GTR-04-05

Influence on Cervical Vertebral Motion of the Interaction between Occupant and Head Restraint/Seat, based on the Reconstruction of Rear-End Collision Using Finite Element Human Model

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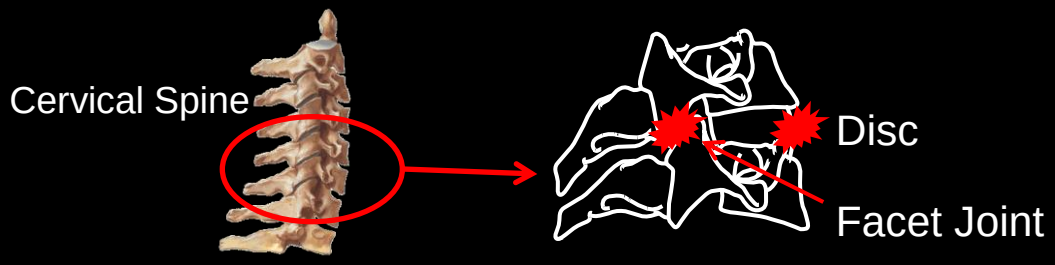
15.09.2010

IRCOBI 2010

Minor neck injury in rear-end accidents

Diagnosing minor neck injuries with CT or MRI is difficult

➡ Neck Injury mechanism has not been clarified yet



PMHS tests : Excessive deflection → Intervertebral Soft tissue injury

Clinical findings : Facet joint injury is most common

Animal tests : The strain of the facet joint capsule is related to pain

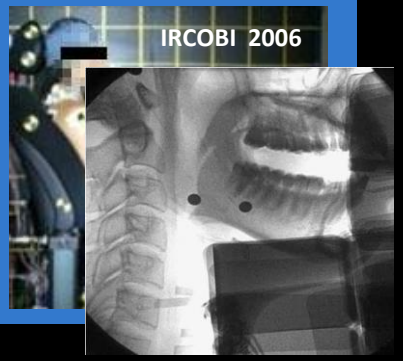
Excessive deflection between vertebrae → Intervertebral soft tissue injury

Investigation of the relationship between strain of intervertebral soft tissue and neck injury severity

Strain of intervertebral soft tissue and neck injury

IRCOBI 2009

Volunteer Tests



Accident Reconstructions

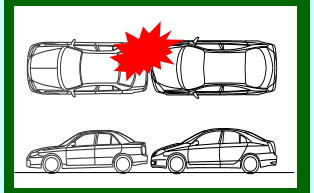
Calculate the strain of intervertebral soft tissue

Volunteer Tests

Discomfort in neck

Maximum strain of intervertebral soft tissue

Accident Data 20 cases



Injury Severity

The maximum strain of intervertebral soft tissue correlates with the neck injury severity

Objective

Clarify the vertebral motion related with neck injury by investigating occupant behavior at the time when the strain of intervertebral soft tissue is maximal

Contents

1. Validation of the human FE model against the PMHS test at ΔV16km/h
2. Investigation of the relationship between the strain of inter-vertebral soft tissue and occupant motion

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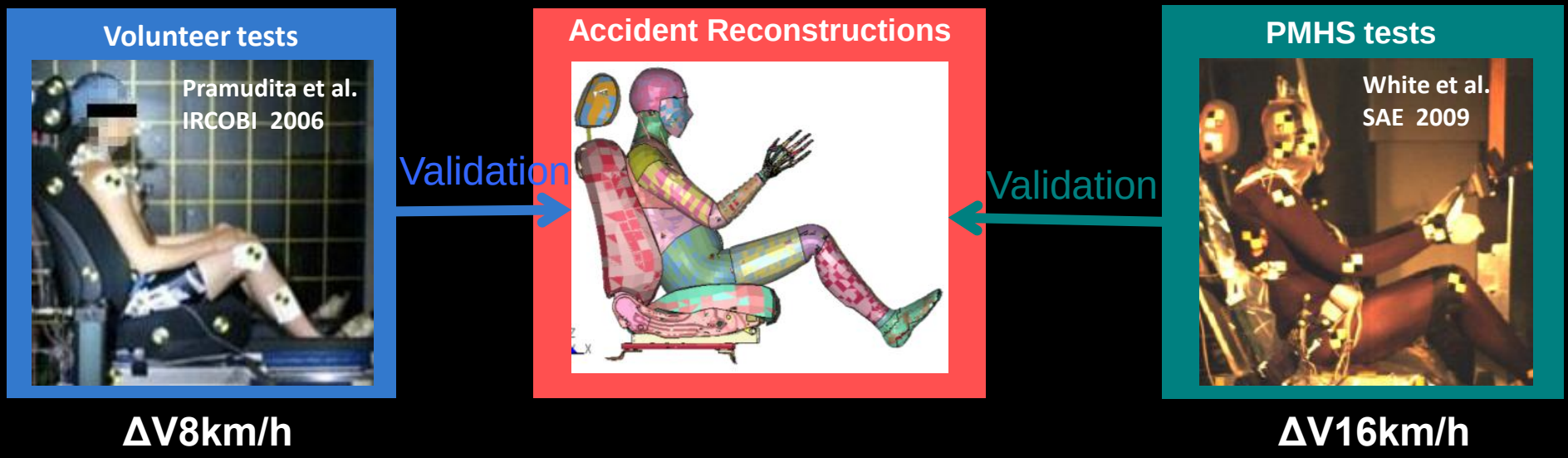

- Validate biofidelity of the human FE model at a higher impact velocity than taht of the volunteer test

