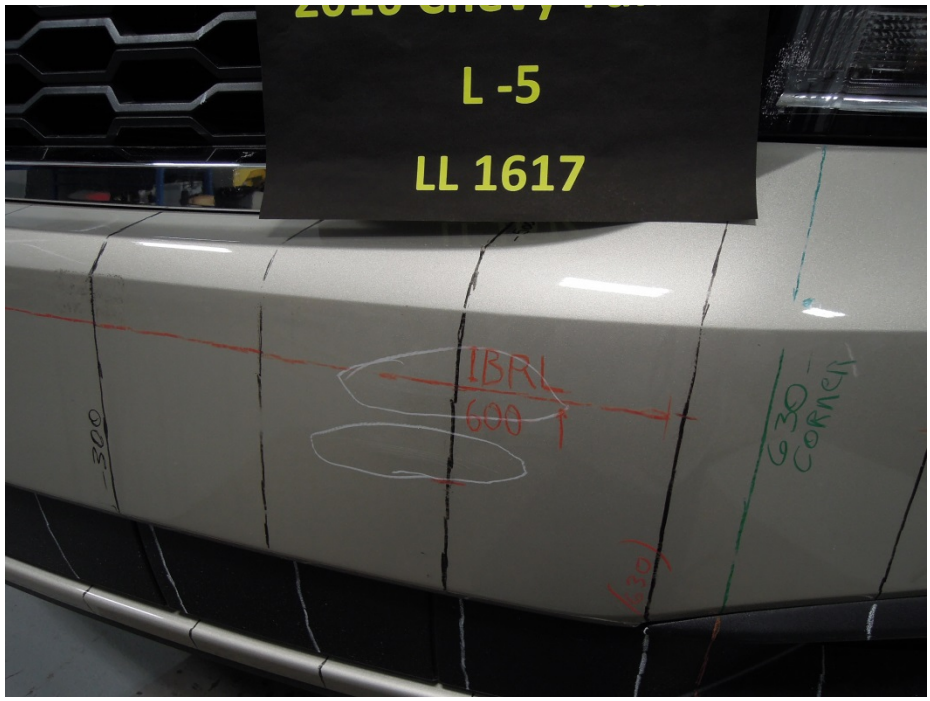
Examples of Post-Test Vehicle Damage

AdultHead 1638

ChildHead 1634



LL 1617




+300

Appendix D: 2016 Ford Edge

Overview

A 2016 Ford Edge was tested.

Exemplar 2016 Ford Edge

Vehicle Information

Pertinent vehicle information is listed in Table D-1 below. Descriptions for the lateral hood width and front-end width can be found in Appendix J.

Table D-1. Vehicle information

Make	Ford
Model	Edge
Year	2016
VIN	2FMPK3G95GBB70020
Type	MPV
GVWR	2413 kg
Lateral Hood Width	1568 mm
Front End Width	1920 mm

Headform Testing

For the 2016 Ford Edge, 10 points were chosen and are shown in Figure D-1 below.

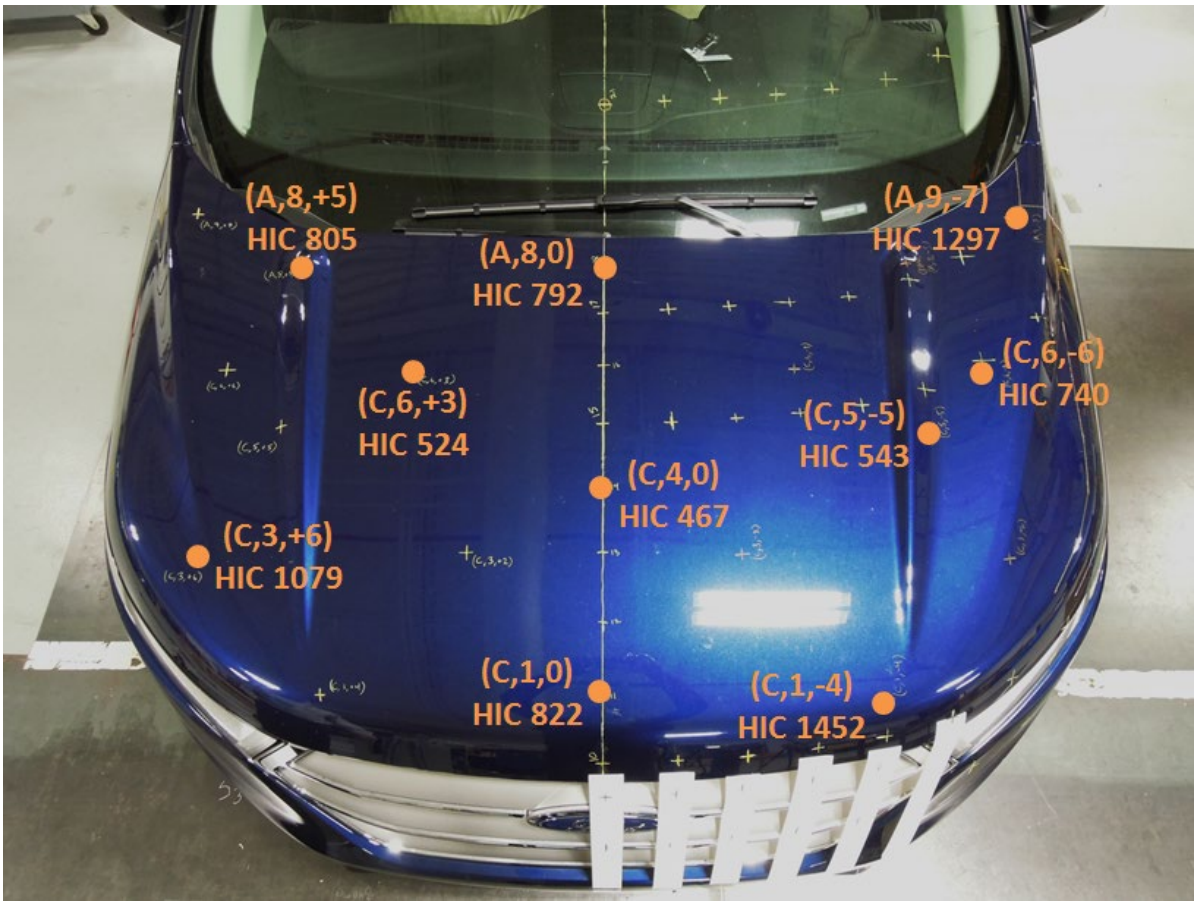


Figure D-1. 2016 Ford Edge selected headform impact points, their corresponding grid coordinates, and HIC results. Additional points that match Euro NCAP grid points are shown in Figure 4.

HIC results and corresponding points for the selected impact points are shown in Table D-2 below. The 2016 Ford Edge earned 12.5 points out of a possible 17 points, resulting in a score of 17.6. For reference, Euro NCAP scores for a European variant of this vehicle are also shown.

Table D-2. 2016 Ford Edge headform impact HIC scores in tests run by NHTSA and Euro NCAP

			HIC SCORES			
Test No.	**Grid point**		**NHTSA (pts)**		**Euro NCAP (for ref only)**	**Ford Predicted (for ref only)**
1652	A	9,-7	**1297**	**0.50**	**---**	***1350 - 1700***
1653	A	8,5	**805**	**0.75**	**---**	***650-1000***
1654	C	1,0	**822**	**0.75**	**---**	***650-1000***
1655	C	6,-6	**740**	**0.75**	**---**	***650-1000***
1656	C	6,3	**524**	**1**	**---**	***< 650***
1657	C	1,-4	**1452**	**0.25**	**---**	***1350 - 1700***
1658	C	4,0	**467**	**1**	**---**	***< 650***
1659	C	3,6	**1079**	**0.50**	**---**	***1000 - 1350***
1660	C	5,-5	**543**	**1**	**---**	***650-1000***
1661	A	8,0	**792**	**0.75**	**---**	***< 650***
1717	C	2,3	**915**	**0.75**	***767***	***650-1000***
1718	C	4,-5	**569**	**1**	***642***	***650 1000***
1711	C	6,-3	**496**	**1**	***594***	***< 650***
1721	A	10,-5	**1827**	**0**	***1904***	***> 1700***
1719	C	5,-2	**496**	**1**	***573***	***< 650***
1710	C	4,7	**1127**	**0.50**	***1332***	***1000 - 1350***
1720	A	12,-6	**449**	**1**	***503***	***< 650***
---	C	5,5	---	----	***601***	***650 - 1000***
---	A	9,-3	---	---	***1301***	***1350 - 1700***
---	A	10,-3	---	---	***790***	***650 - 1000***
Total Points (17 max)			12.5			
Score			17.6		*16.04*	

Lower Legform Testing

The bumper test zone is defined as either the area limited by the bumper corners or the outermost ends of the underlying bumper beam, whichever is larger. The distance from the bumper corner of the fascia to the centerline was measured to be 470 mm. The distance from the outermost ends of the underlying bumper beam to the centerline of the 2016 Ford Edge was measured to be 773 mm. The bumper test zone is the larger of the two distances, and for the 2016 Ford Edge, is 773 mm from the centerline. Grid points are located every 100 mm from the centerline in both lateral directions resulting in 15 grid points for the 2016 Ford Edge. Non-tested grid points are awarded the worst result from one of the adjacent points. In addition, symmetry will be applied to all grid points. Given these conditions, four test points were tested and are shown in Figure D-2 below.

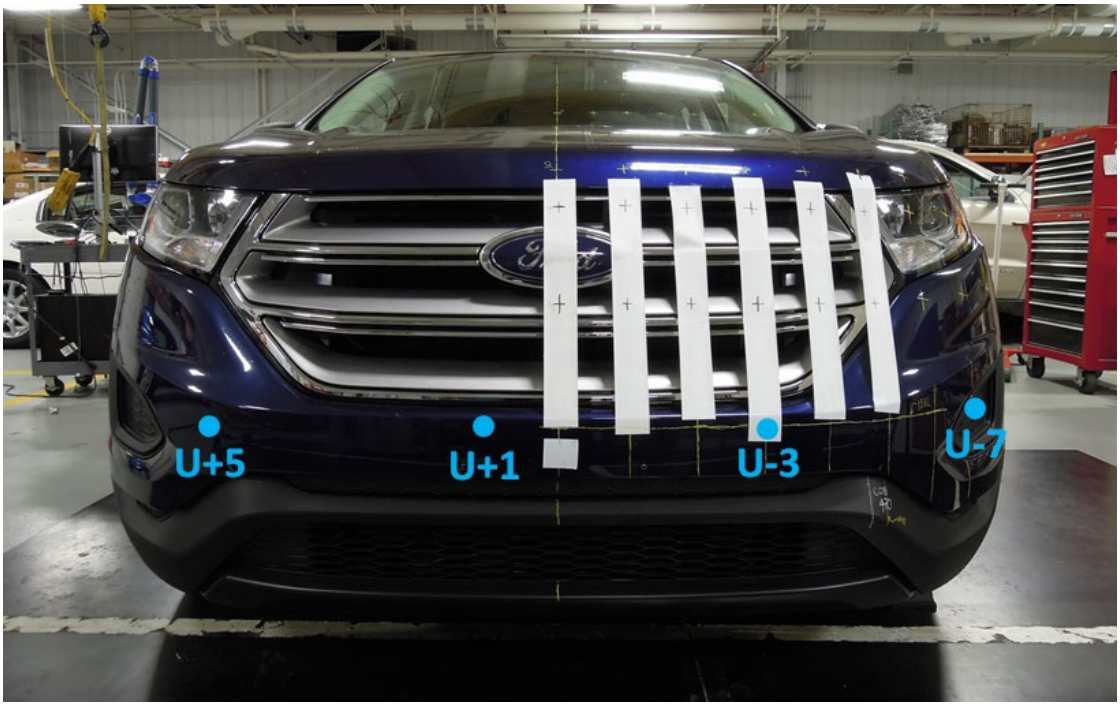


Figure D-2. 2016 Ford Edge selected lower legform impact points

Lower legform results for the selected impact points are shown in Table D-3 and the corresponding score is shown in Table D-4. Results that fall below the lower limit are highlighted in green, above the upper limit are in red, and between the lower and upper limits are in orange. Following the Euro NCAP guidelines, the 2016 Ford Edge earned 1.0 points out of a possible 15 points, resulting in a score of 0.4.

Table D-3. 2016 Ford Edge lower legform impact locations and corresponding results.

		Tibia Bending Limits				*Ligament Elongation Limits*		
		282-340 Nm				*19-22 mm*	*10 mm*	
Test #	**Location**	**Tibia 1**	**Tibia 2**	**Tibia 3**	**Tibia 4**	**MCL**	**ACL**	**PCL**
LL 1619	L+1	382	334	233	99	29.1	11.9	6.7
LL 1624	L-3	365	312	231	115	28.3	12.2	6.9
LL 1625	L+5	348	312	234	125	24.3	10.8	6.2
LL 1626	L-7	258	239	195	112	19.9	10.6	6.0
European Variant (ref only)	*L +6*	*173*	*174*	*145*	*86*	*13.5*	*8.7*	*4.9*
	L +4	*254*	*223*	*160*	*81*	*17.5*	*9.3*	*3.1*
	L 0	*239*	*214*	*155*	*85*	*17.7*	*8.6*	*3.8*
	L -2	*270*	*240*	*195*	*115*	*17.6*	*7.4*	*3.4*
	L -5	*221*	*228*	*173*	*95*	*13.6*	*8.4*	*2.5*

Table D-4. 2016 Ford Edge lower legform grid points and score.

Location	**Points on U.S. variant**			***Points on Euro. variant (for ref. only)***
	Bending	**Elongation**	**Total**	
L+7	0.5	0	**0.5**	
L+6	0	0	**0**	*1*
L+5	0	0	**0**	*1*
L+4	0	0	**0**	*1*
L+3	0	0	**0**	*1*
L+2	0	0	**0**	*1*
L+1	0	0	**0**	*1*
L0	0	0	**0**	*1*
L-1	0	0	**0**	*1*
L-2	0	0	**0**	*1*
L-3	0	0	**0**	*1*
L-4	0	0	**0**	*1*
L-5	0	0	**0**	*1*
L-6	0	0	**0**	*1*
L-7	0.5	0	**0.5**	
Points Total (Out of Max Possible 15 Points)	**1.0**			***13.0***
Score	**0.4**			***6.0***

Upper Legform Testing

Since the lower bumper reference line is less than 425 mm, upper legform impacts were performed at the wrap around distance (WAD) 775 mm. Starting at the vehicle's centerline, grid points are marked every 100 mm in both lateral directions along the WAD 775 mm line up to the corner reference points. Grid points less than 50 mm from the corner reference points are deleted. As with lower leg testing, non-tested grid points are awarded the worst result from one of the adjacent points. In addition, symmetry will be applied to all grid points. Given these conditions, four test points were tested and are shown in Figure D-3 below.

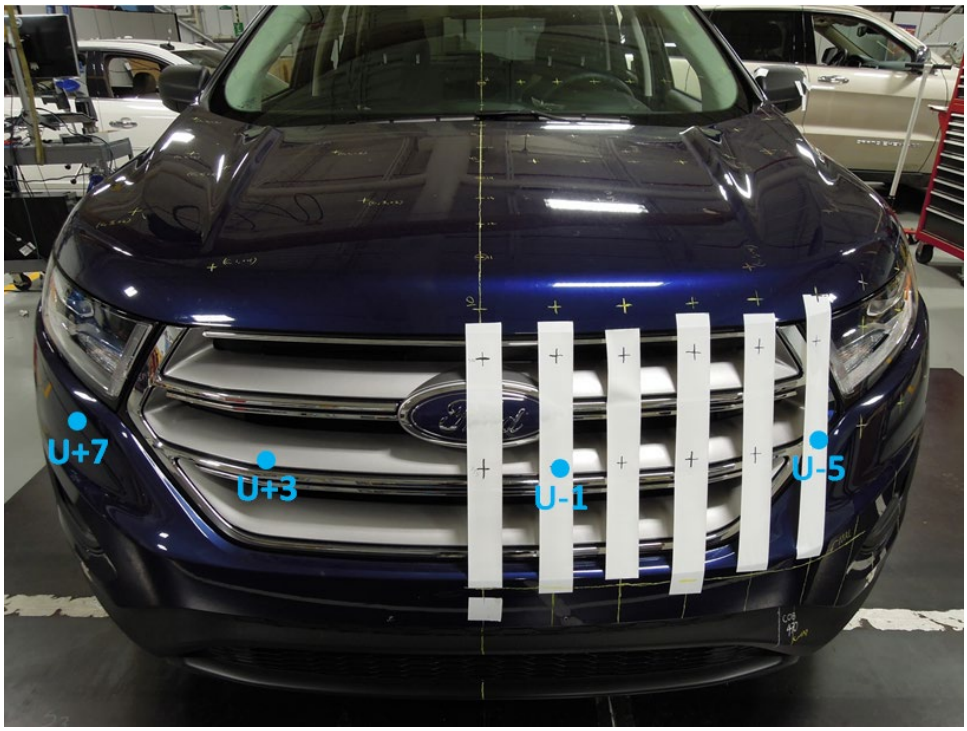


Figure D-3. 2016 Ford Edge selected upper legform impact points

Upper legform results for the selected impact points are shown in Table D-5 below. Results that fall below the lower limit are highlighted in green, above the upper limit are in red, and between the lower and upper limits are in orange. The possible number of points awarded for each injury measure is shown in Table D-6 below. The 2016 Ford Edge earned 2.0 points out of a possible 15 points, resulting in a score of 0.8.

Table D-5. 2016 Ford Edge upper legform impact locations and corresponding results

Test #	Location	Angle (°)	Energy (J)	Femur Bending Moment Limits: 285 – 350 Nm			Sum Femur Loads (N) Limits: 5-6 kN
				Upper	Middle	Lower	
UL 1666	U+3	16.3	405	212	229	187	6309
UL 1668	U-1	15.5	410	235	269	231	6869
UL 1669	U+7	15.2	412	127	137	124	4920
UL 1670	U-5	17.7	397	128	125	100	6545
European Variant (ref only)	*U +4*	---	*397*	*243*	*245*	*200*	*5370*
	U +2	---	*408*	*215*	*235*	*196*	*5270*
	U 0	---	*415*	*322*	*320*	*245*	*7230*
	U -3	---	*399*	*248*	*279*	*241*	*5130*
	U -6	---	*402*	*153*	*156*	*127*	*3410*

Table D-6. Points awarded for each injury measure and resulting score for the upper legform tests. Upper leg performance for each grid point is based on the worst performing parameter.

Location	Points on U.S. variant			*Points on Euro. variant (ref only)*
	Bending	Force	Total	
U+7	1	1	1	
U+6	1	0	**0**	1.00
U+5	1	0	**0**	0.63
U+4	1	0	**0**	0.63
U+3	1	0	**0**	0.87
U+2	1	0	**0**	0.73
U+1	1	0	**0**	**0.00**
U0	1	0	**0**	**0.00**
U-1	1	0	**0**	**0.00**
U-2	1	0	**0**	0.73
U-3	1	0	**0**	0.87
U-4	1	0	**0**	0.63
U-5	1	0	**0**	0.63
U-6	1	0	**0**	1.00
U-7	1	1	1	
Points Total (Out of Max Possible 15 Points)	**2.0**			***7.71***
Score	**0.8**			***3.56***

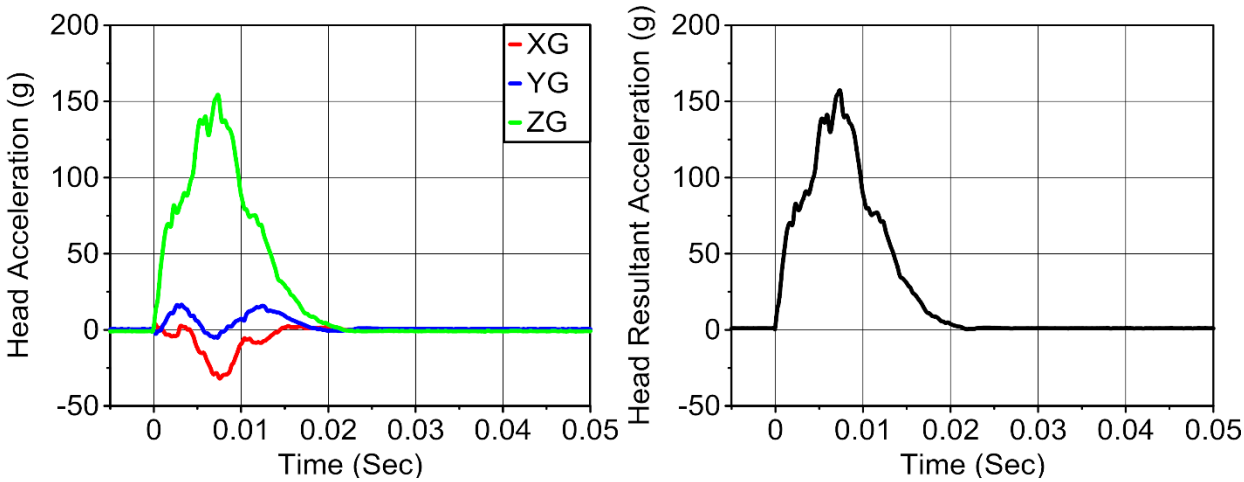
Summary

Table D-7. Summary of results for the 2016 Ford Edge

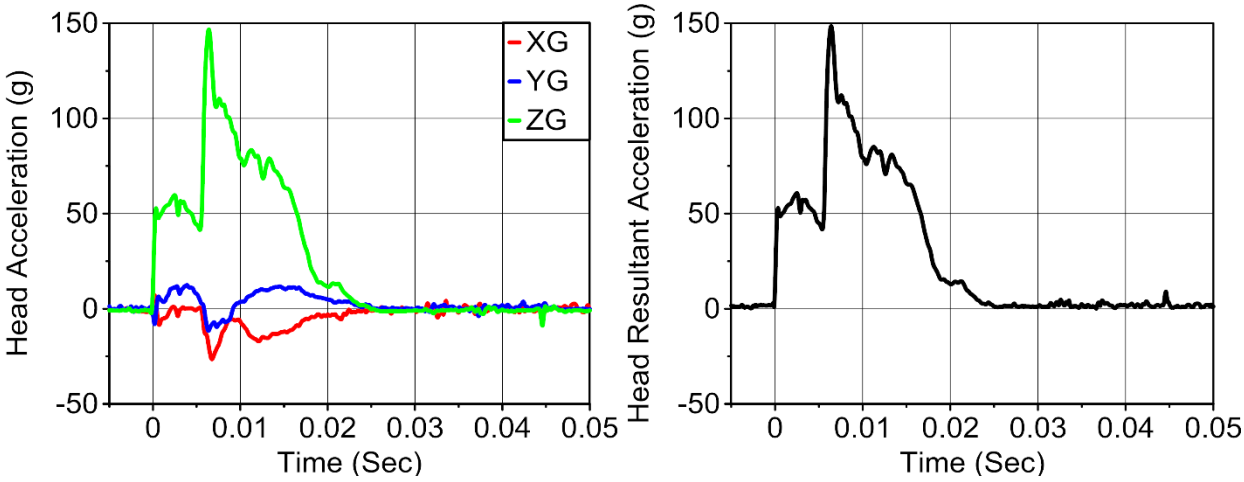
2016 Ford Edge	Head	Lower Leg	Upper Leg	Total	% of Max
Score (Out of 36)	17.4	0.4	0.8	**18.6**	**51.7%**

