National Highway Traffic Safety Administration





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Outline

- Review previous BioRID injury criteria correlation results/issues
 Design and intent of sled test matrix to address issues
- BioRID R&R in production seat sled tests
- New correlation of BioRID injury criteria measures to PMHS injury
- Conclusions / Future options

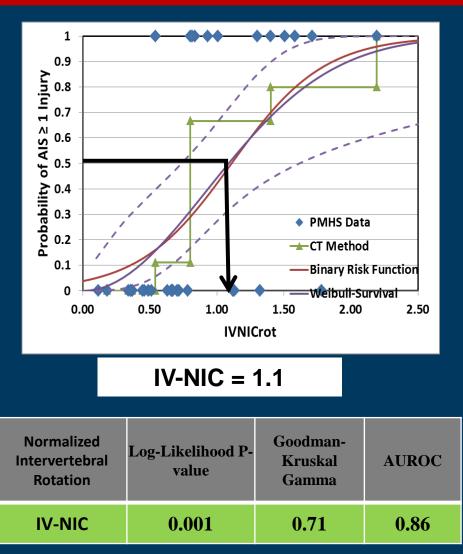


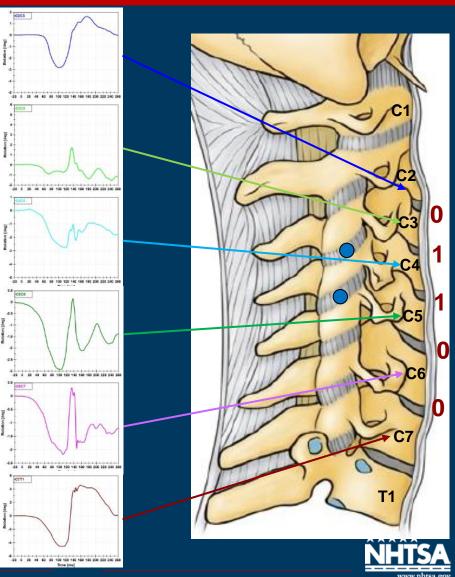
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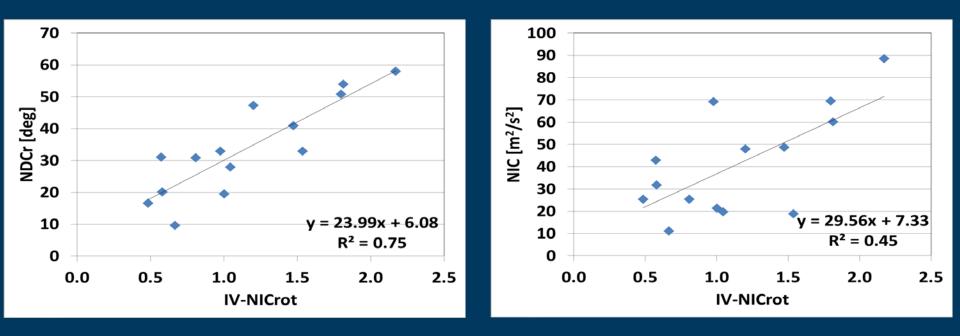


Review of Previous Results PMHS IV-NIC Injury Risk Curve



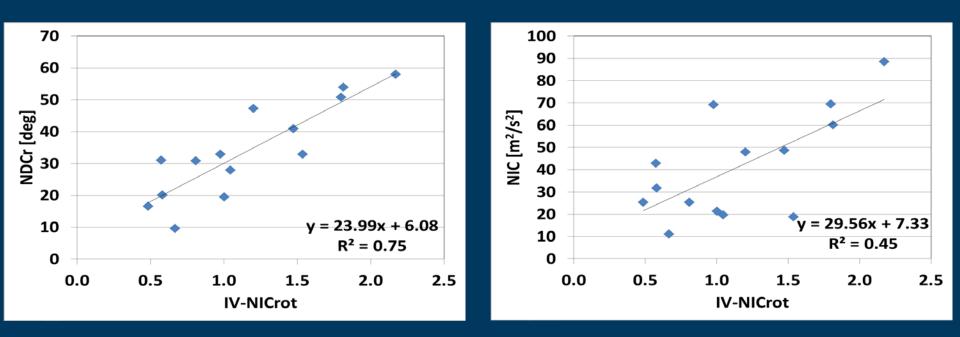


Review of Previous Results Correlation of PMHS Injury Criteria Measures to IV-NIC





Review of Previous Results Correlation of PMHS Injury Criteria Measures to IV-NIC



- Make similar correlations using BioRID measures...



