

Reduction of Minor Neck Injuries during Rear-end Impacts

Evaluation Methods, Selection of Neck Injury Parameters and Its Criteria

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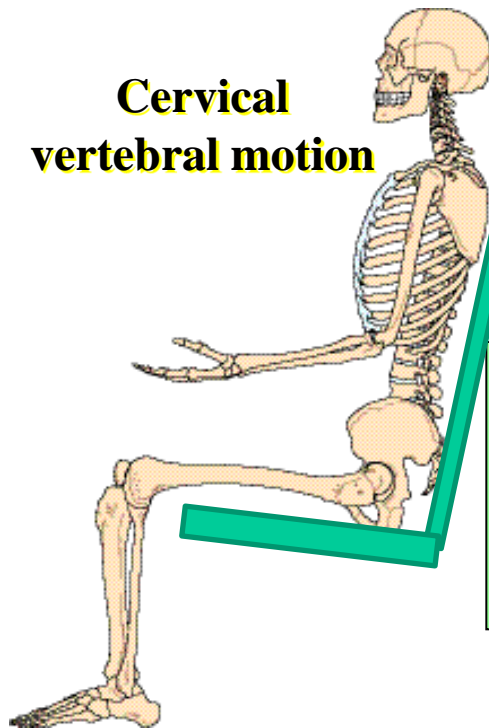
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Waseda University**

Minor neck injury

Not only neck region

Focus on whole spine motion

Cervical
vertebral motion



S-shape motion
(Vertical, Horizontal Motion)

Spine
straightening
Ramping-up

Current evaluation method
Not enough

focuses only on upper neck

- 1) Angle
- 2) Moment, axial force

Neck angle

Additional parameters

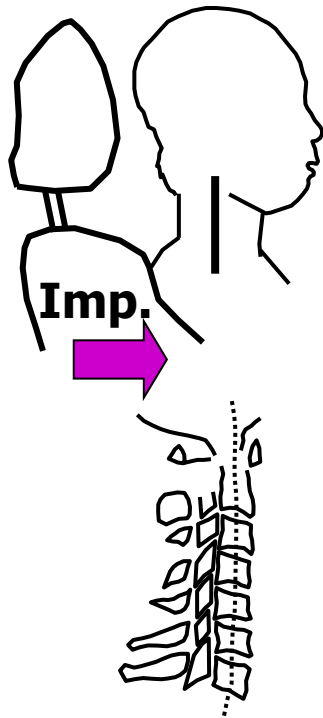
Lower neck

- 1) Axial, shear forces
- 2) Neck angle wrt T1

Needs to consider proper
neck injury parameters

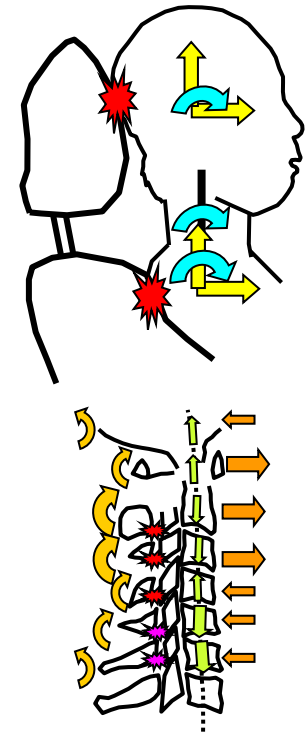
Proper minor neck injury parameters in rear impact

Necessary Method for Neck Injury Evaluation



◆ **Impact loading to the neck is dependent on the interaction patterns between the H/N/T and the seat with HR.**

◆ **To assess the motion of cervical vertebrae caused by impact loading and the interaction between the H/N/T and the seat with HR.**