Headform Impact Data Traces

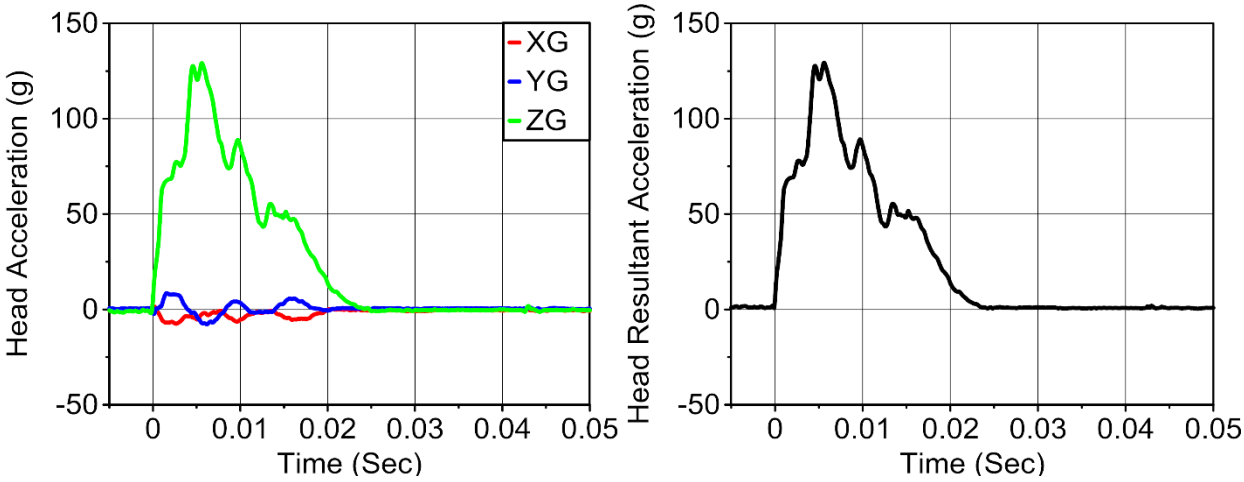
AdultHead 1652



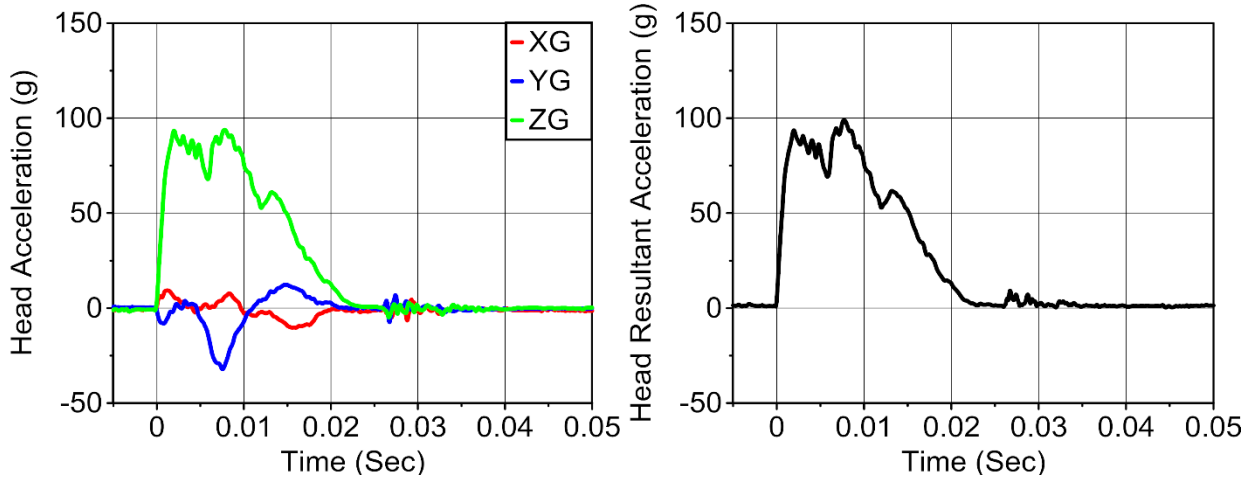
ChildHead 1653



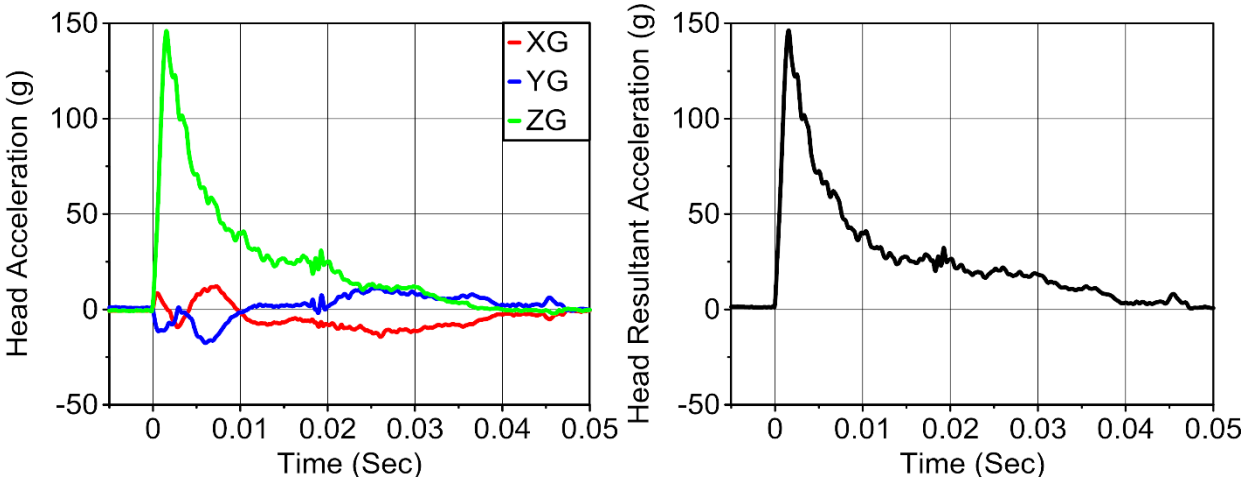
ChildHead 1654



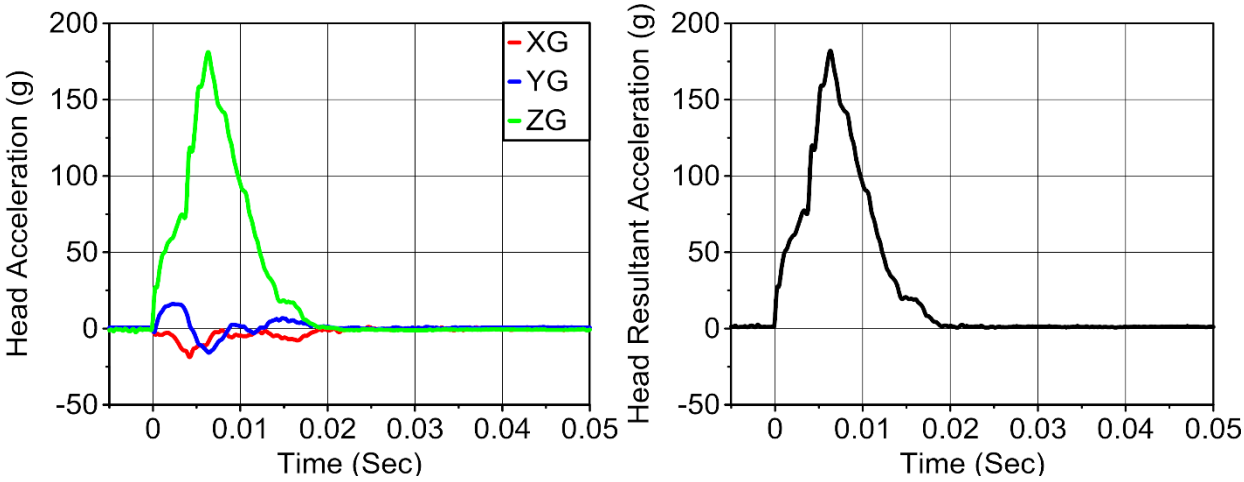
ChildHead 1655



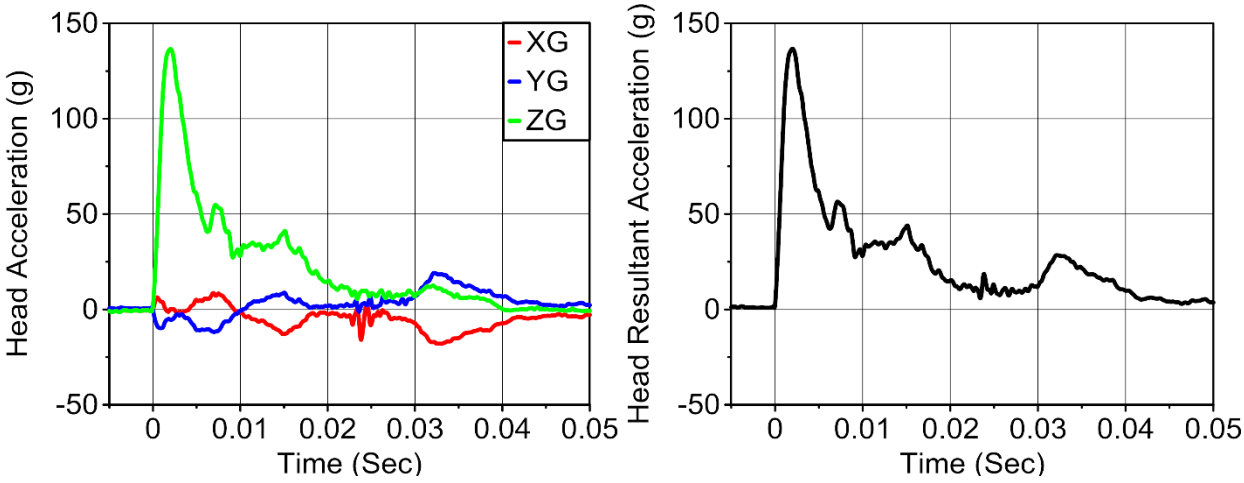
ChildHead 1656



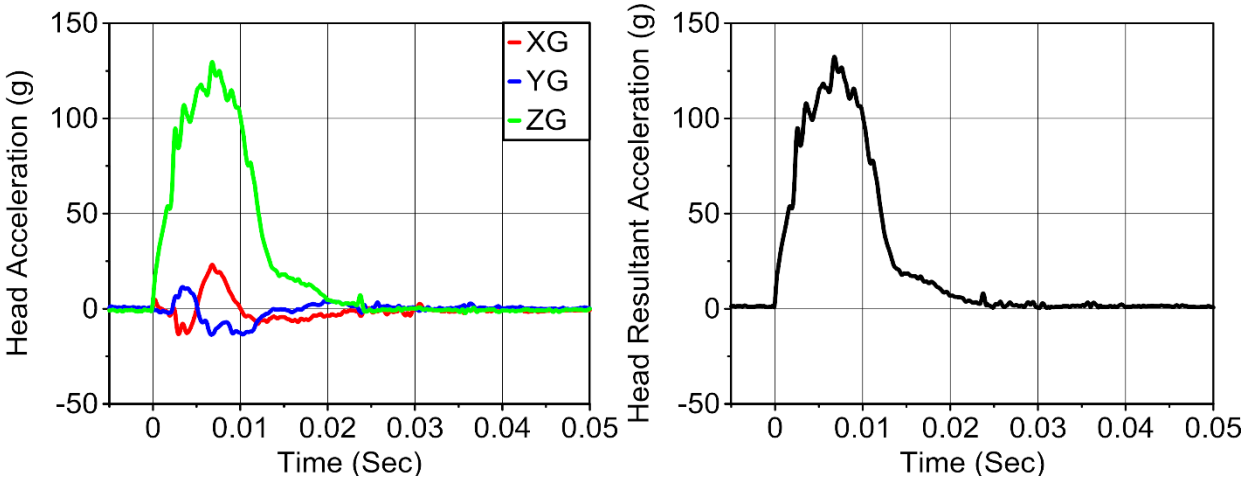
ChildHead 1657



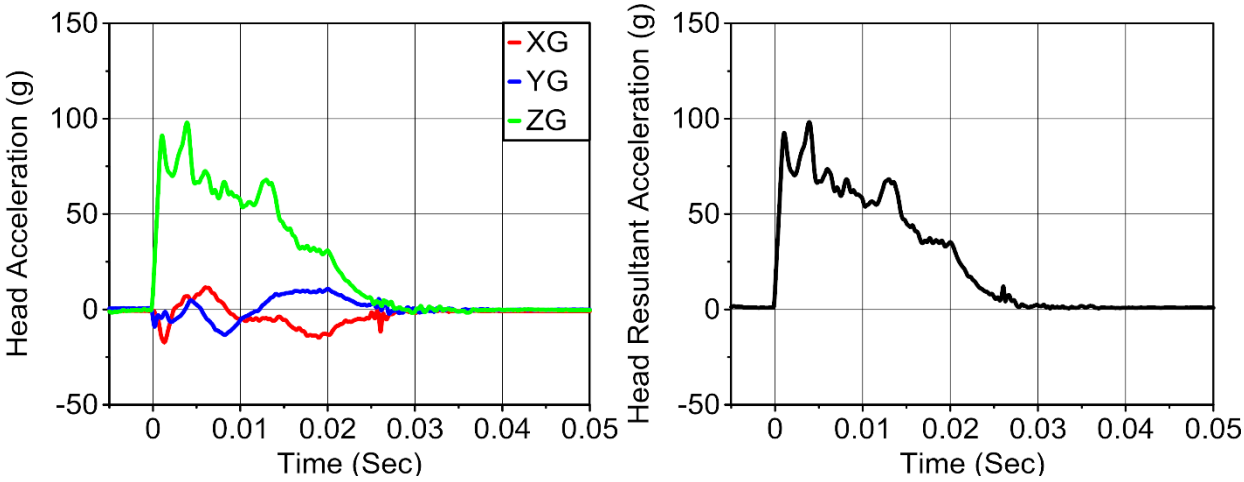
ChildHead 1658



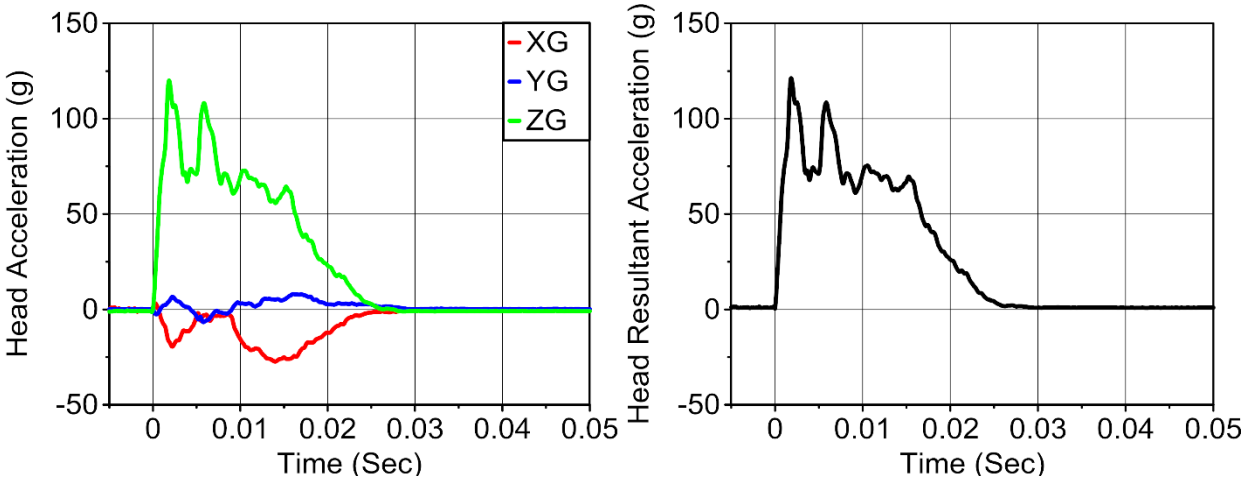
ChildHead 1659



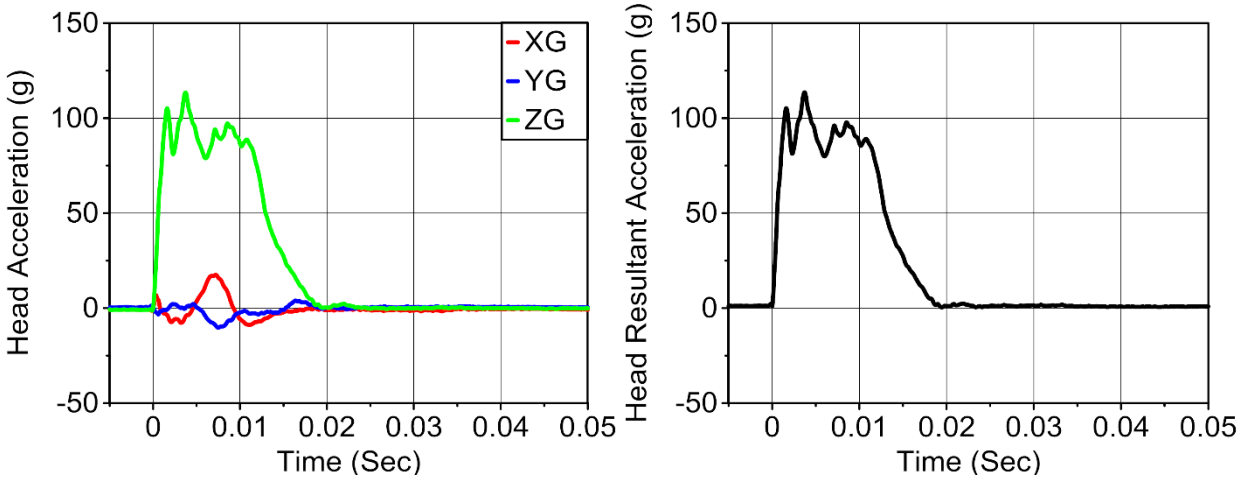
ChildHead 1660



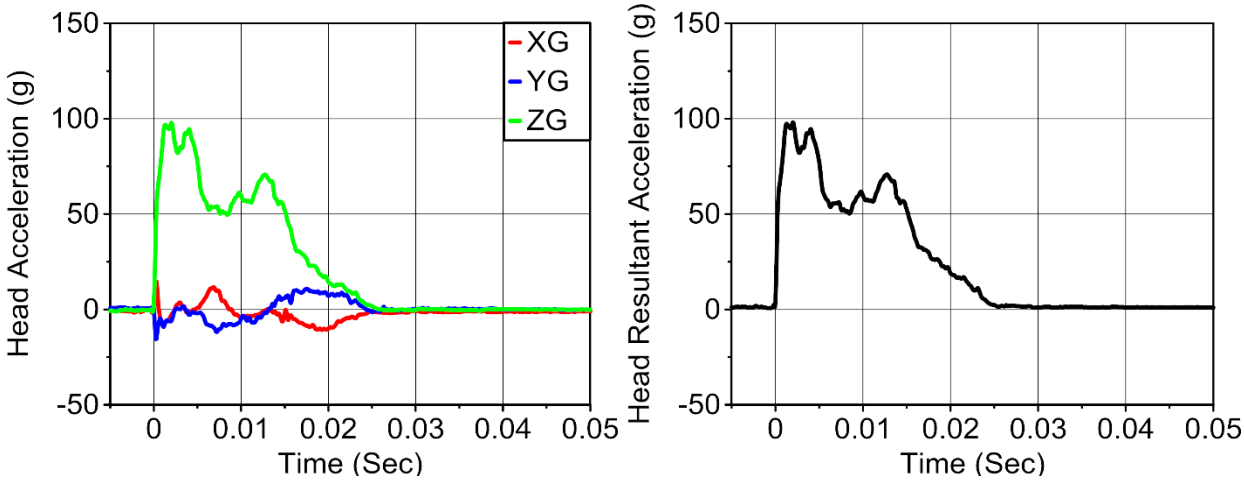
AdultHead 1661



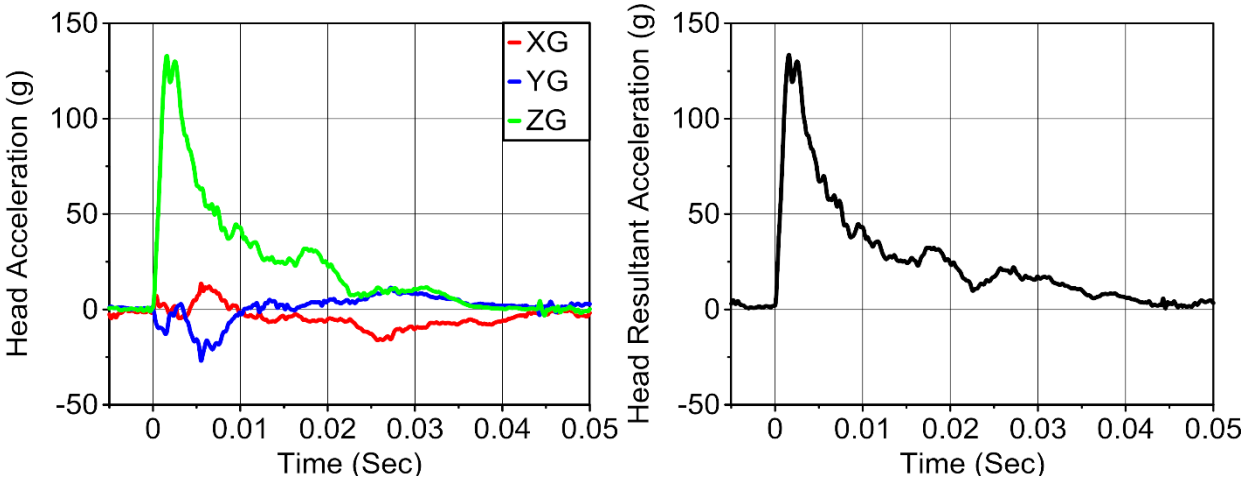
ChildHead 1717



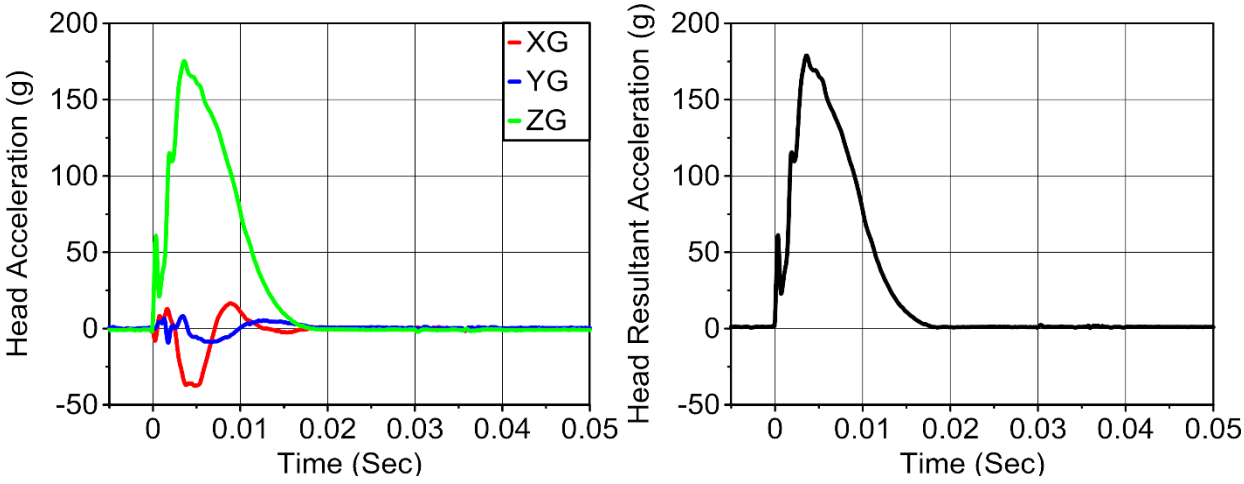
ChildHead 1718



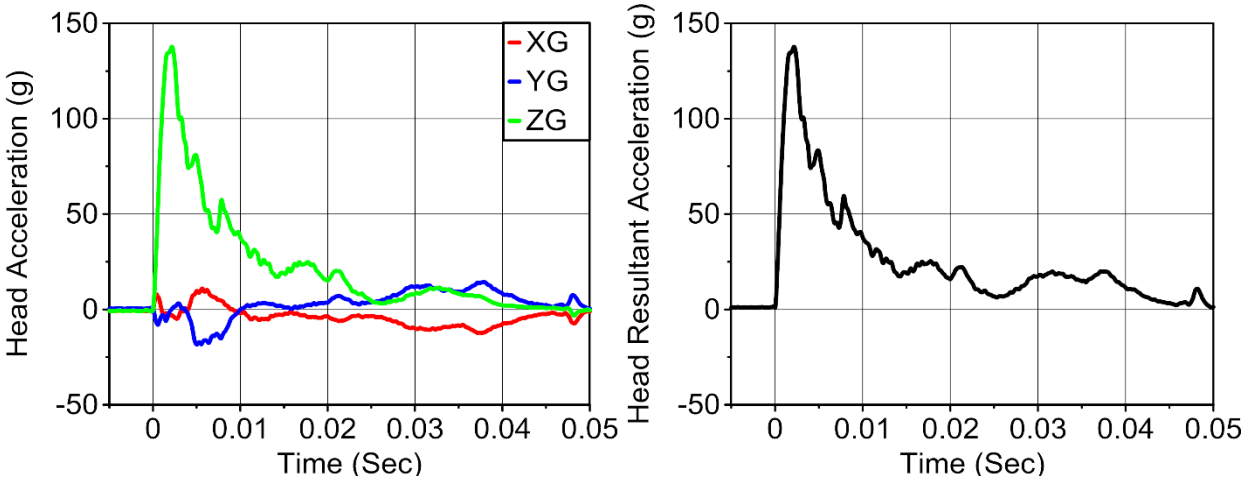
ChildHead 1711



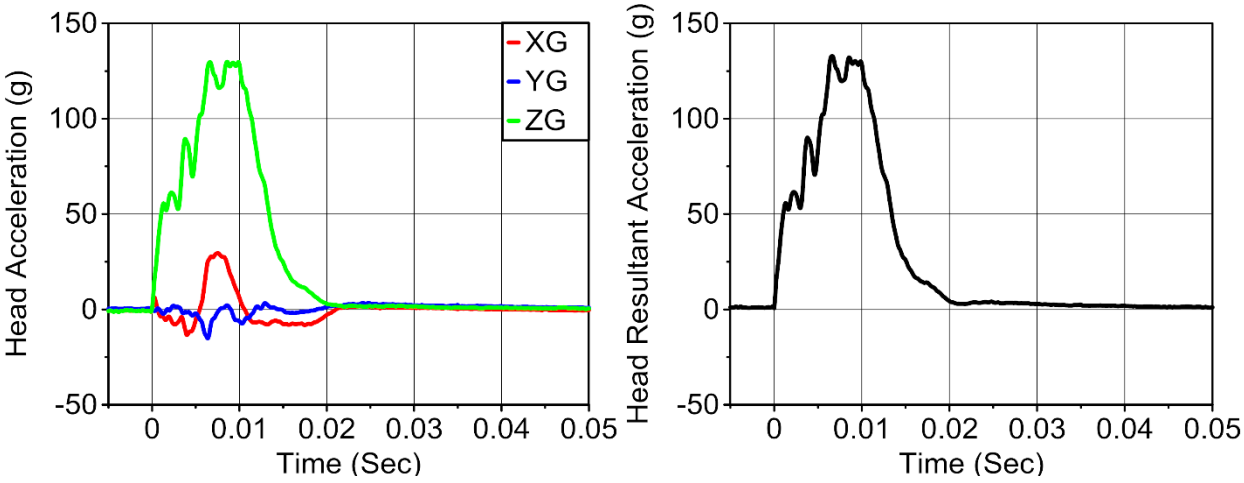
AdultHead 1721



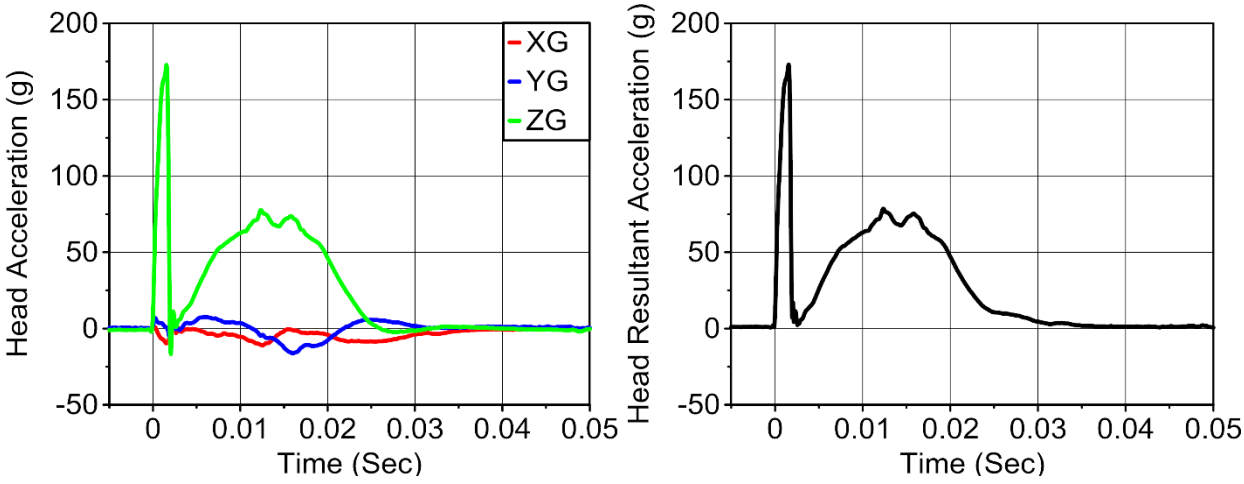
ChildHead 1719



ChildHead 1710

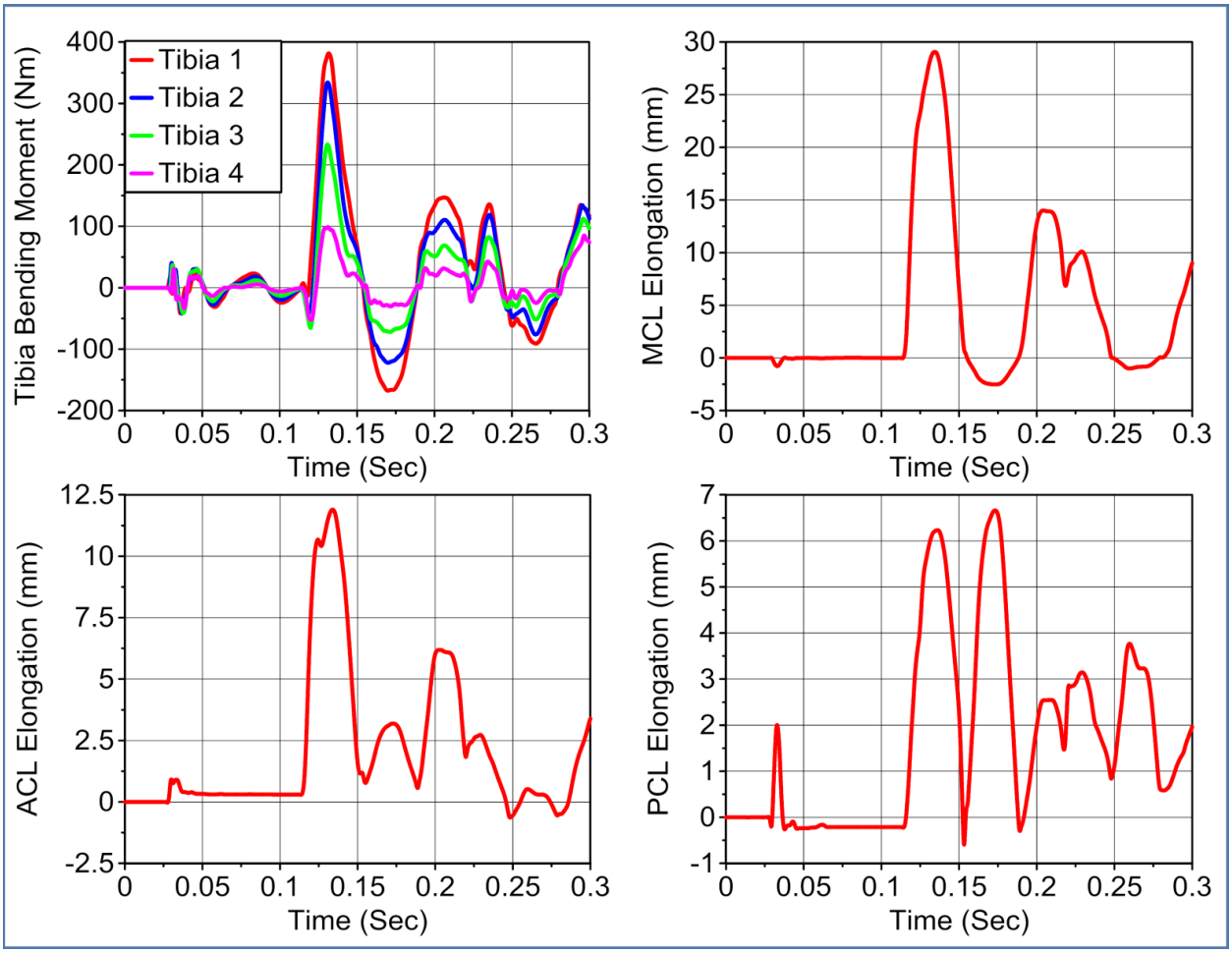


ChildHead 1720

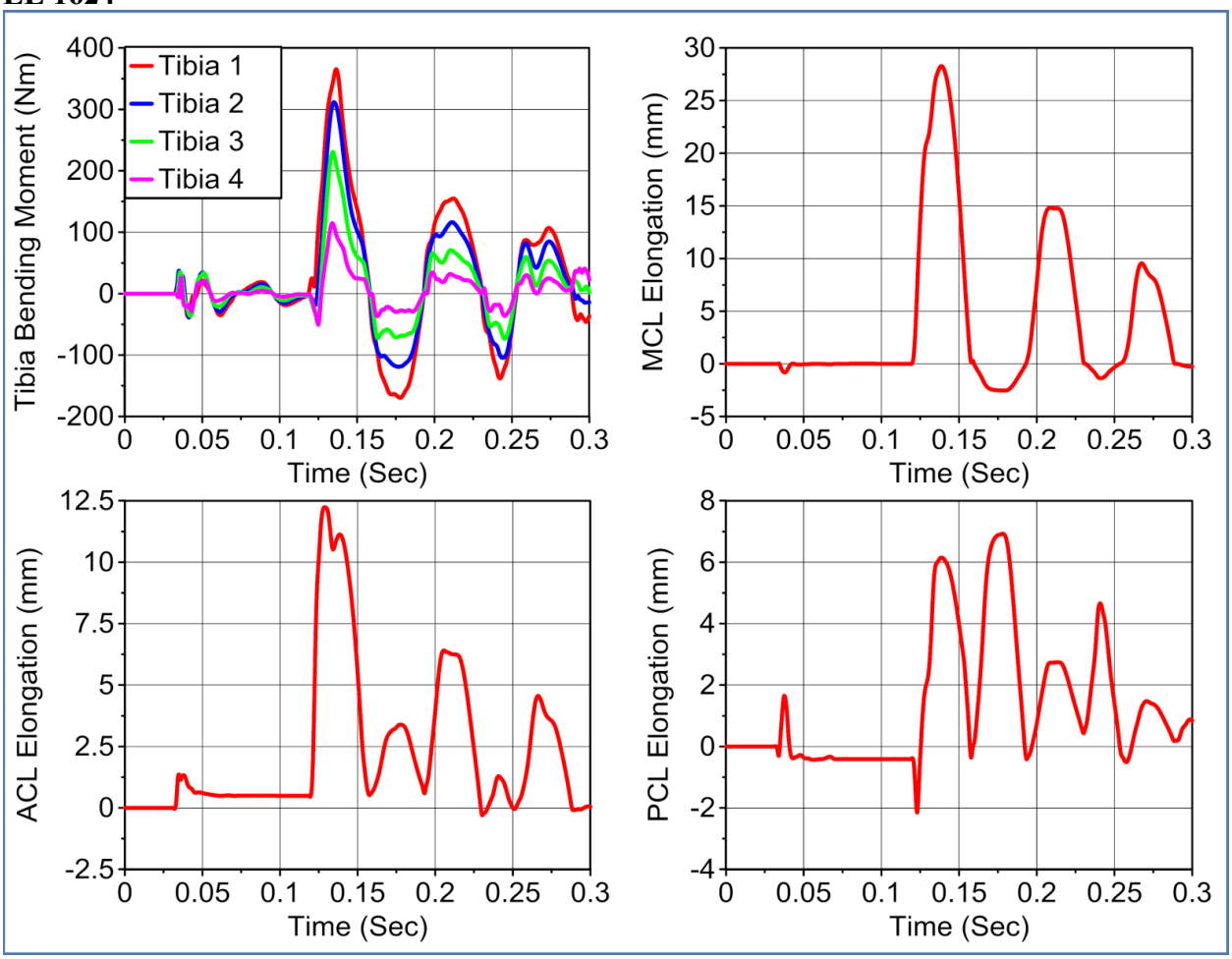


Lower Legform Impact Data Traces

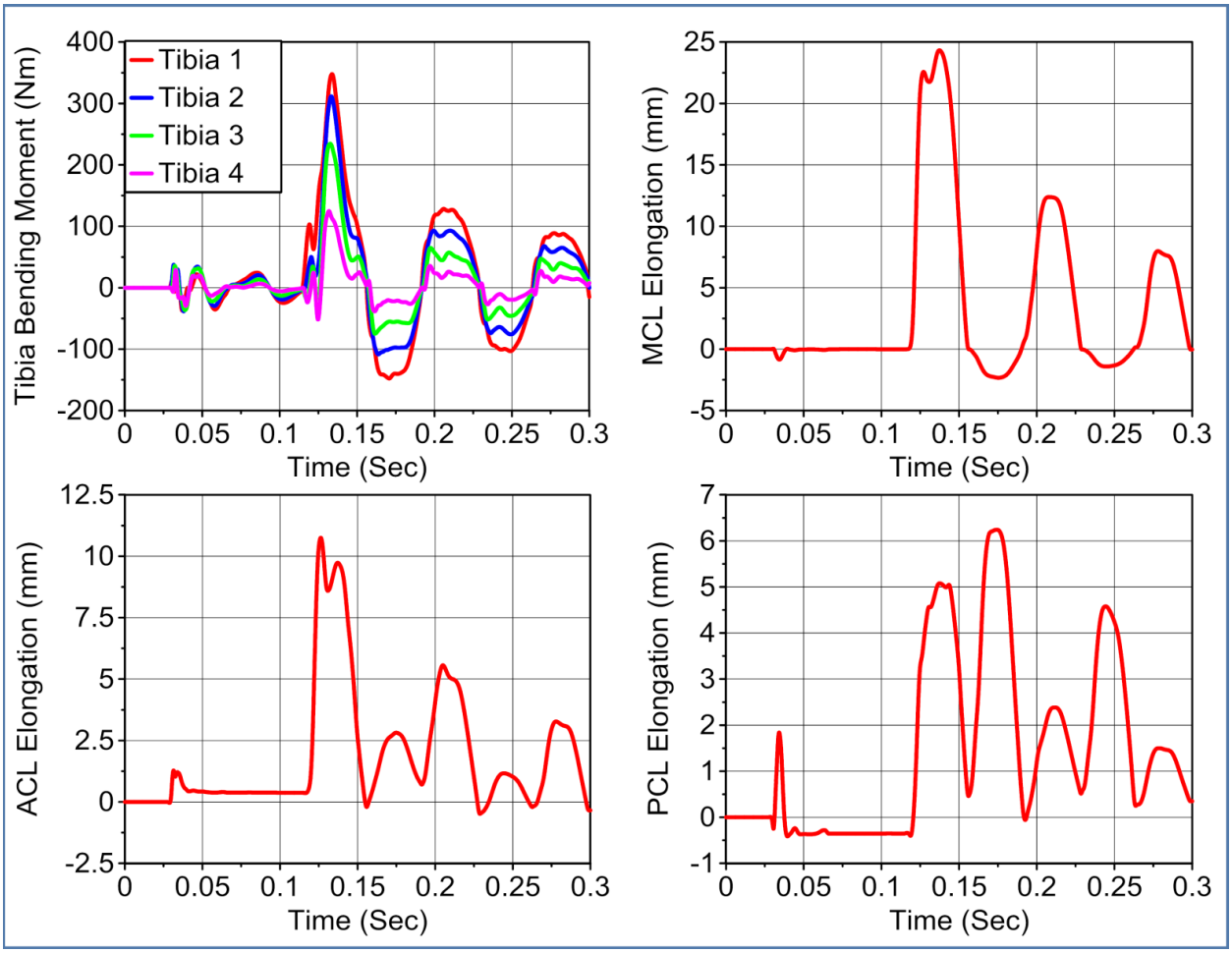
LL 1619



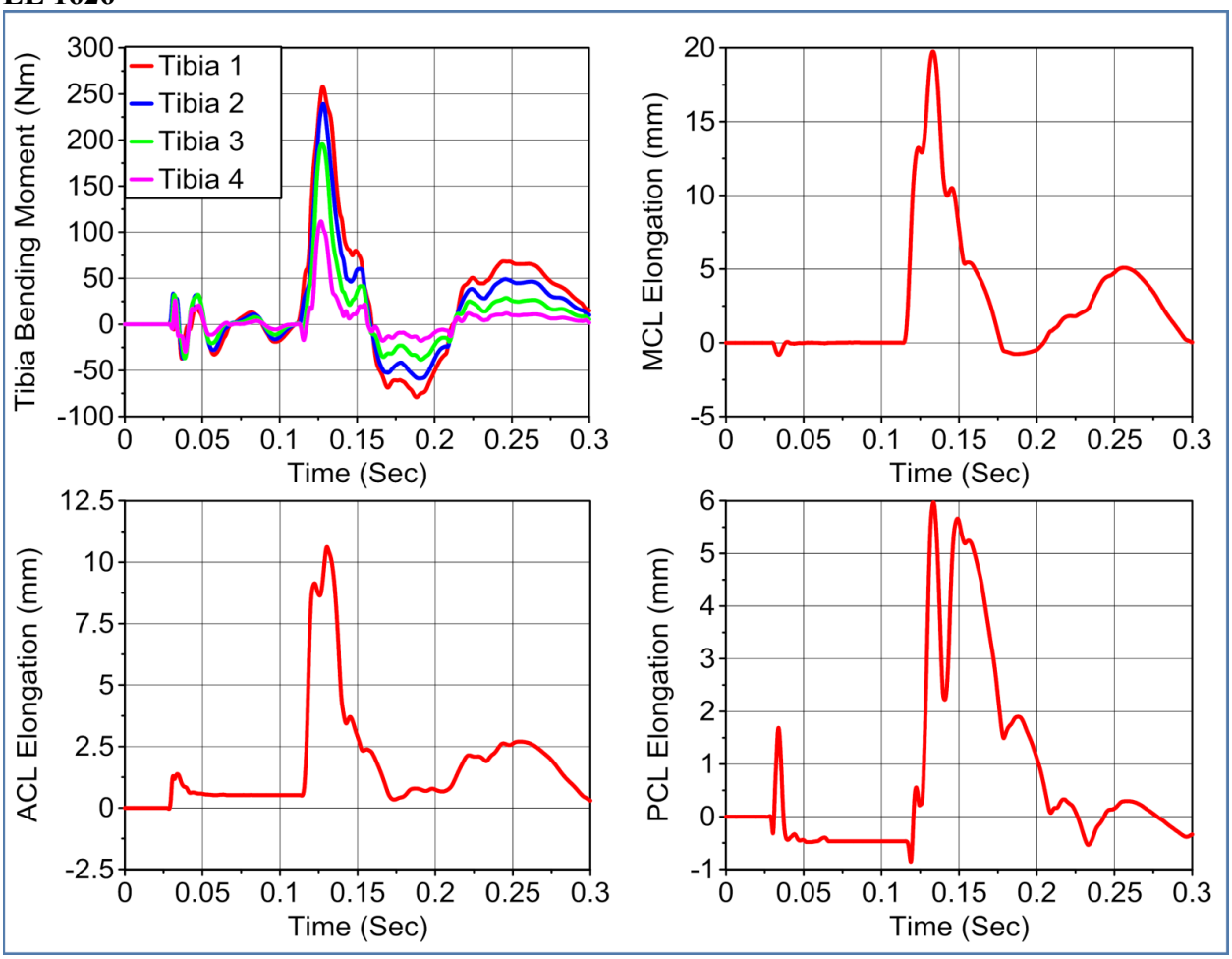
LL 1624


Tibia Bending Moment (Nm)
Tibia 1
Tibia 2
Tibia 3
Tibia 4
Time (Sec)
MCL Elongation (mm)
Time (Sec)
ACL Elongation (mm)
Time (Sec)
PCL Elongation (mm)
Time (Sec)

LL 1625

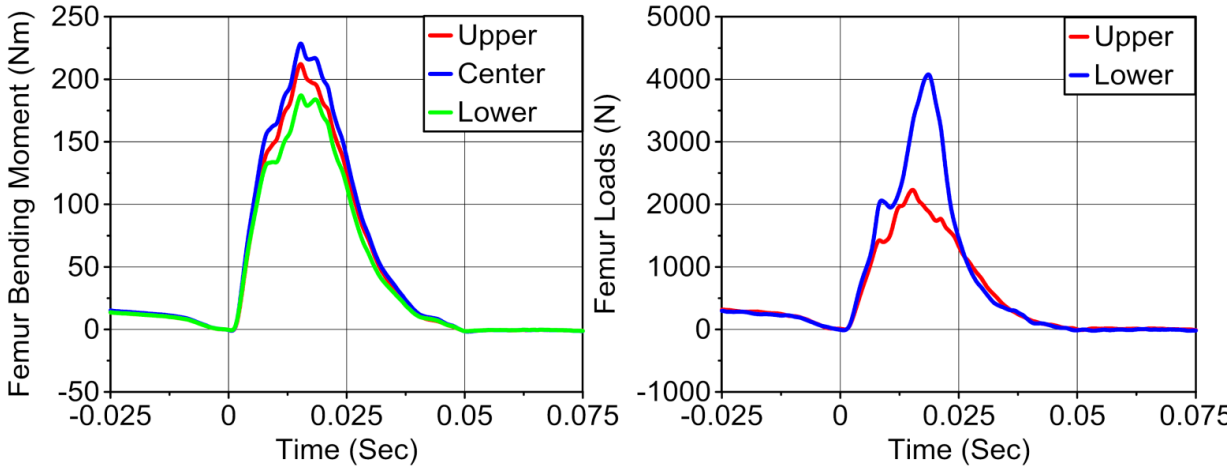

Tibia 1
Tibia 2
Tibia 3
Tibia 4
Tibia Bending Moment (Nm)
400
300
200
100
0
-100
-200
0
0.05
0.1
0.15
0.2
0.25
0.3
Time (Sec)
MCL Elongation (mm)
25
20
15
10
5
0
-5
Time (Sec)
ACL Elongation (mm)
12.5
10
7.5
5
2.5
0
-2.5
Time (Sec)
PCL Elongation (mm)
7
6
5
4
3
2
1
0
-1
Time (Sec)

LL 1626

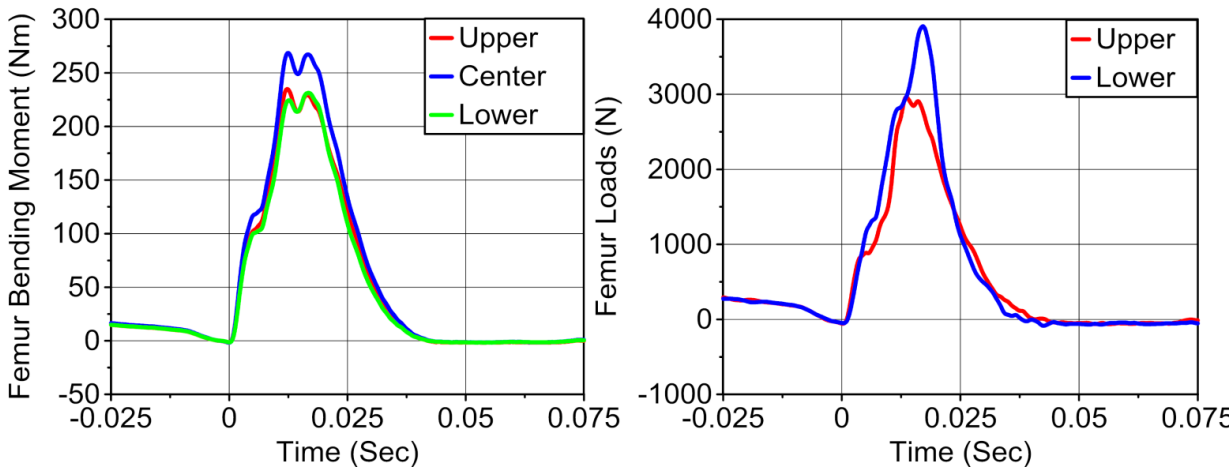

Tibia Bending Moment (Nm)
Tibia 1
Tibia 2
Tibia 3
Tibia 4
Time (Sec)
MCL Elongation (mm)
Time (Sec)
ACL Elongation (mm)
Time (Sec)
PCL Elongation (mm)
Time (Sec)

Upper Legform Impact Data Traces

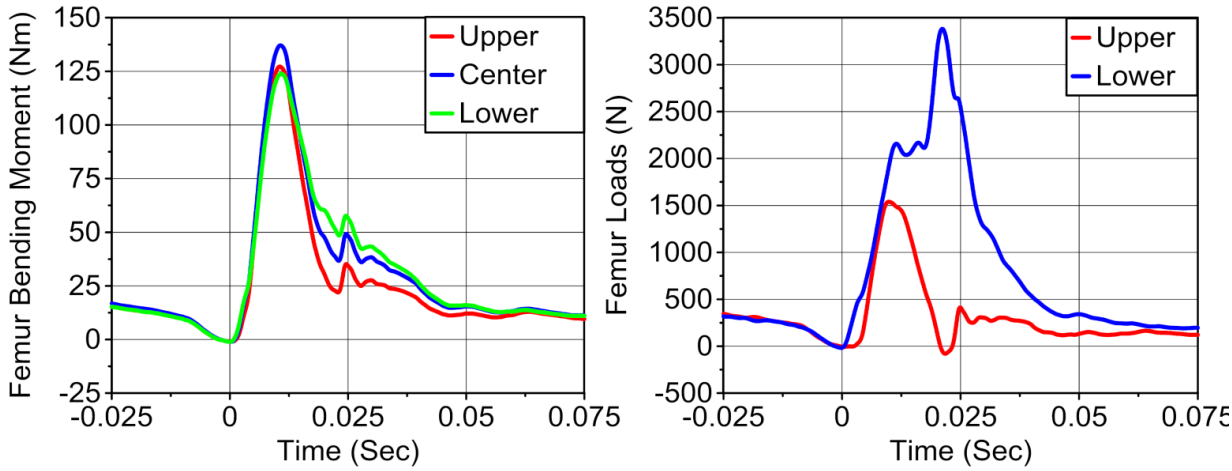
UL 1666



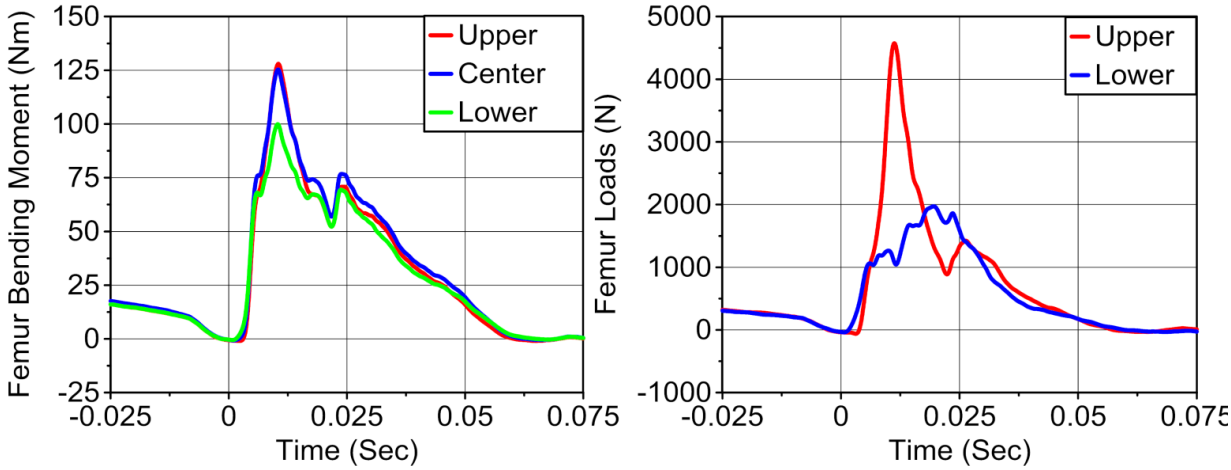
UL 1668



UL 1669



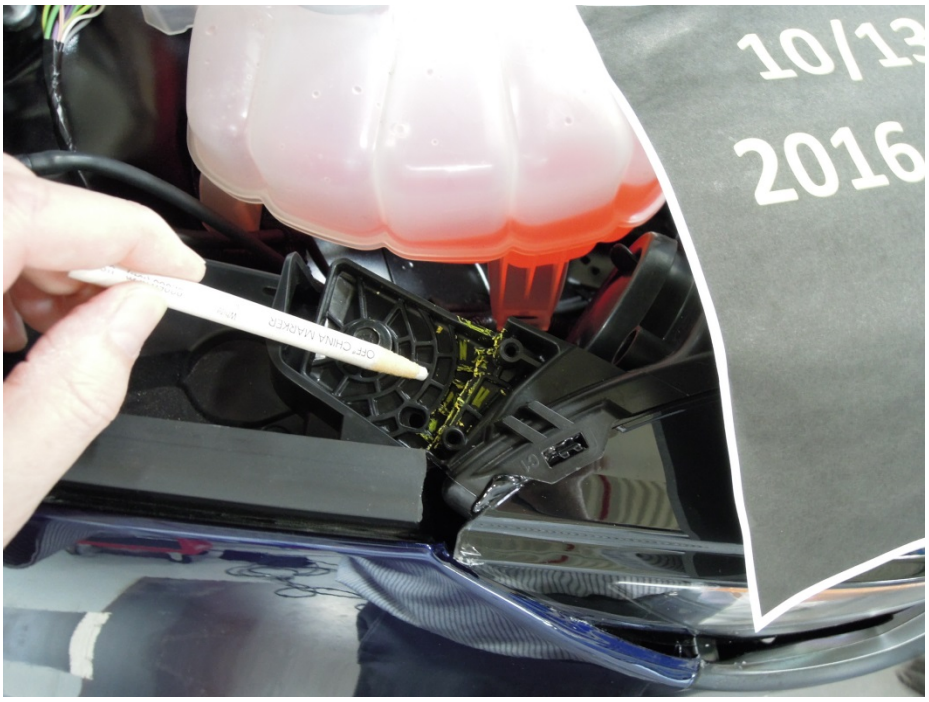
UL 1670

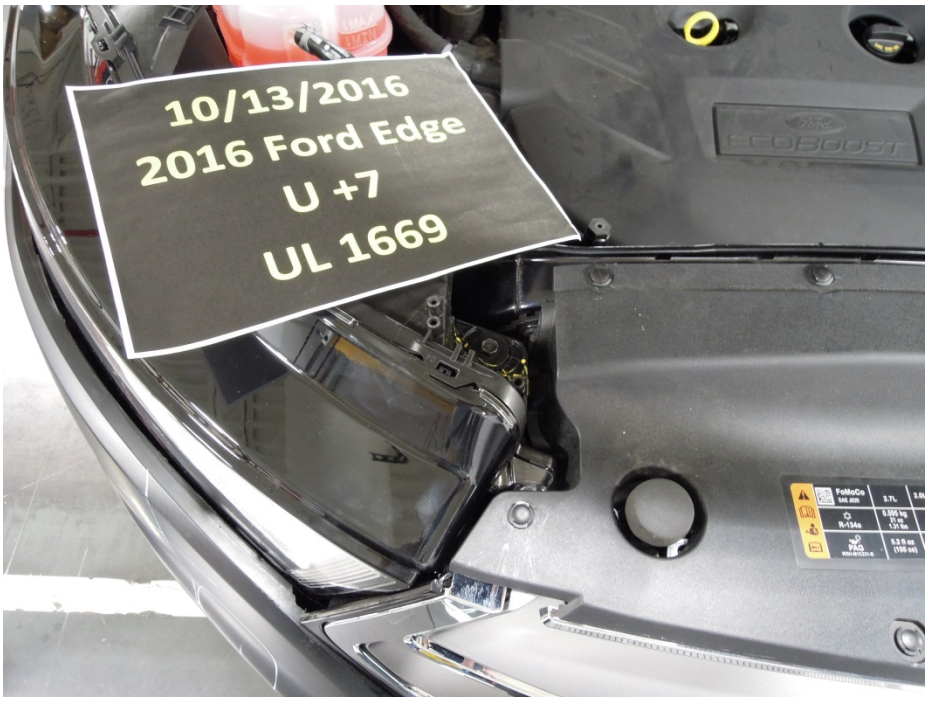


Examples of Post-Test Vehicle Damage

AdultHead 1652

UL 1669





Appendix E: 2015 Ford F-150

Overview

A 2015 Ford F-150 was tested.

Exemplar 2015 Ford F-150

Vehicle Information

Pertinent vehicle information is listed in Table E-1 below. Descriptions for the lateral hood width and front-end width can be found in Appendix J.

Table E-1. Vehicle information

Make	Ford
Model	F-150
Year	2015
VIN	1FTMF1C82FFA69947
Type	Standard Pickup Truck
GVWR	2726 kg
Lateral Hood Width	1646 mm
Front End Width	1970 mm

Headform Testing

For the 2015 Ford F-150, 11 points were chosen and are shown in Figure E-1 below.

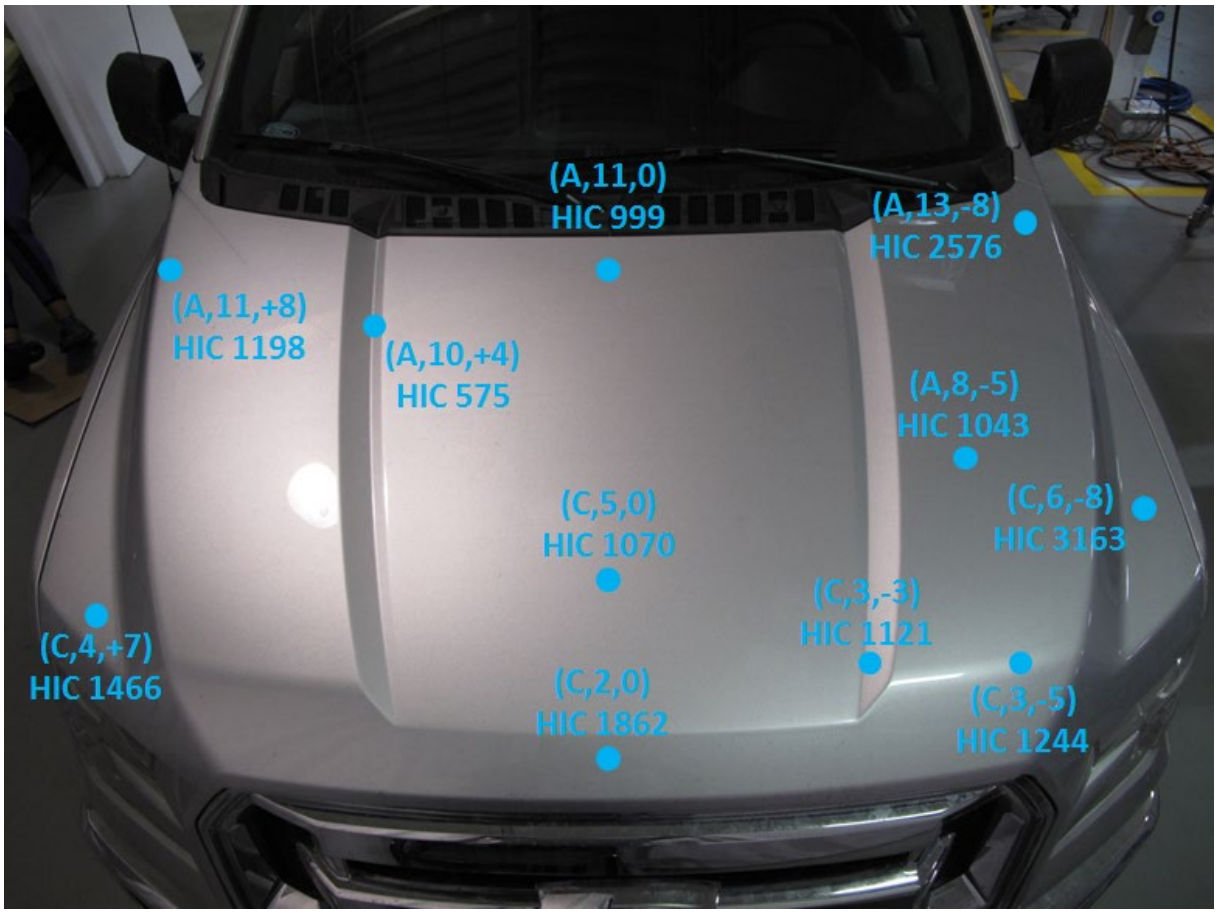


Figure E-1. 2015 Ford F-150 selected headform impact points, their corresponding grid coordinates, and HIC results.

HIC results and corresponding points for the selected impact points are shown in Table E-2 below. The 2015 Ford F-150 earned 4.5 points out of a possible 11 points, resulting in a score of 9.8. There is no Euro NCAP score for a European variant of this vehicle.

Table E-2. 2015 Ford F-150 headform impact locations, HIC results, and resulting score

			HIC SCORES			
Test No.	**Grid point**		***NHTSA (pts)***		***Euro NCAP (for ref only)***	***Ford Predicted (for ref only)***
1501	C	*5,0*	***1070***	***0.50***	---	---
1502	C	*4,7*	***1466***	***0.25***	---	---
1503	C	*3,-5*	***1244***	***0.50***	---	---
1504	A	*13,-8*	***2576***	***0***	---	---
1505	A	*11,0*	***999***	***0.75***	---	---
1506	A	*11,8*	***1198***	***0.50***	---	---
1507	C	*3,-3*	***1121***	***0.50***	---	---
1508	C	*6,-8*	***3163***	***0***	---	---
1509	C	*2,0*	***1862***	***0***	---	---
1510	A	*8,-5*	***1043***	***0.50***	---	---
1511	A	*10,4*	***575***	***1.0***	---	---
Total Points (11 max)			*4.50*		*n/a*	
Score			**9.8**			

Lower Legform Testing

The bumper test zone is defined as either the area limited by the bumper corners or the outermost ends of the underlying bumper beam, whichever is larger. The distance from the bumper corner of the fascia to the centerline was measured to be 565 mm. No bumper beam is present in the Ford F-150. Therefore, the bumper test zone was designated to be the area limited by the bumper corners. Grid points are located every 100 mm from the centerline in both lateral directions resulting in 11 grid points for the 2015 Ford F-150. Non-tested grid points are awarded the worst result from one of the adjacent points. In addition, symmetry will be applied to all grid points. Given these conditions, three test points were tested and are shown in Figure E-2 below.

Figure E-2. 2015 Ford F-150 selected lower legform impact points

Lower legform results for the selected impact points are shown in Table E-3 and corresponding scores are shown in Table E-4. Results that fall below the lower limit are highlighted in green, above the upper limit are in red, and between the lower and upper limits are in orange. Following Euro NCAP guidelines, the 2015 Ford F-150 earned 0.0 points out of a possible 11 points, resulting in a score of 0.0.

Table E-3. 2015 Ford F-150 lower legform impact locations and corresponding results.

		Tibia Bending Limits				*Ligament Elongation Limits*		
		282-340 Nm				*19-22 mm*	*10 mm*	
Test #	**Location**	**Tibia 1**	**Tibia 2**	**Tibia 3**	**Tibia 4**	**MCL**	**ACL**	**PCL**
FlexPLI1501	(L,0)	354	308	199	96	32.8	11.7	9.3
FlexPLI1502	(L,+2)	370	312	204	86	34.1	12.1	9.1
FlexPLI1503	(L,-4)	394	336	211	85	34.3	13.3	9.4

No European Variant

Table E-4. 2015 Ford F-150 lower legform grid points and score.

Location	Points on U.S. variant			*No Euro variant*
	Bending	Elongation	Total	
L+5	0	0	0	---
L+4	0	0	0	---
L+3	0	0	0	---
L+2	0	0	0	---
L+1	0	0	0	---
L0	0	0	0	---
L-1	0	0	0	---
L-2	0	0	0	---
L-3	0	0	0	---
L-4	0	0	0	---
L-5	0	0	0	---
Points Total (Out of Max Possible 11 Points)	0.0			
Score	0.0			*n/a*

Upper Legform Testing

Since the lower bumper reference line is less than 425 mm, upper legform impacts were performed at the wrap around distance (WAD) 775 mm. Starting at the vehicle's centerline, grid points are marked every 100 mm in both lateral directions along the WAD 775 mm line up to the corner reference points. Grid points less than 50 mm from the corner reference points are deleted. As with lower leg testing, non-tested grid points are awarded the worst result from one of the adjacent points. In addition, symmetry will be applied to all grid points. Given these conditions, four test points were tested and are shown in Figure E-3.

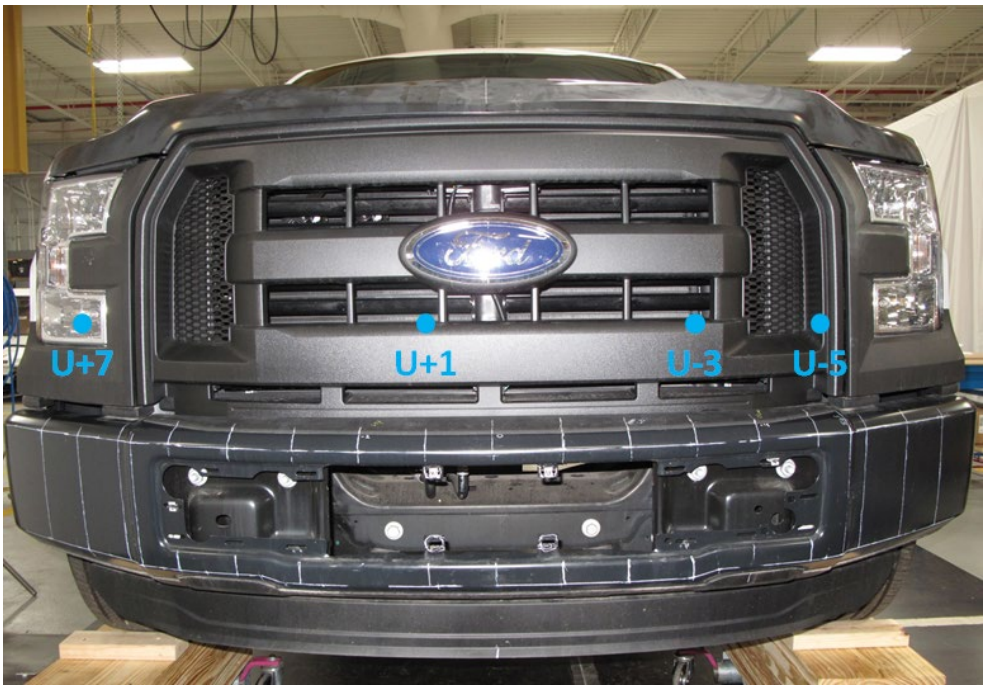


Figure E-3. 2015 Ford F-150 selected upper legform impact points

Upper legform results for the selected impact points are shown in Table E-5 below. Results that fall below the lower limit are highlighted in green, above the upper limit are in red, and between the lower and upper limits are in orange. The possible number of points awarded for each injury measure is shown in Table E-6 below. The 2015 Ford F-150 earned 3.0 points out of a possible 15 points, resulting in a score of 1.2.