May 2013 test series

- Initial paired tests using BioRID 8599 (side-by-side with PMHS)
 - No luck with direct correlations
 - Applied scaling technique between PMHS and BioRID for kinematics
 - Could not use scaling for neck loads (issues with PMHS inverse dynamics)
 - Direct correlation is preferred over scaling if possible
 - Concern that BioRID used in testing wasn't latest design level
 - Single BioRID dummy used in all tests over 8 month span
 - Sent BioRID 8599 and 0073 to HIS for calibration/upgrade



March 2014 test series

- Dummies upgraded to latest build level received
- Conducted sled tests with BioRIDs 8599 and 0073
 - Test Matrix:
 - Two initial tests to evaluate R&R
 - Re-conduct PMHS replicate tests
 - Increased backset tests
 - Small-scale fleet analysis for injury criteria efficacy and seat discrimination
 - Initial two tests showed questionable R&R
 - Dummies sent back to Humanetics for revision and Gen-X testing



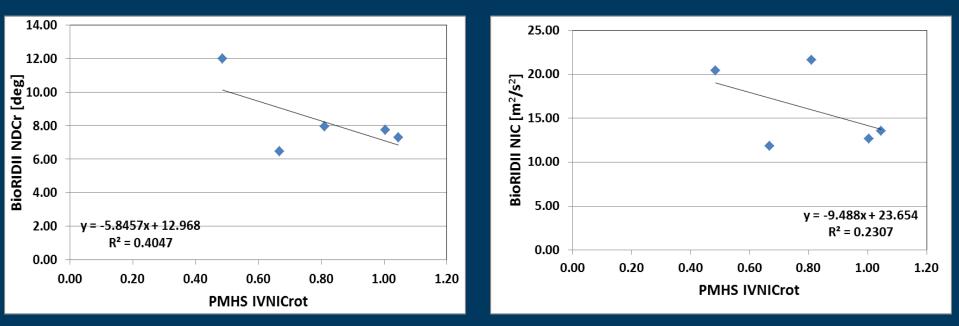
January 2015 test series

- Dummies deemed to have sufficient R&R in Gen-X tests
- Conducted sled tests with BioRIDs 8599, 0073, 0100
 - Test Matrix:
 - Four initial tests to evaluate R&R
 - Re-conduct PMHS replicate tests
 - Increased backset tests
 - Small-scale fleet analysis for injury criteria efficacy and seat discrimination
 - R&R from first four tests still questionable (but not quantifiable)
 - Poor injury criteria correlations



Review of Previous Results Correlation of BioRID Injury Criteria Measures to IV-NIC

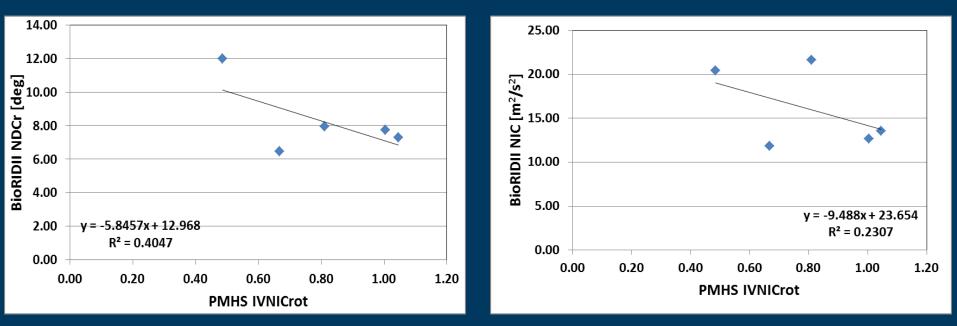
Poor (and negative) correlation for BioRID





Review of Previous Results Correlation of BioRID Injury Criteria Measures to IV-NIC

Poor (and negative) correlation for BioRID



- Poor biofidelity?
- Limited Data?
- Variation due to single data point for each test condition?