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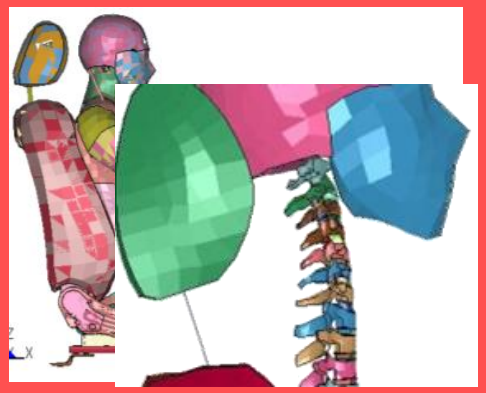
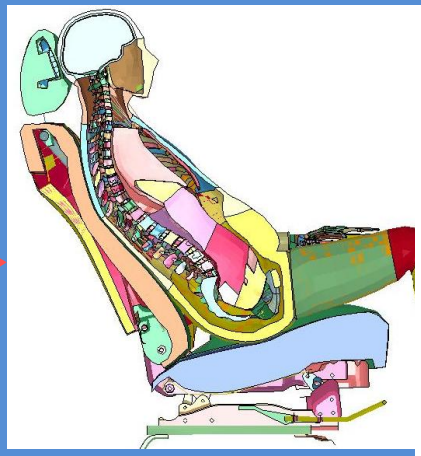
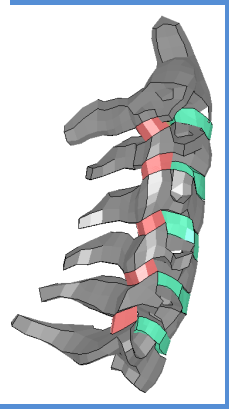


Maximum strain of intervertebral soft tissue

Occupant behaviour



Whole body motion



Cervical spine motion

- Analyse occupant's whole body and cervical spine motion at the the time when the strain of intervertebral soft tissue is maximal

1. Validation of the human FE model against the PMHS test at ΔV16km/h

Validation of the human FE model

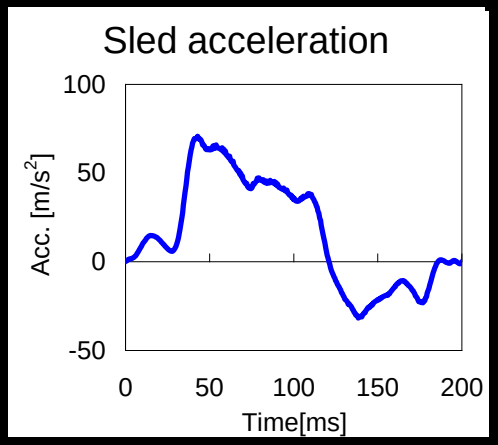
Reconstruction simulation of the PMHS experiment

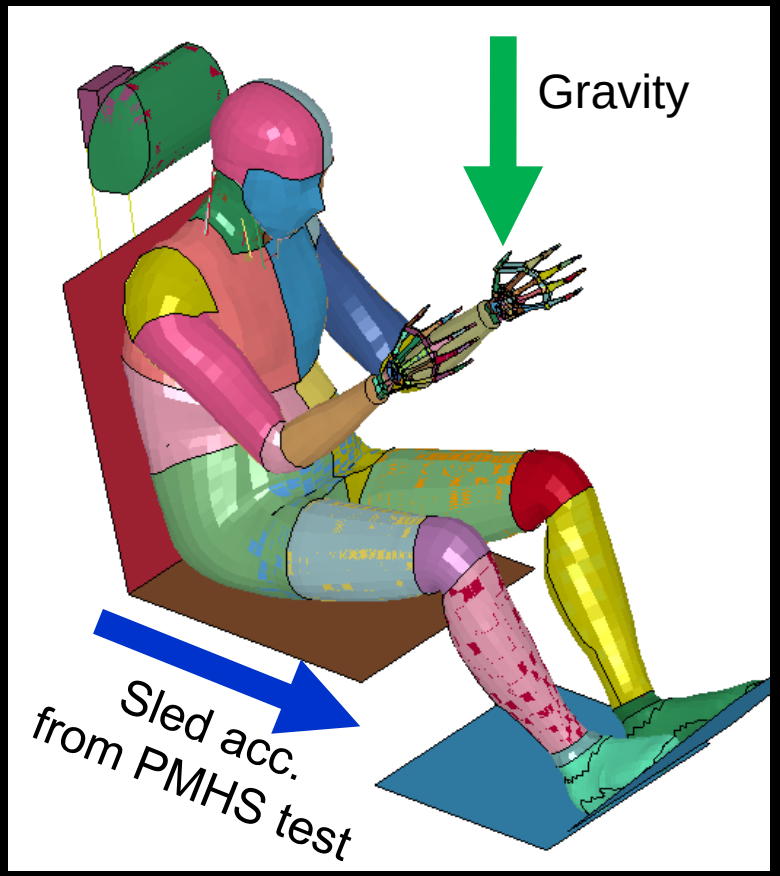
Rear-end impact experiment with PMHS (White et al. 2009)
Comparison of the behavior between the human FE model and PMHS