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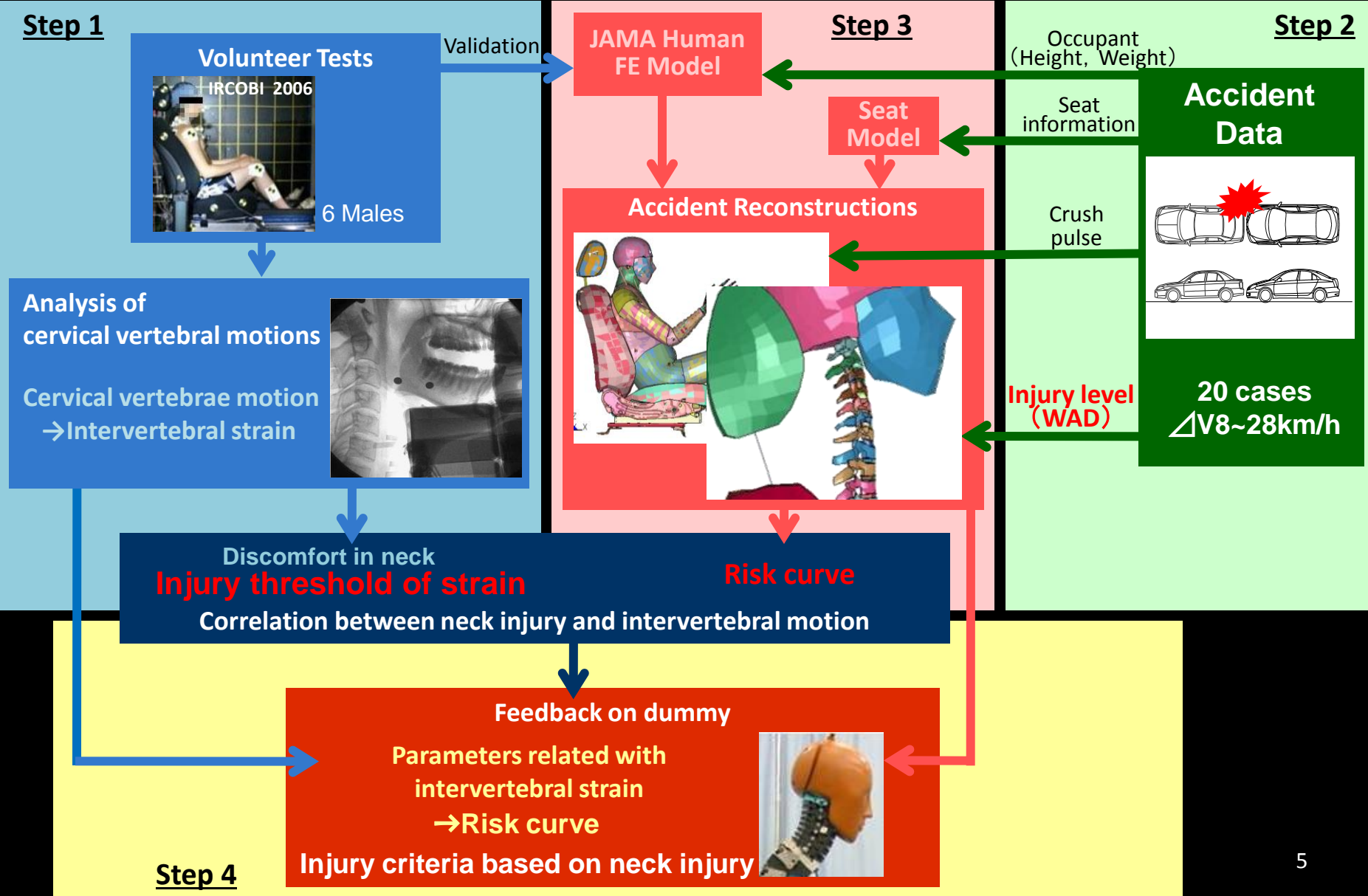
Relationship between cervical strain and WAD

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Research Process - Flowchart



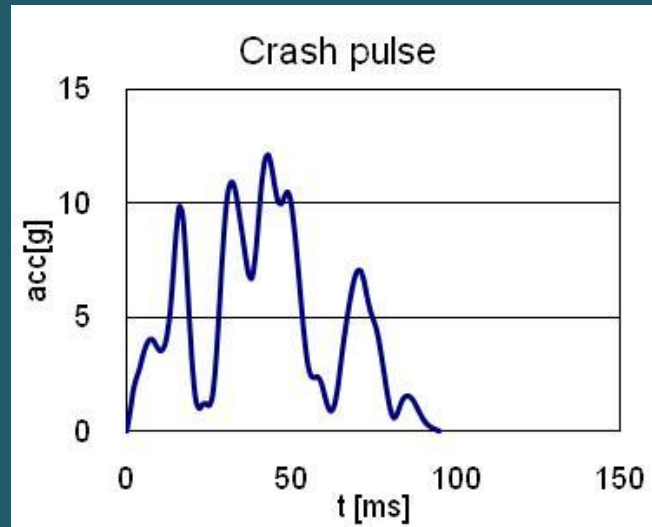
Accident Data (Folksam)