Table E-5. 2015 Ford F-150 upper legform impact locations and corresponding results.

Test #	Location	Angle (°)	Energy (J)	Femur Bending Moment Limits: 285 – 350 Nm			Sum Femur Loads (N) Limits: 5-6 kN
				Upper	Middle	Lower	
UL 1647	U+7	7.3	446	115	164	149	7927
UL 1648	U-5	5.6	450	39	60	64	7549
UL 1649	U-3	4.5	453	85	95	83	7786
UL 1650	U+1	4.2	453	116	119	98	4785

No European Variant

Table E-6. Points awarded for each injury measure and resulting score for the upper legform tests. Upper leg performance for each grid point is based on the worst performing parameter.

Location	Points on U.S. Variant			*No Euro Variant*
	Bending	Force	Total	
U+7	1	0	0	---
U+6	1	0	0	---
U+5	1	0	0	---
U+4	1	0	0	---
U+3	1	0	0	---
U+2	1	0	0	---
U+1	1	1	1.0	---
U0	1	1	1.0	---
U-1	1	1	1.0	---
U-2	1	0	0	---
U-3	1	0	0	---
U-4	1	0	0	---
U-5	1	0	0	---
U-6	1	0	0	---
U-7	1	0	0	---
Points Total (Out of Max Possible 15 Points)	3.0			
Score	1.2			n/a

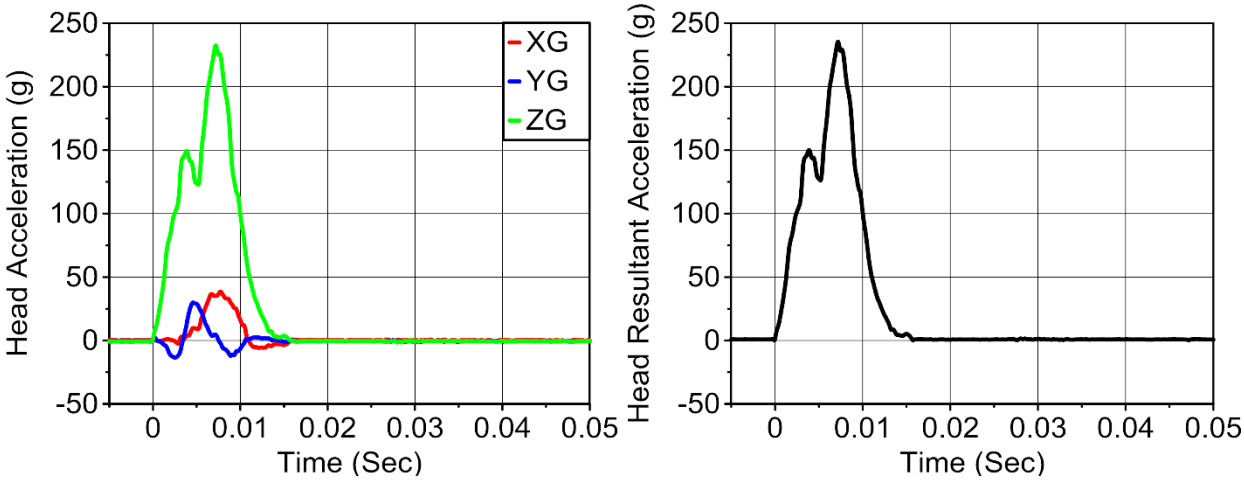
Summary

Table E-7. Summary of results for the 2015 Ford F-150.

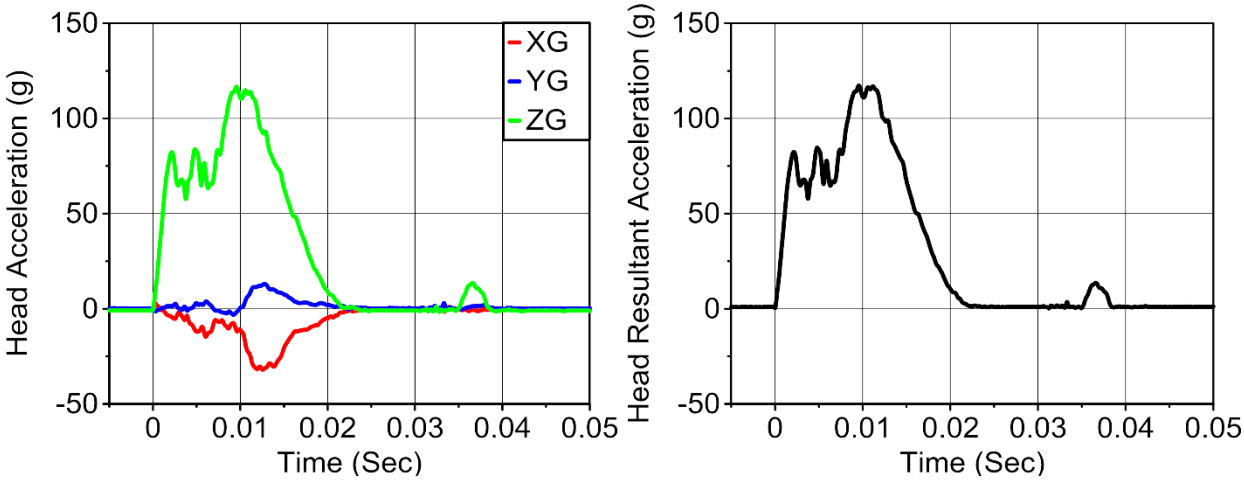
2015 Ford F-150	Head	Lower Leg	Upper Leg	Total	% of Max
Score (Out of 36)	9.8	0.0	1.2	**11.0**	**30.6%**

Headform Impact Data Traces

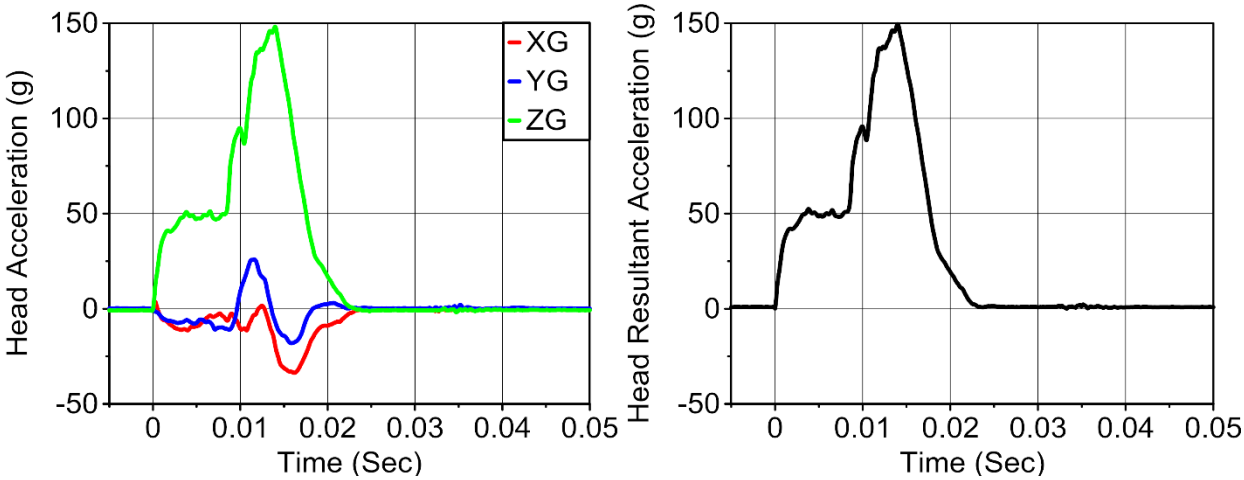
AdultHead 1504



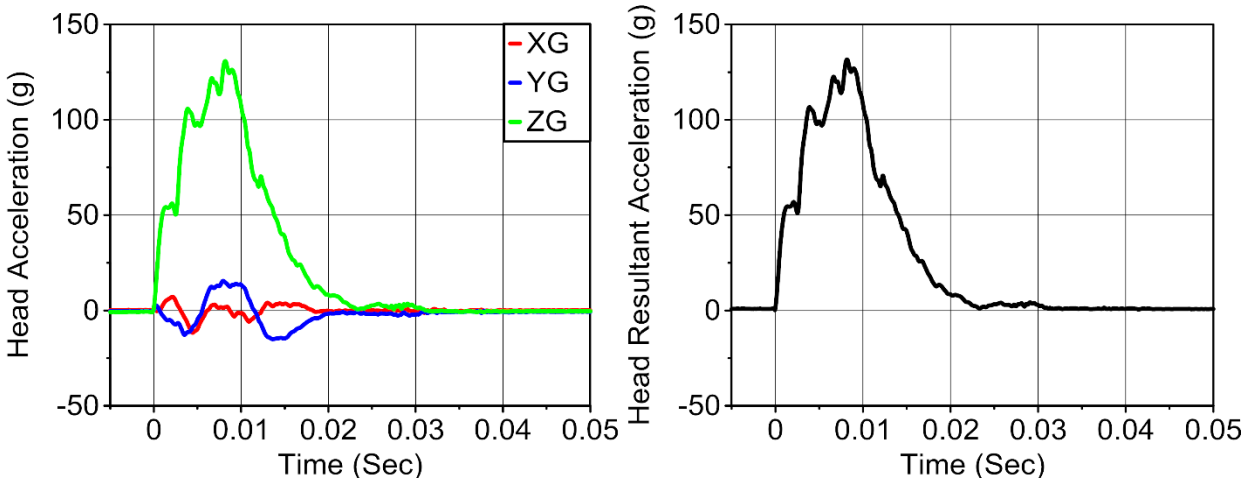
AdultHead 1505



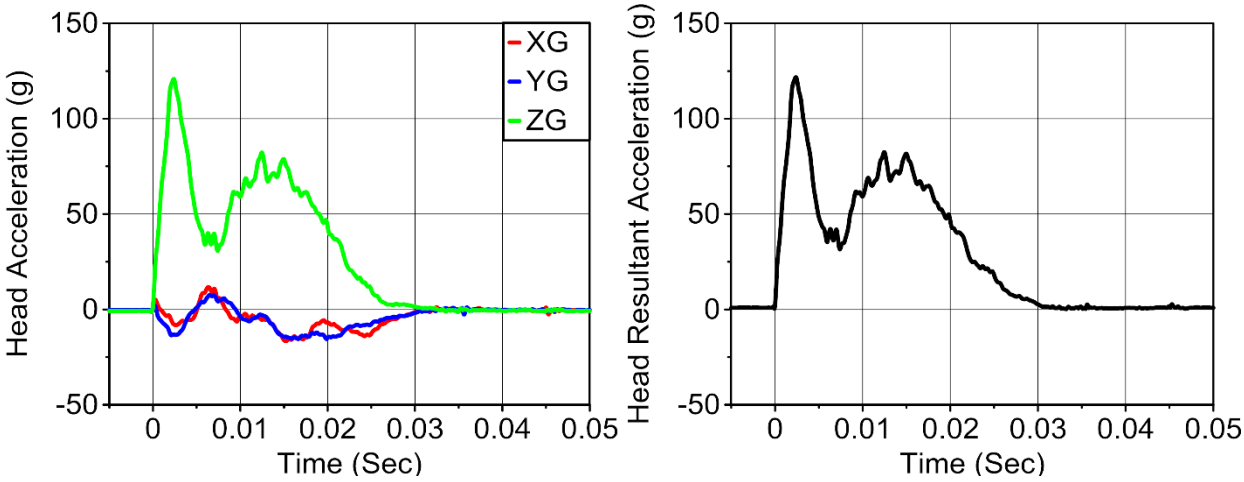
AdultHead 1506



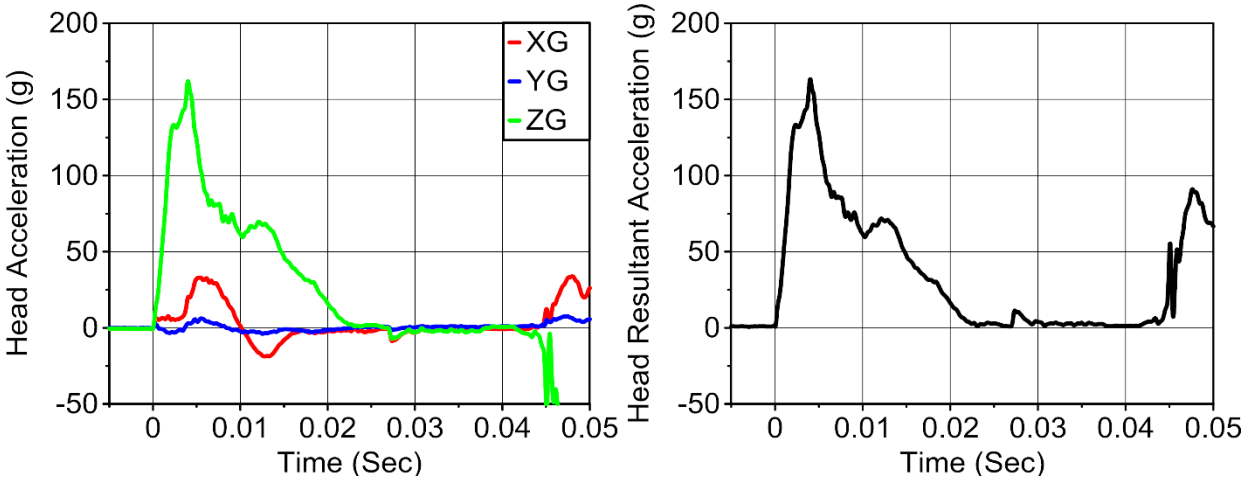
AdultHead 1510



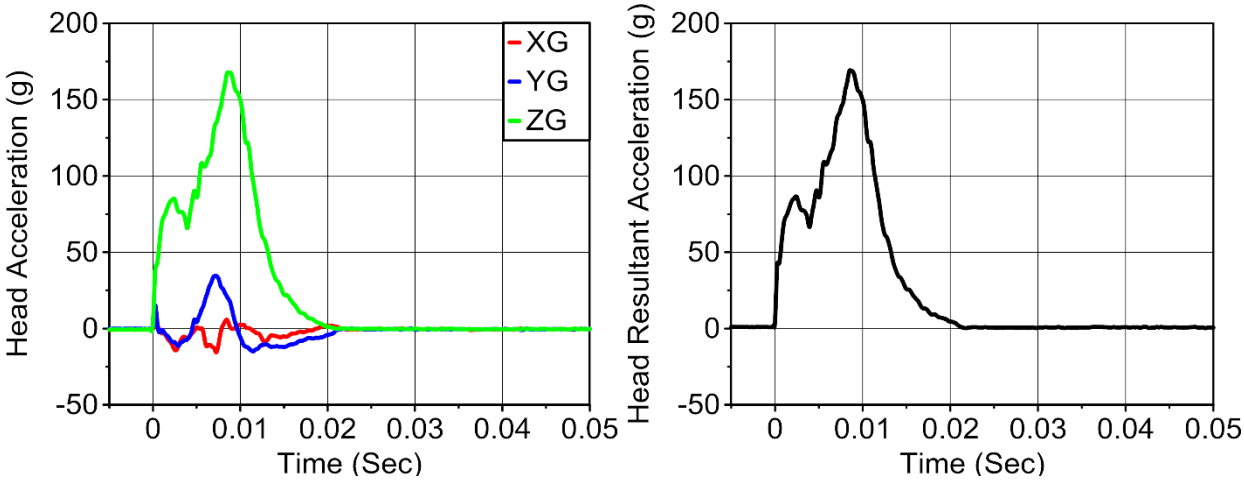
AdultHead 1511



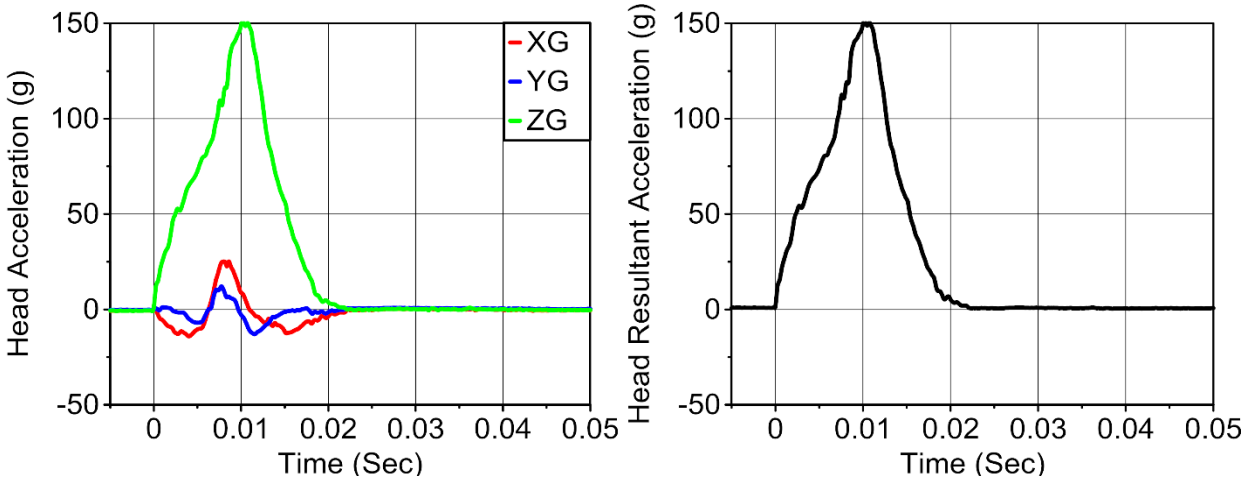
ChildHead 1501



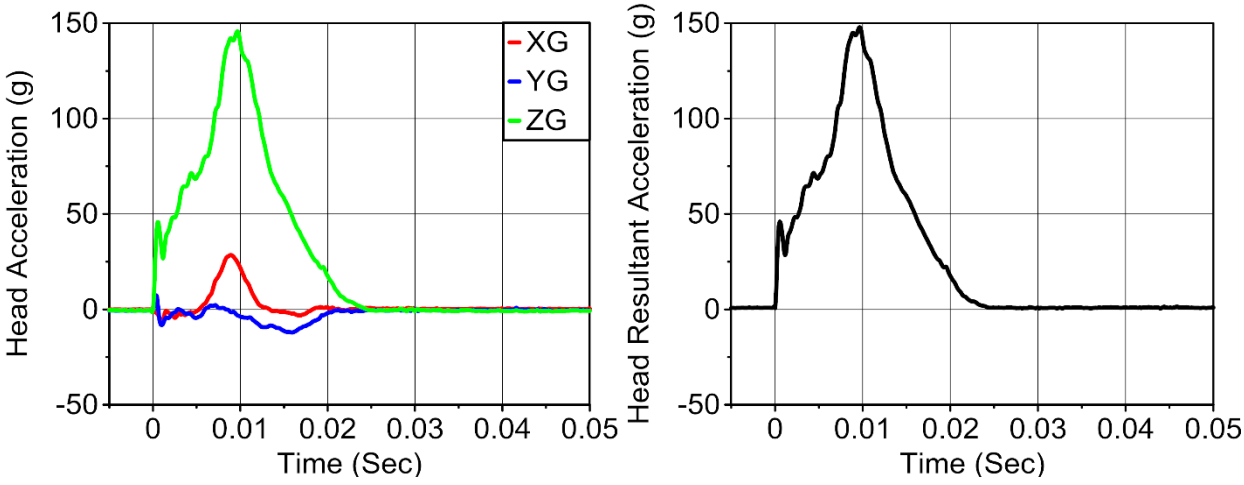
ChildHead 1502



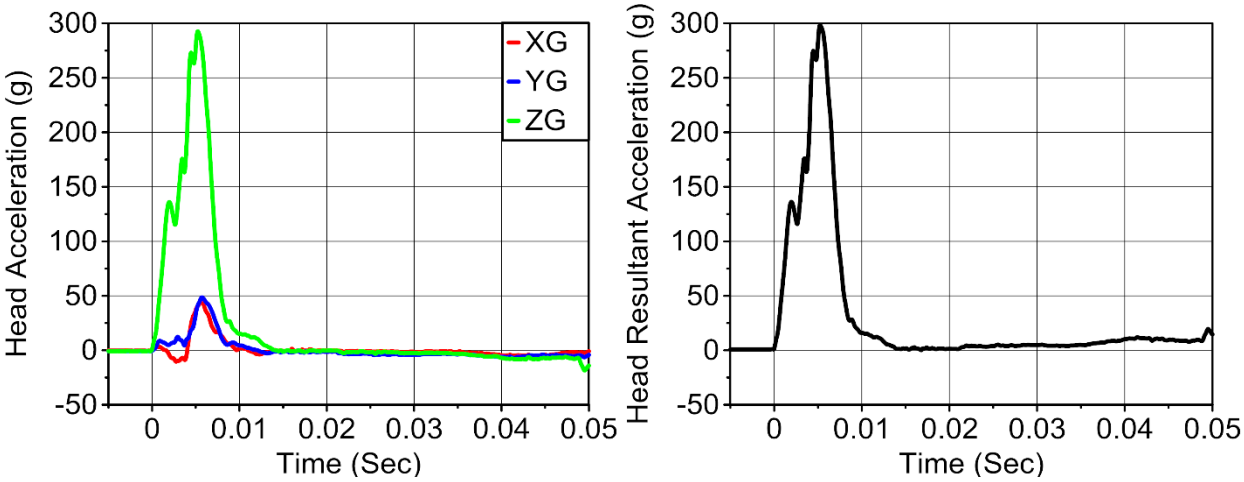
ChildHead 1503



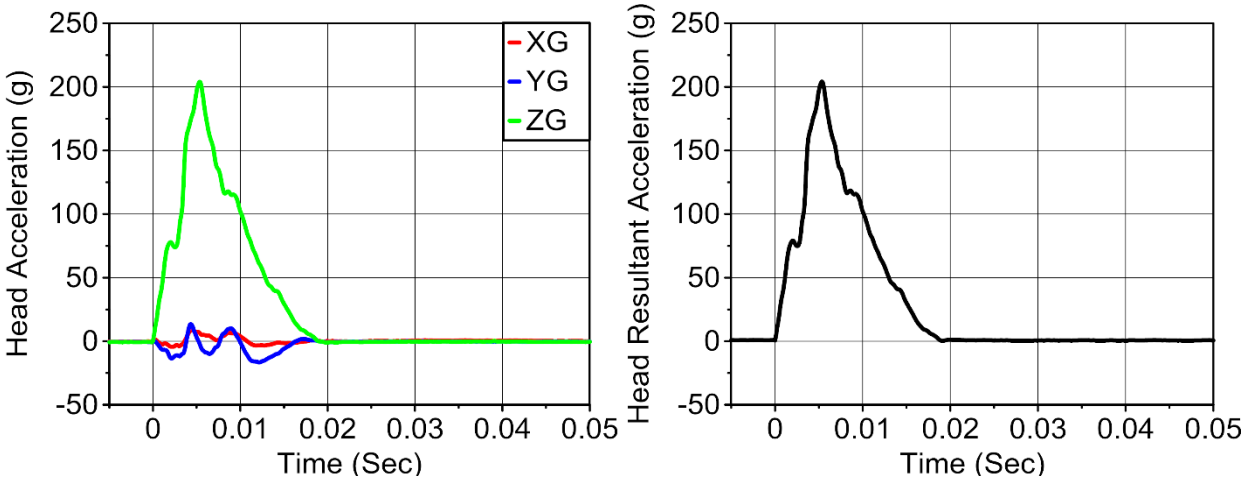
ChildHead 1507



ChildHead 1508

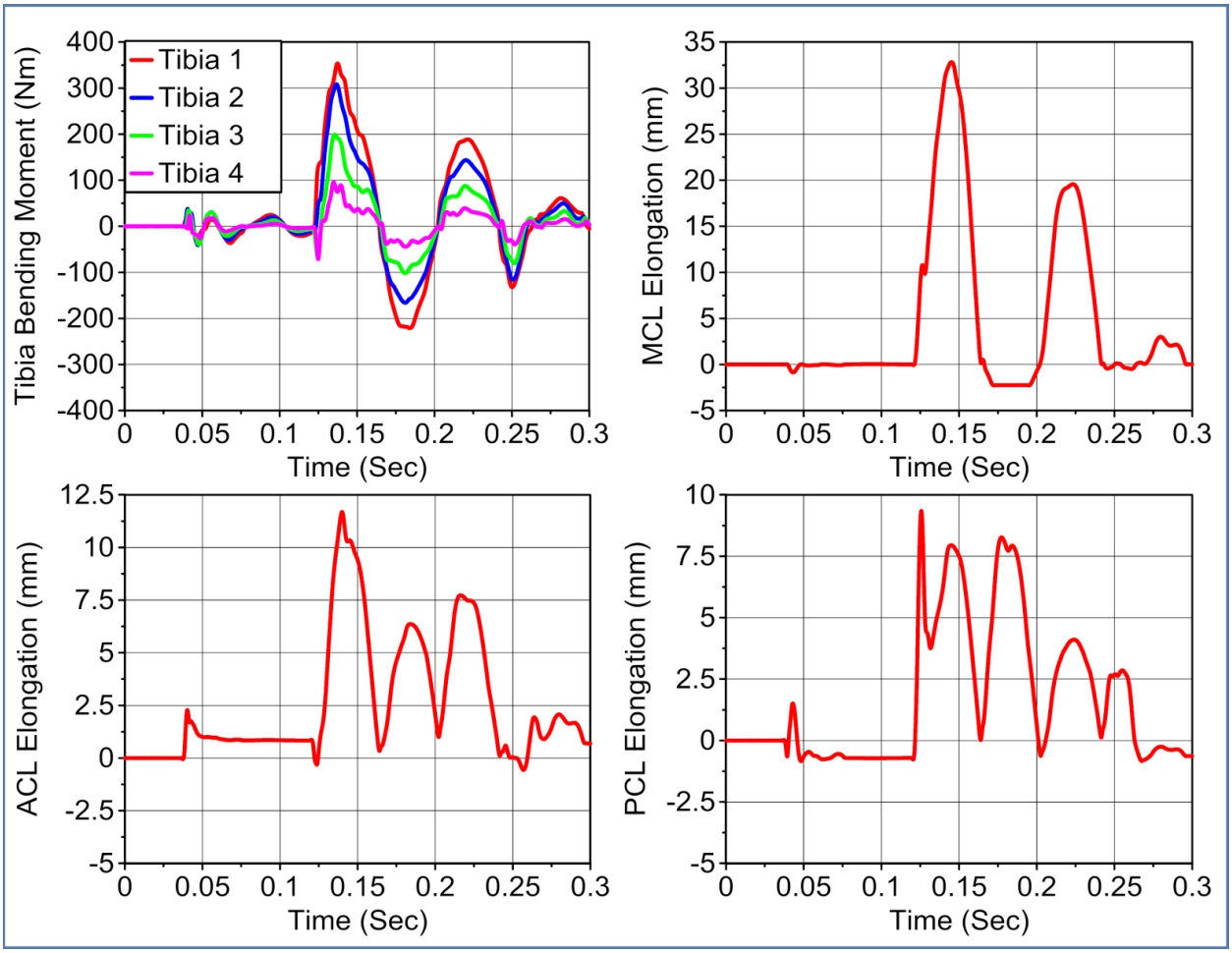


ChildHead 1509

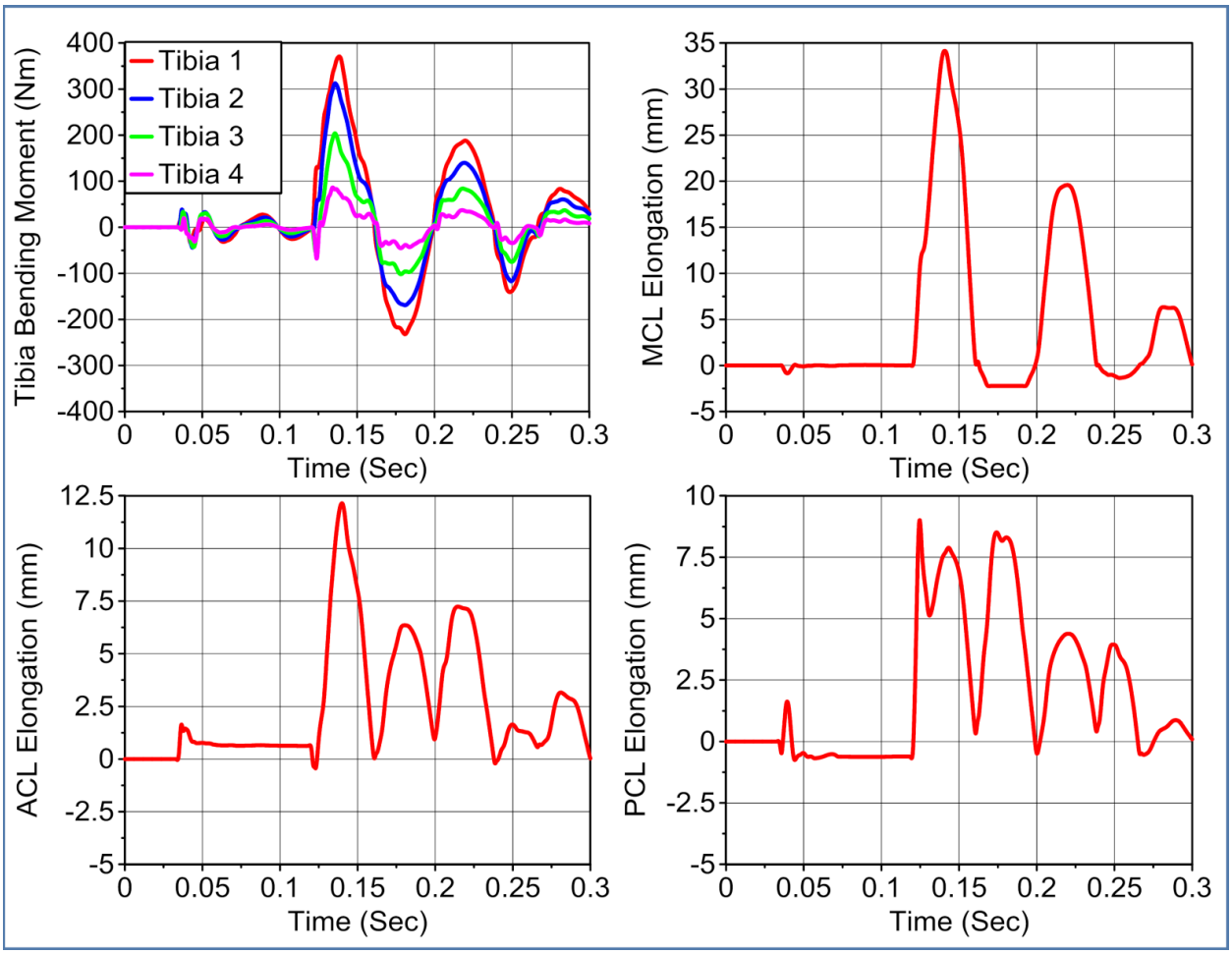


Lower Legform Impact Data Traces

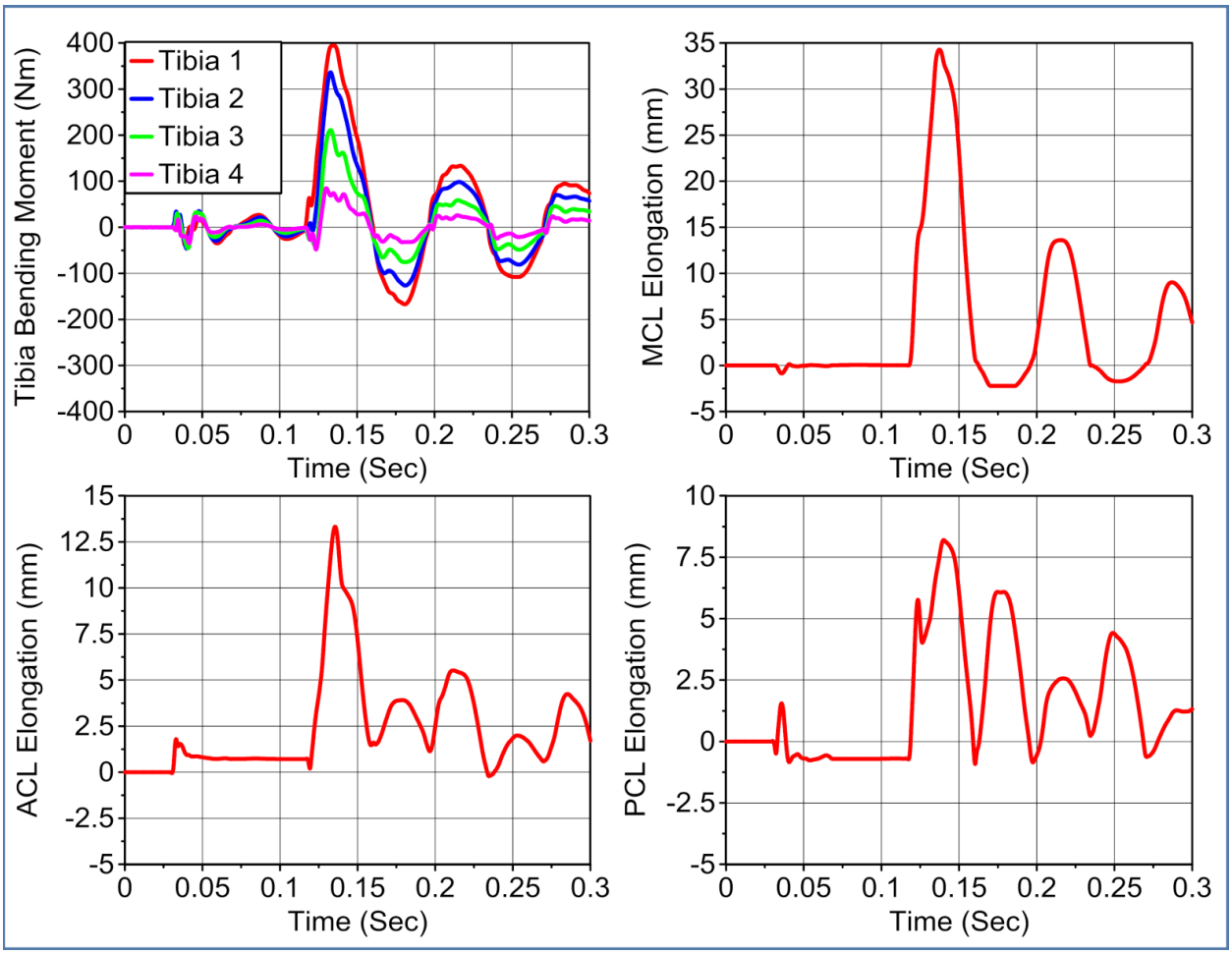
FlexPLI 1501



FlexPLI 1502

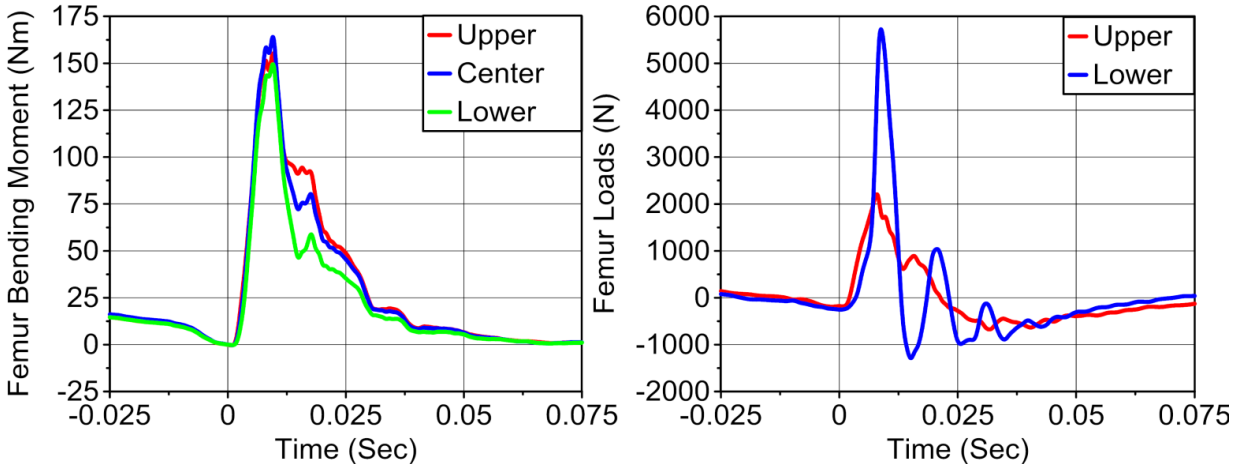


FlexPLI 1503

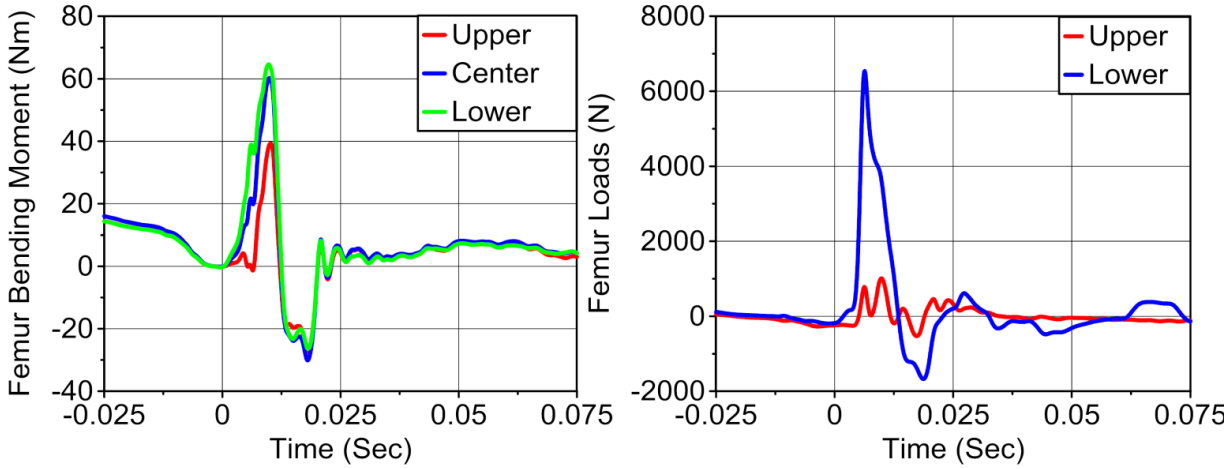


Upper Legform Impact Data Traces

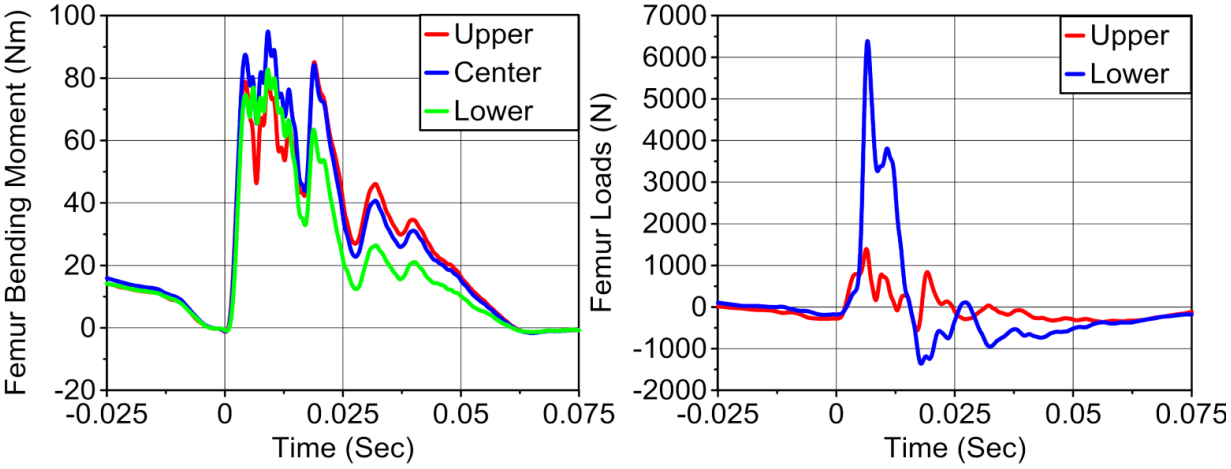
UL 1647



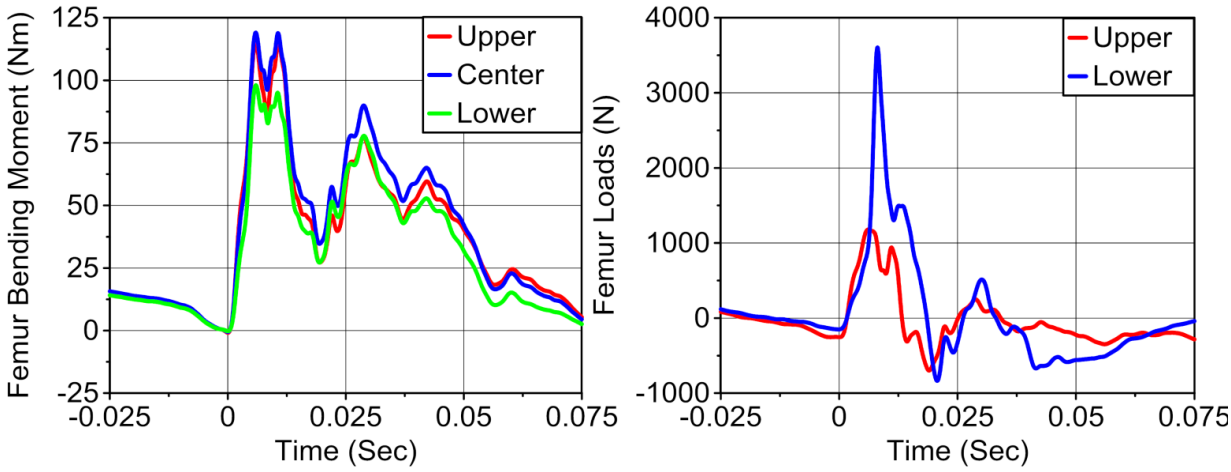
UL 1648



UL 1649



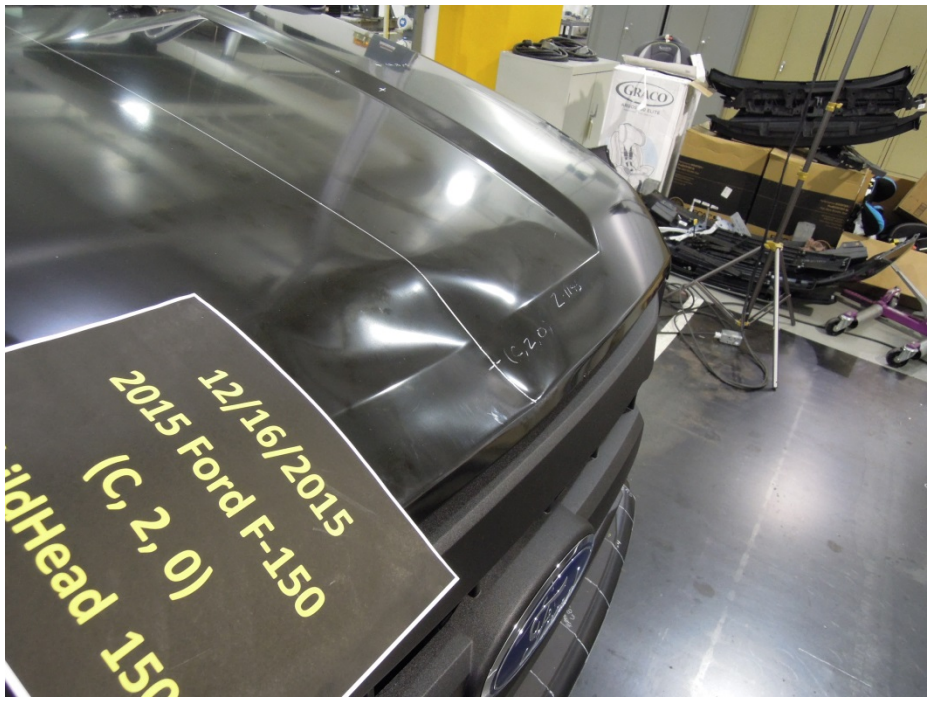
UL 1650



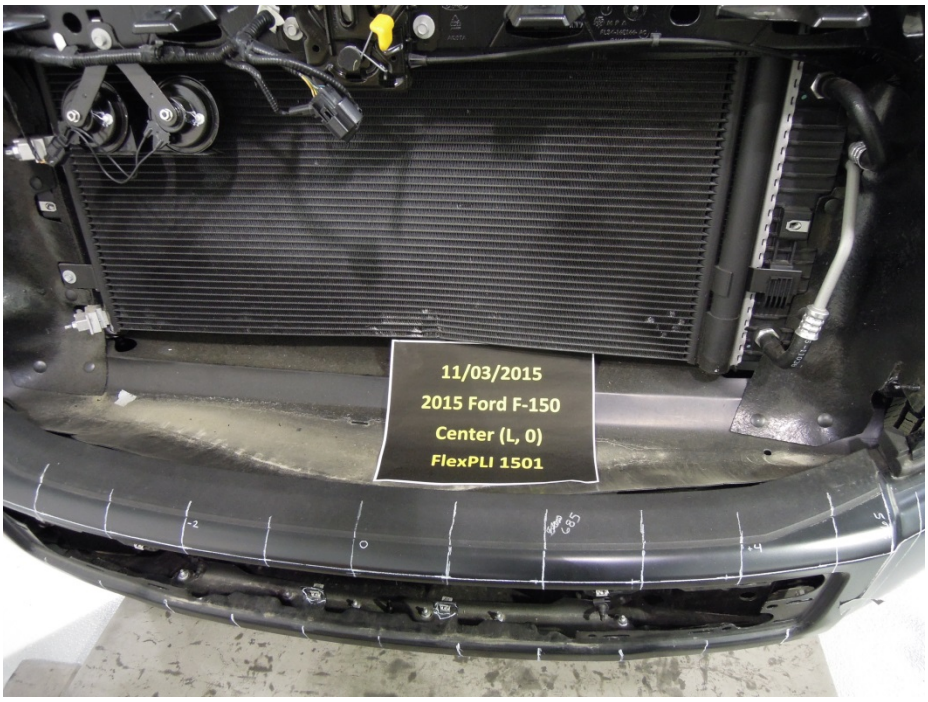
Examples of Post-Test Vehicle Damage

ChildHead 1503

ChildHead 1509



FlexPLI 1501



UL 1647

Appendix F: 2016 Honda Fit

Overview

A 2016 Honda Fit was tested.