PMHS experiment
HYGE mini-sled
Rigid seat with HR
ΔV16km/h
2 cadavers

PMHS	Stature [cm]	Mass [kg]
1	180	99
2	176	82

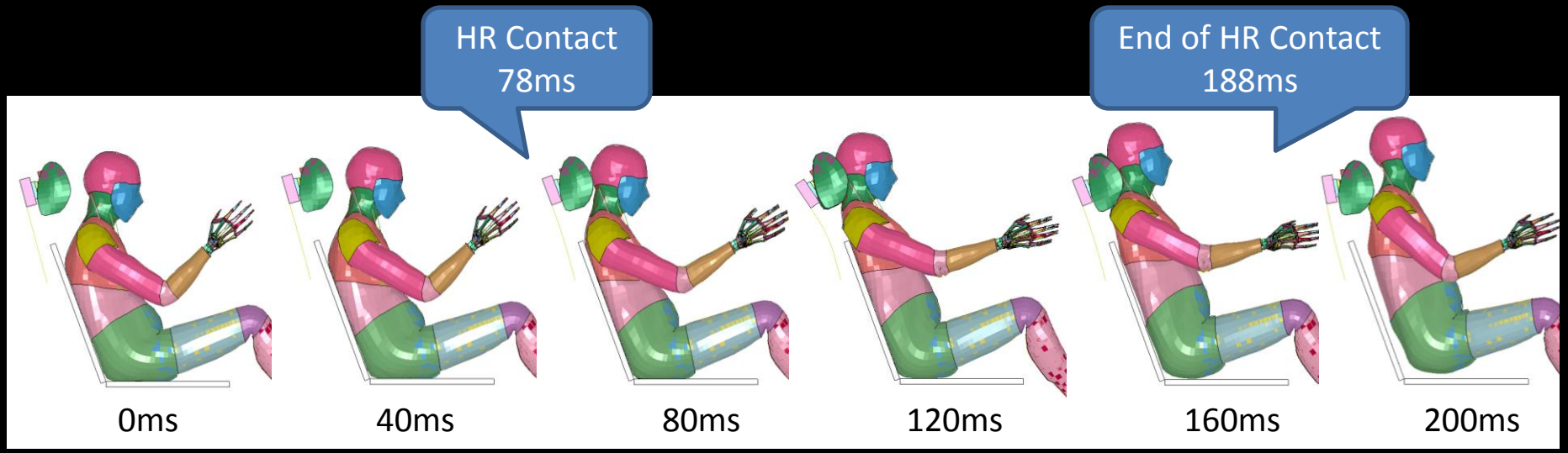
PMHS: Post mortem human subject





White A.N. et al., Investigation of Upper Body and Cervical Spine Kinematics of Post Mortem Human Subjects during Low-Speed Rear-End Impacts, SAE, (2009)