Review of Previous Results

Correlation of BioRID Injury Criteria Measures to IV-NIC

Potential Sources of Poor Correlation

- Poor biofidelity in BioRID?
 - Been shown to have adequate biofidelity and better than other RIDs
 - Can't improve without design change
- Limited Data?
 - Only 5 data points for correlation
 - Can't improve without additional PMHS tests
- Variation due to single data point for each test condition
 - Subject-to-subject variation in PMHS response on x-axis
 - Different subject used in each test condition
 - Can't improve without more PMHS tests
 - Didn't have problem using correlation of PMHS measures



Review of Previous Results

Correlation of BioRID Injury Criteria Measures to IV-NIC

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Review of Previous Results Correlation of BioRID Injury Criteria Measures to IV-NIC

Potential Sources of Poor Correlation

- Variation due to single data point for each test condition

- Variation in BioRID response on y-axis
 - BioRID R&R and/or sensitivity to initial positioning
- Test variation due to seats (cushions, HR, etc)



Review of Previous Results Correlation of BioRID Injury Criteria Measures to IV-NIC

Potential Sources of Poor Correlation

- Variation due to single data point for each test condition

- Variation in BioRID response on y-axis
 - BioRID R&R and/or sensitivity to initial positioning
- Test variation due to seats (cushions, HR, etc)

Conduct repeat tests to average out variation



May 2015 test series

- Dummies sent to Humanetics for Gen-X tests to ensure they still perform similarly
- Conducted sled tests with BioRIDs 8599, 0073, and 0100
 - Test Matrix:
 - Re-conduct all 5 PMHS replicate tests 3 more times
 - 0073 in every test for 4-point repeatability
 - All three BioRIDs exposed at least once in each condition for reproducibility
 - Multiple OSCAR measurements to assess repeatability of seat H-point
 - Tight tolerances on final seating position

- Average BioRID responses to reduce y-axis variation in correlation



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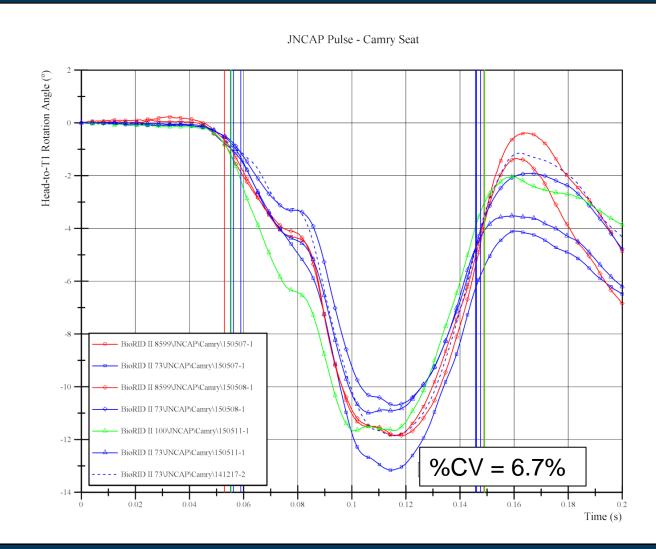
JNCAP Pulse Camry Seats





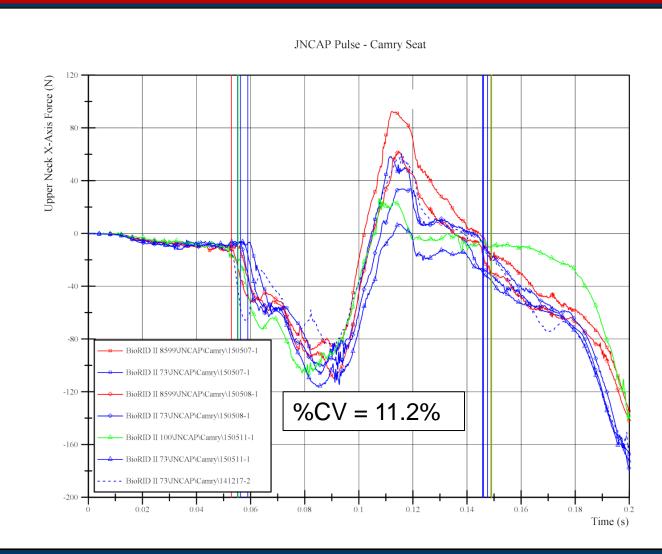
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BioRID Sled Test R&R JNCAP – Camry Seats - NDCr