Exemplar 2016 Honda Fit

Vehicle Information

Pertinent vehicle information is listed in Table F-1 below. Descriptions for the lateral hood width and front-end width can be found in Appendix J.

Table F-1. Vehicle information

Make	Honda
Model	Fit
Year	2016
VIN	JHMGK5H55GX003871
Type	Passenger Car
GVWR	1539 kg
Lateral Hood Width	1660 mm
Front End Width	1990 mm

Headform Testing

For the 2016 Honda Fit, 9 points were chosen and are shown in Figure F-1 below.

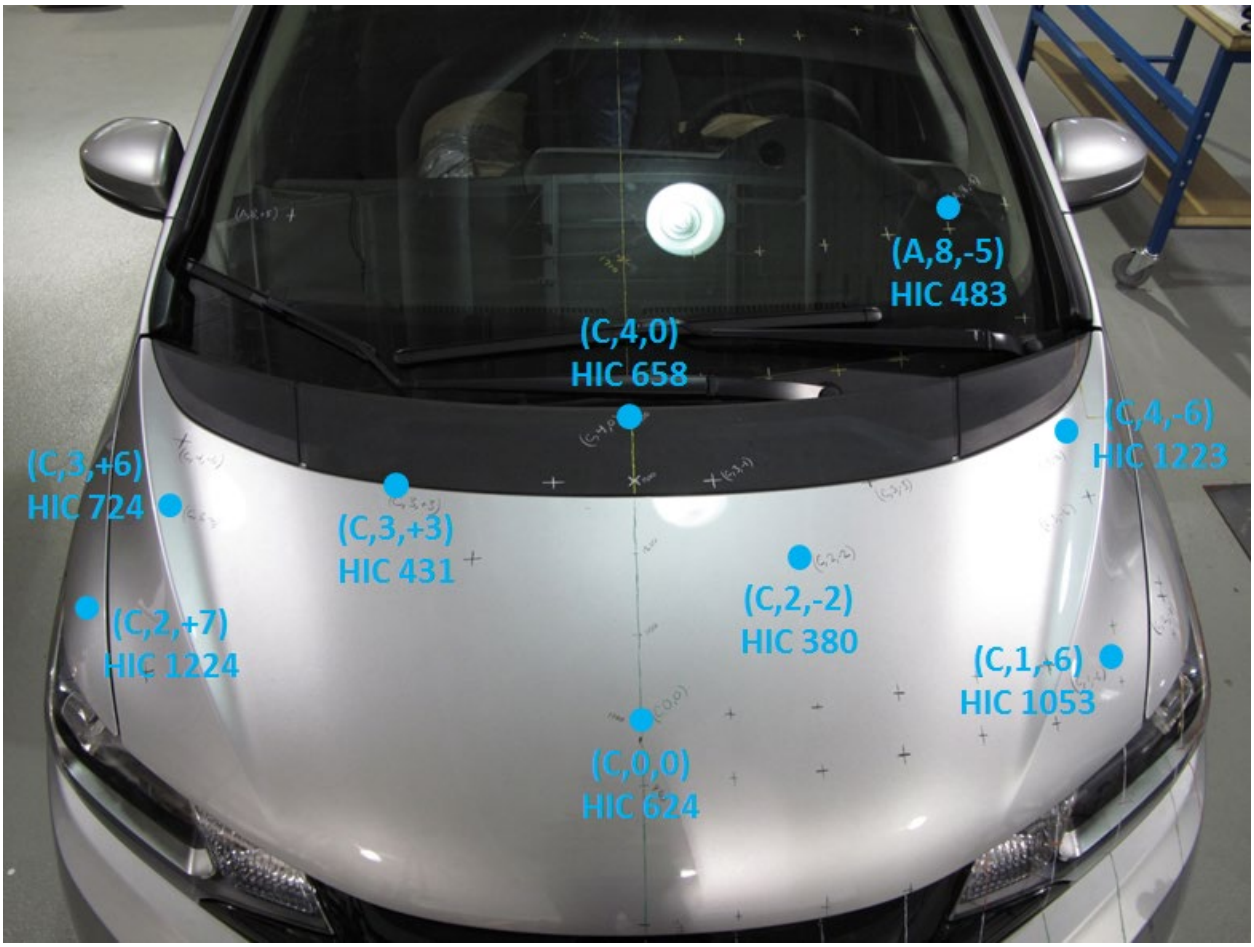


Figure F-1. 2016 Honda Fit selected headform impact points, their corresponding grid coordinates, and HIC results.

HIC results and corresponding points for the selected impact points are shown in Table F-2 below. The 2016 Honda Fit earned 7 points out of a possible 9 points, resulting in a score of 18.7. For reference, the Euro NCAP scores for a European variant of this vehicle are also shown.

Table F-2. 2016 Honda Fit headform impact locations and HIC scores in tests by NHTSA and Euro NCAP.

			HIC SCORES			
Test No.	**Grid point**		**NHTSA (pts)**		***Euro NCAP (for ref only)***	***Honda Predicted (for ref only)***
1617	C	0,0	**624**	**1**	**---**	***< 650***
1618	C	3,6	**724**	**0.75**	**---**	***1000-1350***
1619	C	4,-6	**1223**	**0.50**	**---**	***1350-1700***
1620	C	4,0	**658**	**0.75**	**---**	***1000-1350***
1621	C	1,-6	**1053**	**0.50**	**---**	***1000-1350***
1622	C	2,7	**1224**	**0.50**	**---**	***1350 - 1700***
1623	A	8,-5	**483**	**1**	**---**	***< 650***
1630	C	3,3	**431**	**1**	**---**	***650-1000***
1631	C	2,-2	**380**	**1**	**---**	***< 650***
---	C	1,1	---	---	***542***	***< 650***
---	C	7,6	---	---	***9999***	***> 1700***
---	A	11,-5	---	---	***427***	***< 650***
---	C	1,-5	---	---	***1011***	***1000 - 1350***
---	C	4,2	---	---	***509***	***650 - 1000***
---	C	6,-4	---	---	***1166***	***1350 - 1700***
---	C	4,-5	---	---	***880***	***1000 - 1350***
---	C	6,3	---	----	***965***	***650 - 1000***
---	C	5,6	---	---	***810***	***650 - 1000***
---	C	4,0	---	---	***571***	***650 - 1000***
Total Points (9 max)			**7.0**			
Score			**18.7**		***17.01***	

Lower Legform Testing

The bumper test zone is defined as either the area limited by the bumper corners or the outermost ends of the underlying bumper beam, whichever is larger. The distance from the bumper corner of the fascia to the centerline was measured to be 530 mm. The distance from the outermost ends of the underlying bumper beam to the centerline of the 2016 Honda Fit was measured to be 604 mm. The bumper test zone is the larger of the two distances, and for the 2016 Honda Fit, is 604 mm from the centerline. Grid points are located every 100 mm from the centerline in both lateral directions resulting in 13 grid points for the 2016 Honda Fit. Non-tested grid points are awarded the worst result from one of the adjacent points. In addition, symmetry will be applied to all grid points. Given these conditions, three test points were tested and are shown in Figure F-2 below.

Figure F-2. 2016 Honda Fit selected lower legform impact points

Lower legform results for the selected impact points are shown in Table F-3 below and the corresponding score is shown in Table F-4. Results that fall below the lower limit are highlighted in green, above the upper limit are in red, and between the lower and upper limits are in orange. Following Euro NCAP guidelines, the 2016 Honda Fit earned 0 points out of a possible 13 points, resulting in a score of 0.0.

Table F-3. 2016 Honda Fit lower legform impact locations and corresponding results.

		Tibia Bending Limits				*Ligament Elongation Limits*		
		282-340 Nm				*19-22 mm*	*10 mm*	
Test #	**Location**	**Tibia 1**	**Tibia 2**	**Tibia 3**	**Tibia 4**	**MCL**	**ACL**	**PCL**
LL 1602	L-5	394	325	218	152	21.6	15.9	8.2
LL 1603	L+3	469	401	241	130	26.2	15.9	7.2
LL 1604	L-1	435	391	259	119	27.9	15.6	7.5
European Variant (ref only)	*L +6*	*156*	*139*	*95*	*94*	*13.8*	*6.7*	*6.6*
	L 0	*149*	*172*	*156*	*111*	*16.2*	*5.5*	*4.7*
	L -2	*146*	*170*	*151*	*131*	*15.0*	*5.7*	*4.6*
	L -4	*129*	*188*	*206*	*143*	*11.3*	*5.3*	*3.9*

Table F-4. 2016 Honda Fit lower legform grid points and score,

Location	**Points on U.S. variant**			***Points on Euro. variant (for ref. only)***
	Bending	**Elongation**	**Total**	
L+6	0	0	**0**	*1*
L+5	0	0	**0**	*1*
L+4	0	0	**0**	*1*
L+3	0	0	**0**	*1*
L+2	0	0	**0**	*1*
L+1	0	0	**0**	*1*
L0	0	0	**0**	*1*
L-1	0	0	**0**	*1*
L-2	0	0	**0**	*1*
L-3	0	0	**0**	*1*
L-4	0	0	**0**	*1*
L-5	0	0	**0**	*1*
L-6	0	0	**0**	*1*
Points Total (Out of Max Possible 13 Points)	**0**			***13.0***
Score	**0**			***6.0***

Upper Legform Testing

Since the lower bumper reference line is less than 425 mm, upper legform impacts were performed at the wrap around distance (WAD) 775 mm. Starting at the vehicle's centerline, grid points are marked every 100 mm in both lateral directions along the WAD 775 mm line up to the corner reference points. Grid points less than 50 mm from the corner reference points are deleted. As with lower leg testing, non-tested grid points are awarded the worst result from one of the adjacent points. In addition, symmetry will be applied to all grid points. Given these conditions, three test points were tested and are shown in Figure F-3 below.

Figure F-3. 2016 Honda Fit selected upper legform impact points

Upper legform results for the selected impact points are shown in Table F-5 below. Results that fall below the lower limit are highlighted in green, above the upper limit are in red, and between the lower and upper limits are in orange. The possible number of points awarded for each injury measure is shown in Table F-6 below. The 2016 Honda Fit earned 13 points out of a possible 13 points, resulting in score of 6.0.

Table F-5. 2016 Honda Fit upper legform impact locations and corresponding results.

Test #	Location	Angle (°)	Energy (J)	Femur Bending Moment Limits: 285 – 350 Nm			Sum Femur Loads (N) Limits: 5-6 kN
				Upper	Middle	Lower	
UL 1601	U-1	39.0	214	132	150	128	2757
UL 1602	U+3	38.9	215	193	231	204	3531
UL 1603	U-5	40.7	198	227	245	195	4585
European Variant (ref only)	*U +6*	---	*199*	*155*	*156*	*127*	*3490*
	U +4	---	*203*	*314*	*351*	*285*	*4830*
	U 0	---	*216*	*163*	*210*	*202*	*3330*
	U -2	---	*212*	*154*	*209*	*204*	*3160*

Table F-6. Points awarded for each injury measure and resulting score for the upper legform tests. Upper leg performance for each grid point is based on the worst performing parameter.

Location	Points on U.S. variant			*Points on Euro. variant (ref only)*
	Bending	Force	Total	
U+6	1	1	1	1.00
U+5	1	1	1	**0.00**
U+4	1	1	1	**0.00**
U+3	1	1	1	**0.00**
U+2	1	1	1	1.00
U+1	1	1	1	1.00
U0	1	1	1	1.00
U-1	1	1	1	1.00
U-2	1	1	1	1.00
U-3	1	1	1	**0.00**
U-4	1	1	1	**0.00**
U-5	1	1	1	**0.00**
U-6	1	1	1	1.00
Points Total (Out of Max Possible 13 Points)	**13**			***7.00***
Score	**6.0**			***3.23***

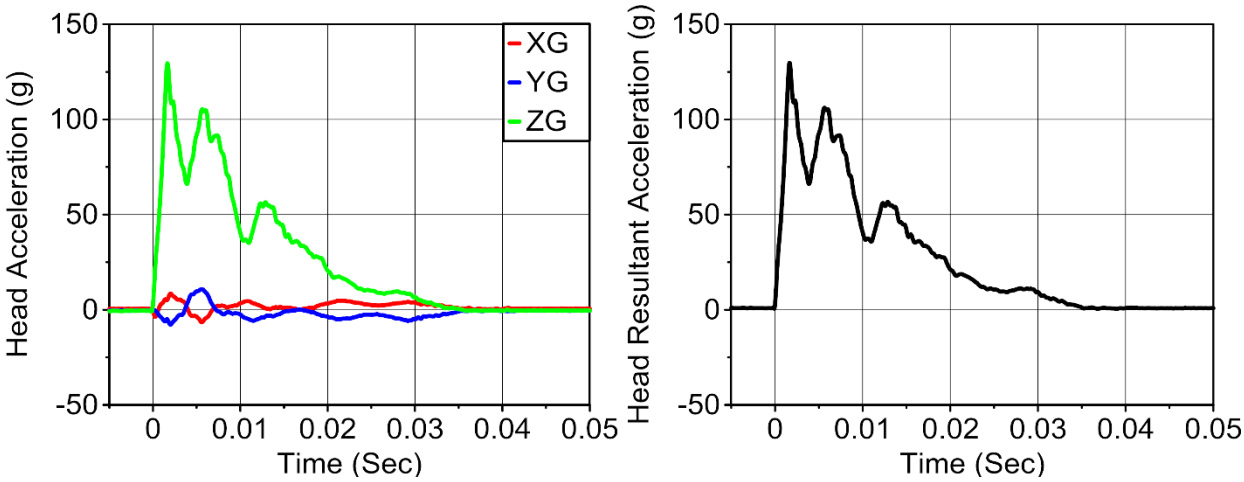
Summary

Table F-7. Summary of results for the 2016 Honda Fit

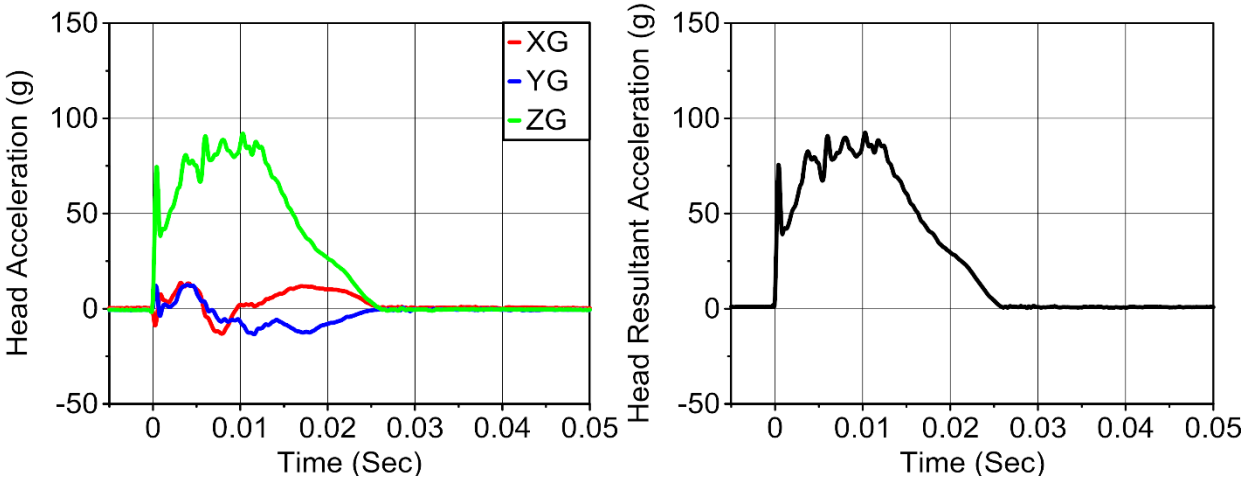
2016 Honda Fit	Head	Lower Leg	Upper Leg	Total	% of Max
Score (Out of 36)	18.7	0.0	6.0	**24.7**	**68.6%**

Headform Impact Data Traces

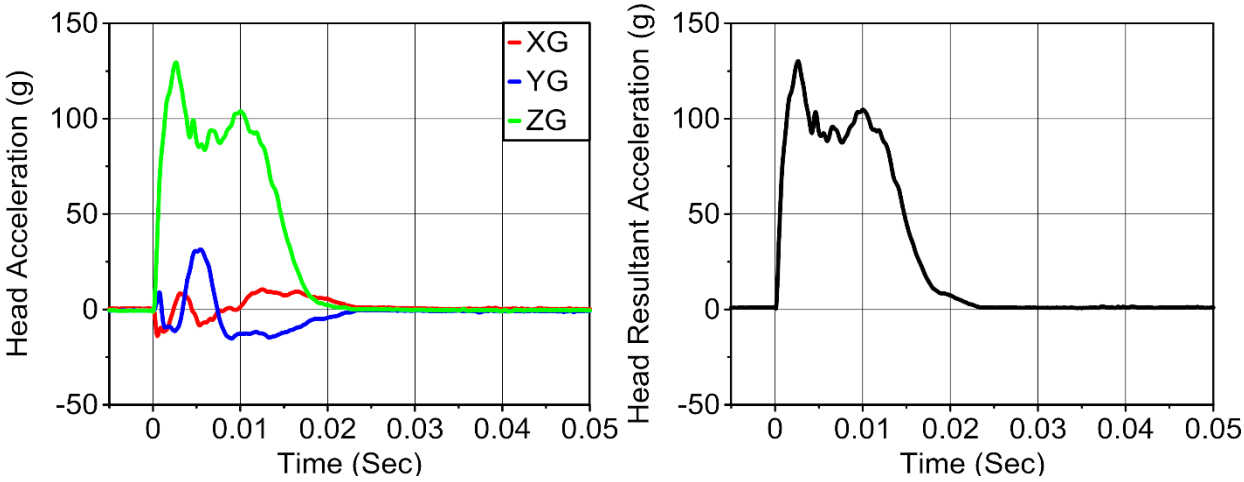
ChildHead 1617



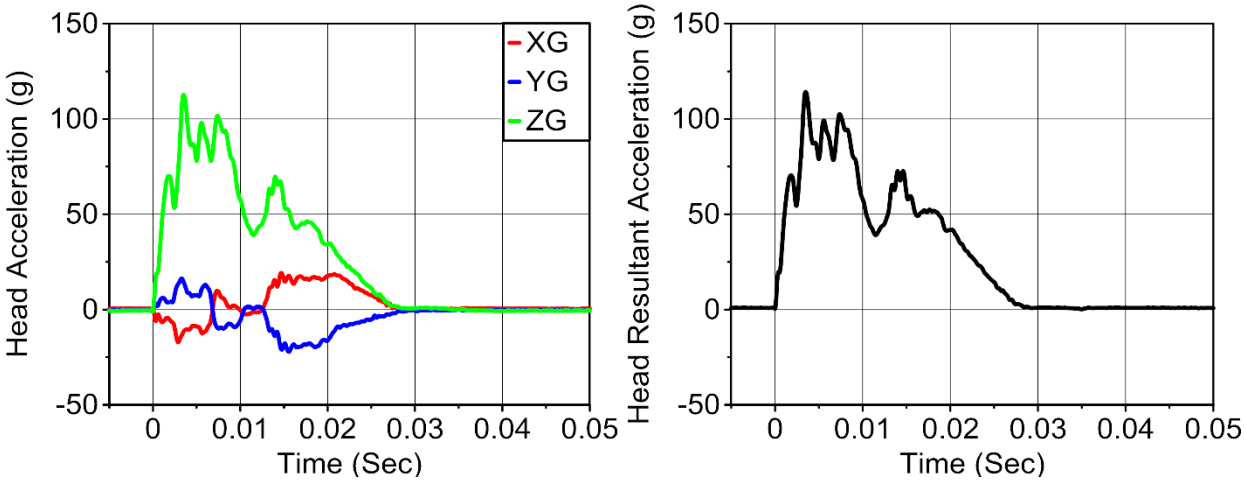
ChildHead 1618



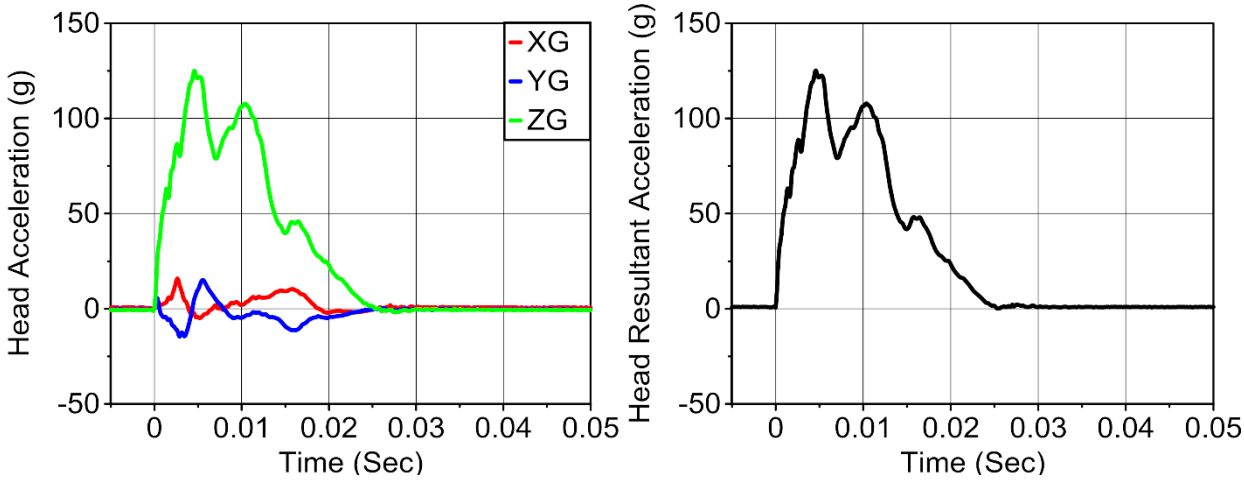
ChildHead 1619



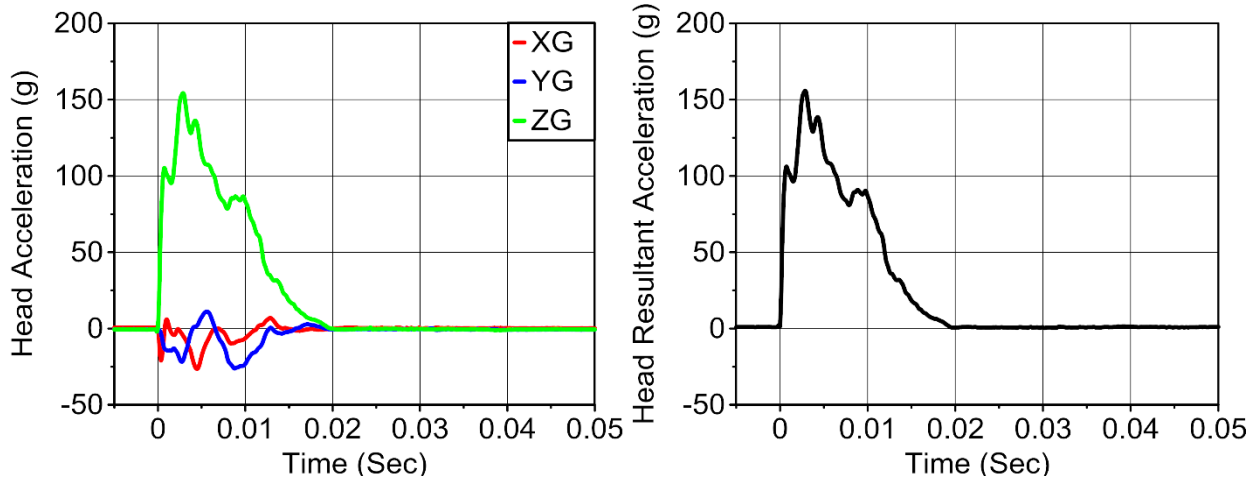
ChildHead 1620



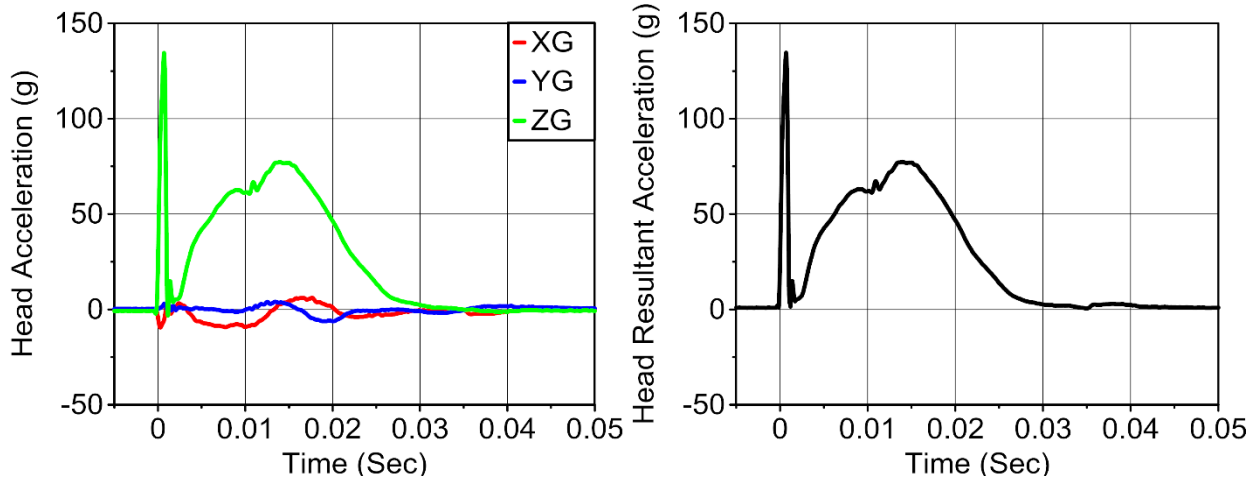
ChildHead 1621



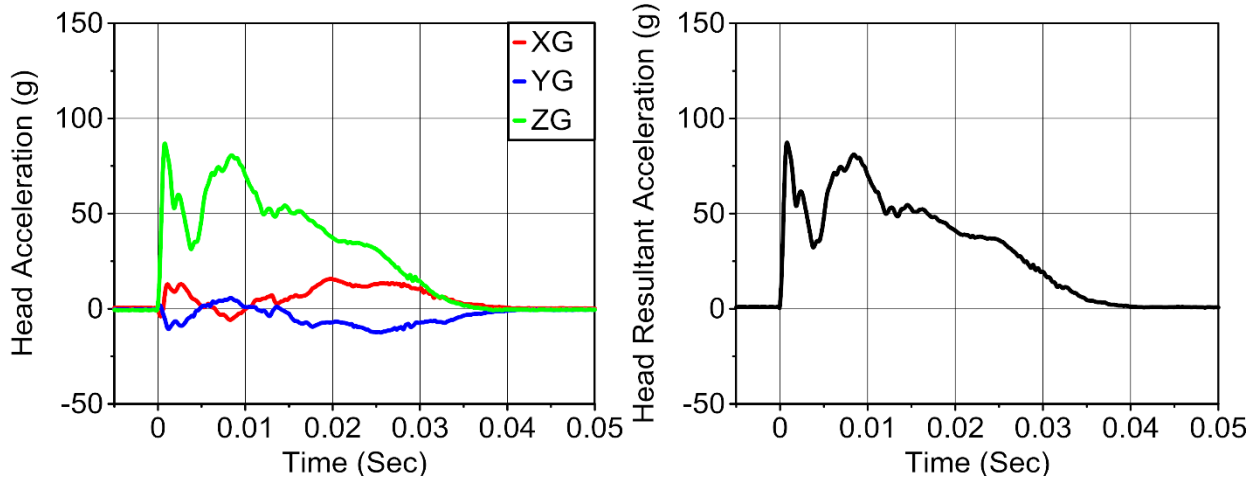
ChildHead 1622



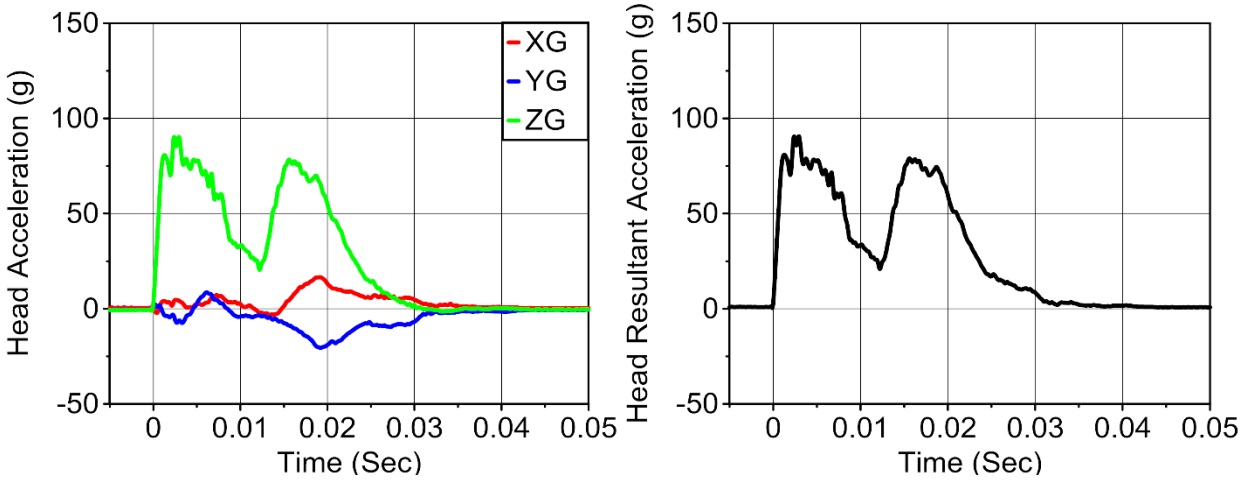
AdultHead 1623



ChildHead 1630

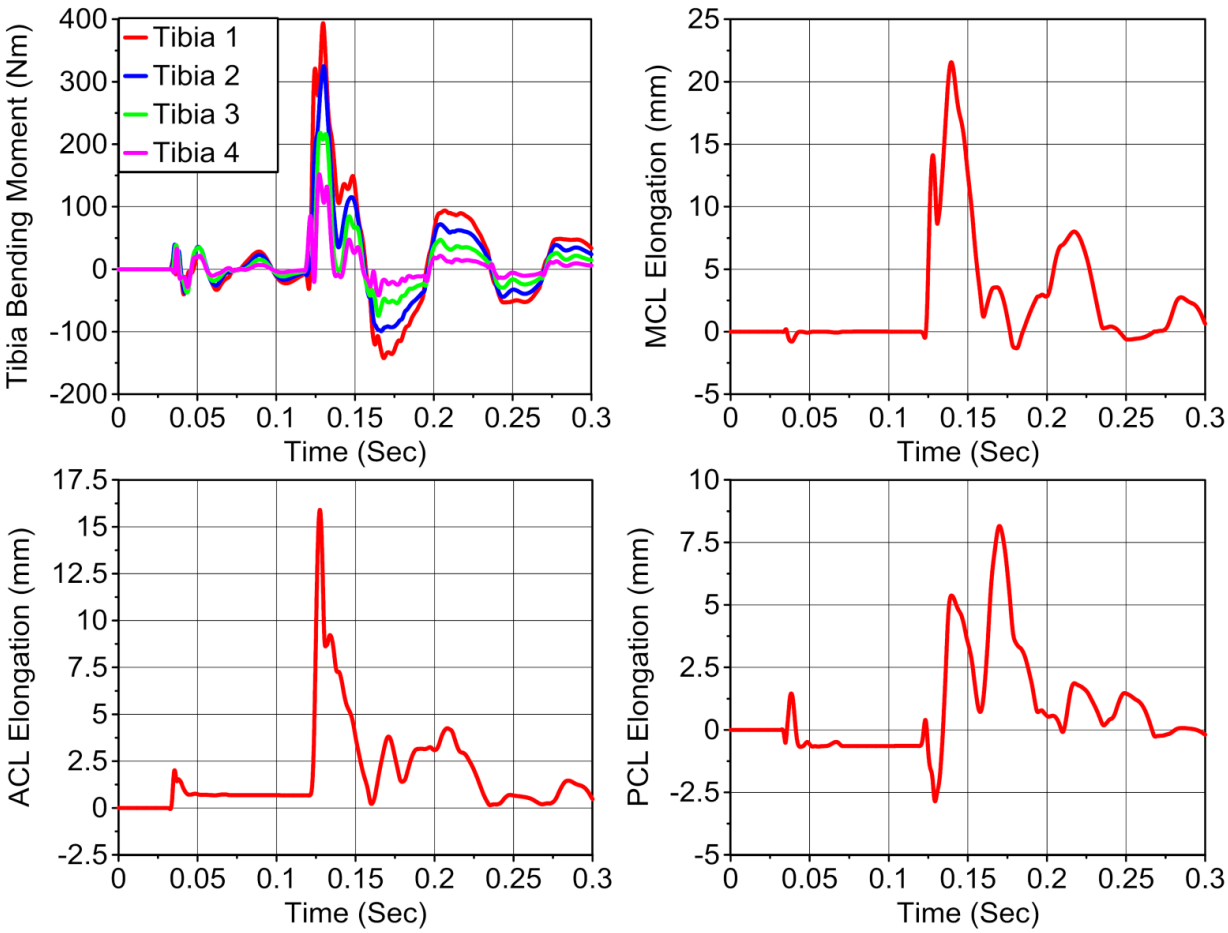


ChildHead 1631

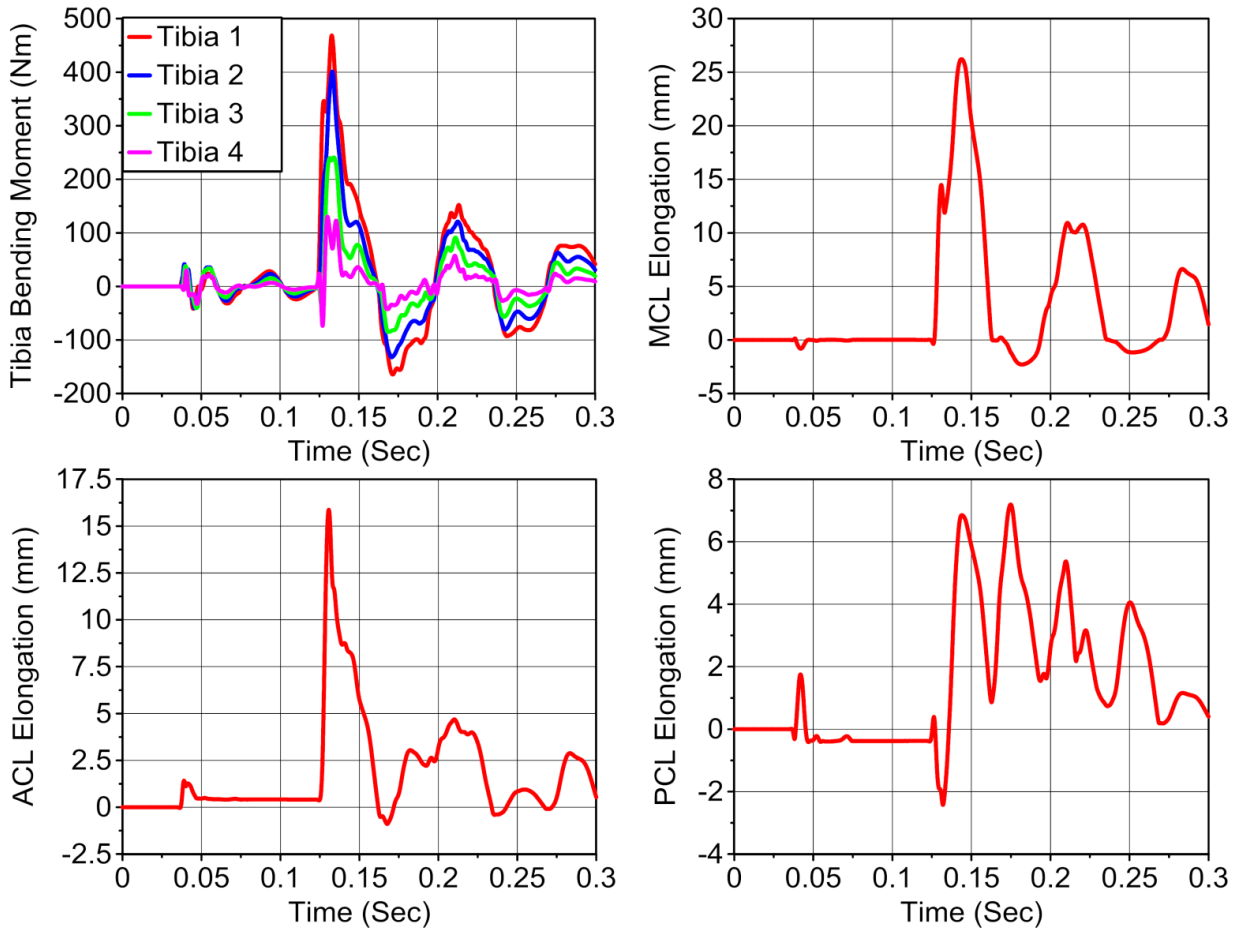


Lower Legform Impact Data Traces

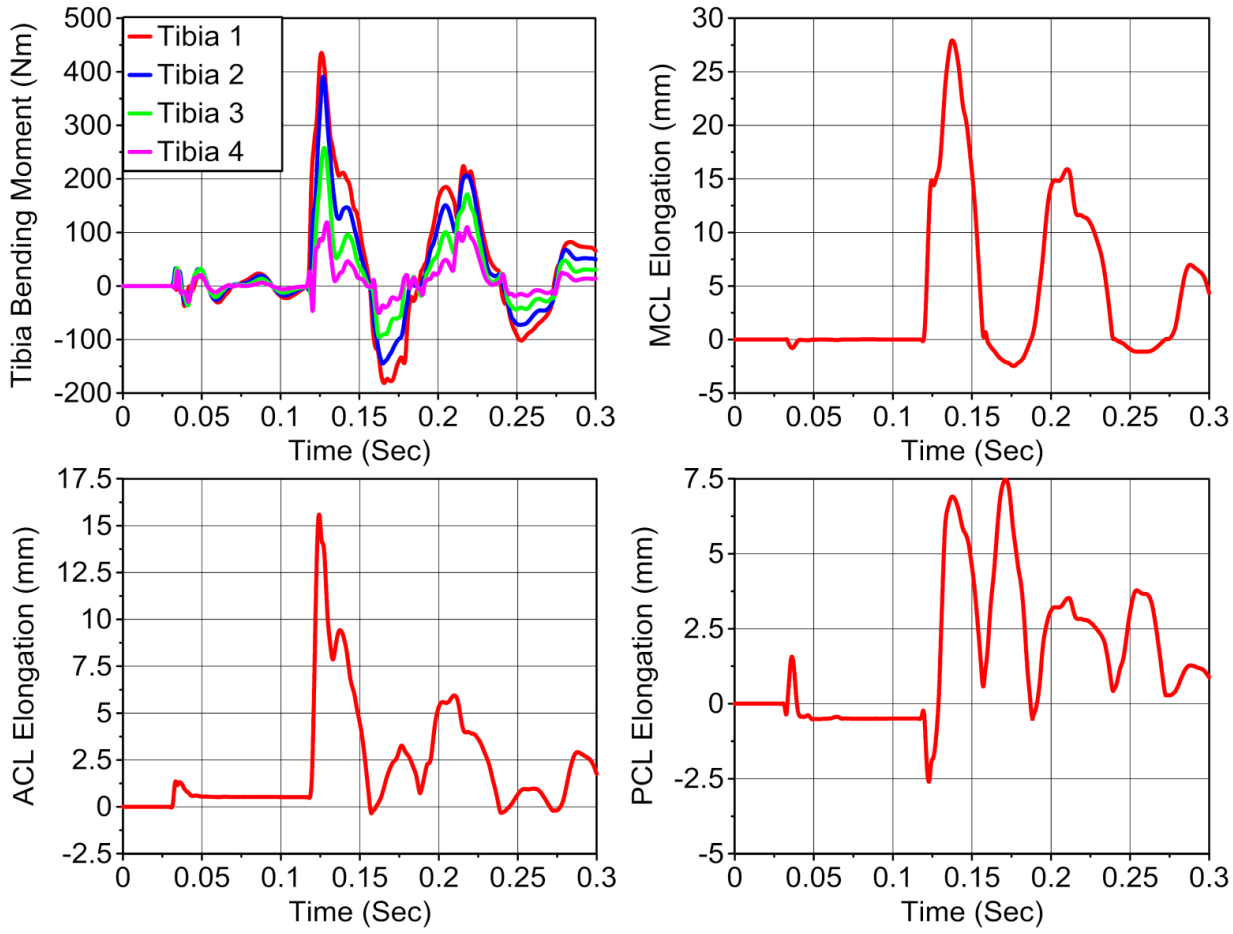
LL 1602



LL 1603

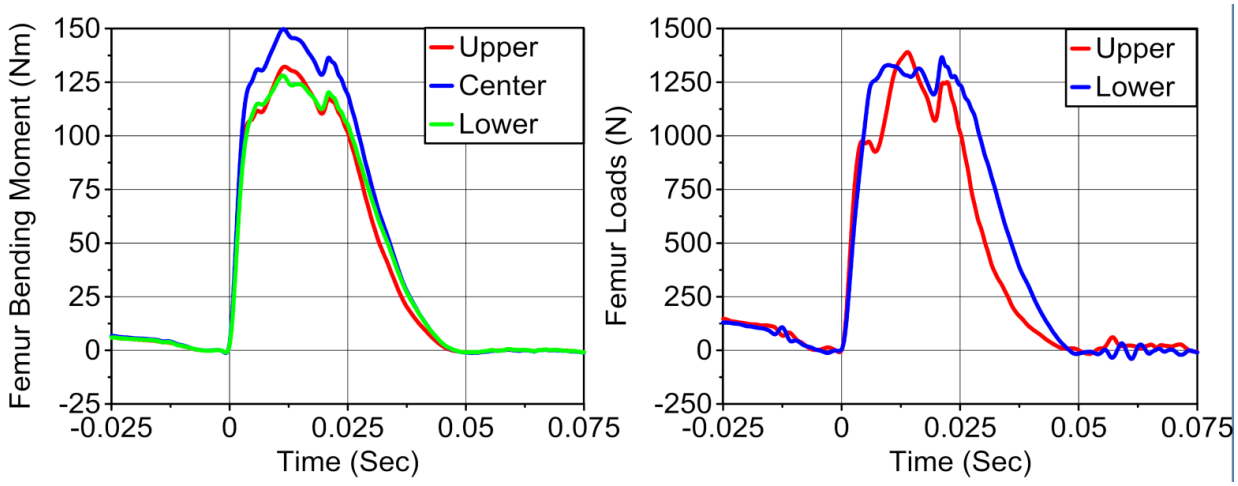

Tibia 1
Tibia 2
Tibia 3
Tibia 4
Tibia Bending Moment (Nm)
Time (Sec)
MCL Elongation (mm)
Time (Sec)
ACL Elongation (mm)
Time (Sec)
PCL Elongation (mm)
Time (Sec)