Acceleration
Crush Pulse

Injury Level
WAD

Occupant
Height • Weight

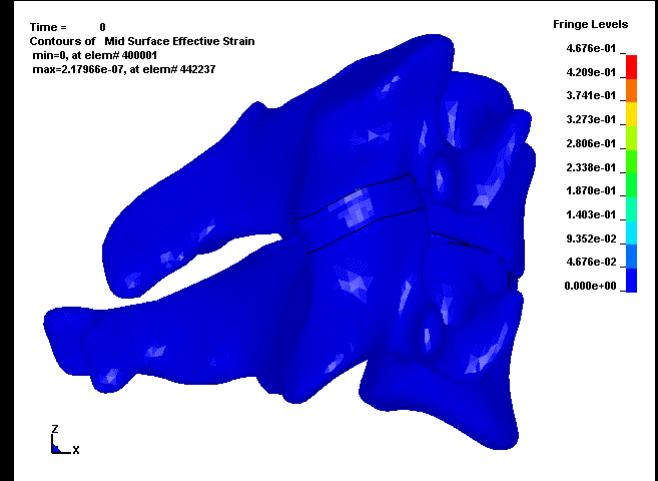
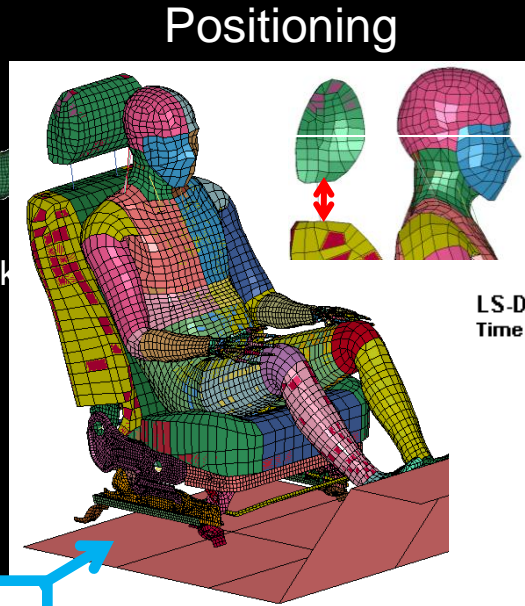
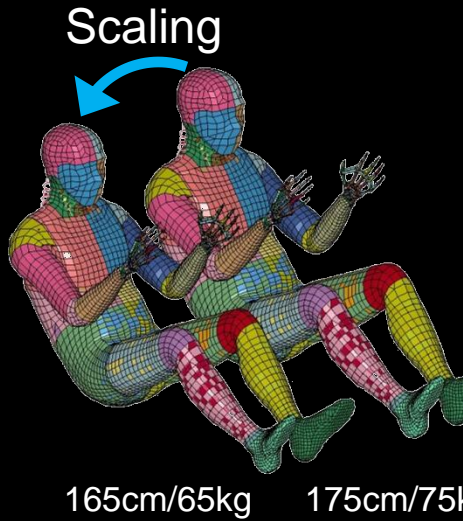
CASE		RECORDED CRASH PULSE			REPORTED INJURY			PASSENGER CHARACTERISTICS			
No.	D/P	Δv [km/h]	Mean Acc.[g]	Peak Acc. [g]	Neck/Spine	Symptoms	WAD	Gender	Age	Height	Weight
1	Driver	28.2	5.8	10.6	Injured	1-6 m	2	F	26	175	55
4	Driver								57	178	100
4	Passenge								57	168	80
2	Driver								59	156	60
8	Driver								22	171	63
8	Passenge								18	179	80
7	Driver								67	167	84
7	Passenge								72	165	63
10	Driver								74	175	62
10	Passenge								74	160	57
6	Driver								59	165	65
6	Passenge								88	170	70
11	Driver								61	176	77
11	Passenge								61	154	69
21	Driver								50	171	85
23	Driver								35	178	65
20	Driver								65	176	82
20	Passenge								68	176	77
24	Driver								35	165	55
3	Driver								35	165	55



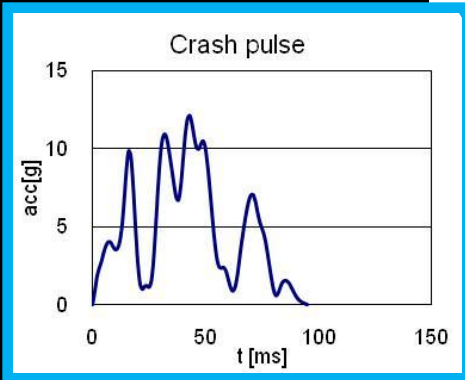
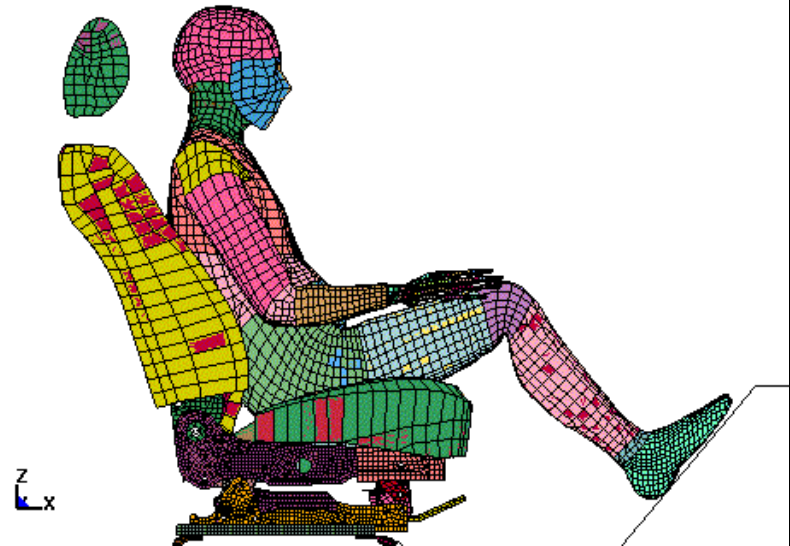
Car acceleration
measured with Crash Pulse Recorder
 ΔV 8 ~ 28 km/h