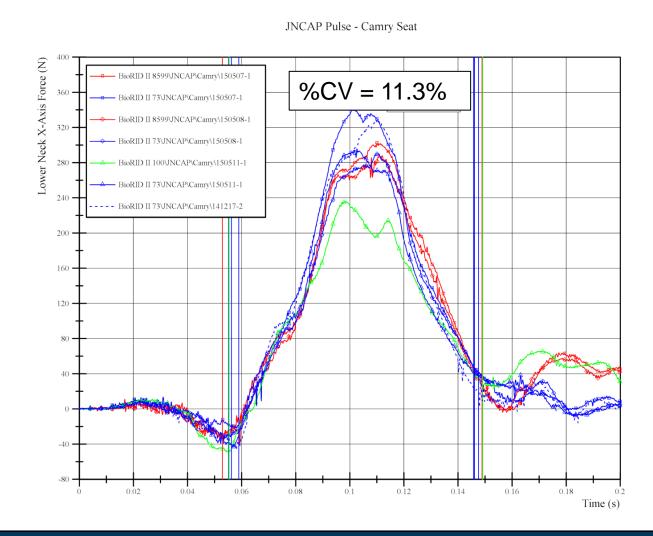
BioRID Sled Test R&R JNCAP – Camry Seats - UNFx



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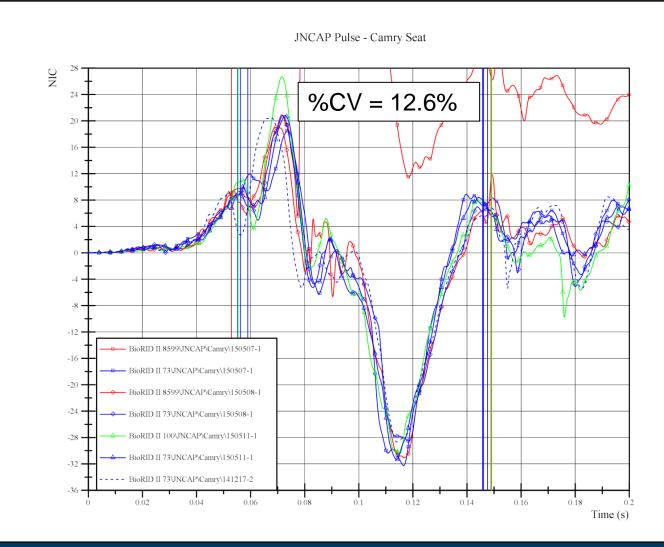
BioRID Sled Test R&R JNCAP – Camry Seats - LNFx



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BioRID Sled Test R&R JNCAP – Camry Seats - NIC





BioRID Sled Test R&R Summary

- 202a pulse
 - Cruze seats
 - NDCr: 6.4%; UNFx = 9.4%; LNFx = 10.6%; NIC = 7.5%



BioRID Sled Test R&R Summary

- 202a pulse
 - Cruze seats
 - NDCr: 6.4%; UNFx = 9.4%; LNFx = 10.6%; NIC = 7.5%
- JNCAP pulse
 - Cruze seats
 - NDCr: 14.2%; UNFx = 8.0%; LNFx = 9.0%; NIC = 8.1%
 - Camry seats
 - NDCr: 6.7%; UNFx = 11.2%; LNFx = 11.3%; NIC = 12.6%



BioRID Sled Test R&R Summary

- 202a pulse
 - Cruze seats
 - NDCr: 6.4%; UNFx = 9.4%; LNFx = 10.6%; NIC = 7.5%
- JNCAP pulse
 - Cruze seats
 - NDCr: 14.2%; UNFx = 8.0%; LNFx = 9.0%; NIC = 8.1%
 - Camry seats
 - NDCr: 6.7%; UNFx = 11.2%; LNFx = 11.3%; NIC = 12.6%
- 10.5g/24kph pulse
 - Cruze seats
 - NDCr: 13.0%; UNFx = 7.7%; LNFx = 14.4%; NIC = 16.0%
 - Camry seats

• NDCr: 22.9%; UNFx = 11.9%; LNFx = 17.8%; NIC = 16.8% Safer drivers. Safer cars. Safer roads. 25