LL 1604

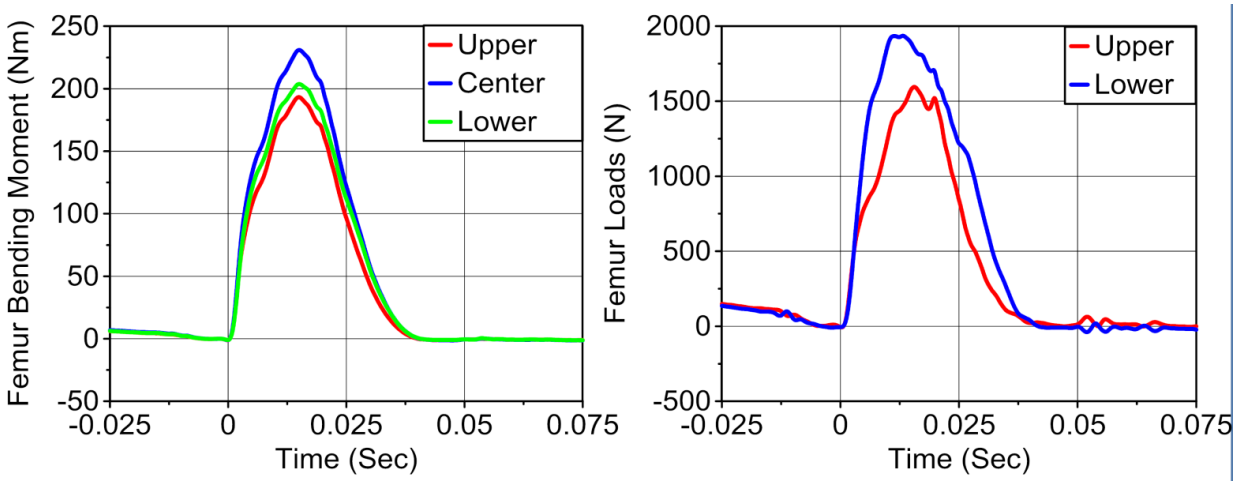

Tibia 1
Tibia 2
Tibia 3
Tibia 4
Tibia Bending Moment (Nm)
MCL Elongation (mm)
ACL Elongation (mm)
PCL Elongation (mm)
Time (Sec)

Upper Legform Impact Data Traces

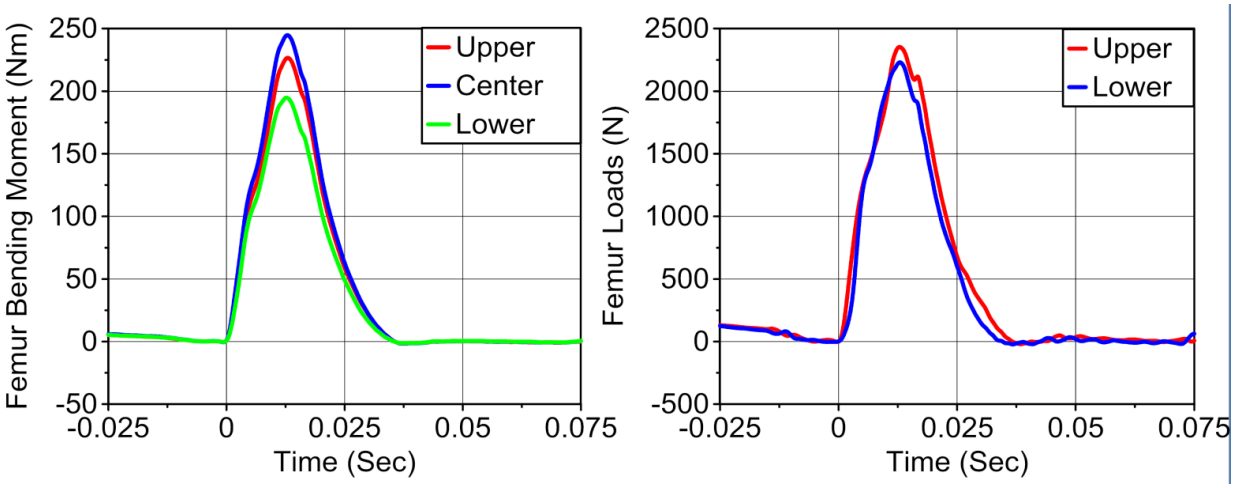
UL 1601



UL 1602



UL 1603

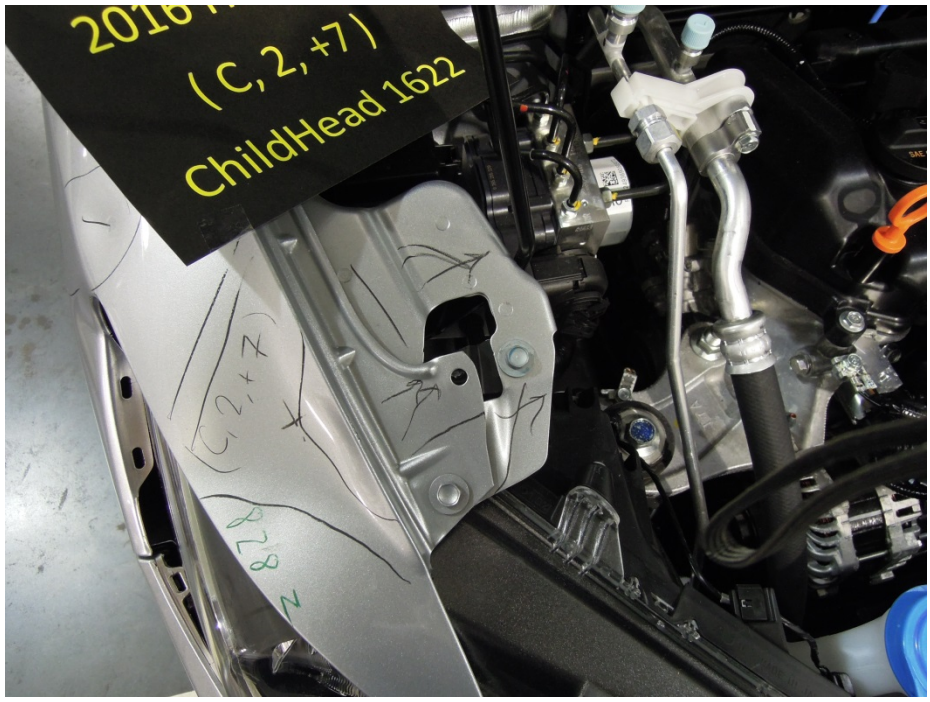


Examples of Post-Test Vehicle Damage

AdultHead 1623

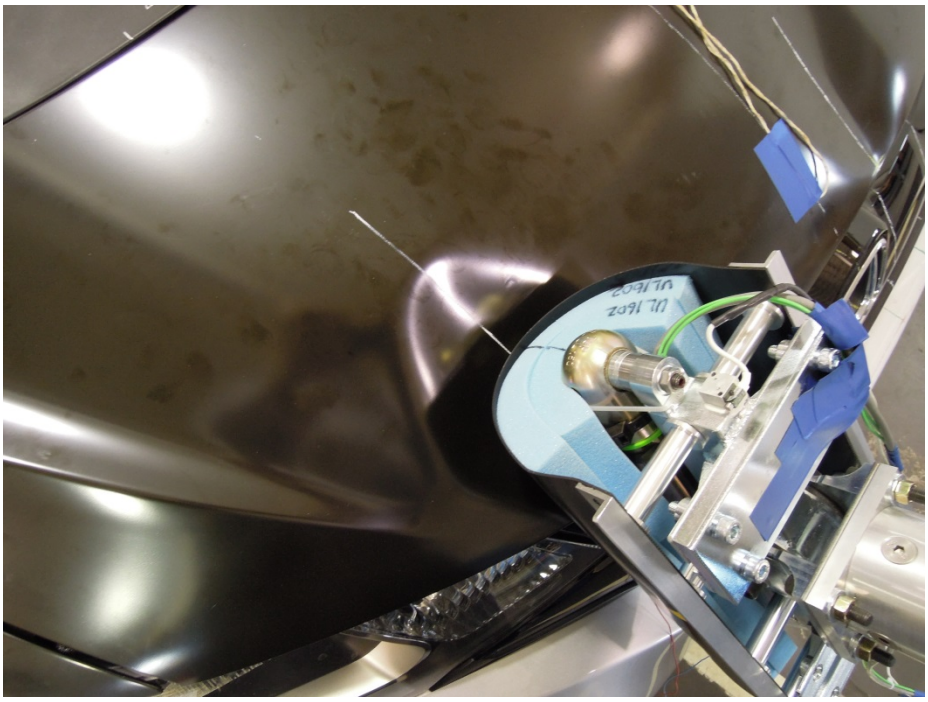
ChildHead 1619

ChildHead 1622



LL 1603

UL 1602



Appendix G: 2016 Nissan Rogue

Overview

A 2016 Nissan Rogue was tested.

Exemplar 2016 Nissan Rogue

Vehicle Information

Pertinent vehicle information is listed in Table G-1 below. Descriptions for the lateral hood width and front-end width can be found in Appendix J.

Table G-1. Vehicle information

Make	Nissan
Model	Rogue
Year	2016
VIN	KNMAT2MV3GP617410
Type	Small SUV
GVWR	2122 kg
Lateral Hood Width	1546 mm
Front End Width	1820 mm

Headform Testing

For the 2016 Nissan Rogue, 11 points were chosen and are shown in Figure G-1 below.

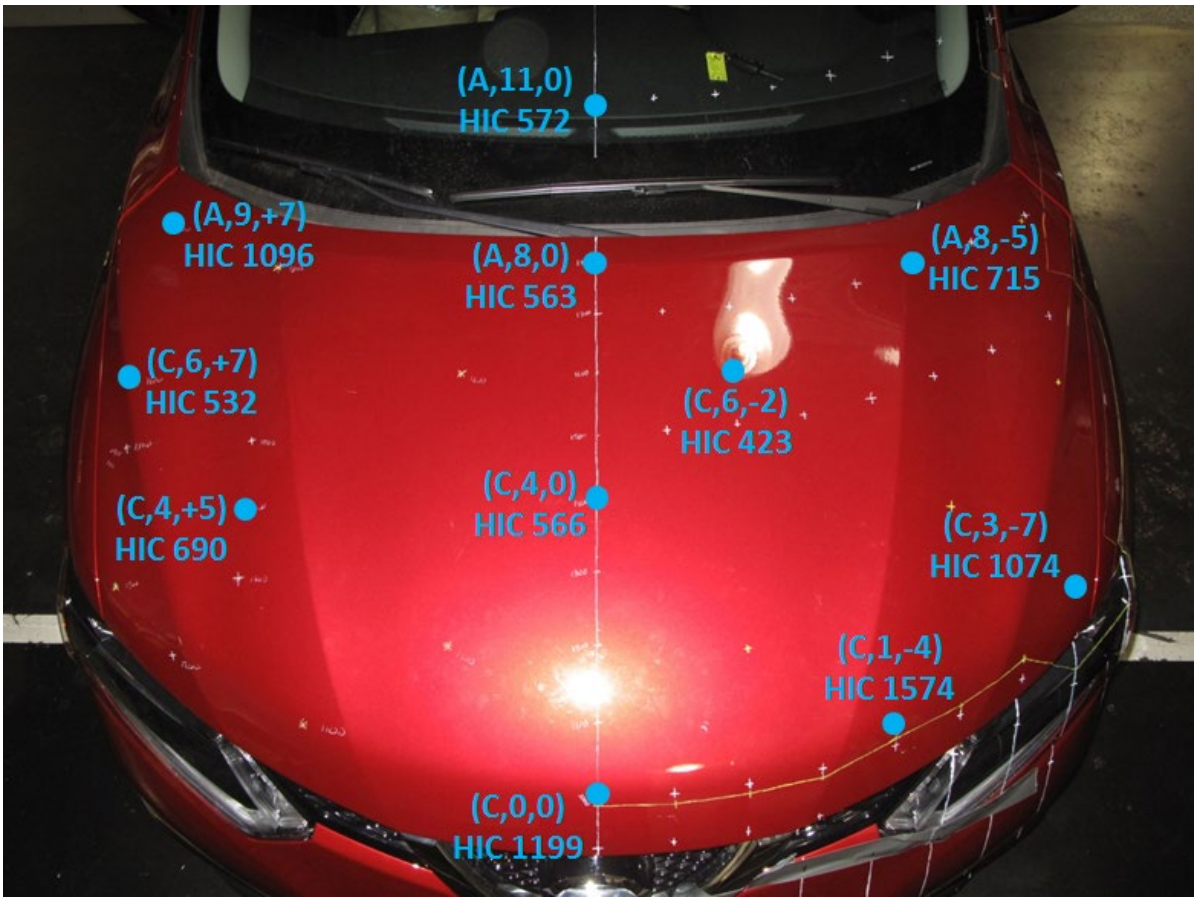


Figure G-1. 2016 Nissan Rogue selected headform impact points, their corresponding grid coordinates, and HIC results.

HIC results and corresponding points for the selected impact points are shown in Table G-2 below. The 2016 Nissan Rogue earned 8.25 points out of a possible 11 points, resulting in a score of 18.0. For reference, the Euro NCAP scores for a European variant of this vehicle are also shown.

Table G-2. 2016 Nissan Rogue headform impact locations and HIC scores, NHTSA and Euro NCAP.

			HIC SCORES			
Test No.	**Grid point**		**NHTSA (pts)**		**Euro NCAP (for ref only)**	**Nissan Predicted (for ref only)**
1601	A	11,0	**572**	**1**	**---**	***< 650***
1602	A	8,0	**563**	**1**	***711***	***650 - 1000***
1603	A	8,-5	**715**	**0.75**	**---**	***650 – 1000***
1604	A	9,7	**1096**	**0.5**	**---**	***650 - 1000***
1605	C	0,0	**1199**	**0.5**	**---**	***1000 - 1350***
1606	C	1,-4	**1574**	**0.25**	**---**	***1000 - 1350***
1607	C	6,-2	**423**	**1**	**---**	***650 - 1000***
1608	C	6,7	**532**	**1**	**---**	***< 650***
1609	C	3,-7	**1074**	**0.5**	**---**	***1350 - 1700***
1610	C	4,0	**566**	**1**	**---**	***650 - 1000***
1611	C	4,5	**690**	**0.75**	**---**	***650 - 1000***
---	C	1,3	---	---	***762***	***650 - 1000***
---	C	2,-2	---	---	***807***	***650 - 1000***
---	C	4,-7	---	---	***1019***	***650 - 1000***
---	C	5,2	---	---	***704***	***1000 - 1350***
---	C	6,0	---	---	***758***	***650 - 1000***
---	A	7,4	---	---	***647***	***650 - 1000***
---	A	8,-6	---	---	***746***	***< 650***
---	A	10,-1	---	----	***1139***	***650 - 1000***
---	A	10,-7'	---	---	***1377***	***1350 - 1700***
---	C	1,3	---	---	***762***	***650 - 1000***
Total Points (11 max)			**8.25**			
Score			**18.0**		***15.44***	

Lower Legform Testing

The bumper test zone is defined as either the area limited by the bumper corners or the outermost ends of the underlying bumper beam, whichever is larger. The distance from the bumper corner of the fascia to the centerline was measured to be 670 mm. The distance from the outermost ends of the underlying bumper beam to the centerline of the 2016 Nissan Rogue was measured to be 588 mm. The bumper test zone is the larger of the two distances, and for the 2016 Nissan Rogue, is 670 mm from the centerline. Grid points are located every 100 mm from the centerline in both lateral directions resulting in 15 grid points for the 2016 Nissan Rogue. Non-tested grid points are awarded the worst result from one of the adjacent points. In addition, symmetry will be applied to all grid points. Given these conditions, three test points were tested and are shown in Figure G-2 below.

Figure G-2. 2016 Nissan Rogue selected lower legform impact points

Lower legform results for the selected impact points are shown in Table G-3 and the corresponding score is shown in Table G-4. Results that fall below the lower limit are highlighted in green, above the upper limit are in red, and between the lower and upper limits are in orange. Following Euro NCAP guidelines, the 2016 Nissan Rogue earned 13.0 points out of a possible 13 points, resulting in a score of 6.0.

Table G-3. 2016 Nissan Rogue lower legform impact locations and corresponding results.

		Tibia Bending Limits				*Ligament Elongation Limits*		
		282-340 Nm				*19-22 mm*	*10 mm*	
Test #	**Location**	**Tibia 1**	**Tibia 2**	**Tibia 3**	**Tibia 4**	**MCL**	**ACL**	**PCL**
LL 1605	L-5	150	173	177	99	14.2	7.5	4.3
LL 1606	L+3	254	246	244	128	11.2	7	3.7
LL 1611	L-1	207	211	207	116	9.8	6.9	4.5
European Variant (ref only)	*L +4*	*232*	*239*	*244*	*128*	*14.5*	*6.0*	*5.0*
	L +2	*190*	*232*	*256*	*143*	*5.6*	*5.1*	*2.7*
	L 0	*192*	*212*	*226*	*132*	*7.5*	*4.7*	*4.5*
	L -6	*132*	*155*	*170*	*101*	*10.7*	*5.1*	*2.5*

Table G-4. 2016 Nissan Rogue lower legform grid points and score.

Location	**Points on U.S. variant**			***Points on Euro. variant (for ref. only)***
	Bending	**Elongation**	**Total**	
L+7				*1*
L+6	0.5	0.5	1	*1*
L+5	0.5	0.5	1	*1*
L+4	0.5	0.5	1	*1*
L+3	0.5	0.5	1	*1*
L+2	0.5	0.5	1	*1*
L+1	0.5	0.5	1	*1*
L0	0.5	0.5	1	*1*
L-1	0.5	0.5	1	*1*
L-2	0.5	0.5	1	*1*
L-3	0.5	0.5	1	*1*
L-4	0.5	0.5	1	*1*
L-5	0.5	0.5	1	*1*
L-6	0.5	.05	1	*1*
L-7				*1*
Points Total (Out of Max Possible 13 Points)	**13.0**			***15.0***
Score	**6.0**			***6.0***

Upper Legform Testing

Since the lower bumper reference line is less than 425 mm, upper legform impacts were performed at the wrap around distance (WAD) 775 mm. Starting at the vehicle's centerline, grid points are marked every 100 mm in both lateral directions along the WAD 775 mm line up to the corner reference points. Grid points less than 50 mm from the corner reference points are deleted. As with lower leg testing, non-tested grid points are awarded the worst result from one of the adjacent points. In addition, symmetry will be applied to all grid points. Given these conditions, four test points were tested and are shown in Figure G-3 below.

Figure G-3. 2016 Nissan Rogue selected upper legform impact points

Upper legform results for the selected impact points are shown in Table G-5 below. Results that fall below the lower limit are highlighted in green, above the upper limit are in red, and between the lower and upper limits are in orange. The possible number of points awarded for each injury measure is shown in Table G-6 below. The 2016 Nissan Rogue earned 15 points out of a possible 15 points, resulting in a score of 6.0.

Table G-5. 2016 Nissan Rogue upper legform impact locations and corresponding results.

Test #	Location	Angle (°)	Energy (J)	Femur Bending Moment Limits: 285 – 350 Nm			Sum Femur Loads (N) Limits: 5-6 kN
				Upper	Middle	Lower	
UL 1610	U+3	19.1	387	104	104	91	4373
UL 1611	U-1	16.8	402	148	171	147	4421
UL 1612	U-5	22.1	366	182	200	168	4239
UL 1613	U+7	24.1	350	148	153	128	3518
European Variant (ref only)	*U +6*	---	---	*287*	*301*	*263*	*4643*
	U +3	---	---	*225*	*240*	*225*	*4846*
	U 0	---	---	*143*	*196*	*218*	*4576*
	U -2	---	---	*177*	*207*	*212*	*4540*
	U -3	---	---	*207*	*235*	*249*	*4817*
	U -4	---	---	*212*	*255*	*256*	*5097*
	U -8	---	---	*187*	*205*	*192*	*4307*

Table G-6. Points awarded for each injury measure and resulting score for the upper legform tests. Upper leg performance for each grid point is based on the worst performing parameter.

Location	Points on U.S. variant			*Points on Euro. variant (ref only)*
	Bending	Force	Total	
U+8				1.00
U+7	1	1	1	0.75
U+6	1	1	1	0.75
U+5	1	1	1	0.75
U+4	1	1	1	0.90
U+3	1	1	1	1.00
U+2	1	1	1	1.00
U+1	1	1	1	1.00
U0	1	1	1	1.00
U-1	1	1	1	1.00
U-2	1	1	1	1.00
U-3	1	1	1	1.00
U-4	1	1	1	0.90
U-5	1	1	1	0.75
U-6	1	1	1	0.75
U-7	1	1	1	0.75
U-8				1.00
Points Total (Out of Max Possible 15 Points)	**15.0**			***15.30***
Score	**6.0**			***5.40***

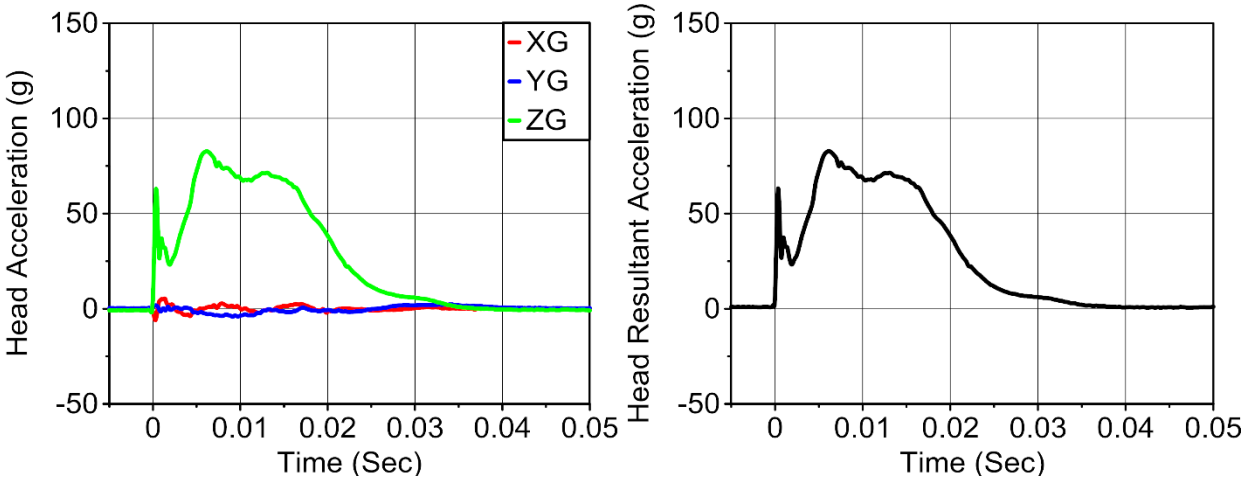
Summary

Table G-7. Summary of results for the 2016 Nissan Rogue

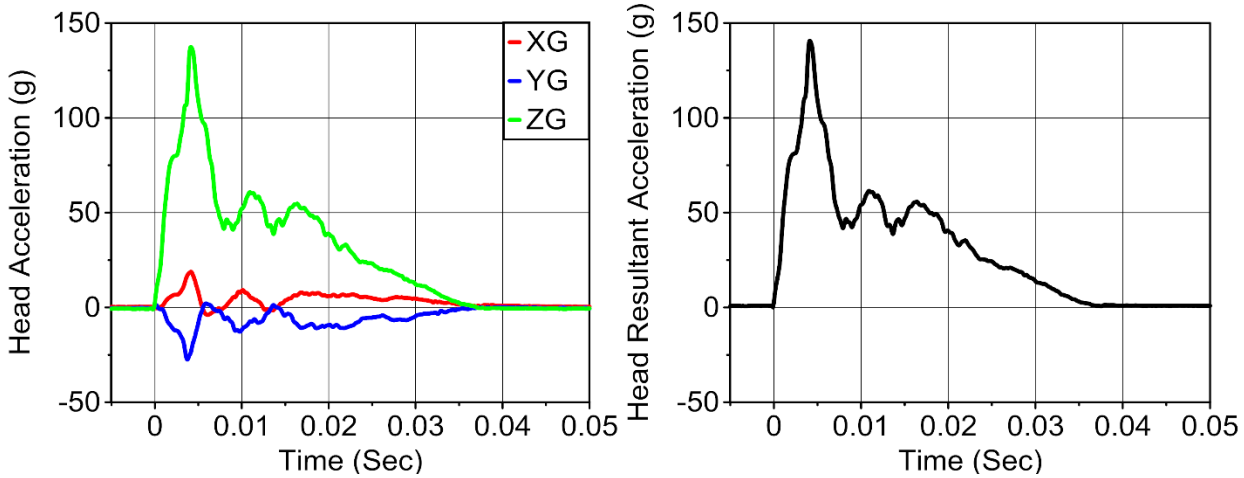
2016 Nissan Rogue	Head	Lower Leg	Upper Leg	Total	% of Max
Score (Out of 36)	18.0	6.0	6.0	**30.0**	**83.3%**