20
Cases

Accident Reconstruction - FE Model Simulations

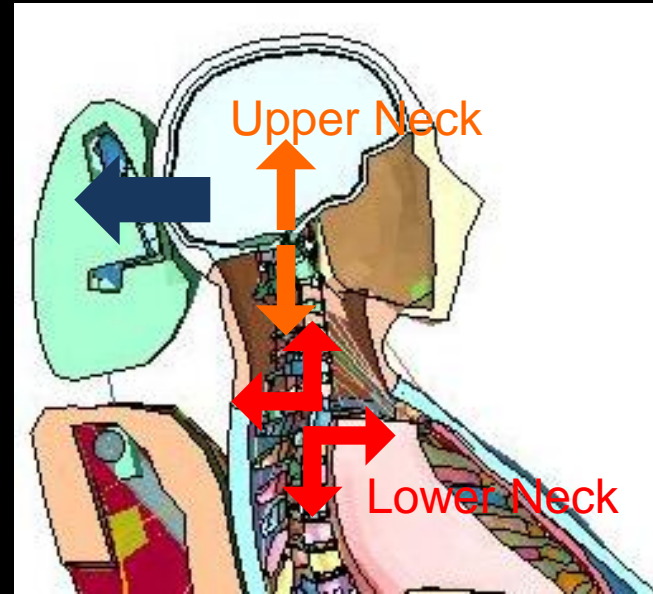
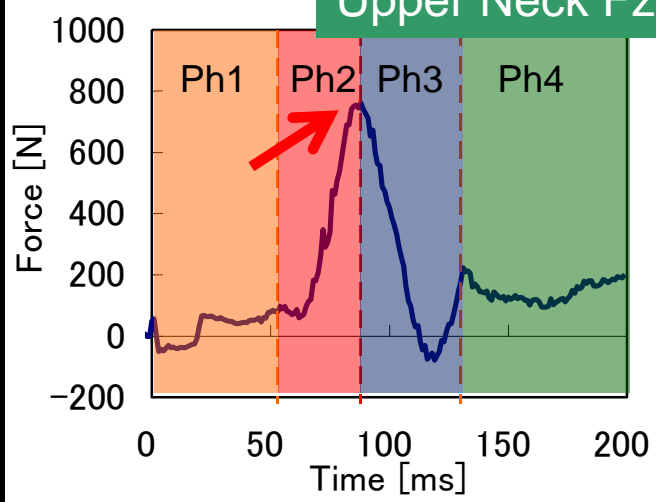