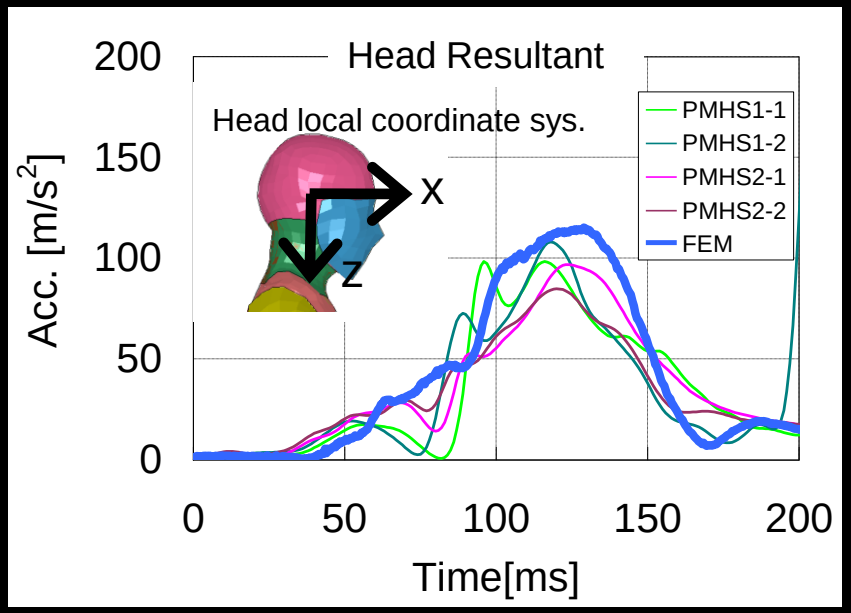
Visual motion

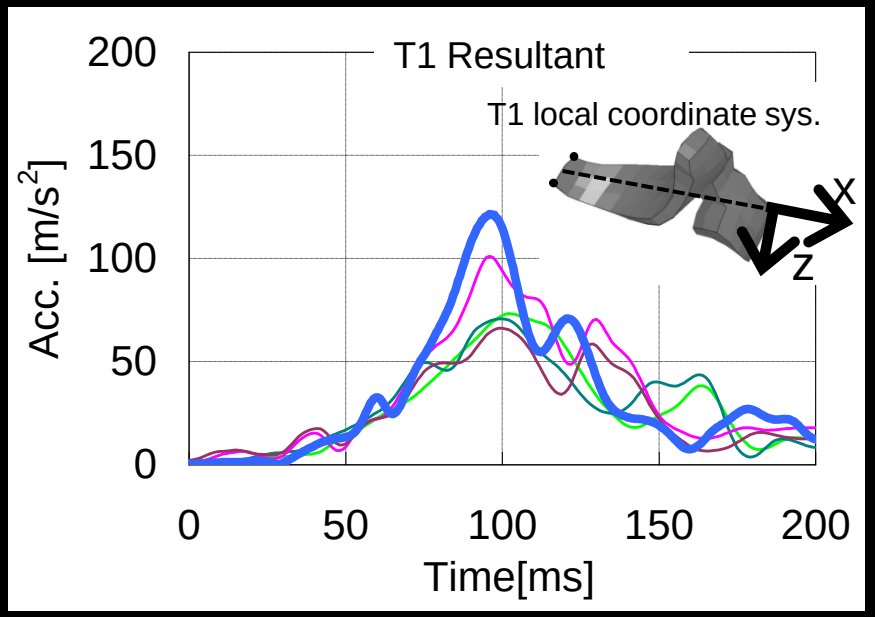


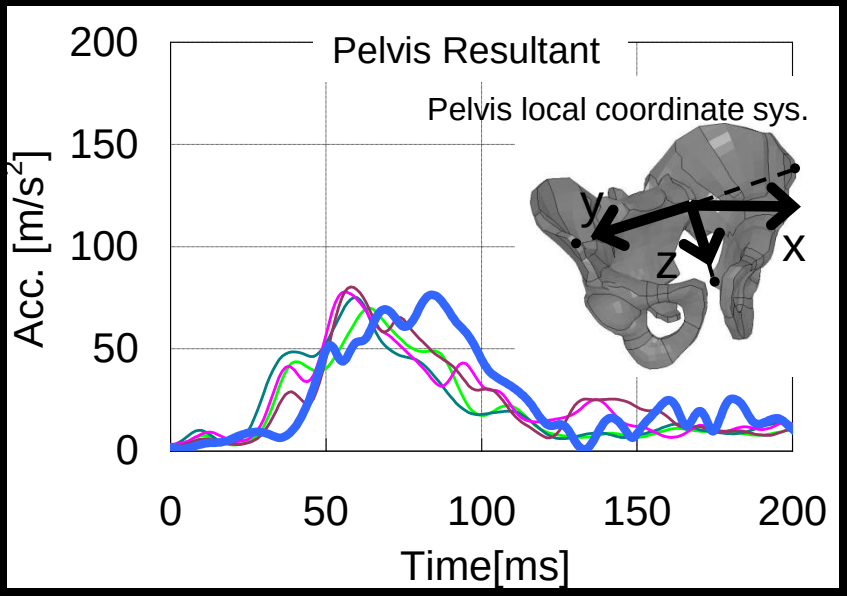
HR contact time（PMHS）

Test	Start [ms]	End [ms]
PMHS 1-1	72.3	n/a
PMHS 1-2	66.3	n/a
PMHS 2-1	77.6	n/a
PMHS 2-2	70.8	n/a