Headform Impact Data Traces

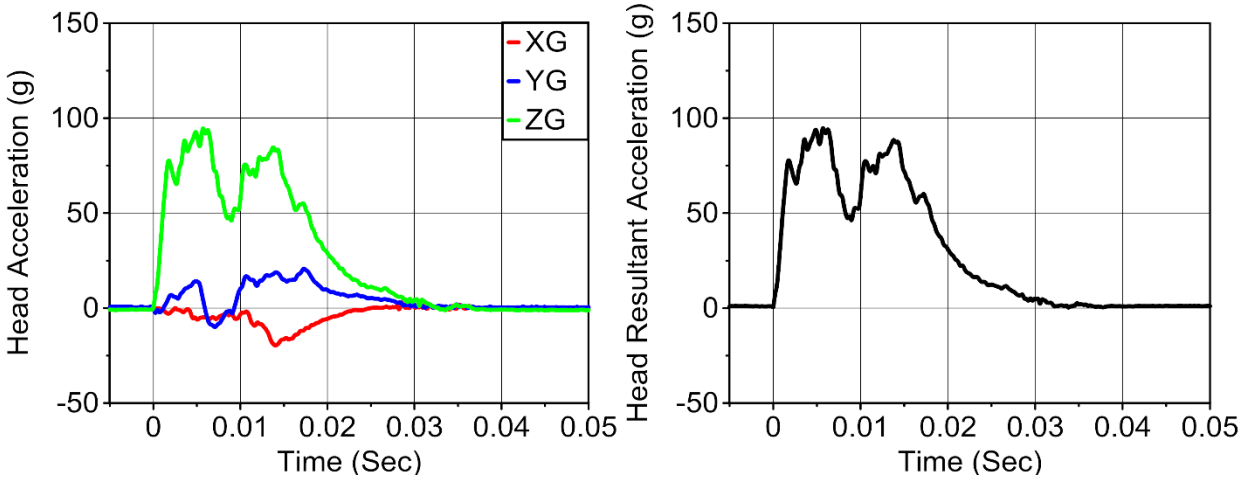
AdultHead 1601



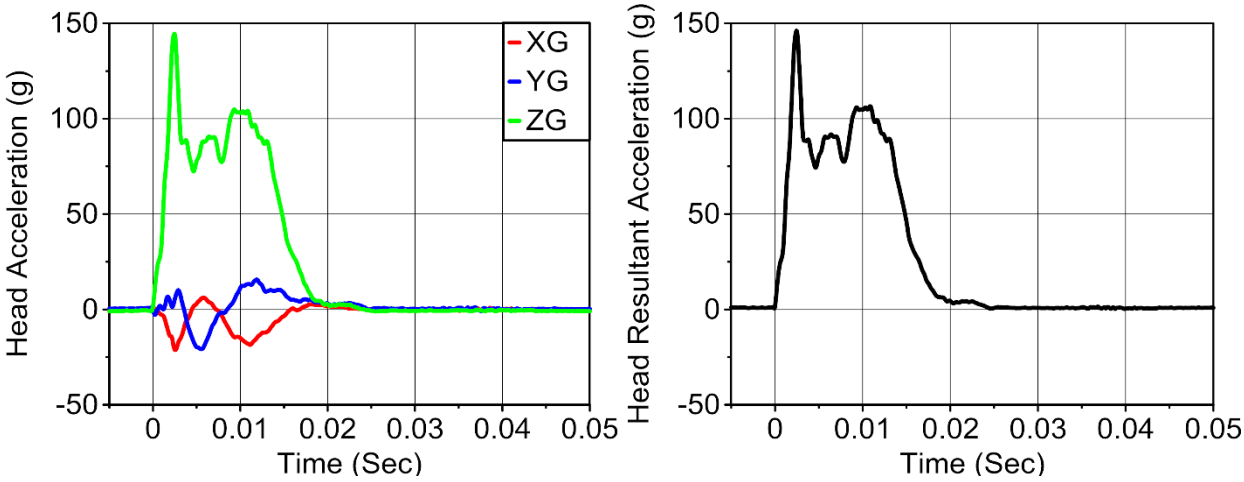
AdultHead 1602



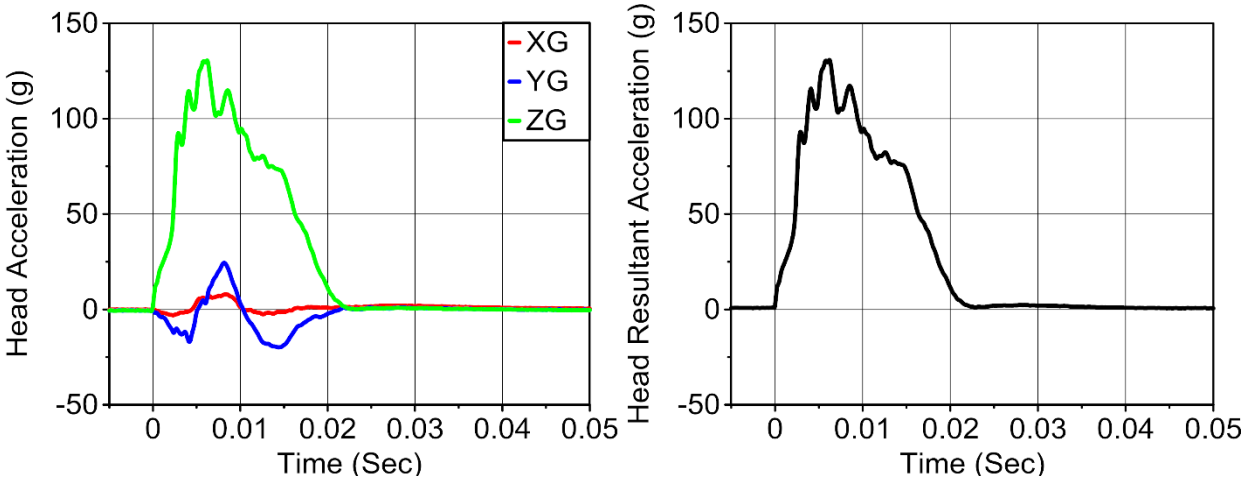
AdultHead 1603



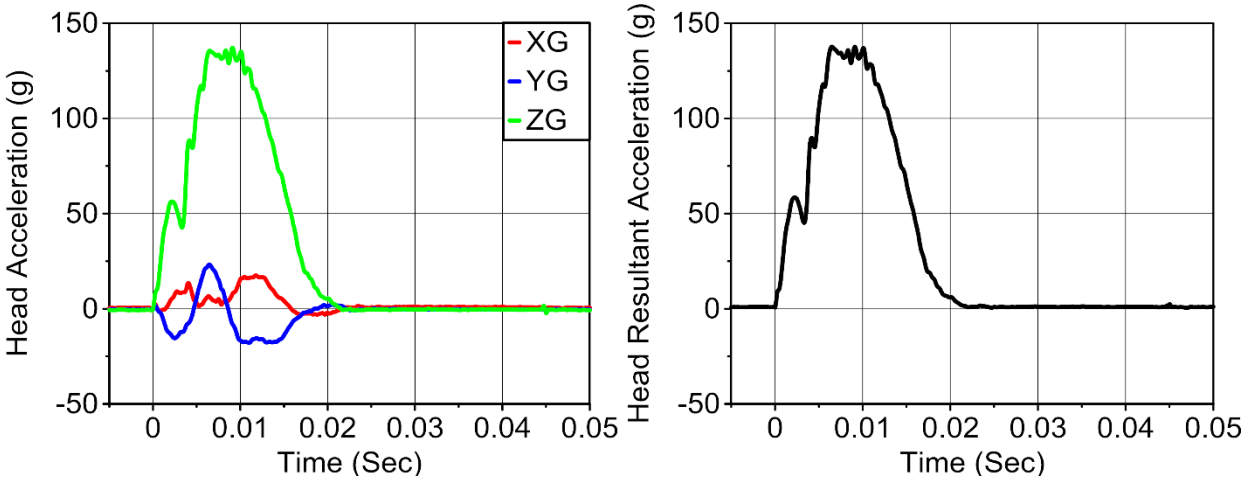
AdultHead 1604



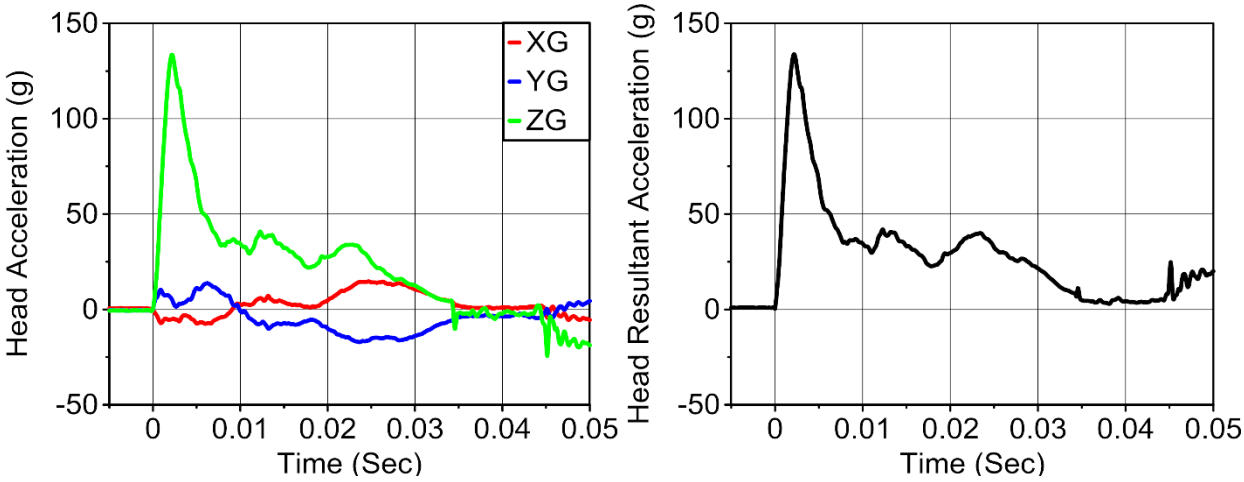
ChildHead 1605



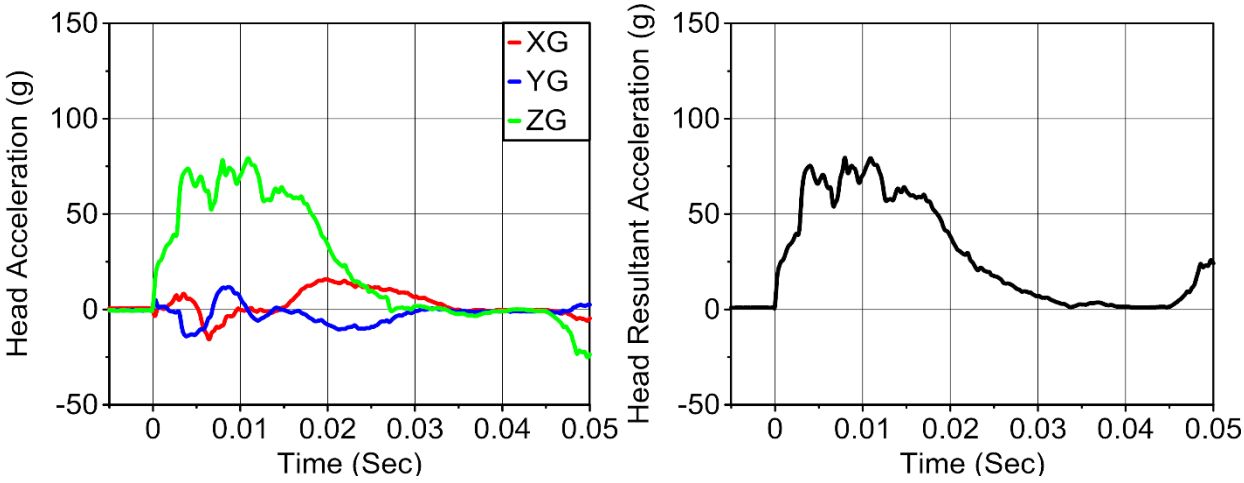
ChildHead 1606



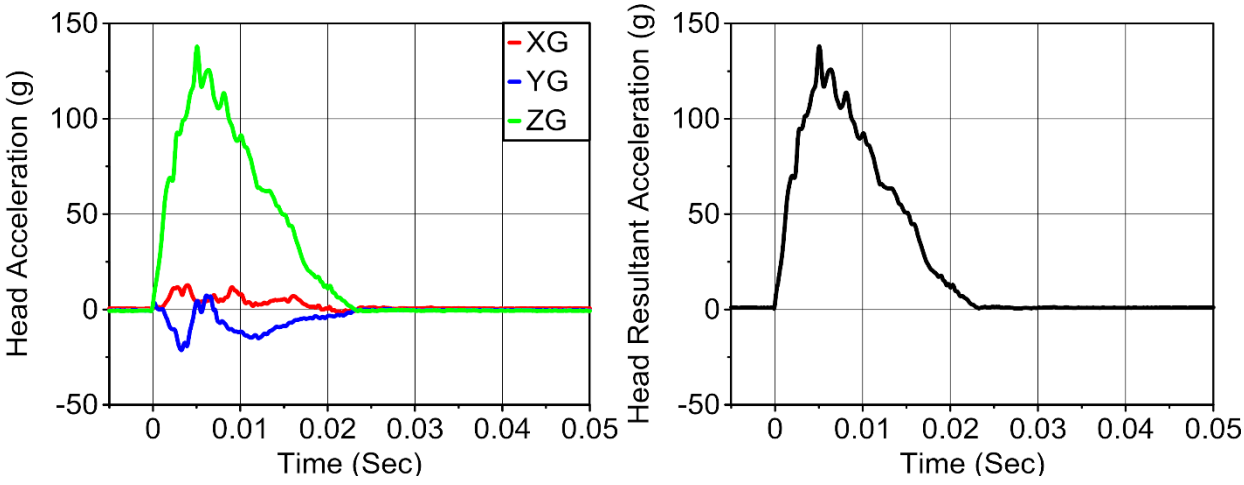
ChildHead 1607



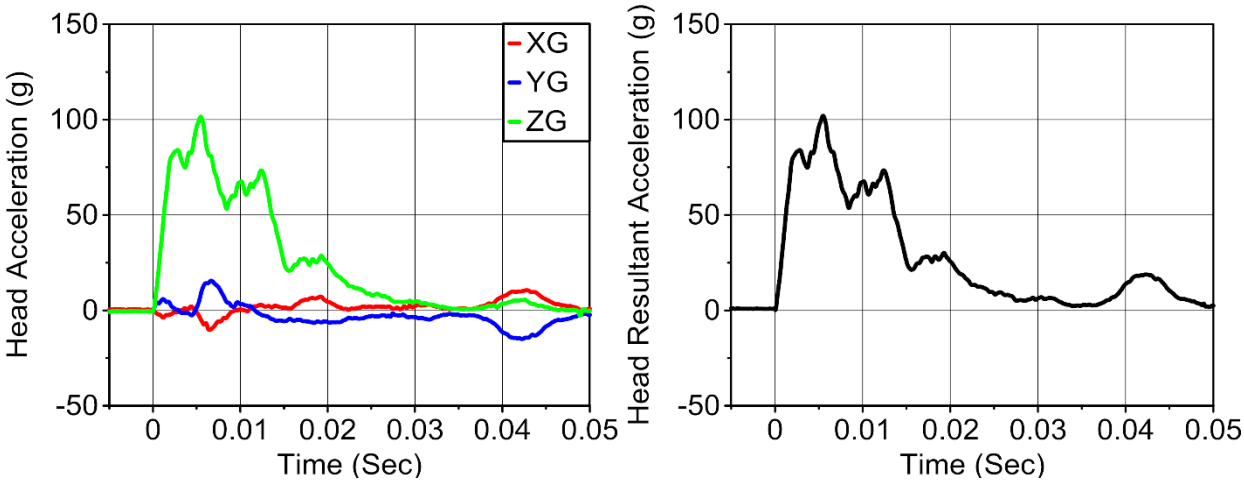
ChildHead 1608



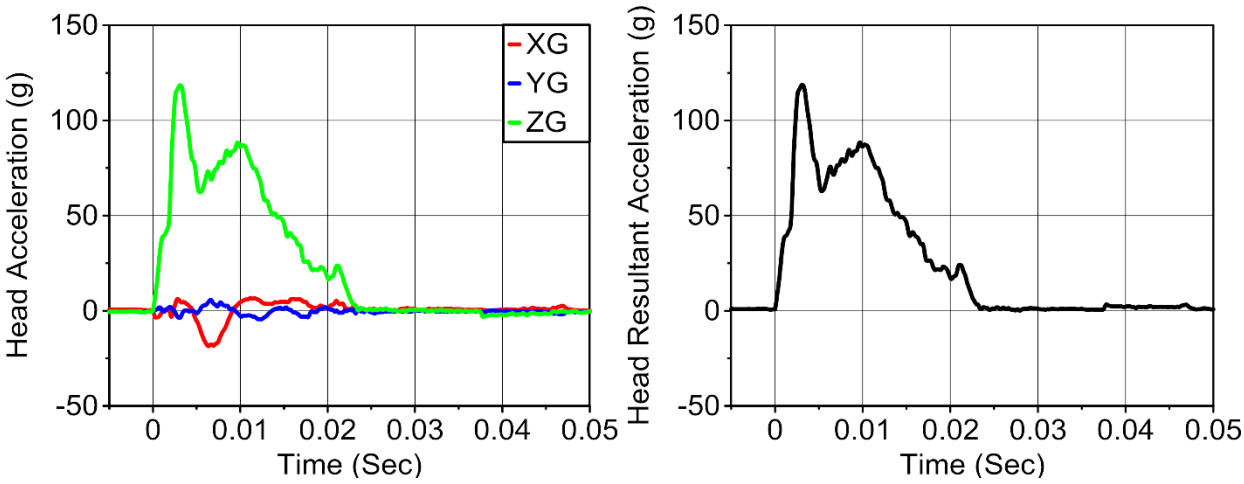
ChildHead 1609



ChildHead 1610

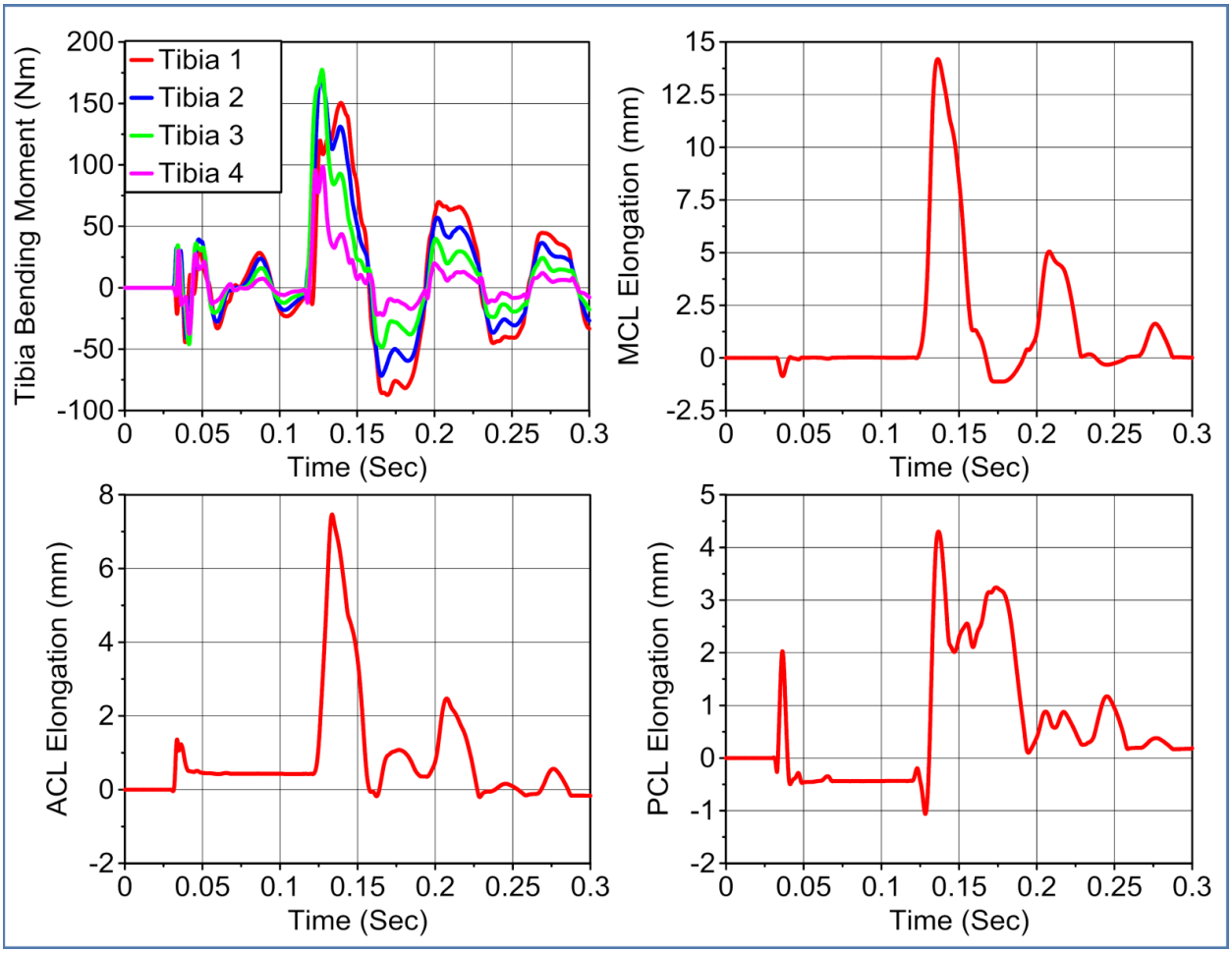


ChildHead1611

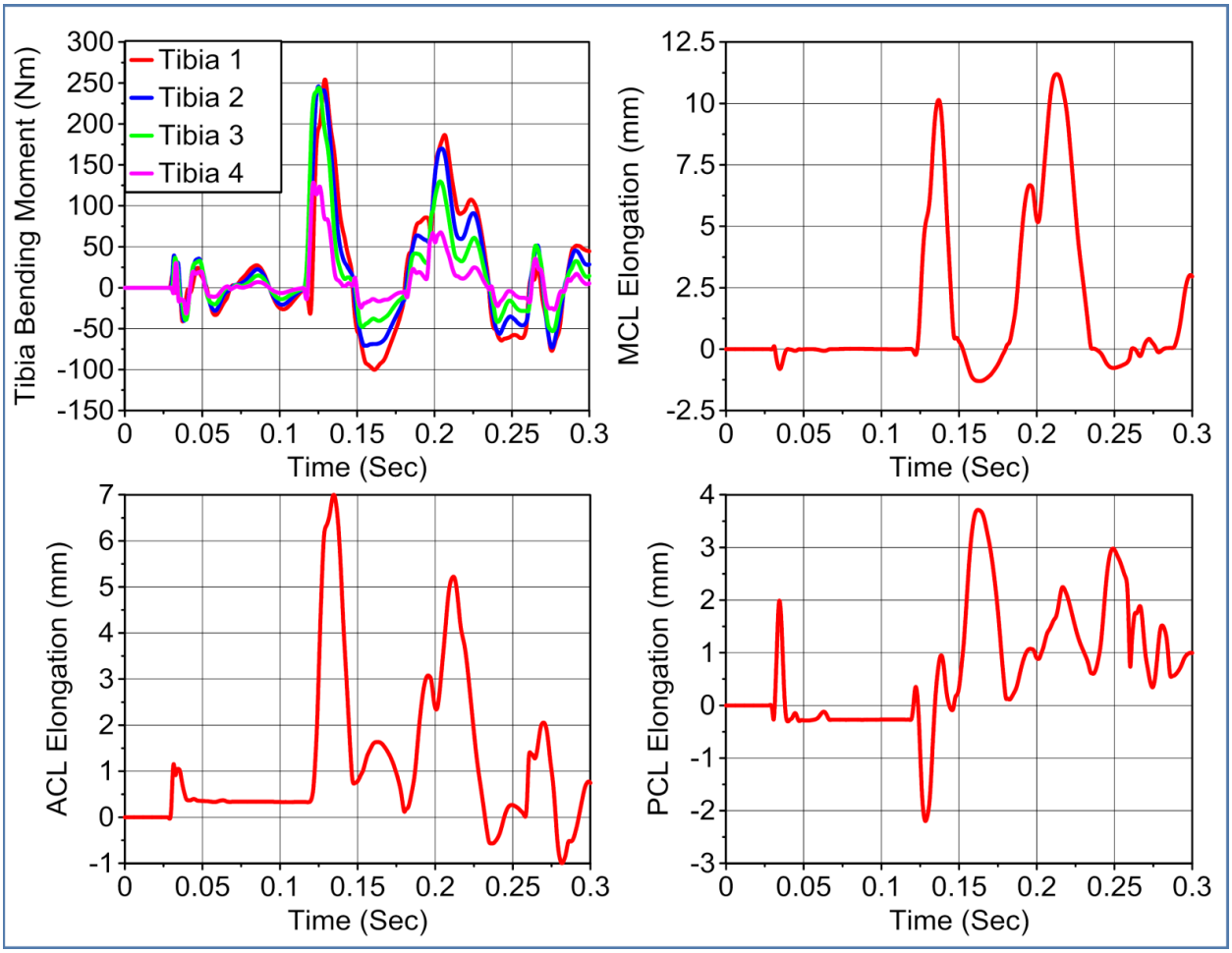


Lower Legform Impact Data Traces

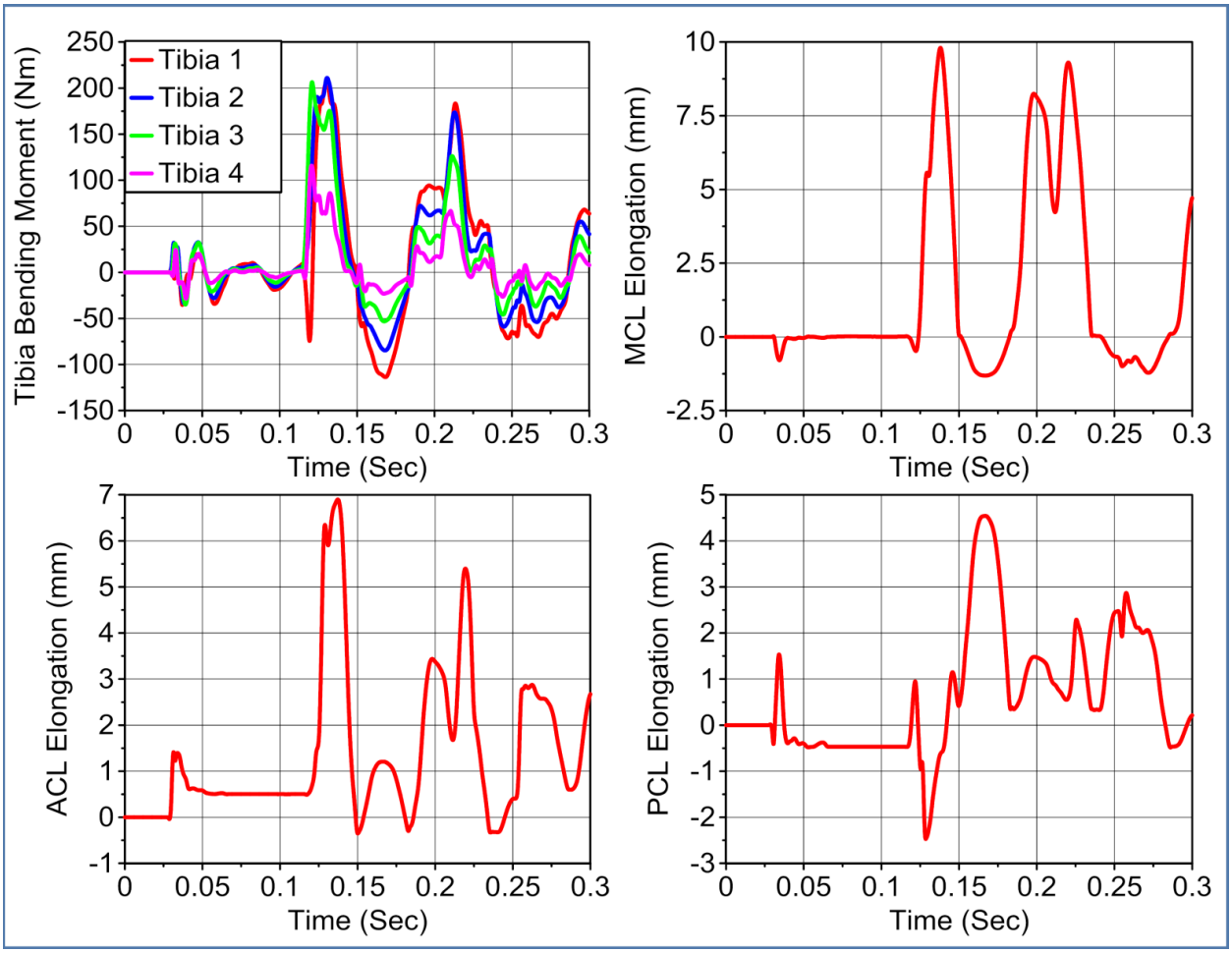
LL 1605



LL 1606

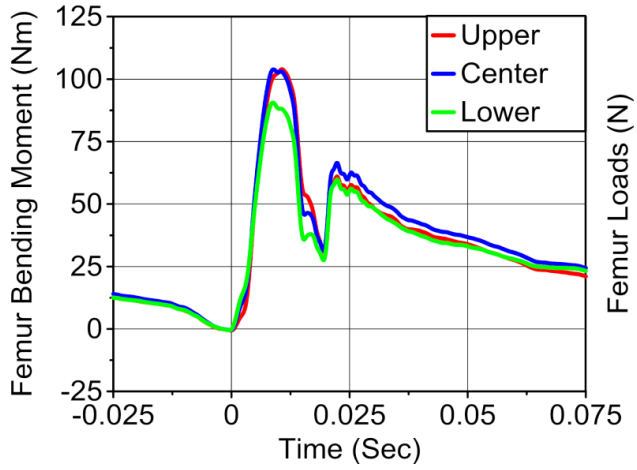

Tibia Bending Moment (Nm)
Tibia 1
Tibia 2
Tibia 3
Tibia 4
Time (Sec)
MCL Elongation (mm)
Time (Sec)
ACL Elongation (mm)
Time (Sec)
PCL Elongation (mm)
Time (Sec)

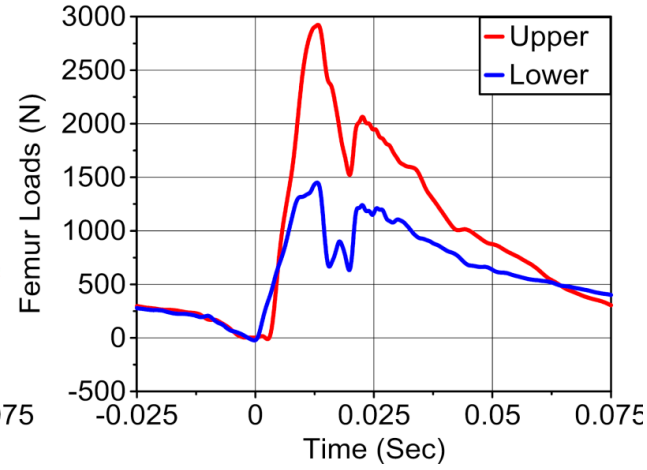
LL 1611


Tibia Bending Moment (Nm)
Tibia 1
Tibia 2
Tibia 3
Tibia 4
Time (Sec)
MCL Elongation (mm)
Time (Sec)
ACL Elongation (mm)
Time (Sec)
PCL Elongation (mm)
Time (Sec)

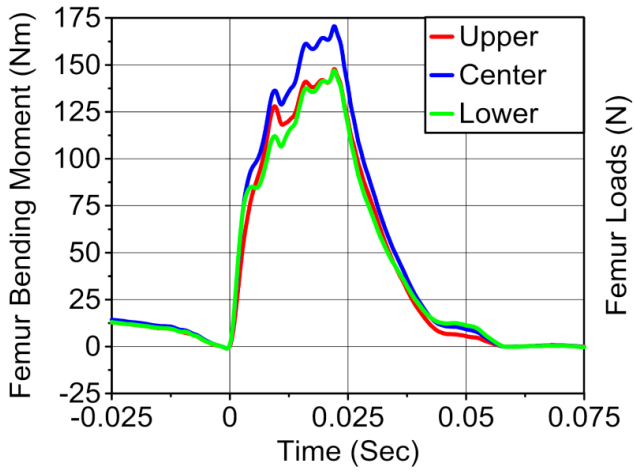
Upper Legform Impact Data Traces

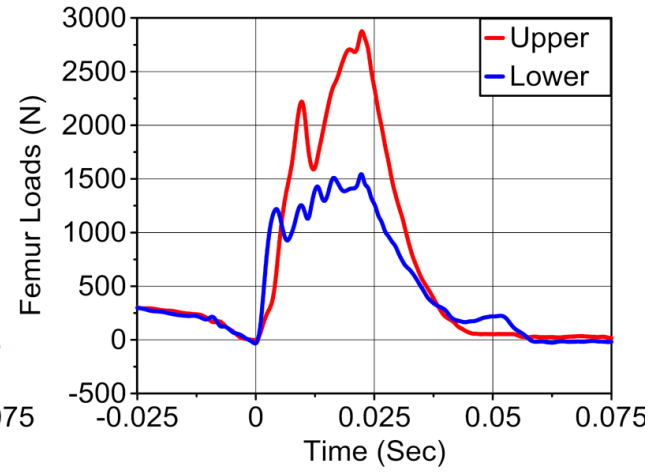
UL 1610



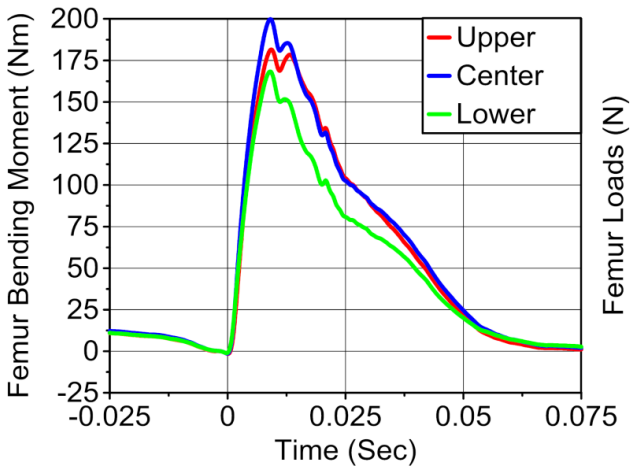


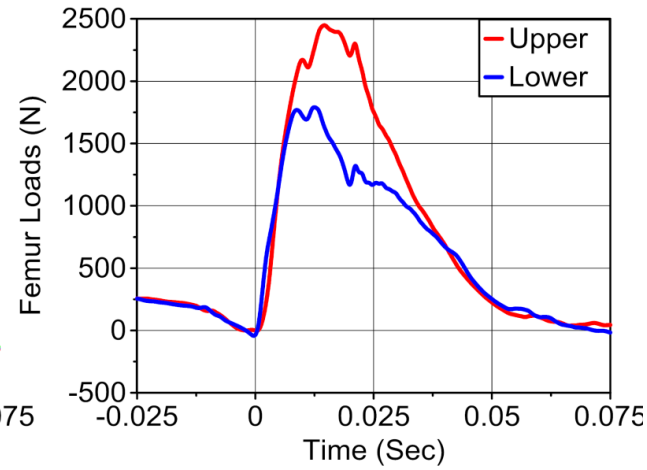
UL 1611



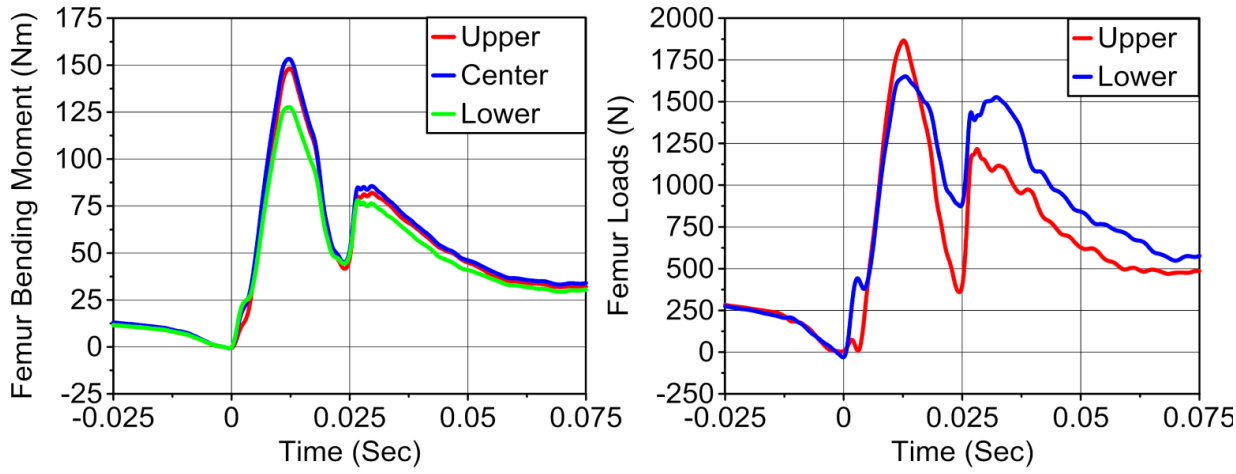


UL 1612



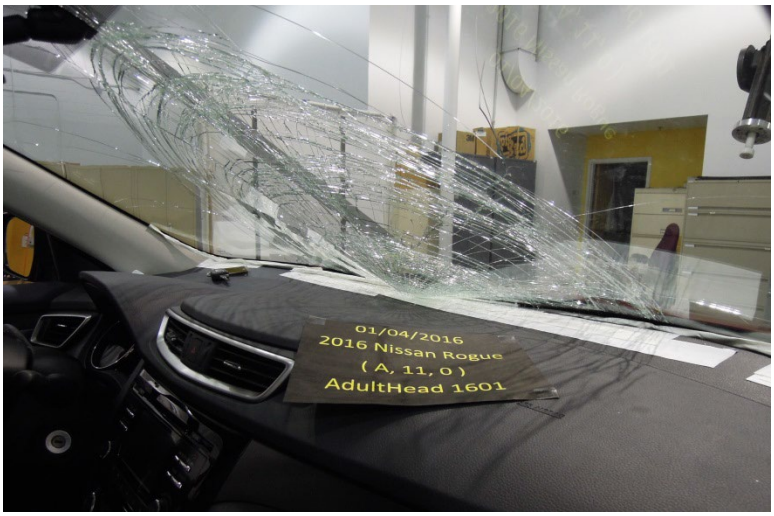


UL 1613

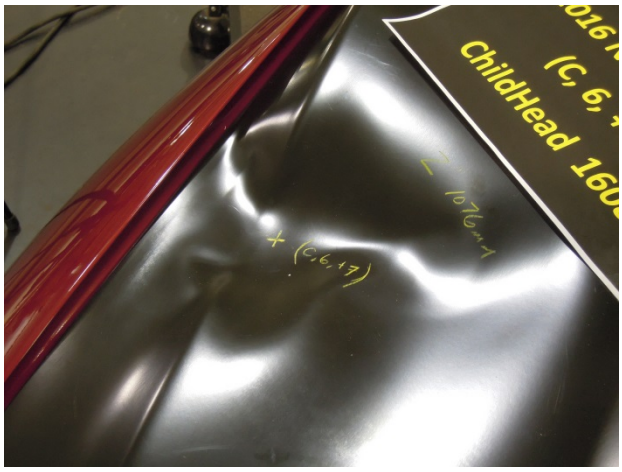


Examples of Post-Test Vehicle Damage

AdultHead 1601



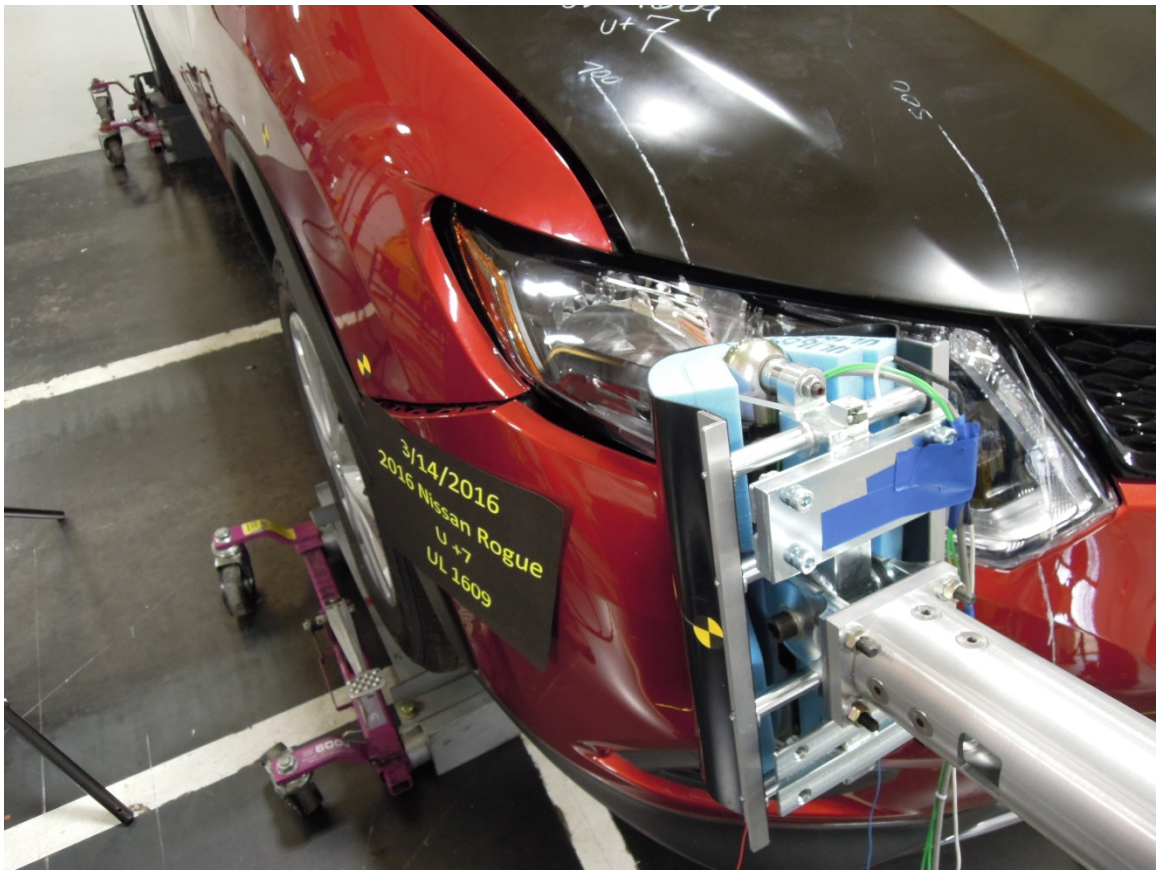
ChildHead 1608



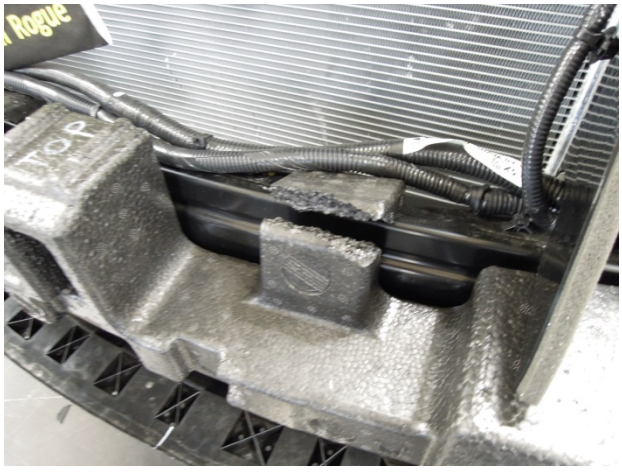
ChildHead 1606

LL 1605

UL 1609



UL 1611



Appendix H: 2016 Toyota Prius

Overview

A 2016 Toyota Prius was tested.

Exemplar 2016 Toyota Prius

Vehicle Information

Pertinent vehicle information is listed in Table H-1 below. Descriptions for the lateral hood width and front-end width can be found in Appendix J.

Table H-1. Vehicle information

Make	Toyota
Model	Prius
Year	2016
VIN	JTDKBRFU0G3020601
Type	Passenger Car
GVWR	1776 kg
Lateral Hood Width	1480 mm
Front End Width	1758 mm

Headform Testing

For the 2016 Toyota Prius, 10 points were chosen and are shown in Figure H-1 below.

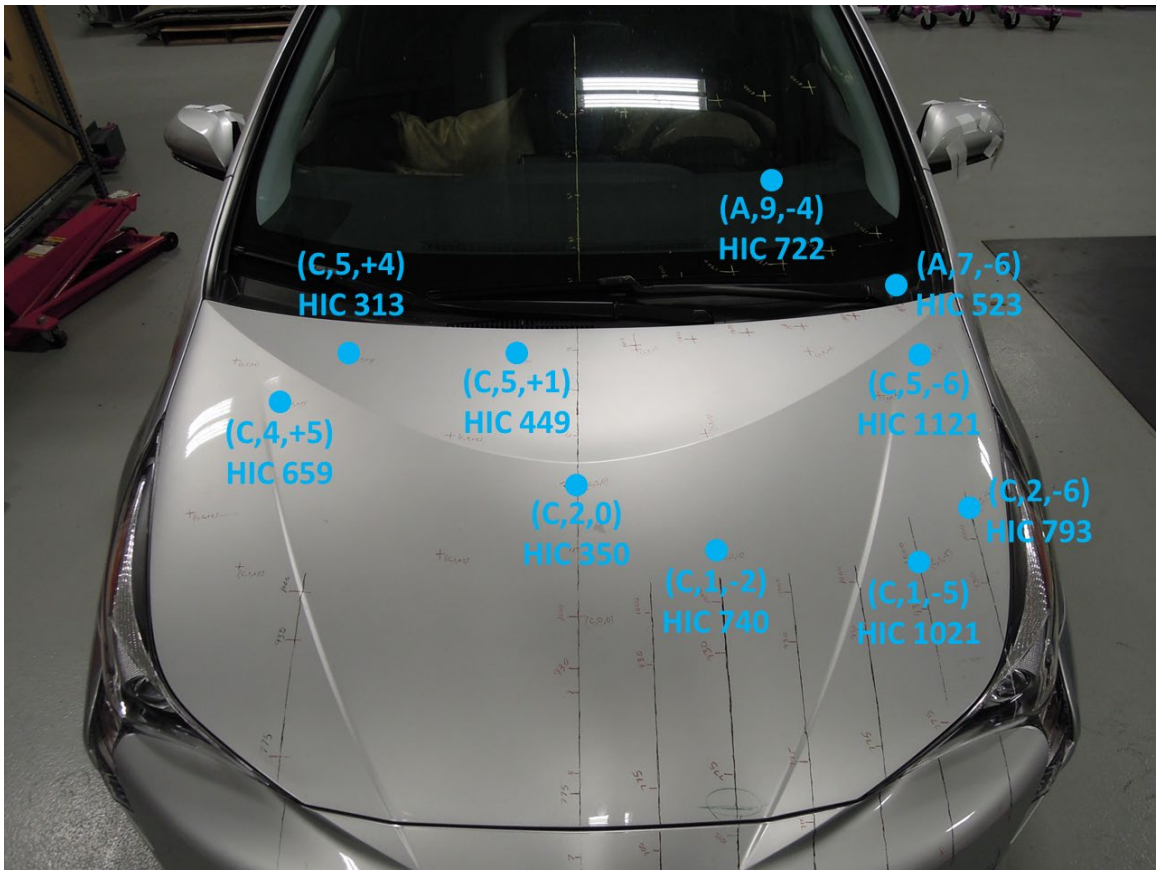


Figure H-1. 2016 Toyota Prius selected headform impact points, their corresponding grid coordinates, and HIC results.

HIC results and corresponding points for the selected impact points are shown in Table H-2 below. The 2016 Toyota Prius earned 8.25 points out of a possible 10 points, resulting in a score of 19.8. For reference, the Euro NCAP scores for a European variant of this vehicle are also shown.

Table H-2. 2016 Toyota Prius headform impact locations, HIC results, and resulting score.

			HIC SCORES			
Test No.	**Grid point**		**NHTSA (pts)**		***Euro NCAP (for ref only)***	***Toyota Predicted (for ref only)***
1714	C	1,-2	**495**	**1.0**	***595***	***< 650***
1715	C	1,-5	**999**	**0.75**	***1043***	***1350 - 1700***
1664	C	4,5	**659**	**0.75**	***720***	***< 650***
1713	C	5,4	**366**	**1.0**	***605***	***< 650***
1723	C	7,-6	**918**	**0.75**	***909***	***1000 - 1350***
1662	A	9,-4	**722**	**0.75**	***1017***	***650 - 1000***
1671	C	2,0	**350**	**1.0**	---	***< 650***
1670	C	2,-6	**793**	**0.75**	---	***1000 - 1350***
1716	C	5,1	**335**	**1.0**	---	***< 650***
1663	C	5,-6	**1121**	**0.50**	---	***1000 - 1350***
---	C	6,1	---	---	***591***	***< 650***
---	C	5,-1	---	---	***351***	***< 650***
---	C	7,2	---	---	***1143***	***650 - 1000***
---	C	7,-7	---	---	***1557***	***> 1700***
---	A	8,-1	---	---	***1152***	***1000 - 1350***
Total Points (10 max)			8.25			
Score			**19.8**		*16.91*	

Lower Legform Testing

The bumper test zone is defined as either the area limited by the bumper corners or the outermost ends of the underlying bumper beam, whichever is larger. The distance from the bumper corner of the fascia to the centerline was measured to be 446 mm. The distance from the outermost ends of the underlying bumper beam to the centerline of the 2016 Toyota Prius was measured to be 598 mm. The bumper test zone is the larger of the two distances, and for the 2016 Toyota Prius, is 598 mm from the centerline. Grid points are located every 100 mm from the centerline in both lateral directions resulting in 13 grid points for the 2016 Toyota Prius. Non-tested grid points are awarded the worst result from one of the adjacent points. In addition, symmetry will be applied to all grid points. Given these conditions, four test points were tested and are shown in Figure H-2.

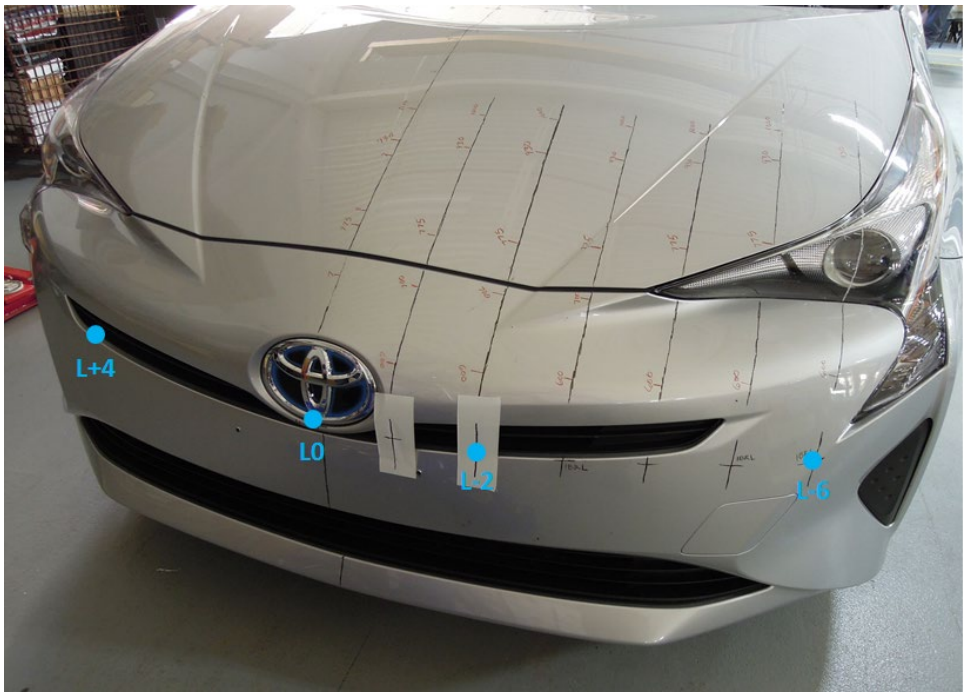


Figure H-2. 2016 Toyota Prius selected lower legform impact points

Lower legform results for the selected impact points are shown in Table H-3 and the corresponding score is shown in Table H-4. Results that fall below the lower limit are highlighted in green, above the upper limit are in red, and between the lower and upper limits are in orange. Following the Euro NCAP guidelines, the 2016 Toyota Prius earned 9.55 points out of a possible 13 points, resulting in a score of 4.4.

Table H-3. 2016 Toyota Prius lower legform impact locations and corresponding results

		Tibia Bending Limits				*Ligament Elongation Limits*		
		282-340 Nm				*19-22 mm*	*10 mm*	
Test #	**Location**	**Tibia 1**	**Tibia 2**	**Tibia 3**	**Tibia 4**	**MCL**	**ACL**	**PCL**
LL 1620	L0	185	224	220	194	13.1	5	3.7
LL 1621	L-6	324	296	234	157	18	10.8	5.4
LL 1622	L+4	160	162	146	123	14.1	5	6.8
LL 1623	L-2	195	193	177	186	13.9	6	4.4
European Variant (ref only)	*L +6*	*181*	*146*	*115*	*116*	*14.9*	*5.1*	*8.7*
	L +2	*156*	*119*	*115*	*145*	*14.4*	*4.6*	*4.9*
	L 0	*144*	*109*	*105*	*141*	*13.4*	*4.0*	*3.9*
	L -4	*154*	*119*	*125*	*149*	*12.7*	*4.5*	*3.8*

Table H-4. 2016 Toyota Prius lower legform grid points and score.

Location	Points on U.S. variant			*Points on Euro. variant (for ref. only)*
	Bending	Elongation	Total	
L+6	0.138	0	**0.138**	*1*
L+5	0.138	0	**0.138**	*1*
L+4	0.5	0.5	1	*1*
L+3	0.5	0.5	1	*1*
L+2	0.5	0.5	1	*1*
L+1	0.5	0.5	1	*1*
L0	0.5	0.5	1	*1*
L-1	0.5	0.5	1	*1*
L-2	0.5	0.5	1	*1*
L-3	0.5	0.5	1	*1*
L-4	0.5	0.5	1	*1*
L-5	0.138	0	**0.138**	*1*
L-6	0.138	0	**0.138**	*1*
Points Total (Out of Max Possible 13 Points)	**9.55**			***13.0***
Score	**4.4**			***6.0***

Upper Legform Testing

Since the lower bumper reference line is less than 425 mm, upper legform impacts were performed at the wrap around distance (WAD) 775 mm. Starting at the vehicle's centerline, grid points are marked every 100 mm in both lateral directions along the WAD 775 mm line up to the corner reference points. Grid points less than 50 mm from the corner reference points are deleted. As with lower leg testing, non-tested grid points are awarded the worst result from one of the adjacent points. In addition, symmetry will be applied to all grid points. Given these conditions, four test points were tested and are shown in Figure H-3.

Figure H-3. 2016 Toyota Prius selected upper legform impact points

Upper legform results for the selected impact points are shown in Table H-5 below. Results that fall below the lower limit are highlighted in green, above the upper limit are in red, and between the lower and upper limits are in orange. The possible number of points awarded for each injury measure is shown in Table H-6 below. The 2016 Toyota Prius earned 12.8 points out of a possible 13 points, resulting in a score of 5.9.

Table H-5. 2016 Toyota Prius upper legform impact locations and corresponding results.

Test #	Location	Angle (°)	Energy (J)	Femur Bending Moment Limits: 285 – 350 Nm			Sum Femur Loads (N) Limits: 5-6 kN
				Upper	Middle	Lower	
UL 1661	U-6	42.9	177	233	288	256	3891
UL 1662	U+4	46.3	146	140	194	184	2996
UL 1663	U0	45.3	155	111	152	146	2769
UL 1664	U-2	46.4	145	98	136	135	1087
European Variant (ref only)	*U +6*	---	*187*	*271*	*327*	*292*	*4297*
	U 0	---	*161*	*119*	*157*	*161*	*3728*
	U -4	---	*161*	*182*	*251*	*243*	*3606*

Table H-6. Points awarded for each injury measure and resulting score for the upper legform tests. Upper leg performance for each grid point is based on the worst performing parameter.

Location	Points on U.S. variant			*Points on Euro. variant (ref only)*
	Bending	Force	Total	
U+6	0.95	1	0.95	*0.36*
U+5	0.95	1	0.95	*0.36*
U+4	1	1	1	*1.00*
U+3	1	1	1	*1.00*
U+2	1	1	1	*1.00*
U+1	1	1	1	*1.00*
U0	1	1	1	*1.00*
U-1	1	1	1	*1.00*
U-2	1	1	1	*1.00*
U-3	1	1	1	*1.00*
U-4	1	1	1	*1.00*
U-5	0.95	1	0.95	*0.36*
U-6	0.95	1	0.95	*0.36*
Points Total (Out of Max Possible 15 Points)	12.8			*10.44*
Score	5.9			*4.82*

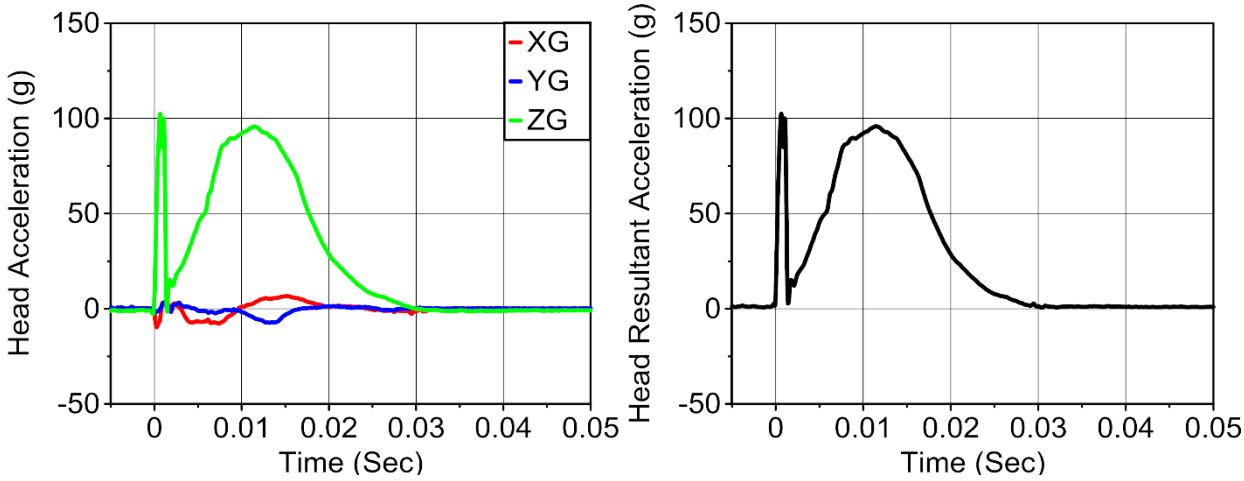
Summary

Table H-7. Summary of results for the 2016 Toyota Prius

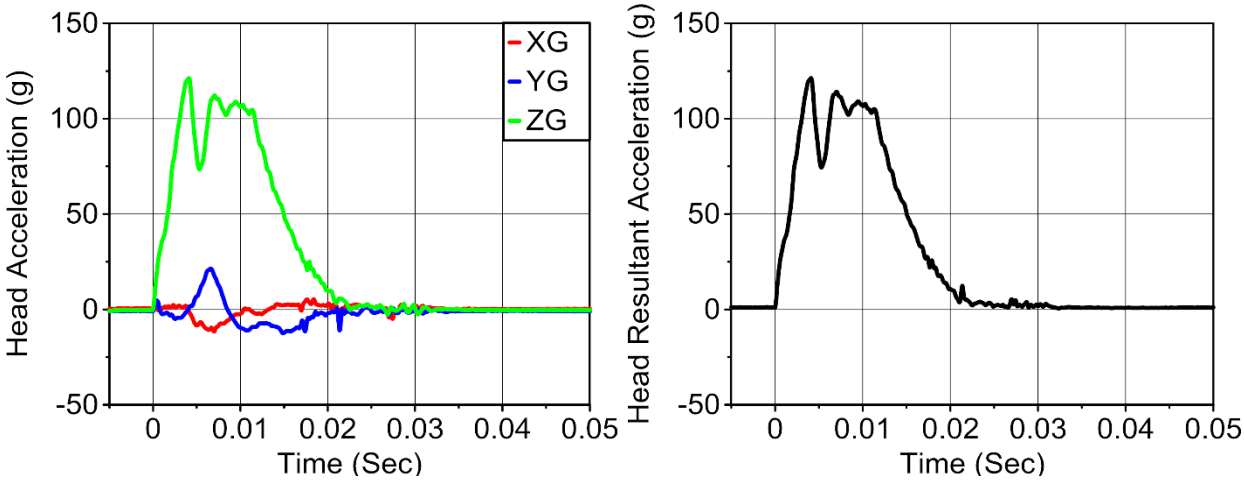
2016 Toyota Prius	Head	Lower Leg	Upper Leg	Total	% of Max
Score (Out of 36)	19.8	4.4	5.9	**30.1**	**83.6%**