LS-DYNA KEYWORD DECK BY LS-PRE
Time = 0

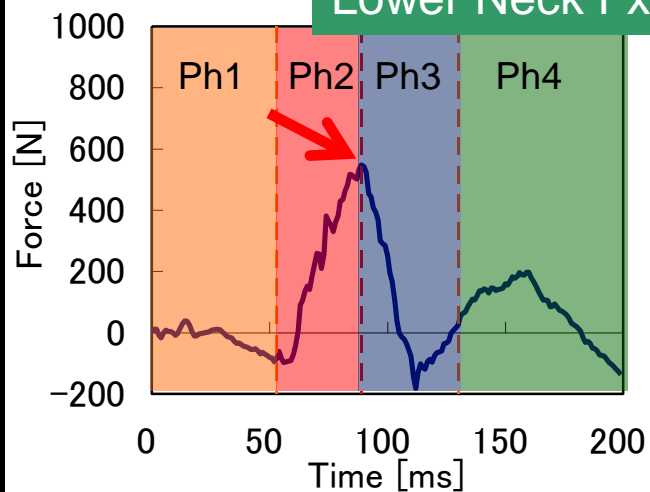


Occupant behavior — Neck force

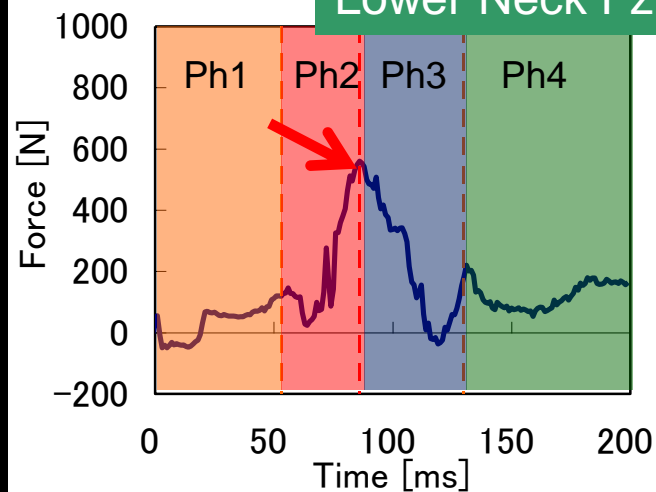
Upper Neck Fz



Lower Neck Fx

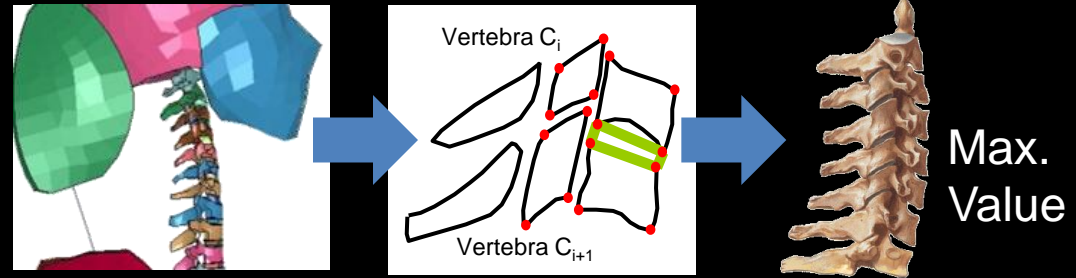


Lower Neck Fz

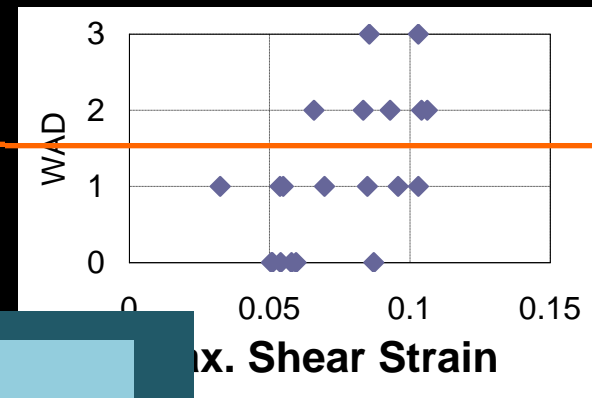
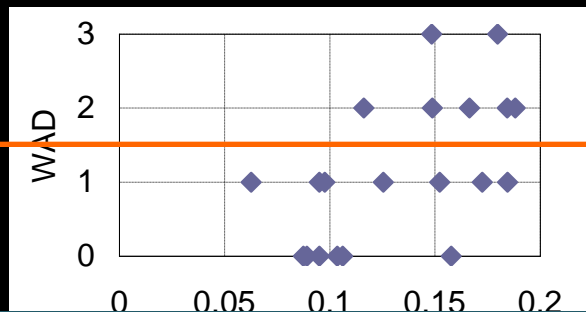


Relationship between cervical strain and WAD (1)

- Calculate cervical strain with Volunteer's method
- Extract max. value of the strain (C2/C3~C6/C7)



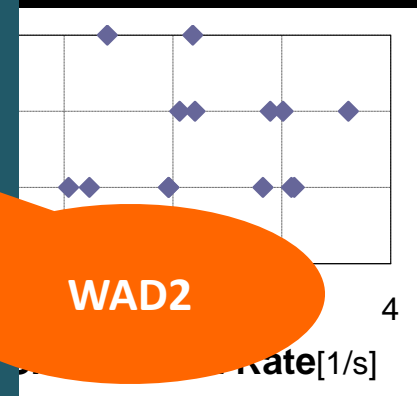
Cervical Strain



Classification of WAD (Whiplash-associated disorders)

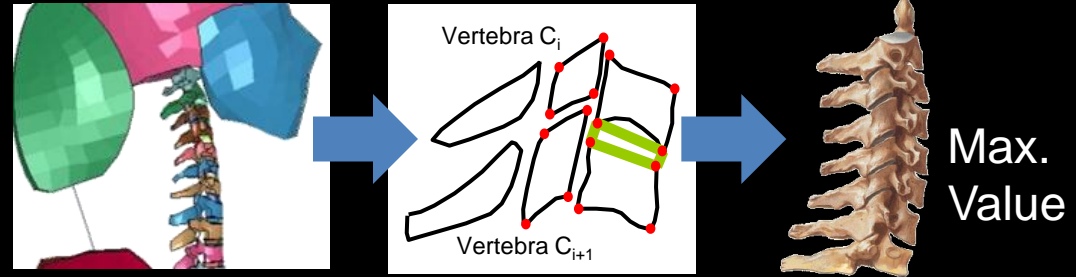
- grade 0: No complaint
- grade 1: Pain, stiffness (no physical sign(s))
- grade 2: Musculoskeletal sign(s)
- grade 3: Neurological sign(s)
- grade 4: Fracture or dislocation