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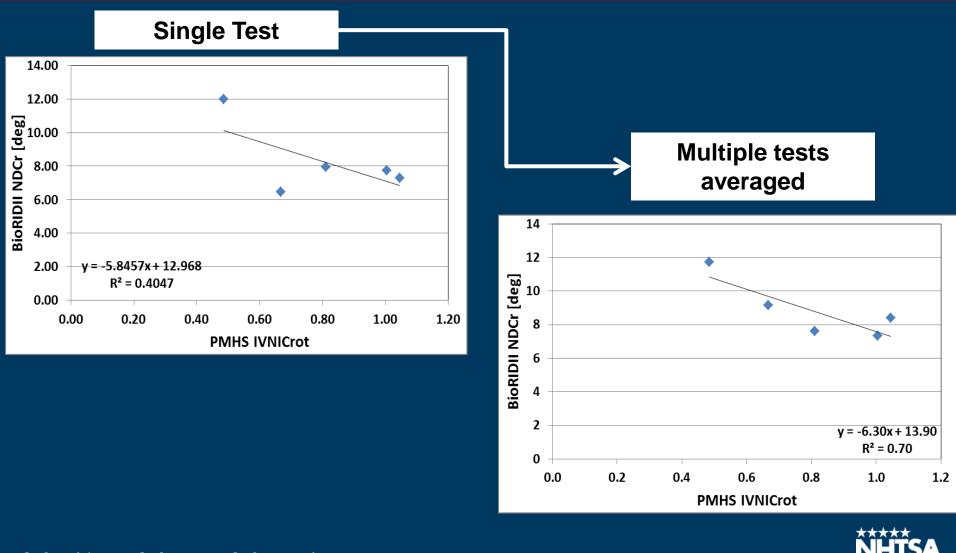
BioRID Injury Criteria Correlations

	BioRID II	PMHS IV-NICrot	
		\mathbb{R}^2	P - value
	NIC	0.09	0.62
Nij	Nte	0.06	0.68
	Ntf	0.05	0.71
	Nce	0.08	0.64
	Ncf	0.11	0.59
	Nij	0.04	0.75
Nkm	Nae	0.00	0.97
	Naf	0.32	0.32
	Npe	0.08	0.64
	Npf	0.11	0.58
	Nkm	0.29	0.35
NDC	NDCx	0.11	0.58
	NDCx rate	0.04	0.74
	NDCx product (max-max)	0.07	0.68
	NDCx product (max)	0.11	0.59
	NDCz	0.36	0.29
	NDCz rate	0.02	0.81
	NDCz product (max-max)	0.55	0.15
	NDCz product (max)	0.02	0.81
	NDCr	0.70	0.08
	NDCr rate	0.72	0.07
	NDCr product (max-max)	0.71	0.08
	NDCr product (max)	0.83	0.03
	C2 to T1 rotation	0.13	0.54

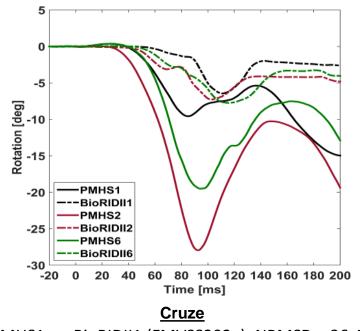
BioRID II			PMHS IV-NICrot	
			R ²	P - value
	Fx	+	0.05	0.71
		-	0.41	0.24
Upper	Fz	+	0.17	0.49
Neck	T Z	-	NA	NA
	My	+	0.60	0.12
		-	0.01	0.87
	Fx	+	0.00	0.93
		-	NA	NA
Lower	Fz	+	0.19	0.46
Neck		-	0.40	0.25
	Му	+	NA	NA
		-	0.04	0.76



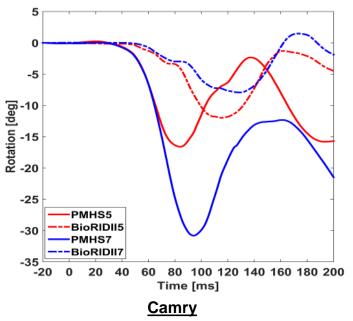
BioRID Injury Criteria Correlations NDCr