Acceleration

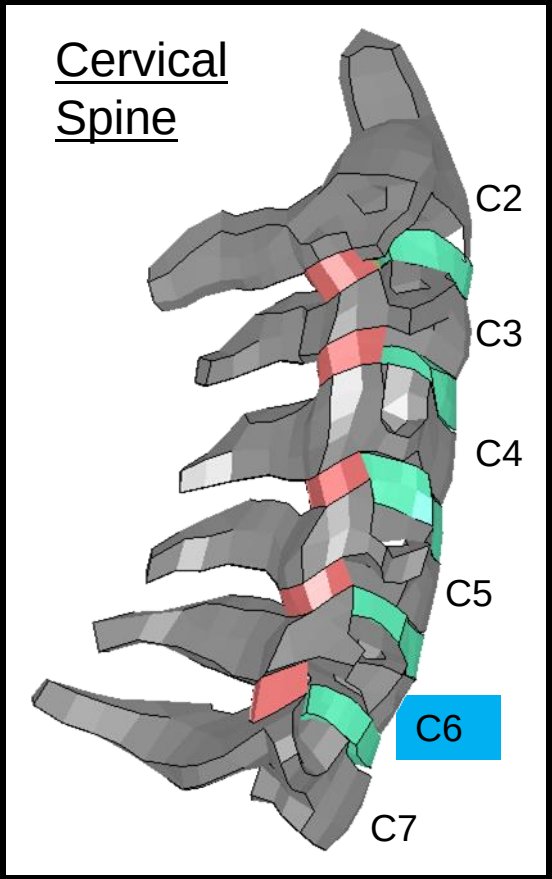


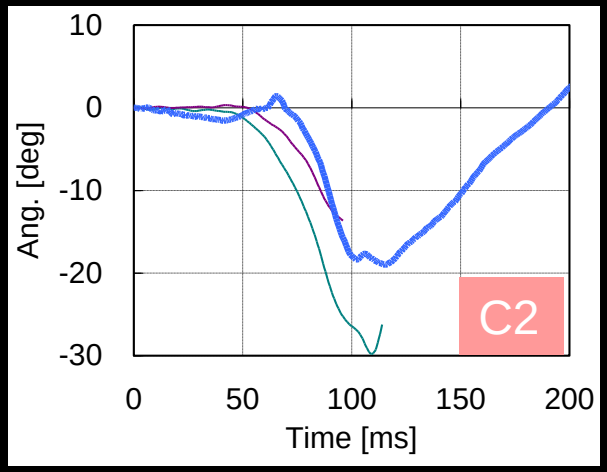


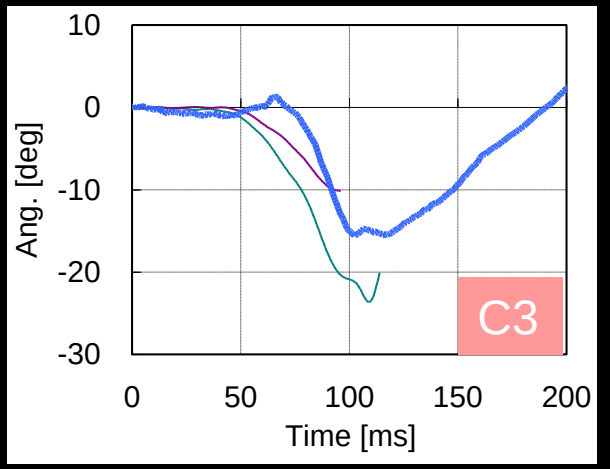


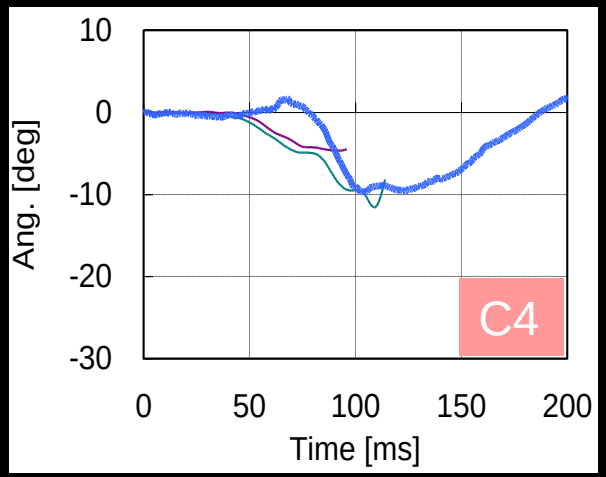
Vertebral motion

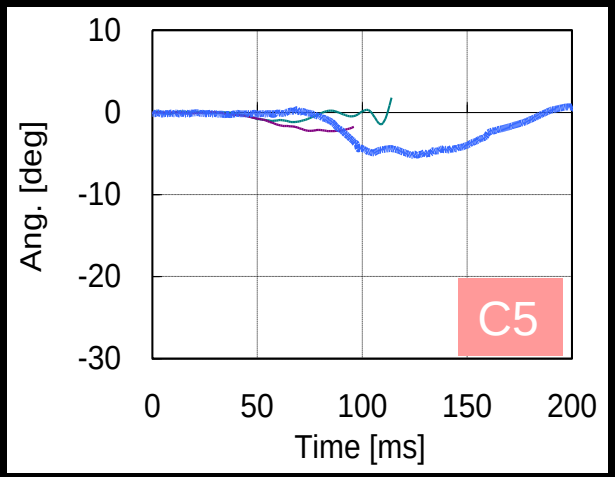
Vertebral angular displacement with respect to C6











2. Investigation of the relationship between the strain of inter-vertebral soft tissue and occupant motion

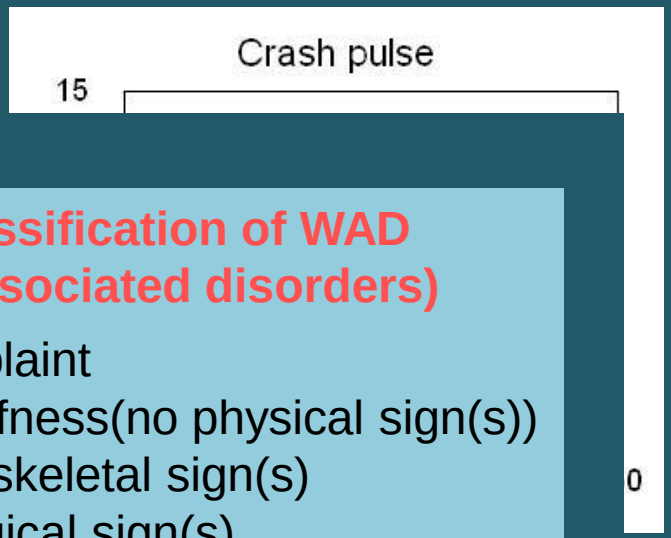
Accident Data（Folksam）

Acceleration
Crush Pulse

Injury Level
WAD

Occupant
Height・Weight

CASE		RECORDED CRASH PULSE			REPORTED INJURY			PASSENGER CHARACTERISTICS			
No.	D/P	⊿v [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
									22	171	63
									18	179	80
									67	167	84
									72	165	63
									74	175	62
									74	160	57
									59	165	65
									88	170	70
									61	176	77
									61	154	69
									50	171	85
									35	178	65
									65	176	82
									68	176	77
24	Driver								35	165	55
3	Driver	14.7	5.2	7.3	Injured	>6 m	2	M	35	165	55



Quebec Classification of WAD
(Whiplash-associated disorders)

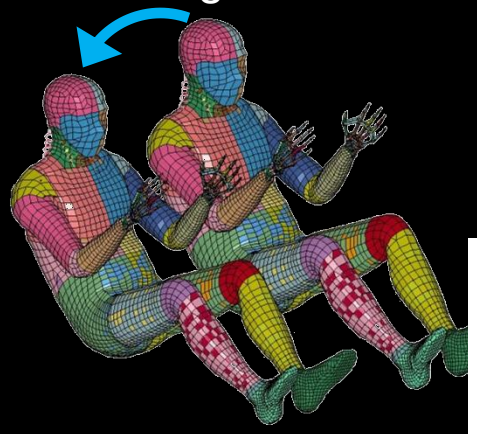
grade 0：No complaint
grade 1：Pain, stiffness(no physical sign(s))
grade 2：Musculoskeletal sign(s)
grade 3：Neurological sign(s)
grade 4：Fracture or dislocation

ecorder

⊿v 8 ~ 28 km/h

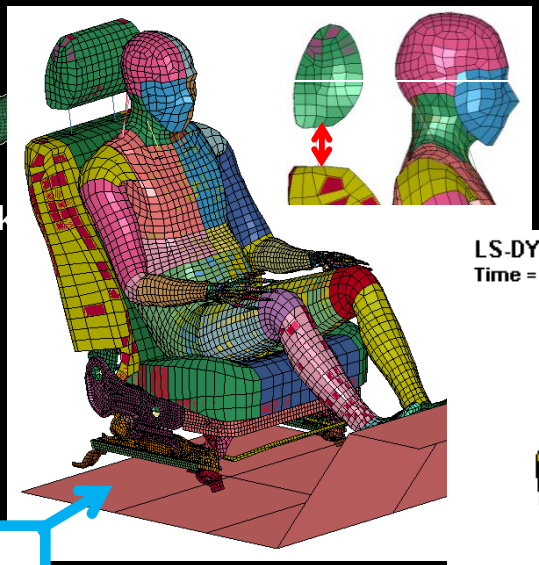
Accident Reconstruction -FE Model Simulations