WAD2

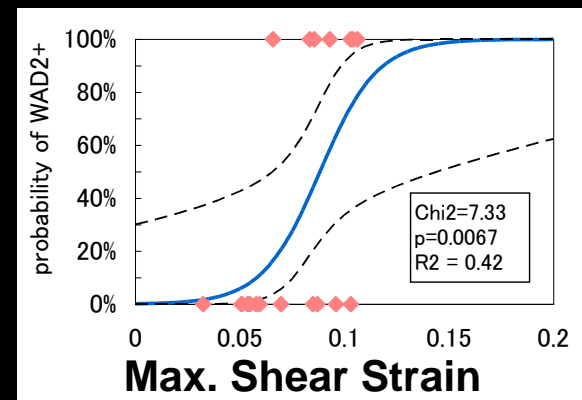
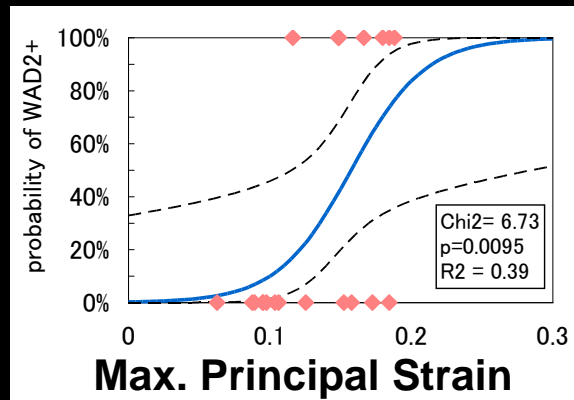


Relationship between cervical strain and WAD (2)

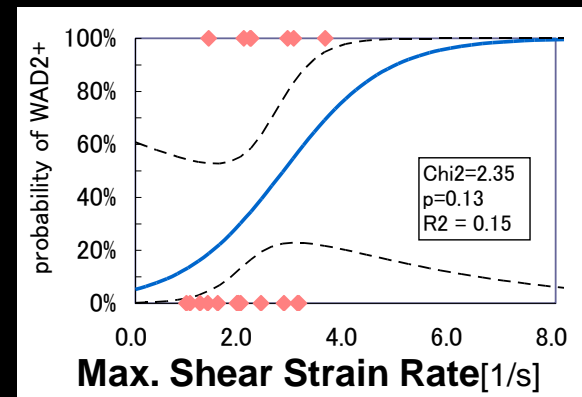
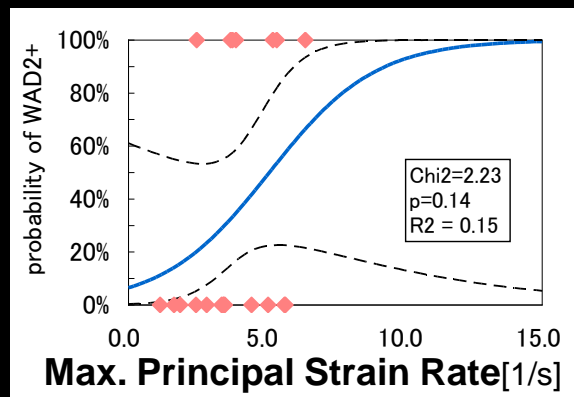
- Calculate cervical strain with Volunteer's method
- Extract max. value of the strain (C2/C3~C6/C7)