Headform Impact Data Traces

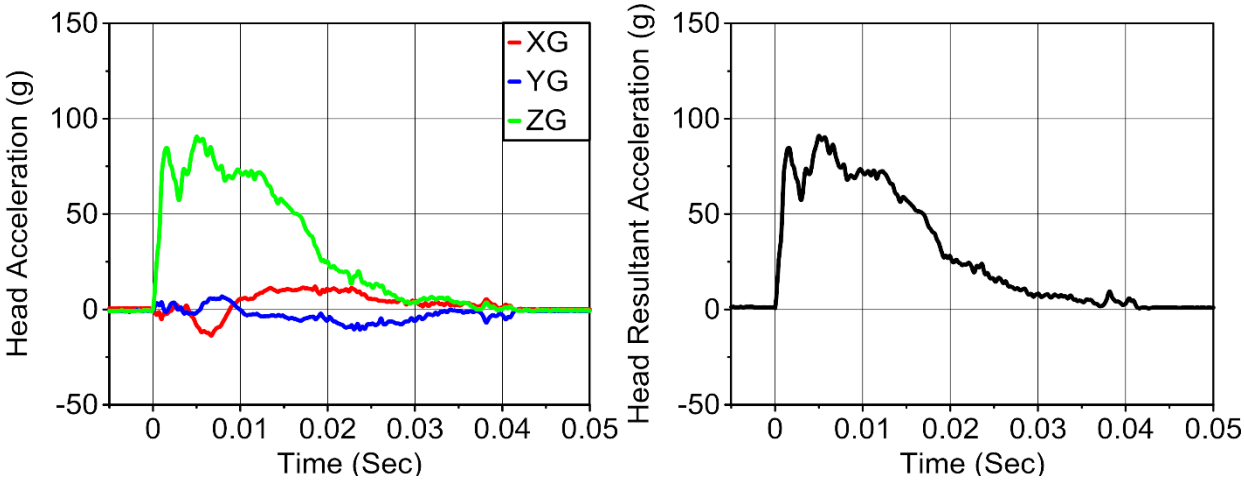
AdultHead 1662



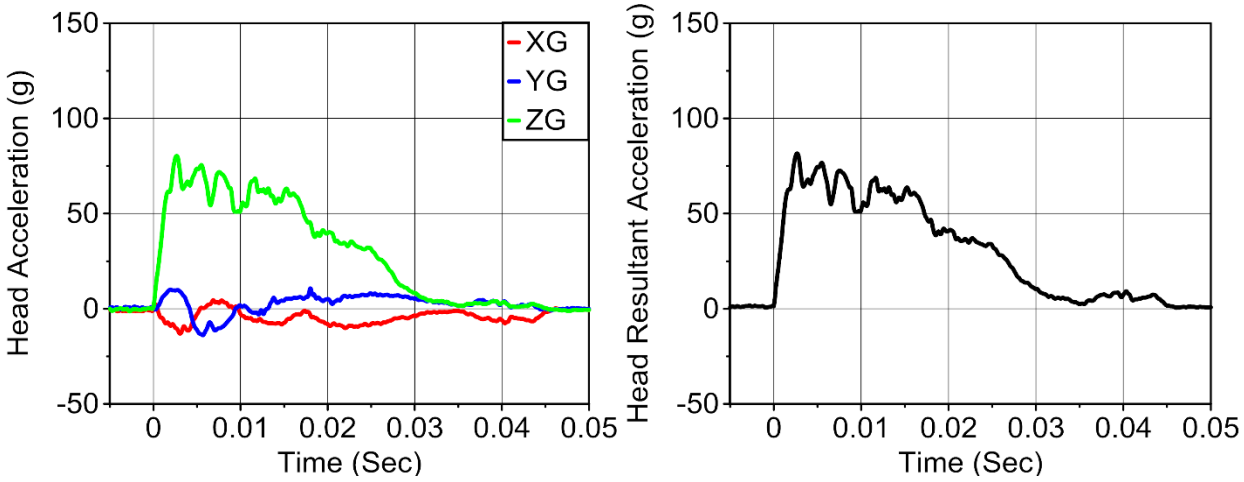
ChildHead 1663



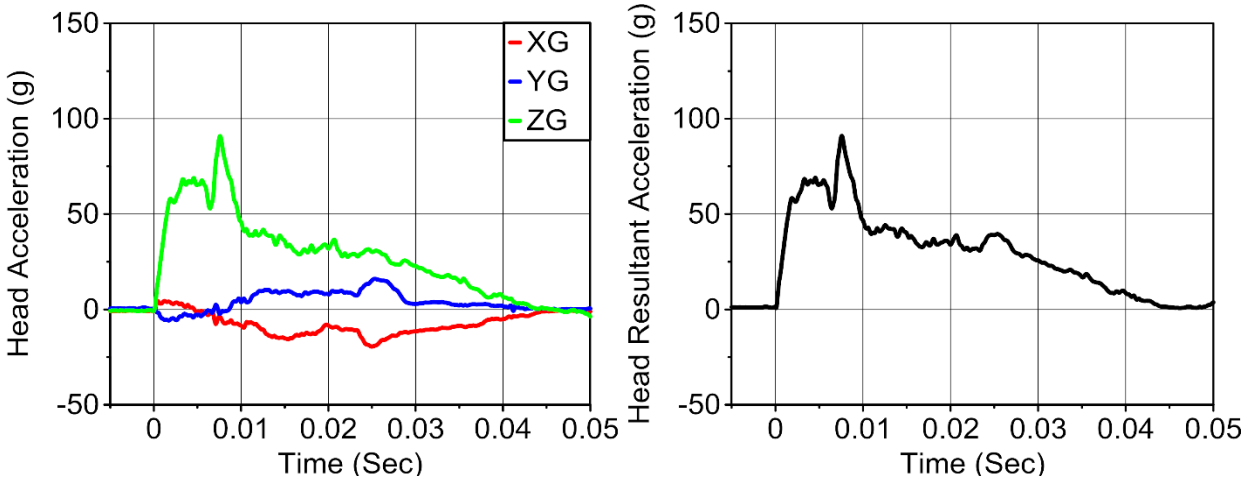
ChildHead 1664



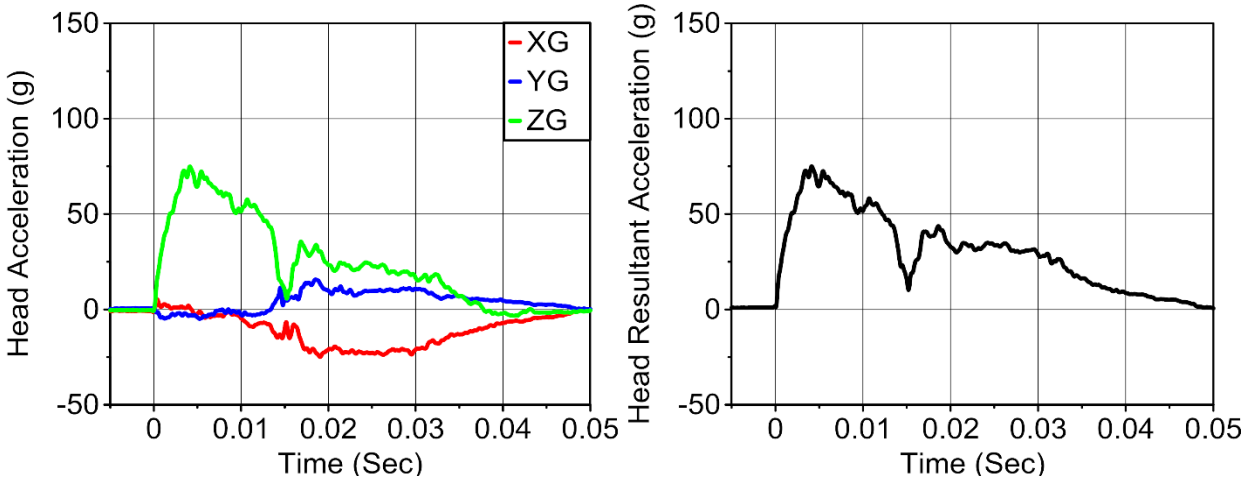
ChildHead 1714



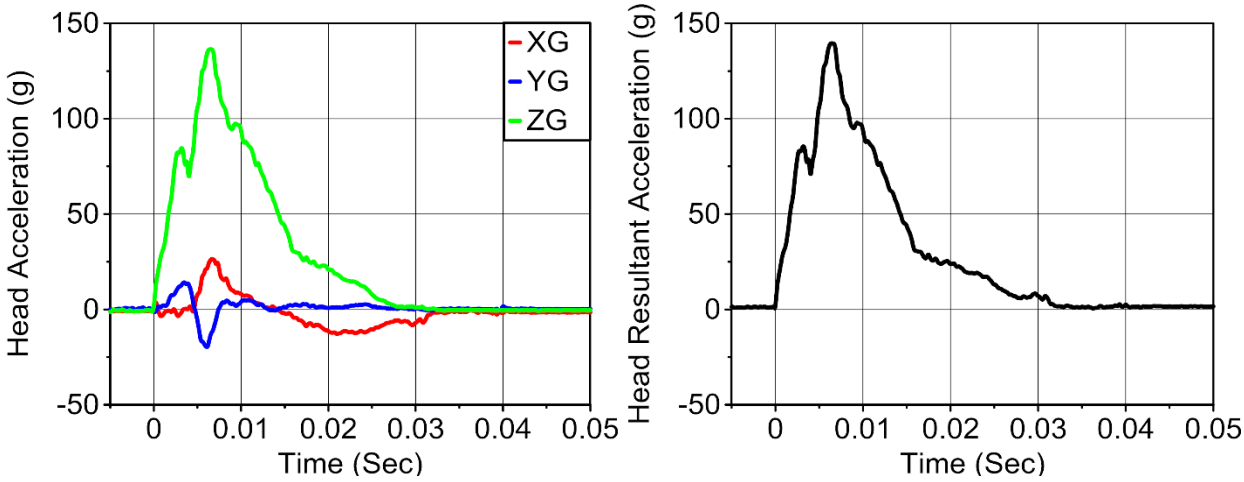
ChildHead 1716



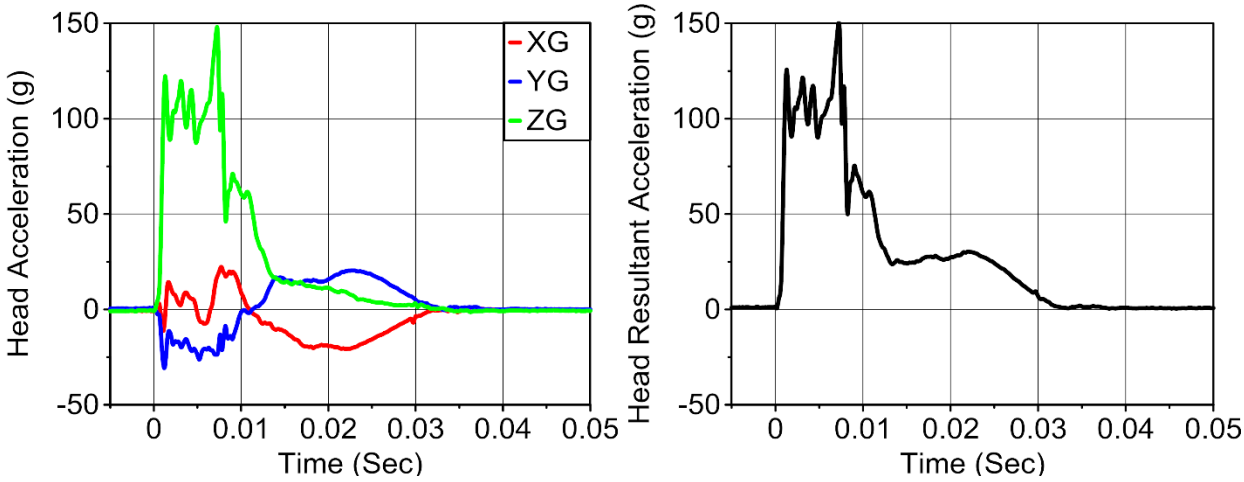
ChildHead 1713



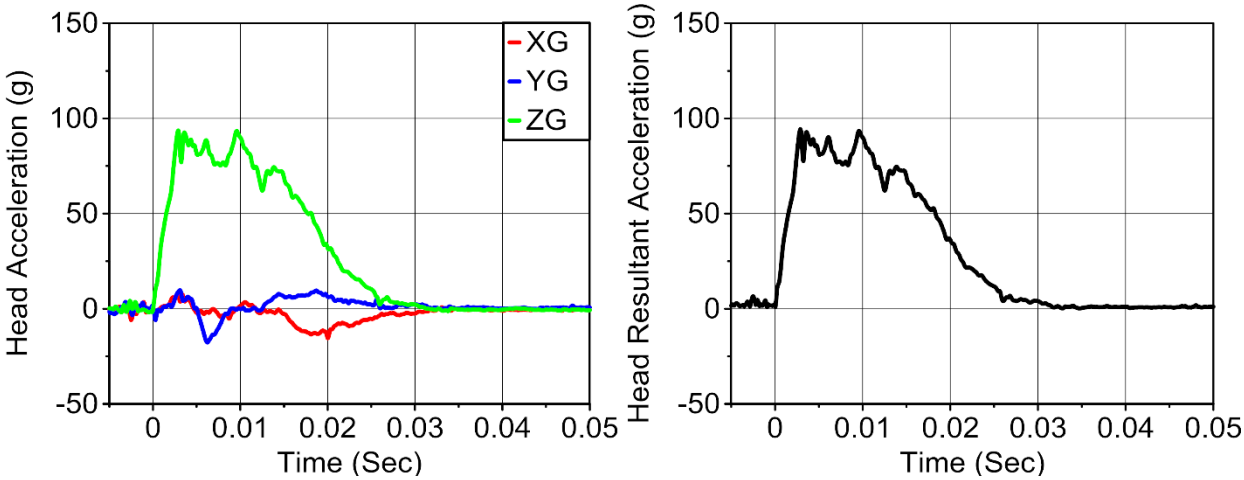
ChildHead 1715



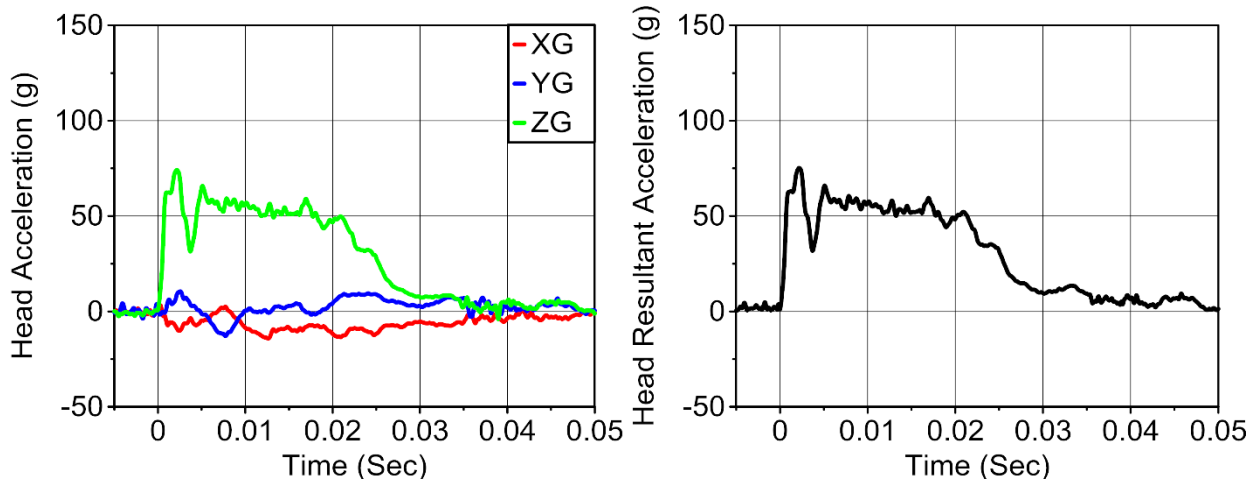
AdultHead 1723



ChildHead 1670

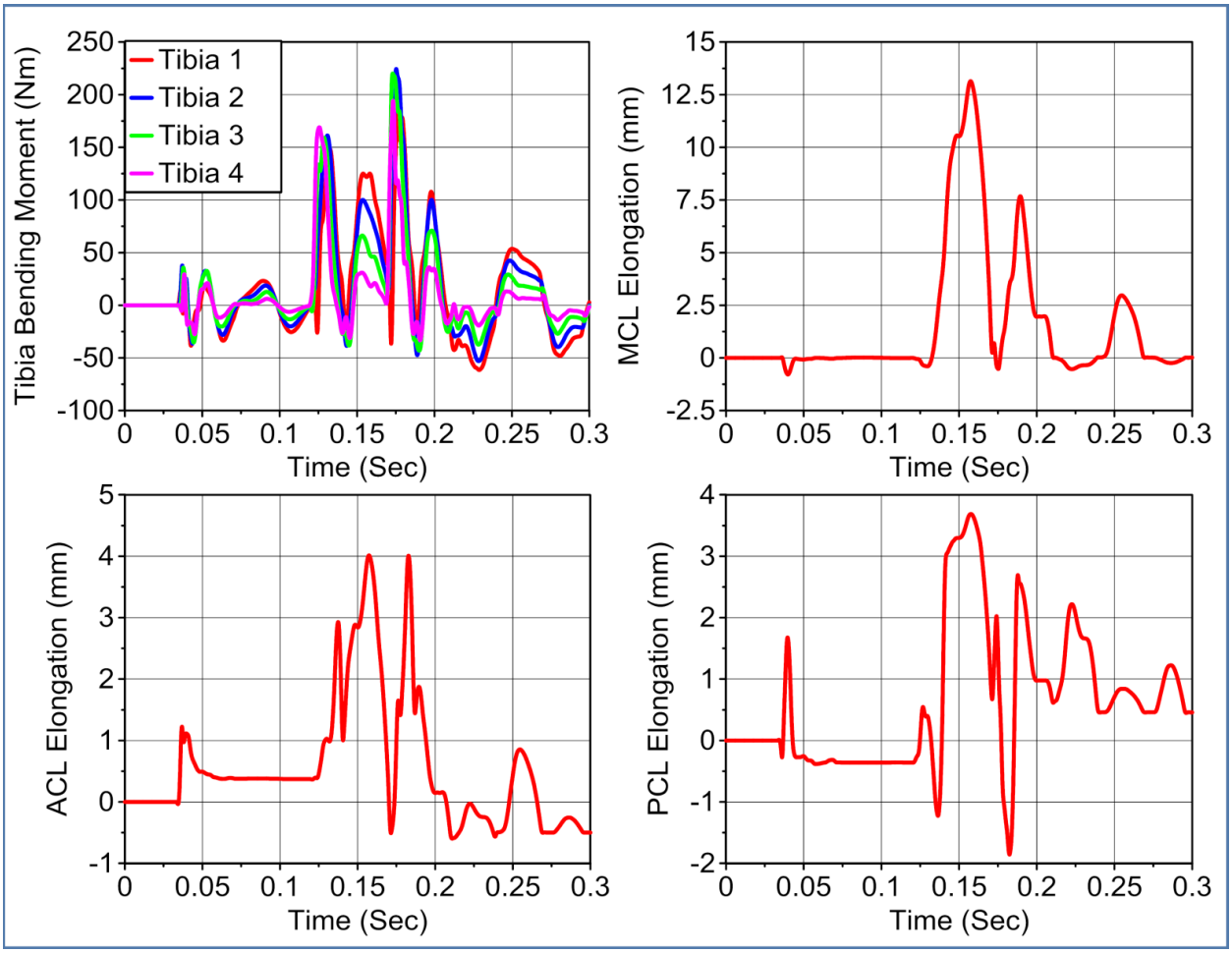


ChildHead 1671

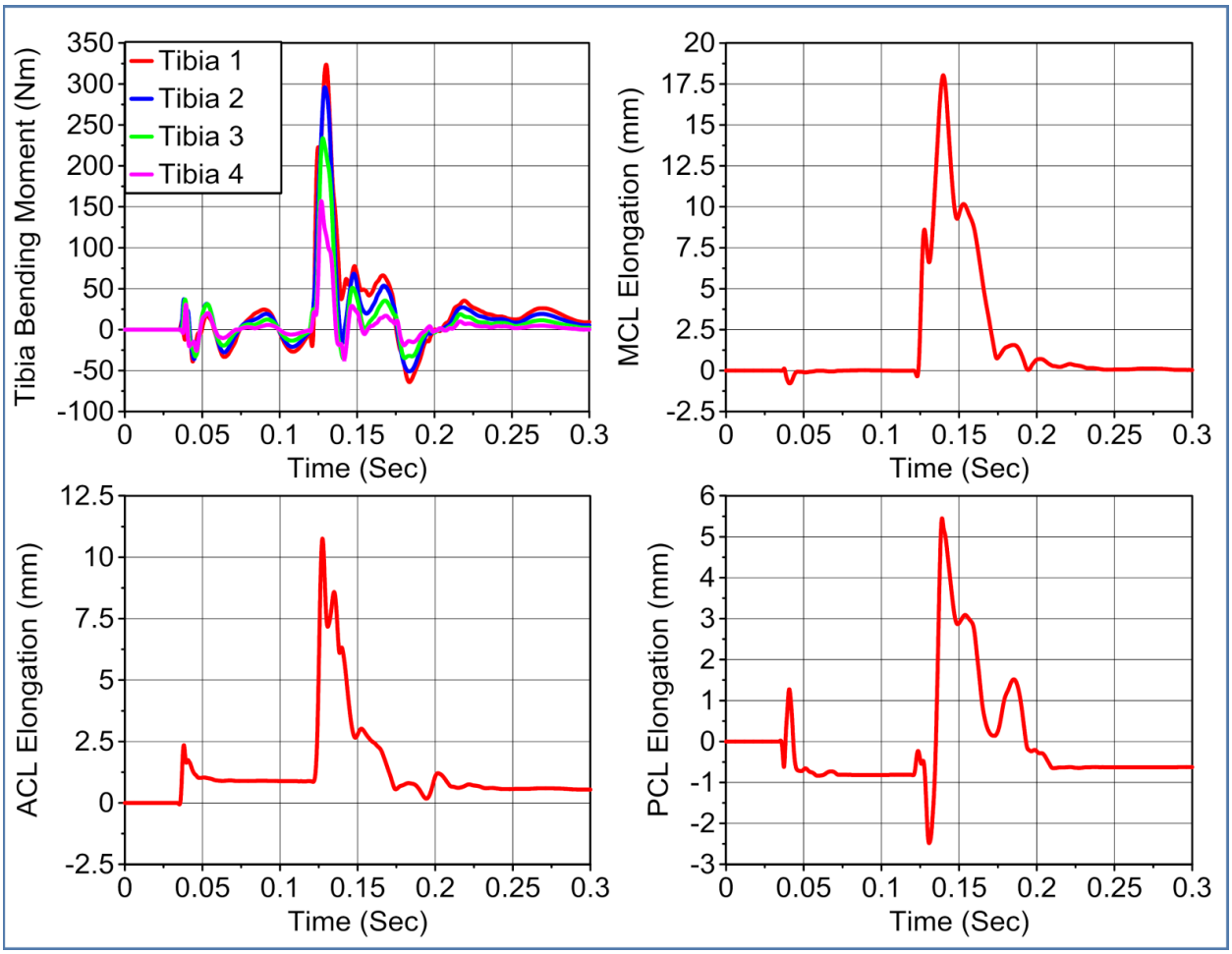


Lower Legform Impact Data Traces

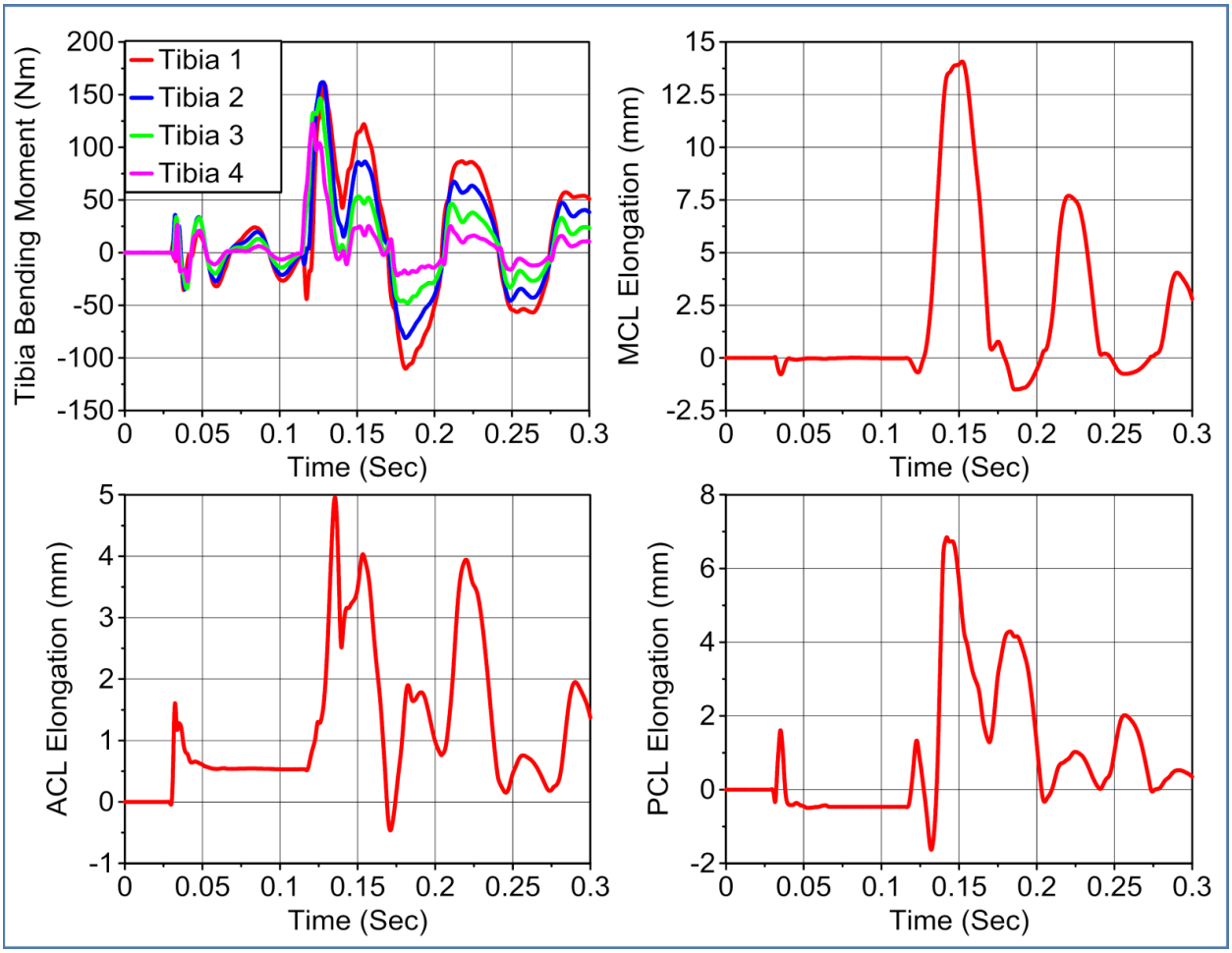
LL 1620



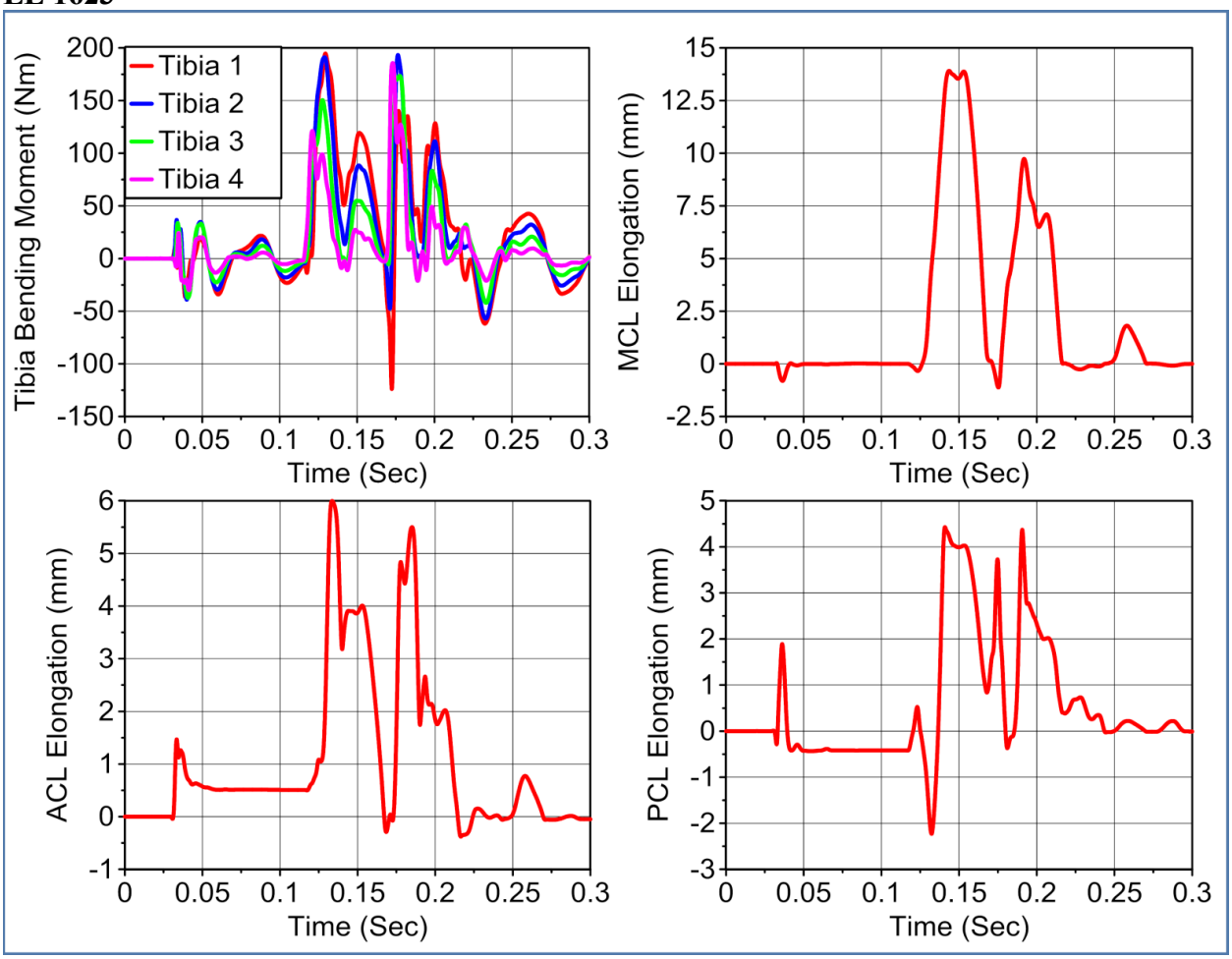
LL 1621


Tibia Bending Moment (Nm)
Tibia 1
Tibia 2
Tibia 3
Tibia 4
Time (Sec)
MCL Elongation (mm)
Time (Sec)
ACL Elongation (mm)
Time (Sec)
PCL Elongation (mm)
Time (Sec)

LL 1622

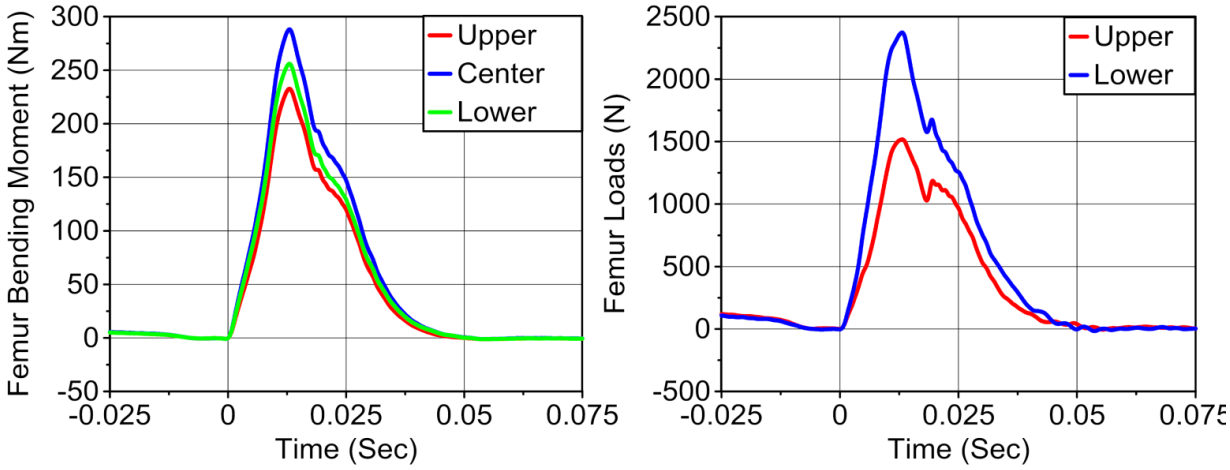

Tibia 1
Tibia 2
Tibia 3
Tibia 4
Tibia Bending Moment (Nm)
Time (Sec)
MCL Elongation (mm)
Time (Sec)
ACL Elongation (mm)
Time (Sec)
PCL Elongation (mm)
Time (Sec)

LL 1623

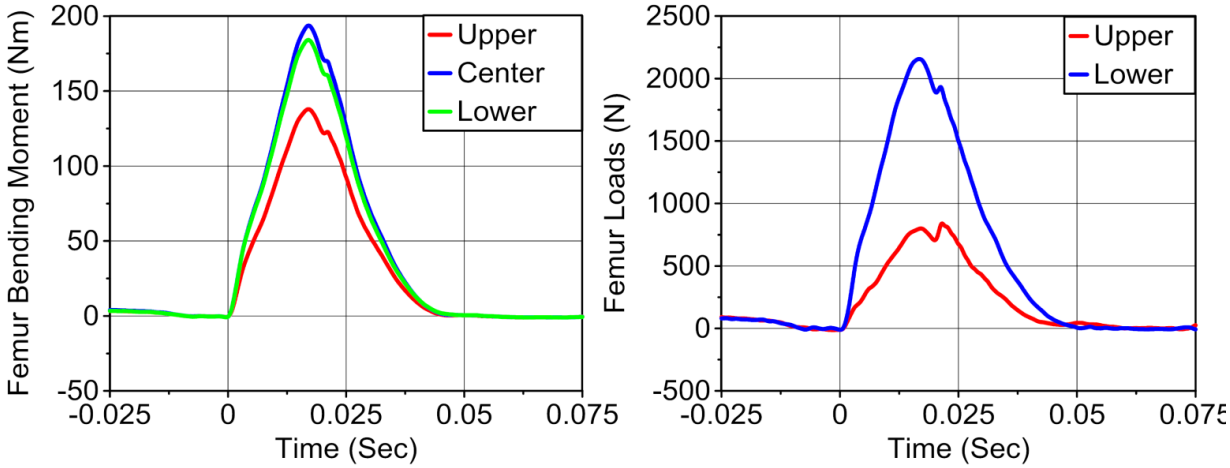

Tibia 1
Tibia 2
Tibia 3
Tibia 4
Tibia Bending Moment (Nm)
Time (Sec)
MCL Elongation (mm)
Time (Sec)
ACL Elongation (mm)
Time (Sec)
PCL Elongation (mm)
Time (Sec)

Upper Legform Impact Data Traces

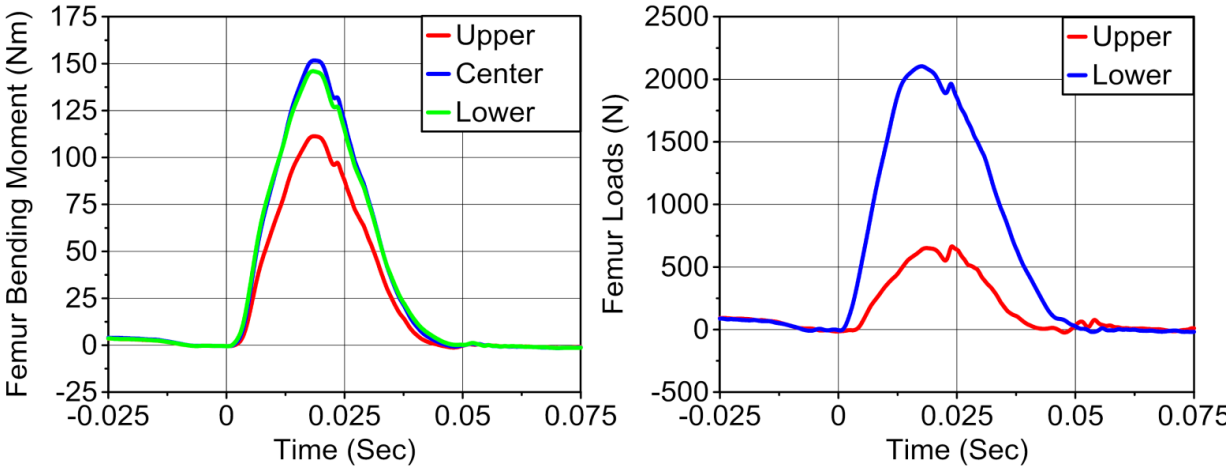
UL 1661



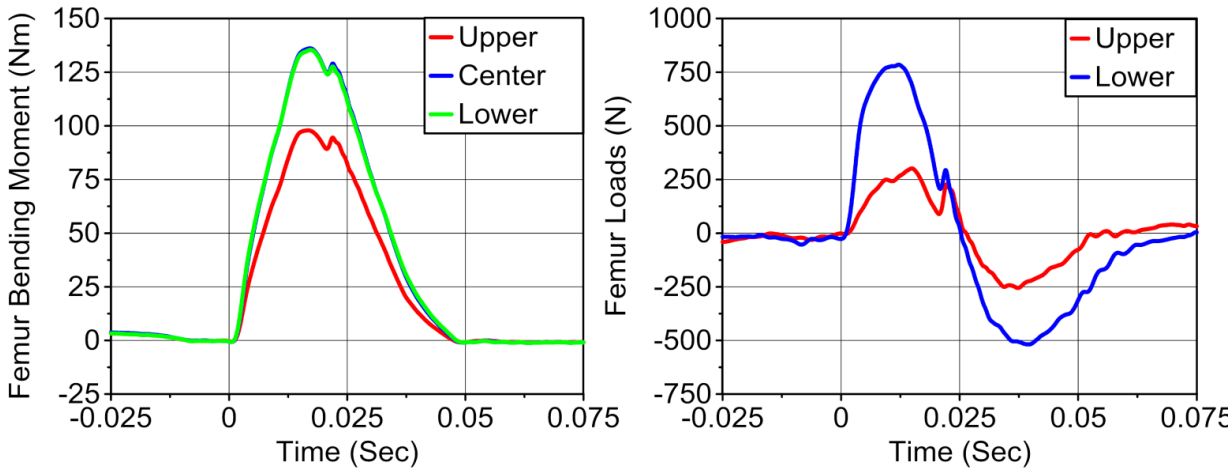
UL 1662



UL 1663



UL 1664



Examples of Post-Test Vehicle Damage

AdultHead 1662

AdultHead 1723

Appendix I: 2015 Toyota Sienna

Overview

A 2015 Toyota Sienna was tested.

Exemplar 2015 Toyota Sienna

Vehicle Information

Pertinent vehicle information is listed in Table I-1 below. Descriptions for the lateral hood width and front-end width can be found in Appendix J.

Table I-1. Vehicle information

Make	Toyota
Model	Sienna
Year	2015
VIN	5TDKK3DC8FS687274
Type	Minivan
GVWR	2715 kg
Lateral Hood Width	1660 mm
Front End Width	1990 mm

Headform Testing

For the 2015 Toyota Sienna, 9 points were chosen and are shown in Figure I-1 below.

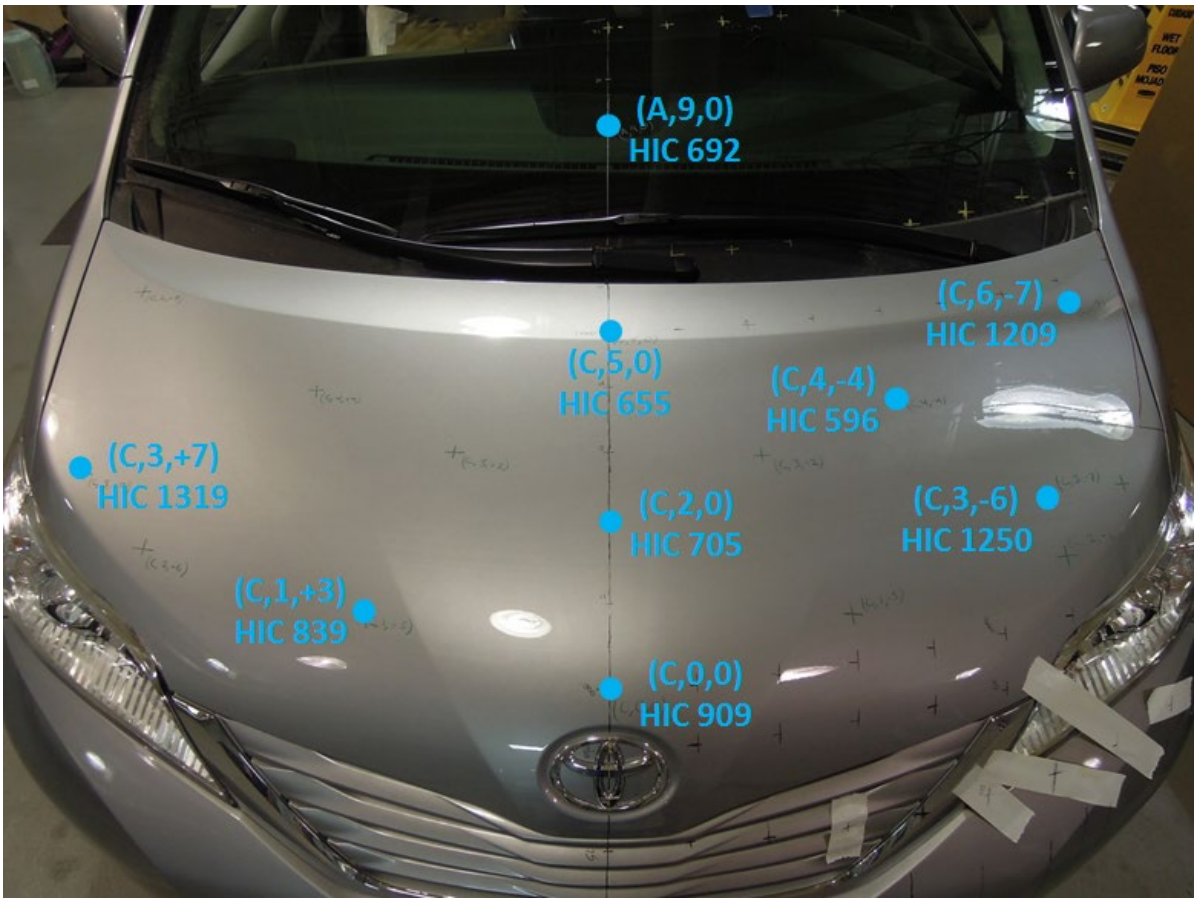


Figure I-1. 2015 Toyota Sienna selected headform impact points, their corresponding grid coordinates, and HIC results.

HIC results and corresponding points for the selected impact points are shown in Table I-2 below. The 2015 Toyota Sienna earned 6.25 points out of a possible 9 points, resulting in a score of 16.7. There is no Euro NCAP score for a European variant of this variant of this vehicle.

Table I-2. 2015 Toyota Sienna headform impact locations, HIC results, and resulting score.

			HIC SCORES			
Test No.	**Grid point**		**NHTSA (pts)**		**Euro NCAP (for ref only)**	**Toyota Predicted (for ref only)**
1643	A	9,0	**692**	**0.75**	---	---
1644	C	5,0	**655**	**0.75**	---	---
1645	C	0,0	**909**	**0.75**	---	---
1646	C	6,-7	**1209**	**0.50**	---	---
1647	C	4,-4	**596**	**1.0**	---	---
1648	C	1,3	**839**	**0.75**	---	---
1649	C	3,7	**1319**	**0.50**	---	---
1650	C	2,0	**705**	**0.75**	---	---
1651	C	3,-6	**1250**	**0.50**	---	---
Total Points (9 max)			6.25		*n/a*	
Score			**16.7**			

Lower Legform Testing

The bumper test zone is defined as either the area limited by the bumper corners or the outermost ends of the underlying bumper beam, whichever is larger. The distance from the bumper corner of the fascia to the centerline was measured to be 655 mm. The distance from the outermost ends of the underlying bumper beam to the centerline of the 2015 Toyota Sienna was measured to be 750 mm. The bumper test zone is the larger of the two distances, and for the 2015 Toyota Sienna, is 750 mm from the centerline. Grid points are located every 100 mm from the centerline in both lateral directions resulting in 15 grid points for the 2015 Toyota Sienna. Non-tested grid points are awarded the worst result from one of the adjacent points. In addition, symmetry will be applied to all grid points. Given these conditions, four test points were tested and are shown in Figure I-2.

Figure I-2. 2015 Toyota Sienna selected lower legform impact points

Lower legform results for the selected impact points are shown in Table I-3 and corresponding NCAP scores are shown in Table I-4. Results that fall below the lower limit are highlighted in green, above the upper limit are in red, and between the lower and upper limits are in orange. Following Euro NCAP guidelines, the 2015 Toyota Sienna earned 0.0 points out of a possible 15 points, resulting in a score of 0.0.

Table I-3. 2015 Toyota Sienna lower legform impact locations and corresponding results.

		Tibia Bending Limits				*Ligament Elongation Limits*		
		282-340 Nm				*19-22 mm*	*10 mm*	
Test #	**Location**	**Tibia 1**	**Tibia 2**	**Tibia 3**	**Tibia 4**	**MCL**	**ACL**	**PCL**
LL 1612	L-5	389	349	250	125	29.9	11.5	8.3
LL 1613	L+3	375	327	247	147	31	11.6	8.2
LL 1614	L+7	421	363	248	112	28.5	14.2	8.7
LL 1615	L-1	374	342	242	146	29.1	11	9.5

No European Variant

Table I-4. 2015 Toyota Sienna lower legform grid points and score

Location	Points on U.S. variant			*No Euro variant*
	Bending	Elongation	Total	
L+7	0	0	0	---
L+6	0	0	0	---
L+5	0	0	0	---
L+4	0	0	0	---
L+3	0	0	0	---
L+2	0	0	0	---
L+1	0	0	0	---
L0	0	0	0	---
L-1	0	0	0	---
L-2	0	0	0	---
L-3	0	0	0	---
L-4	0	0	0	---
L-5	0	0	0	---
L-6	0	0	0	---
L-7	0	0	0	---
Points Total (Out of Max Possible 15 Points)	0.0			
Score	0.0			*n/a*

Upper Legform Testing

Since the lower bumper reference line is less than 425 mm, upper legform impacts were performed at the wrap around distance (WAD) 775 mm. Starting at the vehicle's centerline, grid points are marked every 100 mm in both lateral directions along the WAD 775 mm line up to the corner reference points. Grid points less than 50 mm from the corner reference points are deleted. As with lower leg testing, non-tested grid points are awarded the worst result from one of the adjacent points. In addition, symmetry will be applied to all grid points. Given these conditions, four test points were tested and are shown in Figure I-3.

Figure I-3. 2015 Toyota Sienna selected upper legform impact points

Upper legform results for the selected impact points are shown in Table I-5 below. Results that fall below the lower limit are highlighted in green, above the upper limit are in red, and between the lower and upper limits are in orange. The possible number of points awarded for each injury measure is shown in Table I-6 below. The 2015 Toyota Sienna earned 6.1 points out of a possible 15 points, resulting in a score of 2.4.

Table I-5. 2015 Toyota Sienna upper legform impact locations and corresponding results

Test #	Location	Angle (°)	Energy (J)	Femur Bending Moment Limits: 285 – 350 Nm			Sum Femur Loads (N) Limits: 5-6 kN
				Upper	Middle	Lower	
UL 1614	U+3	26	334	224	229	185	5861
UL 1615	U-1	22.6	362	257	267	210	5969
UL 1616	U-5	28.3	315	194	197	158	5154
UL 1617	U+7	25	343	135	137	114	3877

No European Variant

Table I-6. Points awarded for each injury measure and resulting score for the upper legform tests. Upper leg performance for each grid point is based on the worst performing parameter.