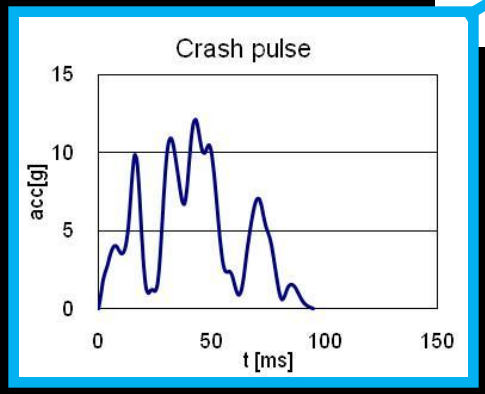
Scaling

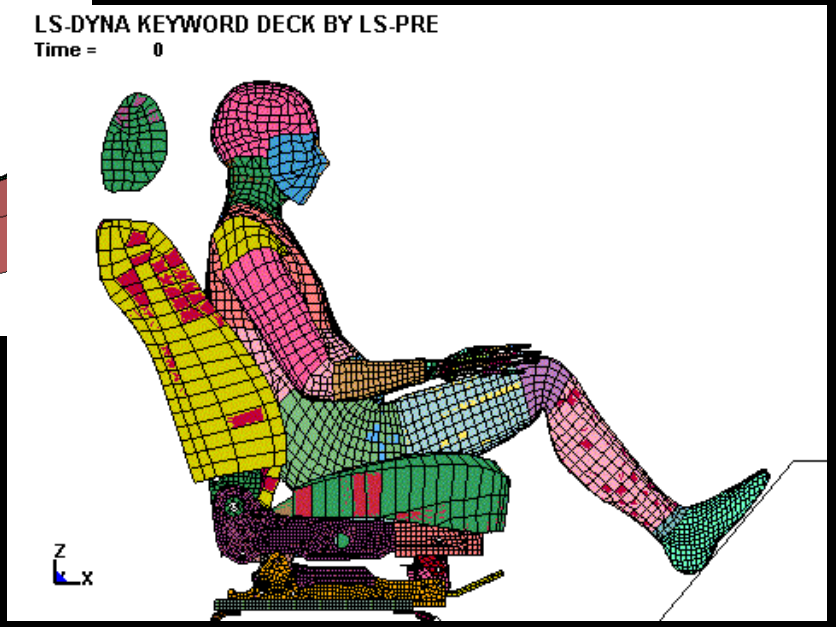


165cm/65kg 175cm/75k

Positioning





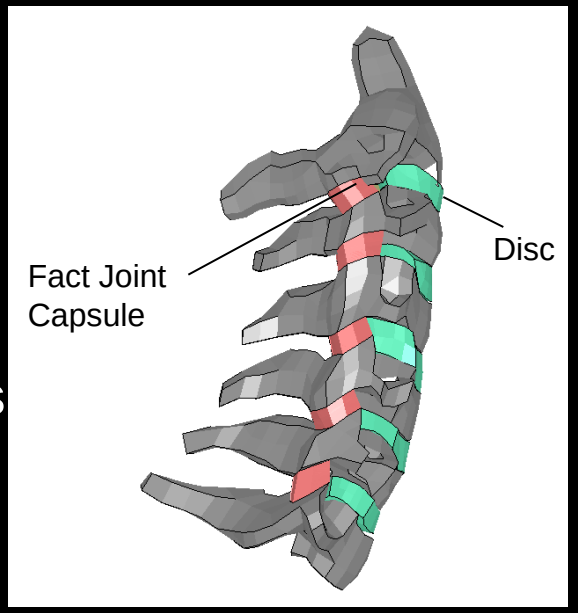


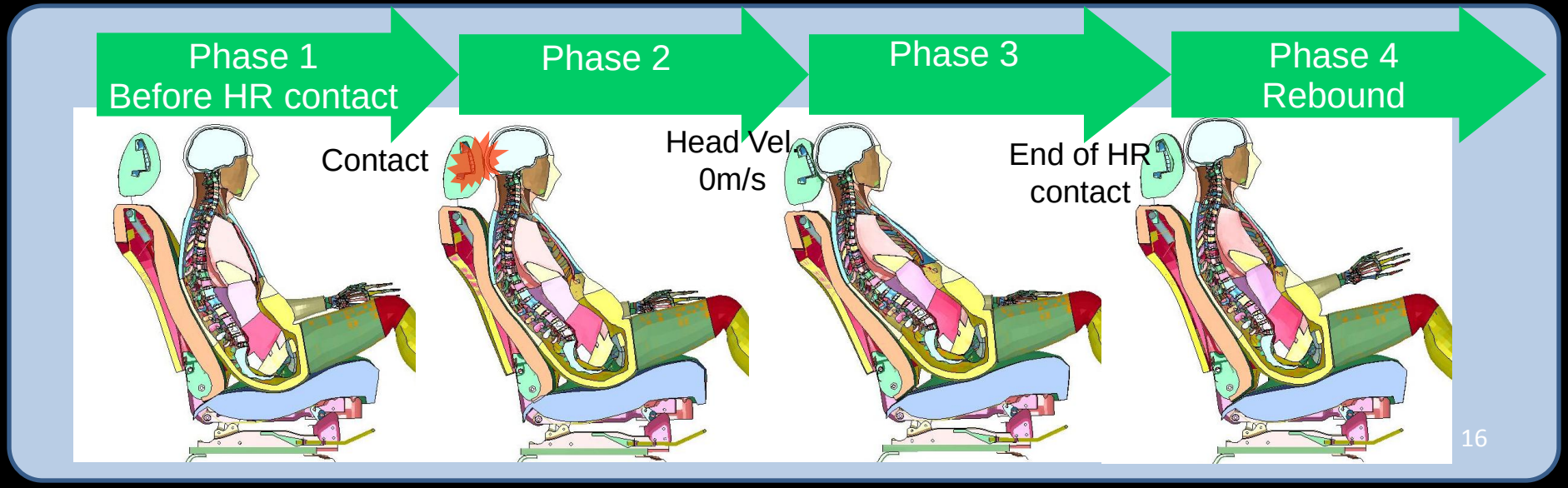
Occupant behavior

- Spine Motion

- Local deformation of soft tissue between vertebrae