BioRID Injury Criteria Correlations Biofidelity: NDCr



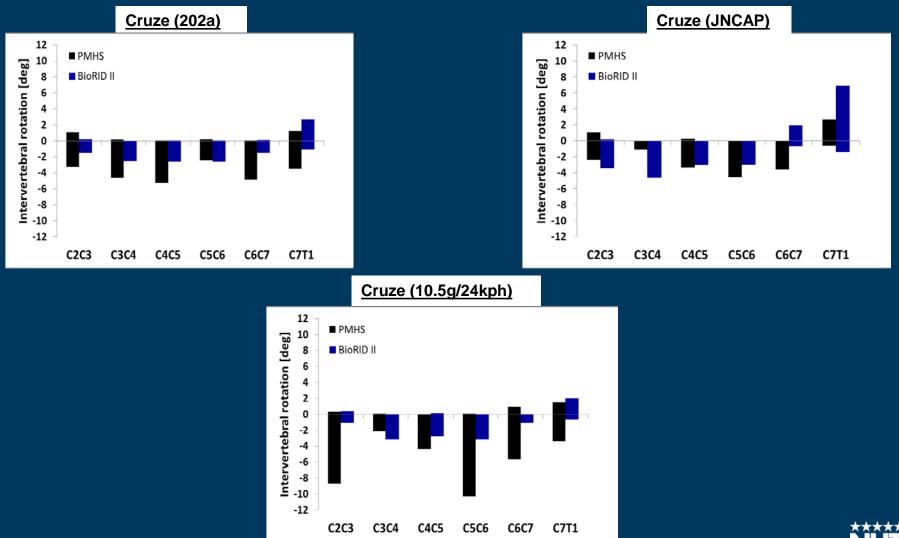
PMHS1 vs. BioRIDII1 (FMVSS202a): NRMSD = 36.44% PMHS2 vs. BioRIDII2 (JNCAP): NRMSD = 40.10% PMHS6 vs. BioRIDII6 (24 km/h): NRMSD = 35.60%



PMHS5 vs. BioRIDII5 (JNCAP): NRMSD = 34.50% PMHS7 vs. BioRIDII7 (24 km/h): NRMSD = 42.01%

Fig. 3. Head rotation relative to T1 rotation (average NRMSD of $37.7 \pm 3.2\%$)

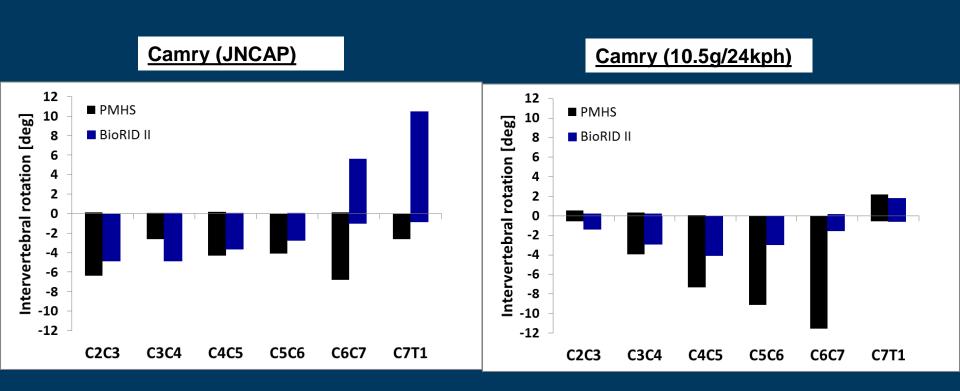
BioRID Injury Criteria Correlations Biofidelity: Intervertebral Rotations



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BioRID Injury Criteria Correlations Biofidelity: Intervertebral Rotations





BioRID Injury Criteria Correlations Summary

• NDCr range:

BioRID: 8 to 12 deg
12 deg 202a, 10.5 deg JNCAP, 8.5 deg 10.5g/24kph
PMHS: 9 to 30 deg
9 deg 202a, 22 deg JNCAP, 24.5 deg 10.5/24kph

Intervertebral Rotation range:
BioRID: 1.1 deg to 4.9 deg
PMHS: 1.0 deg to 12.0 deg



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Conclusions

- BioRID seems adequately repeatable and reproducible based on Gen-X tests and production seat sled tests
- BioRID appears to exhibit poor biofidelity in flexion
 - Unable to correlate BioRID measures to PMHS flexion injuries
 - BioRID designed and tuned to match extension kinematics
 Small 4.5 deg ROM in flexion
 - Does not mean BioRID is not a suitable tool for advancing safety in rear impact
 - Use of seat criteria (e.g., ENCAP/JNCAP/IIHS) may be capable of reducing whiplash injuries even though the criteria may not be directly linked to the injury mechanism
 - Results might be different if extension kinematics and extension injuries occurred



Potential Future Work

• Develop injury criteria directly linked to the injury mechanism:

– Options for flexion injuries:

- Expand range of motion of BioRID cervical vertebrae in flexion
- Short-term: Re-conduct the BioRID sled test series with new design
- Longer-term: strengthen correlations by conducting more PMHS tests

– Options for extension injuries:

- Conduct increased backset tests (modified production seats) using PMHS
 - Induces extension kinematics and injuries necessary to develop IV-NIC injury risk curves for extension
 - Conduct paired BioRID and Hybrid III tests.
 - Would expect better BioRID correlation to injury due to better biofidelity in extension