Location	Points on U.S. Variant			*No Euro Variant*
	Bending	Force	Total	
U+7	1	1	1	---
U+6	1	0.85	0.85	---
U+5	1	0.85	0.85	---
U+4	1	0.14	**0.14**	---
U+3	1	0.14	**0.14**	---
U+2	1	0.03	**0.03**	---
U+1	1	0.03	**0.03**	---
U0	1	0.03	**0.03**	---
U-1	1	0.03	**0.03**	---
U-2	1	0.03	**0.03**	---
U-3	1	0.14	**0.14**	---
U-4	1	0.14	**0.14**	---
U-5	1	0.85	0.85	---
U-6	1	0.85	0.85	---
U-7	1	1	1	---
Points Total (Out of Max Possible 15 Points)	**3.0**			
Score	**1.2**			**n/a**

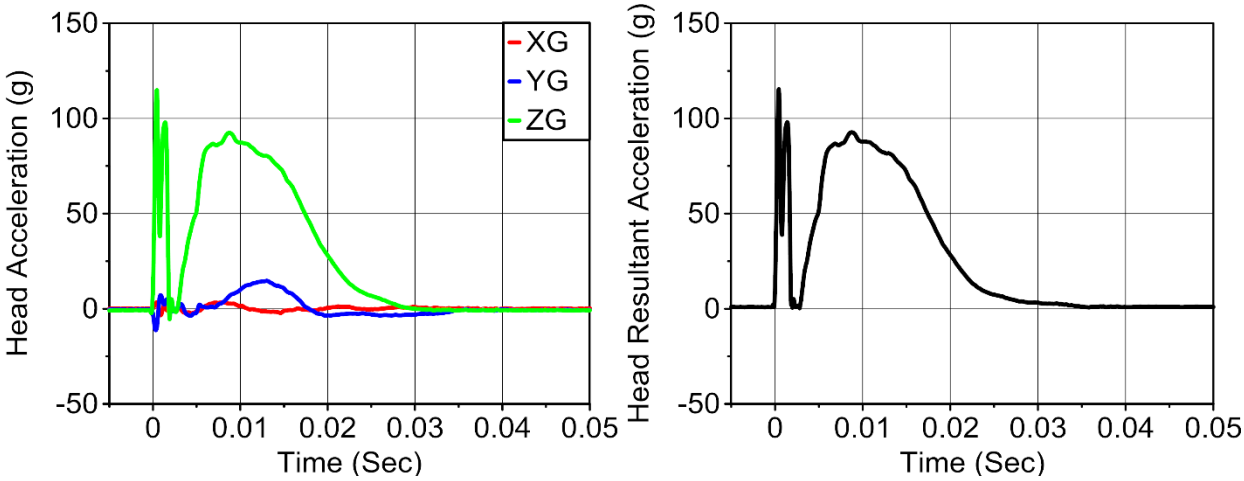
Summary

Table I-7. Summary of results for the 2015 Toyota Sienna

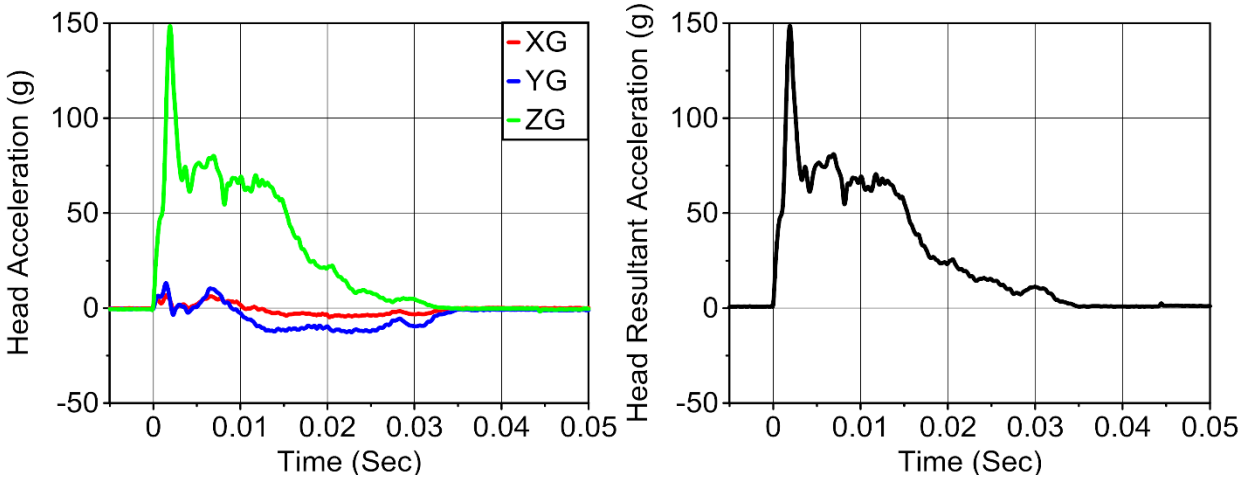
2015 Toyota Sienna	Head	Lower Leg	Upper Leg	Total	% of Max
Score (Out of 36)	16.7	0.0	2.4	**19.1**	**53.1%**

Headform Impact Data Traces

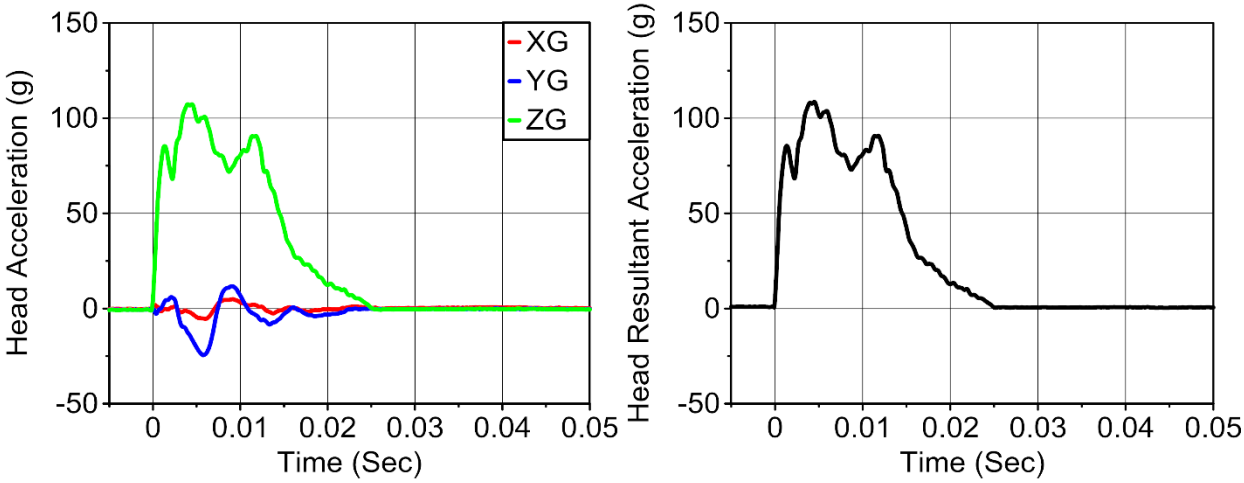
AdultHead 1643



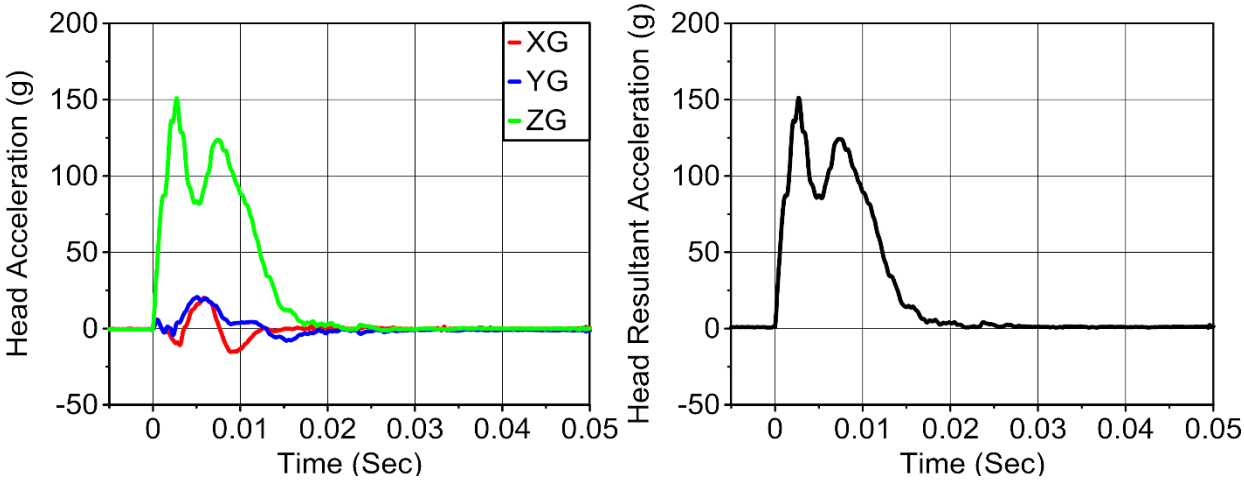
ChildHead 1644



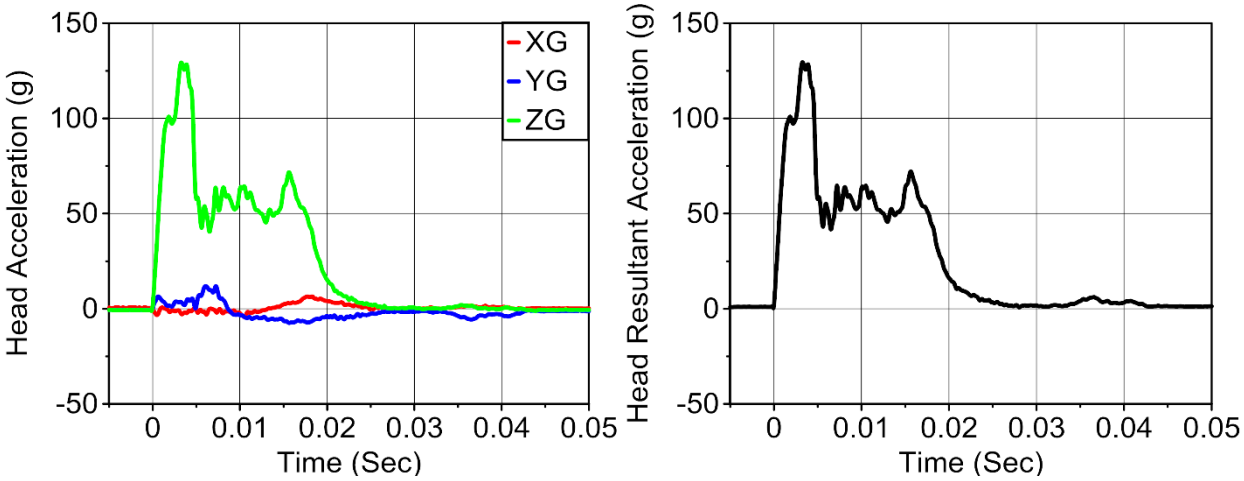
ChildHead 1645



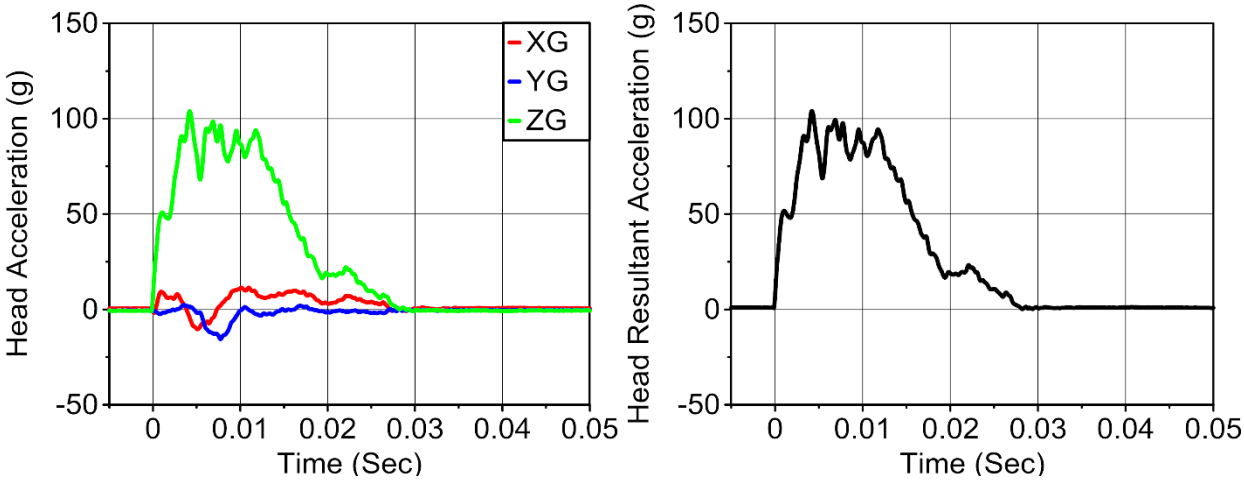
ChildHead 1646



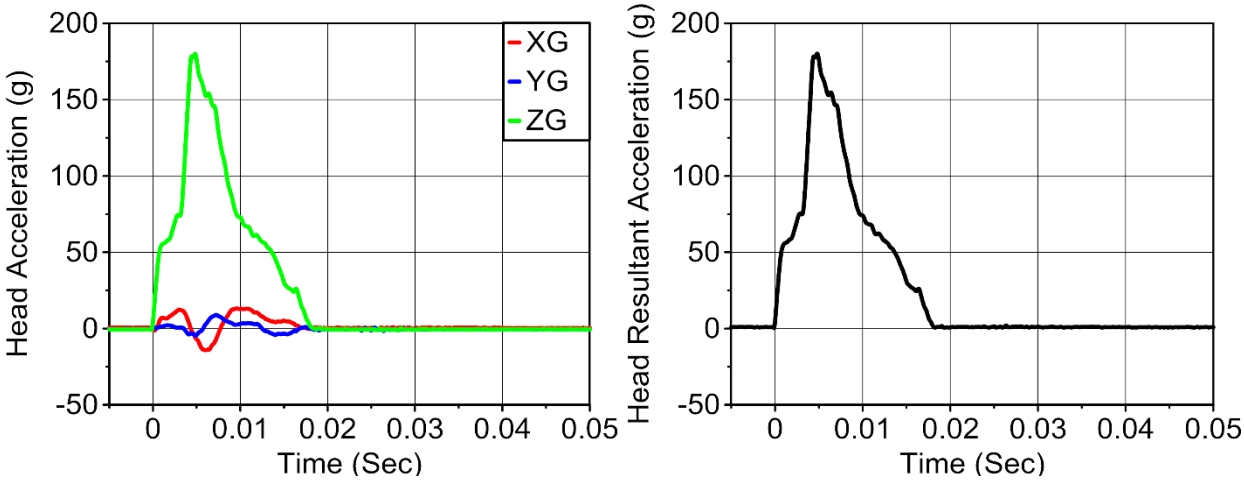
ChildHead 1647



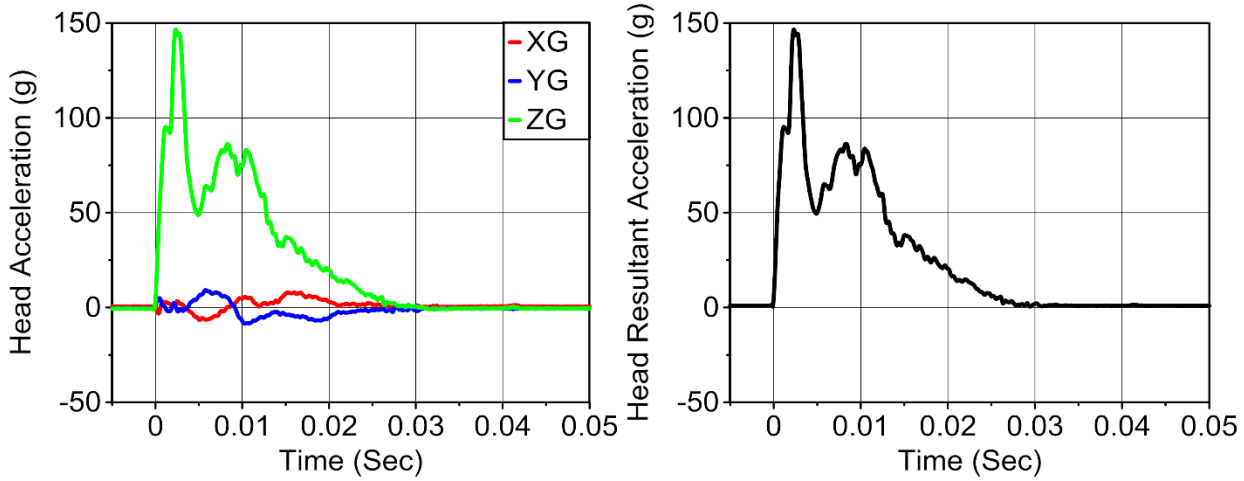
ChildHead 1648



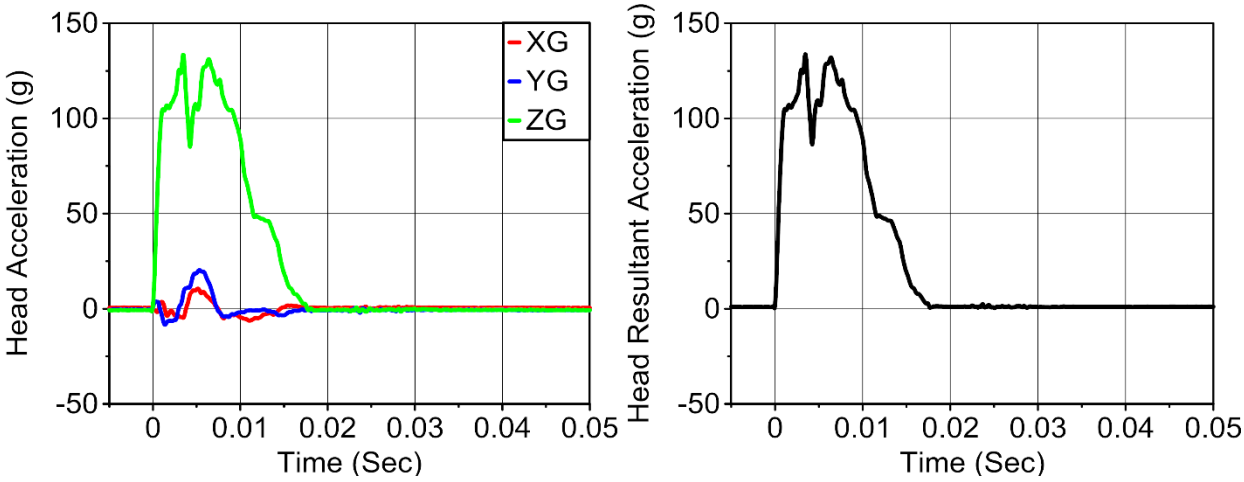
ChildHead 1649



ChildHead 1650

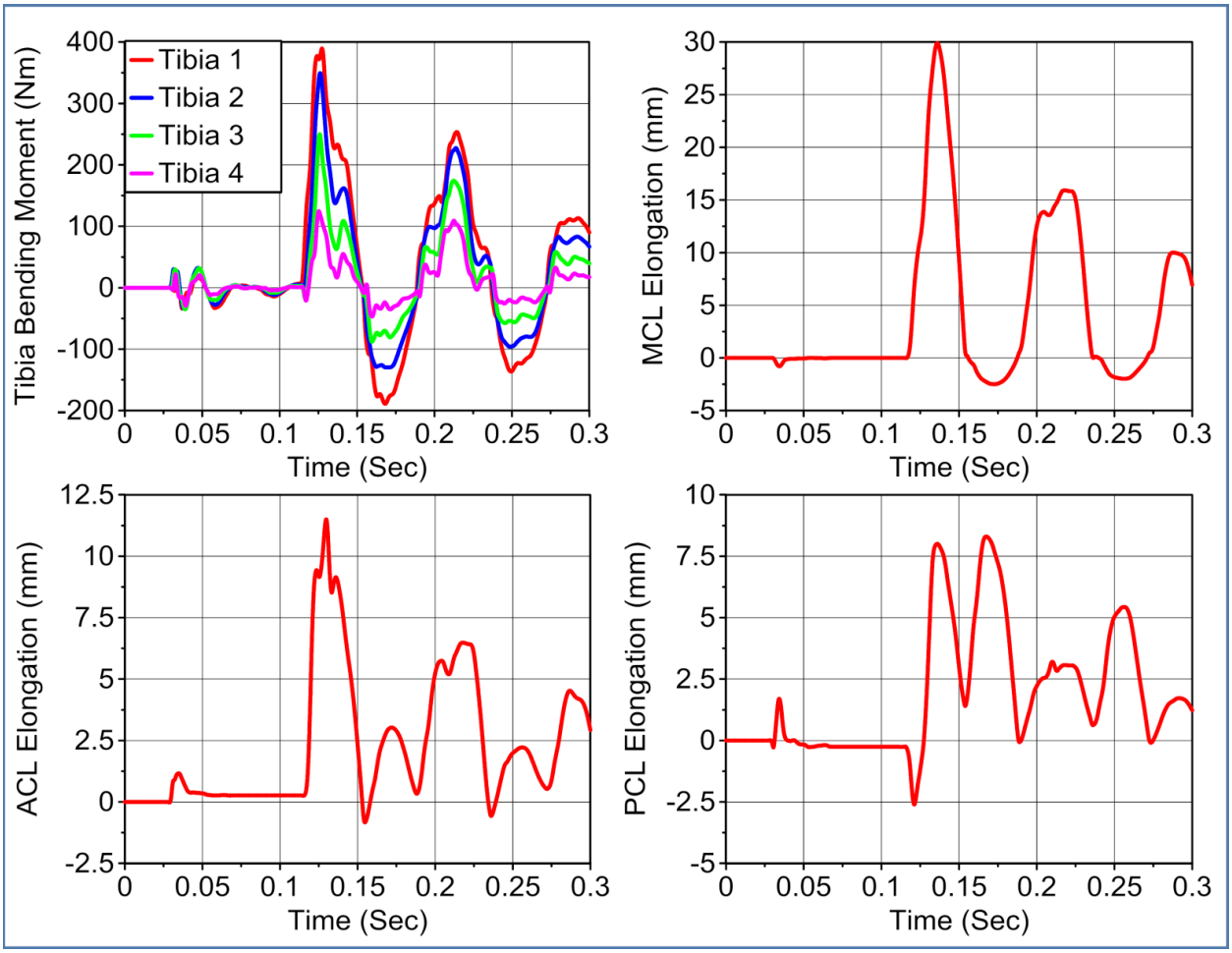


ChildHead 1651

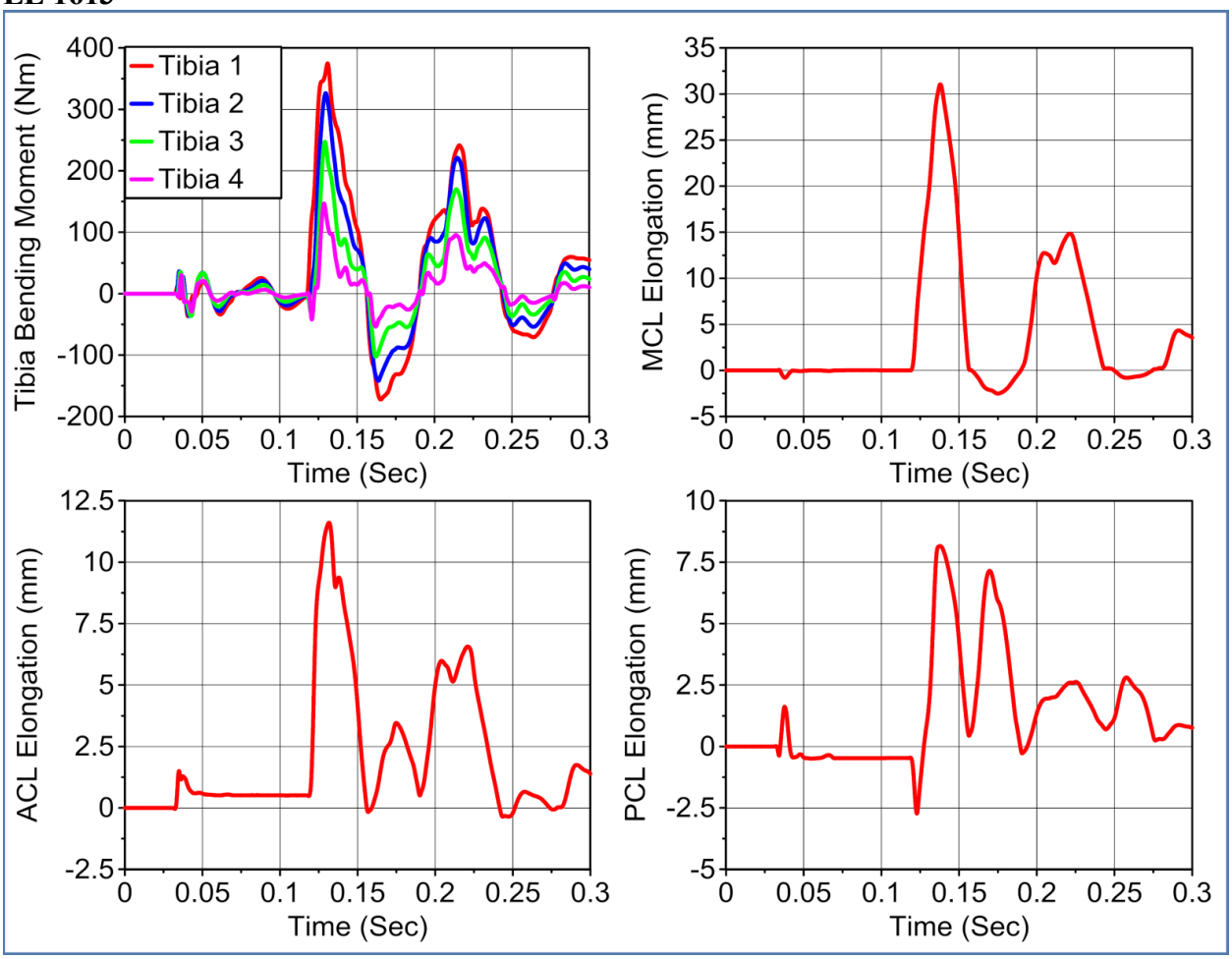


Lower Legform Impact Data Traces

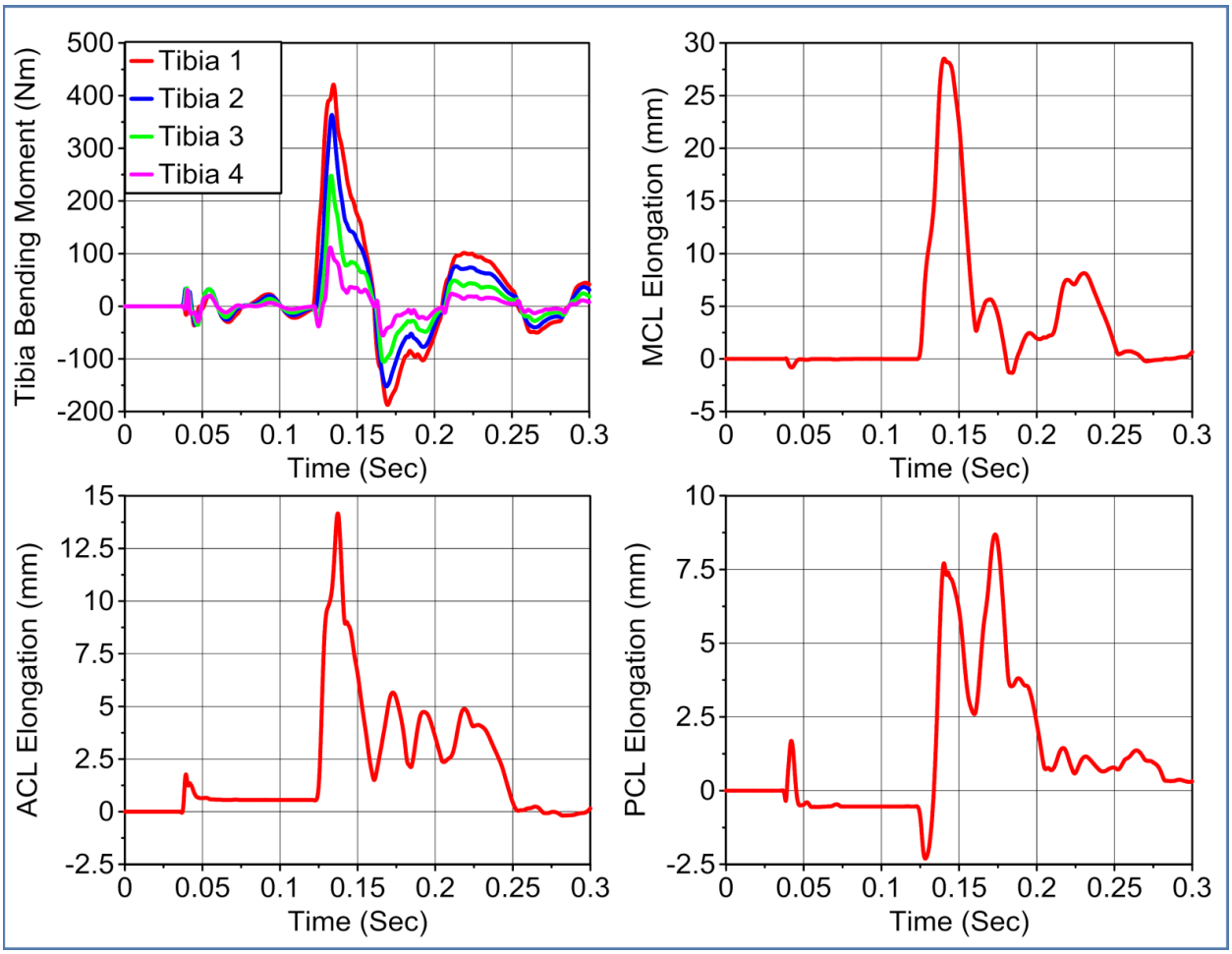
LL 1612



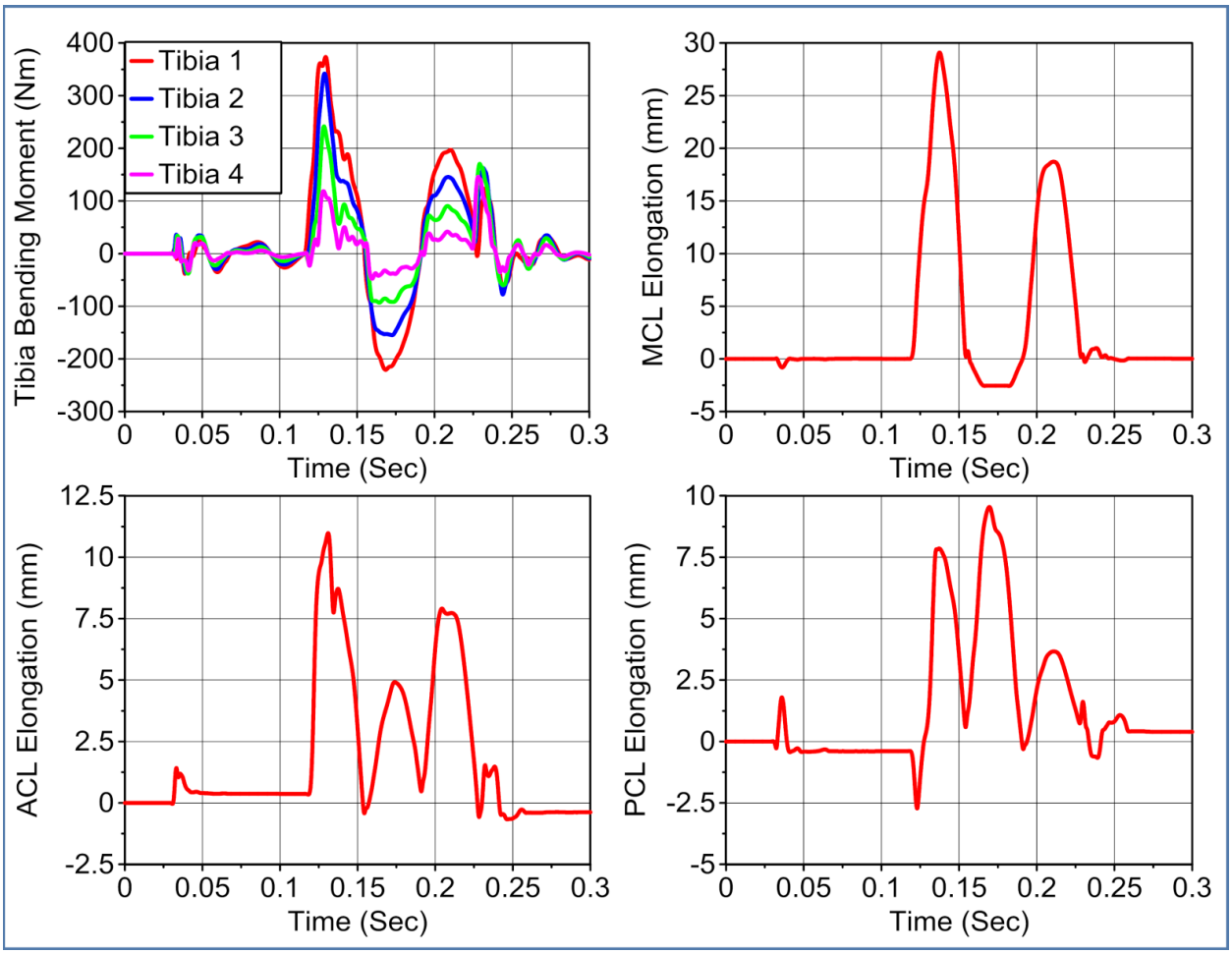
LL 1613


Tibia 1
Tibia 2
Tibia 3
Tibia 4
Tibia Bending Moment (Nm)
400
300
200
100
0
-100
-200
0
0.05
0.1
0.15
0.2
0.25
0.3
Time (Sec)
MCL Elongation (mm)
35
30
25
20
15
10
5
0
-5
Time (Sec)
ACL Elongation (mm)
12.5
10
7.5
5
2.5
0
-2.5
Time (Sec)
PCL Elongation (mm)
10
7.5
5
2.5
0
-2.5
-5
Time (Sec)

LL 1614

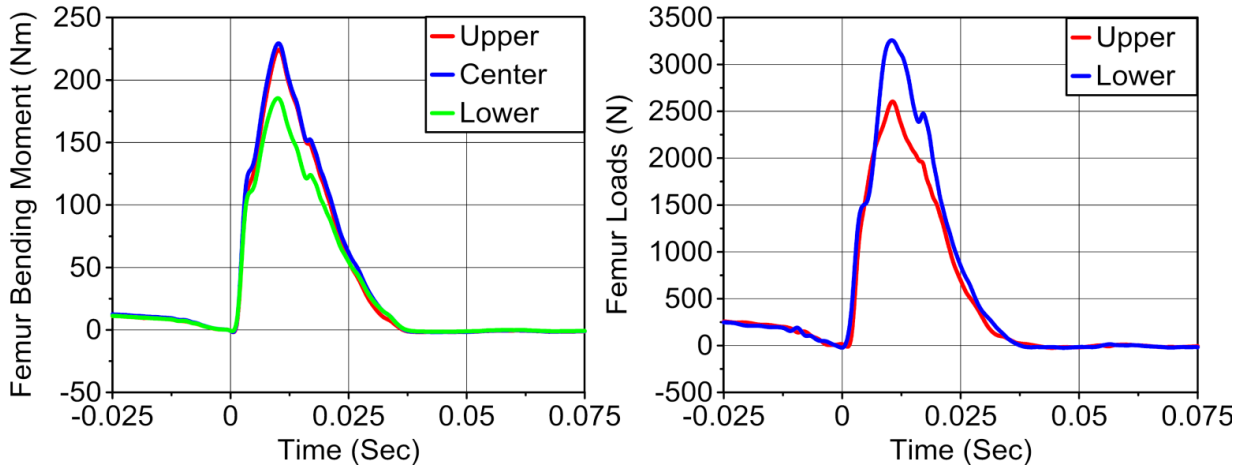

Tibia Bending Moment (Nm)
Tibia 1
Tibia 2
Tibia 3
Tibia 4
Time (Sec)
MCL Elongation (mm)
Time (Sec)
ACL Elongation (mm)
Time (Sec)
PCL Elongation (mm)
Time (Sec)

LL 1615

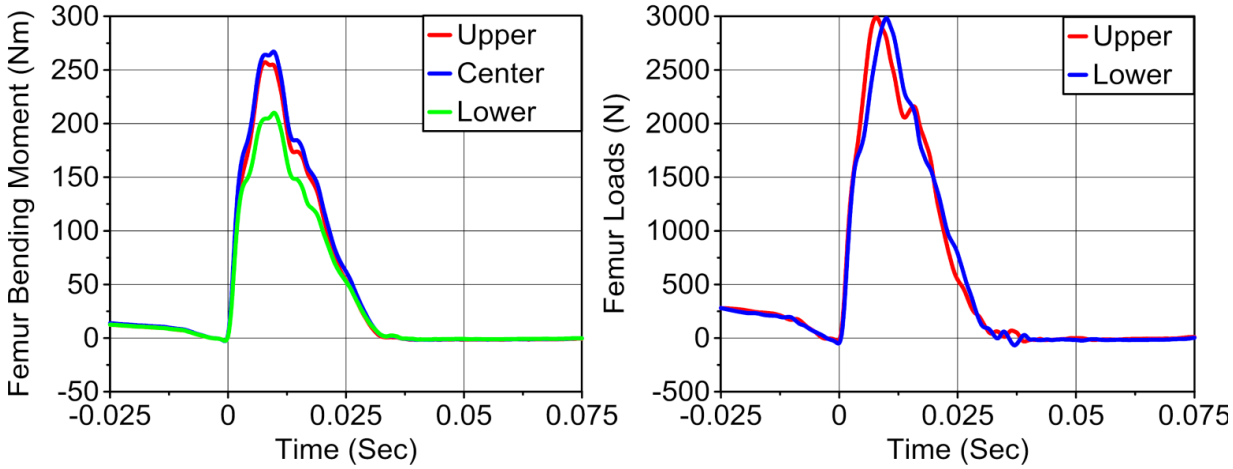

Tibia Bending Moment (Nm)
Tibia 1
Tibia 2
Tibia 3
Tibia 4
Time (Sec)
MCL Elongation (mm)
Time (Sec)
ACL Elongation (mm)
Time (Sec)
PCL Elongation (mm)
Time (Sec)

Upper Legform Impact Data Traces

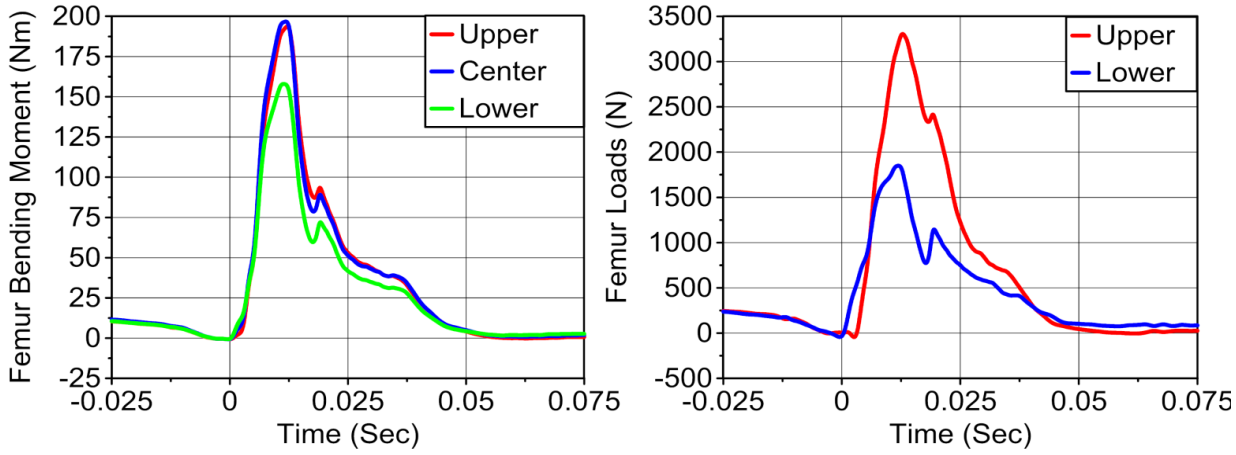
UL 1614



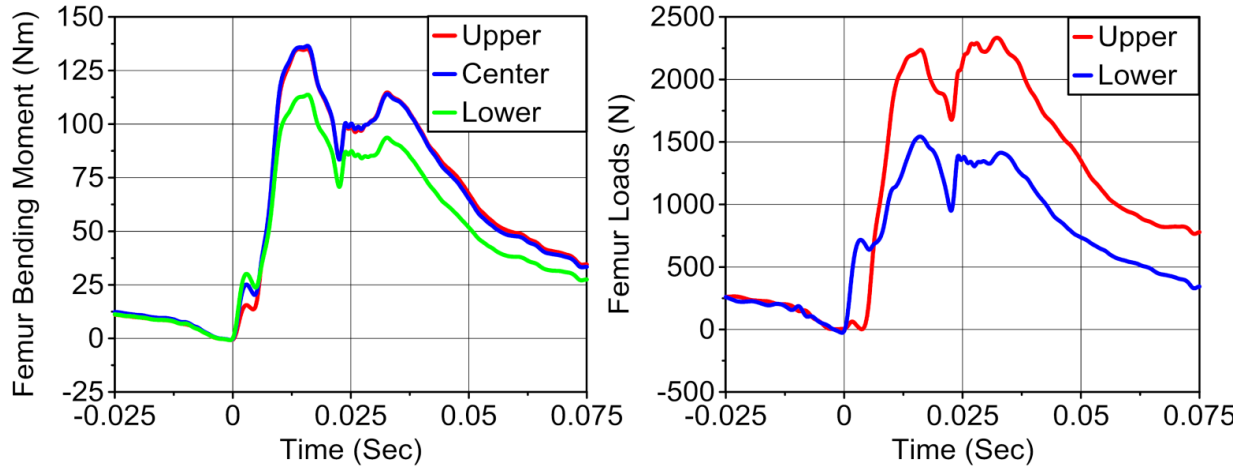
UL 1615



UL 1616



UL 1617



Examples of Post-Test Vehicle Damage

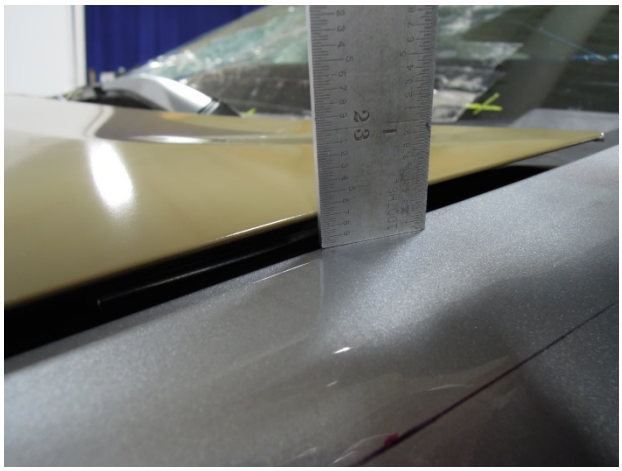
AdultHead 1643

ChildHead 1645

LL 1612

LL 1613

UL 1615



Appendix J: Vehicle Measurement Descriptions

For reference purposes, the lateral width and front-end width are provided for each vehicle tested by NHTSA. The measurements are listed in the Appendices for each vehicle. The definition of the width measurements is provided below.

Lateral Hood Width

Description

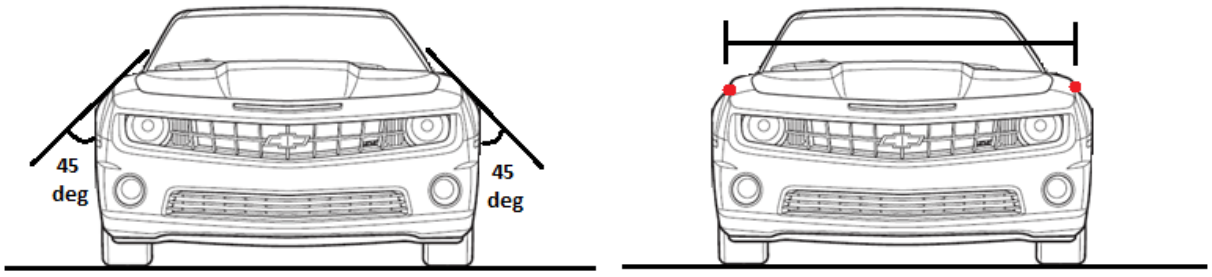
The lateral hood width, as the name suggests, is the distance between two points on the hood of the car. The measurement is taken from two points along the contour located after WAD1000 that have 45-degree angles.

Finding Two Reference Points

- Starting from the WAD1000 along the centerline, move the inclinometer outwards toward the fender of the car and find the first point that reads 45 degrees.
- Mark the point where the inclinometer first reads 45 degrees.
- To find the other point:
    - Repeat the first two steps on the other side of the vehicle,
    - If possible create a line directly perpendicular to the centerline of the vehicle from the first marked point to the other side. Somewhere along this line, the same 45degree angle will exist.

Measurement Instructions

- Using a rigid tool such as a yard stick or a meter stick, measure the distance between these points.
- Using the flexible measuring tape, measure from one point to another making sure to keep the tape taut.



Front End Width

Description

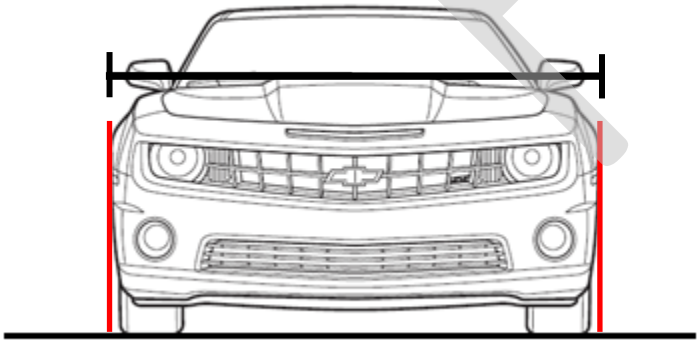
The front-end width, as the name suggests, is the distance between two points on the front end of the car. The measurement is taken from two points where the front fascia meets the front fender.

Finding Two Reference Points

- On one side of the vehicle, place a long vertical level at the point where the front fascia meets the fender.
- Make sure the level is perpendicular to the ground
- Repeat on the other side of the vehicle

Measurement Instructions

- Using a rigid tool such as a yard stick or a meter stick, measure the distance between the two levels.
- Using the flexible measuring tape, measure from one level to another making sure to keep the tape taut.



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**National Highway
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