Cervical Strain

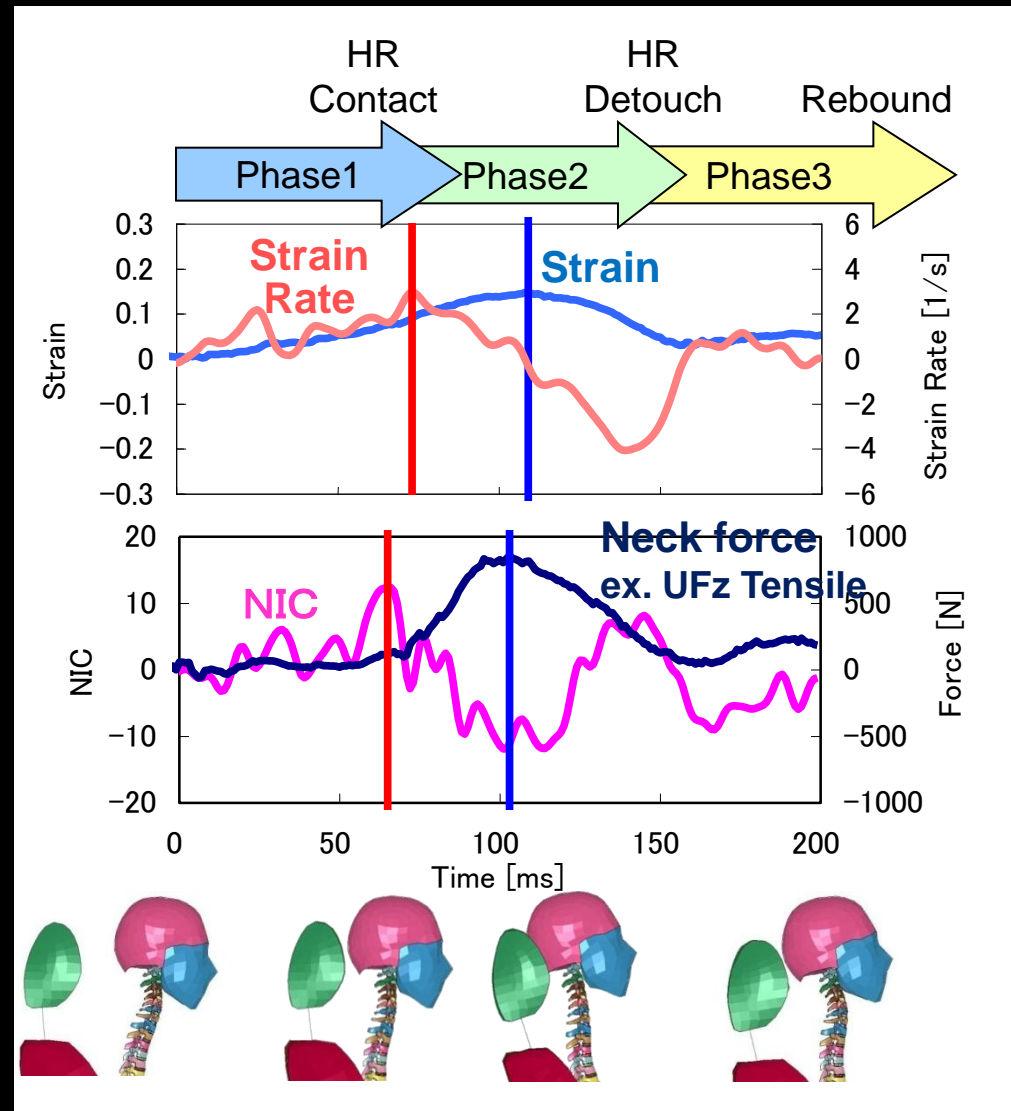


Cervical Strain rate

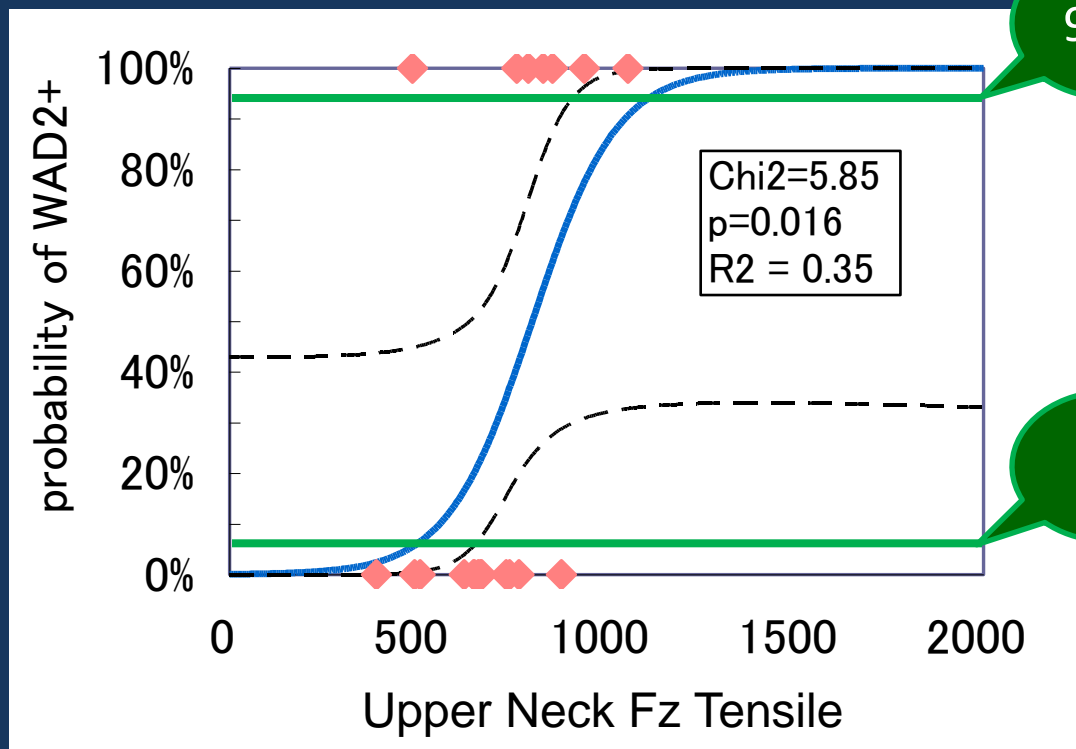
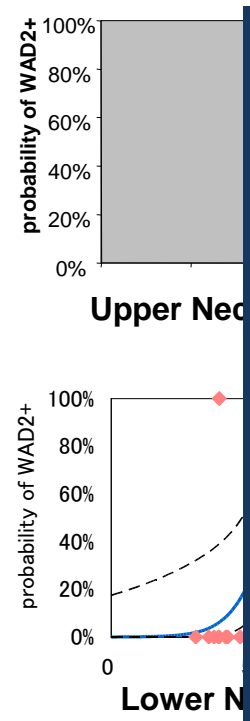