  ➡ Strain distribution of discs and facet joint capsules





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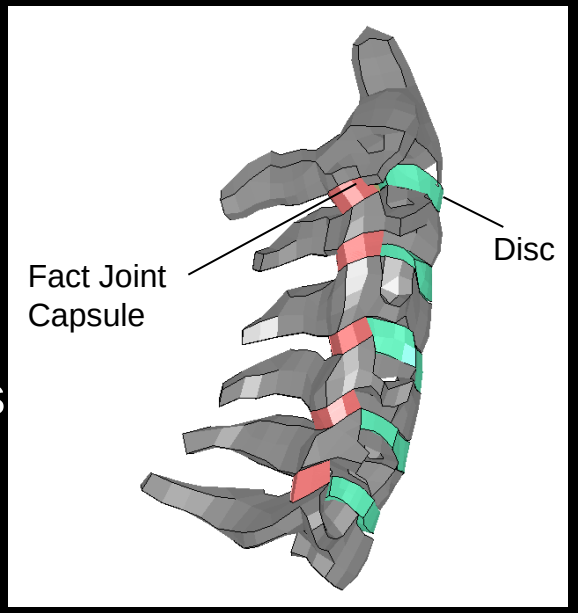
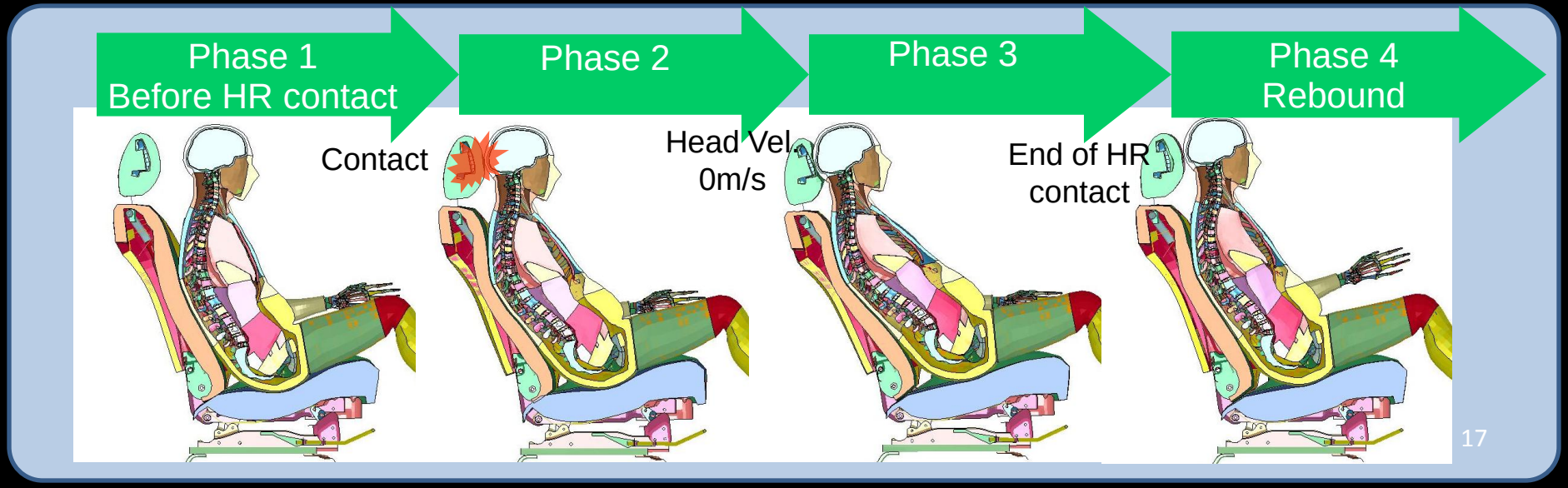
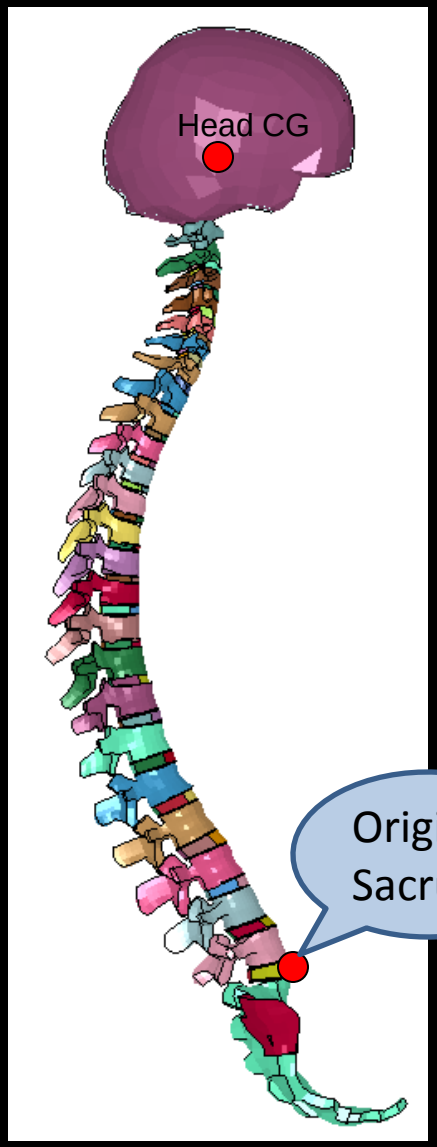
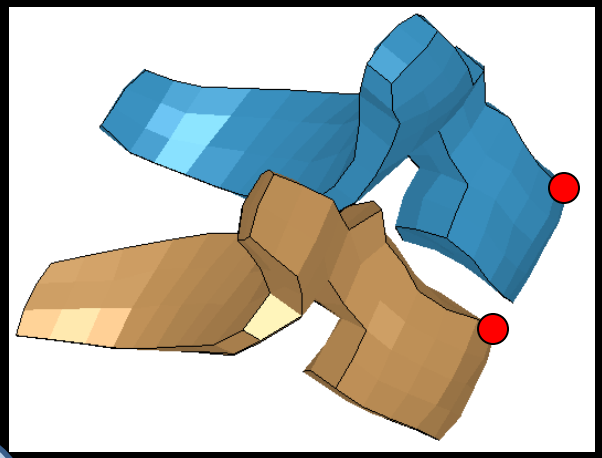