Selection of Neck Injury Evaluation Parameters

Neck Force	Upper	Fx	Forward
			Backward
		Fz	Tensile
		Compression	
	My	Extension	
		Flexion	
Lower	Fx	Forward	
		Backward	
	Fz	Tensile	
	Compression		
My	Extension		
	Flexion		
NIC			
T1G			
Nkm			
LNL			
Rebound V			
OC-T1 disp			
Head-Chest rot. ang.			

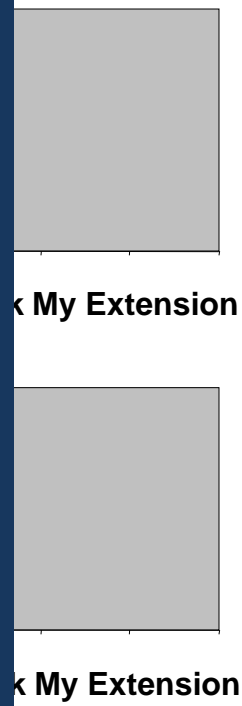
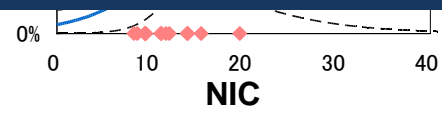


Neck Injury Risk Curve



95%

5%



Injury Criteria

Evaluation Parameters		WAD 2+		Volunteer Threshold	Literature Human Tolerance
		5%	95%		
Max. Principal Strain		0.08	0.24	0.06	-
Max. Shear Strain		0.05	0.13	0.05	-
Max. Principal Strain Rate		-	10.8	2.68	-
Max. Shear Strain Rate		-	5.8	1.81	-
NIC		8	30	(7)	-
Upper Fx	Backward	(340)	(730)	(150)	845 ¹⁾²⁾
Upper Fz	Tensile	475	1130	(200)	1134 ¹⁾²⁾
Upper My	Extension	(12)	(40)	(8)	20.3 ²⁾
	Flexion	12	40	(15)	50.2 ²⁾
Lower Fx	Backward	340	730	-	600~800 ³⁾ ΔV24~25km/h
Lower Fz	Tensile	257	1480	-	-
Lower My	Extension	(12)	(40)	-	-
	Flexion	(12)	(40)	-	-

References

- 1) Mertz, 1971
Strength and Response of the Human Neck, 15th Stapp
- 2) SAE J885, 2003
Human Tolerance to Impact Condition as related to Motor Vehicle Design
- 3) Stemper, 2009
Verification of Lower Neck Shear Force as a Rear Impact Injury Criterion

Conclusions

In the past, an evaluation method for minor neck injuries did not exist. Now, the evaluation parameters and thresholds for the reduction of minor neck injuries are obtained.

1. Based on the results of volunteer tests, the threshold of the strain and the strain rate that caused subjects to feel neck discomfort (minor neck injuries) during the test were well defined.
2. The relationship between the strain/strain rate and parameters which can be obtained from dummy was investigated based on the results of the volunteer test and FE analysis. Then, the parameters which have good correlations with the strain/strain rate were selected as evaluation parameters for neck injury.

Conclusions (continued)

3. The risk curve of WAD2+ concerning neck forces/moments and NIC based on the results of volunteer tests and accidents reconstruction simulation was recommended.
4. The risk curve values of 5% and 95% for causation of neck injury were determined as neck injury criteria based on the volunteer test results and FE analysis using the Human FE model.
5. The risk curve value of 5% was the level where volunteers would experience neck discomfort during the volunteer tests, and the risk curve value of 95% was almost the same as the human tolerance values in literature.

Adoption as an Evaluation Injury Criteria for JNACP Test

The proposed neck injury evaluation parameters and criteria were adopted as one of J-NCAP tests for the minor neck injury assessment in rear impact test, starting April 2009.

The result will also be focused at being a primary candidate for an injury evaluation method that would be scrutinized by WP29/GRSP/HR GTR.

Acknowledgment

We would like to acknowledge the accident data provided by Folksam.

Thank you for your attention.