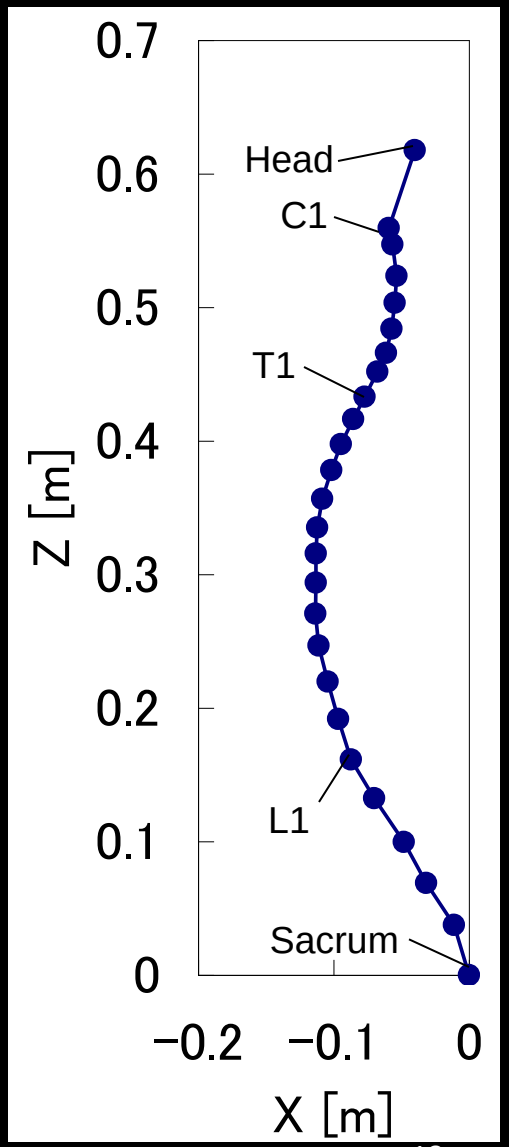


Occupant behavior —Spine motion

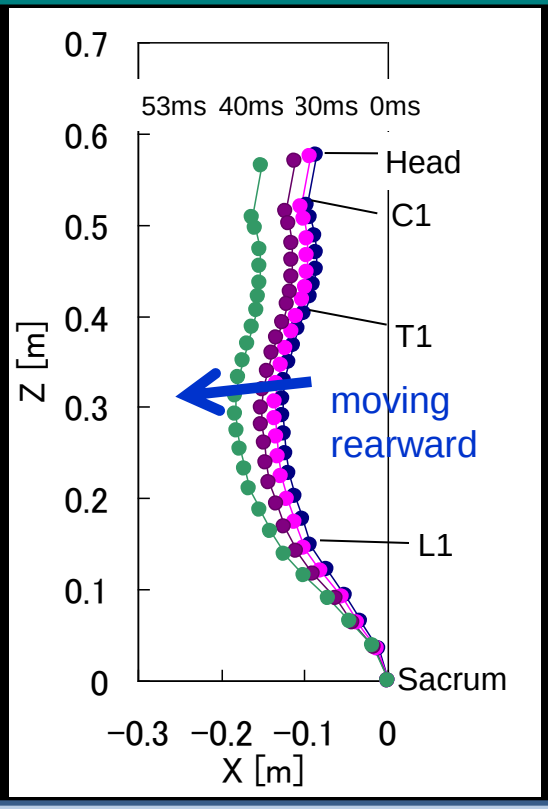


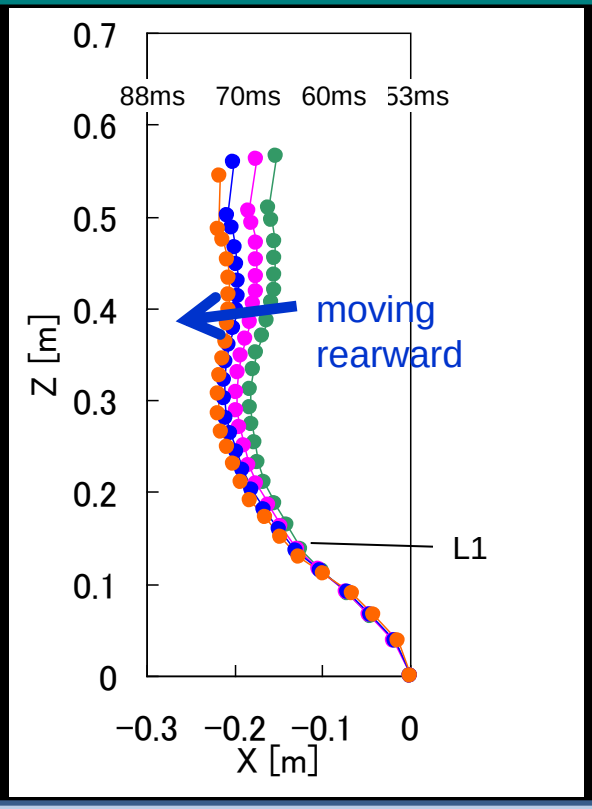


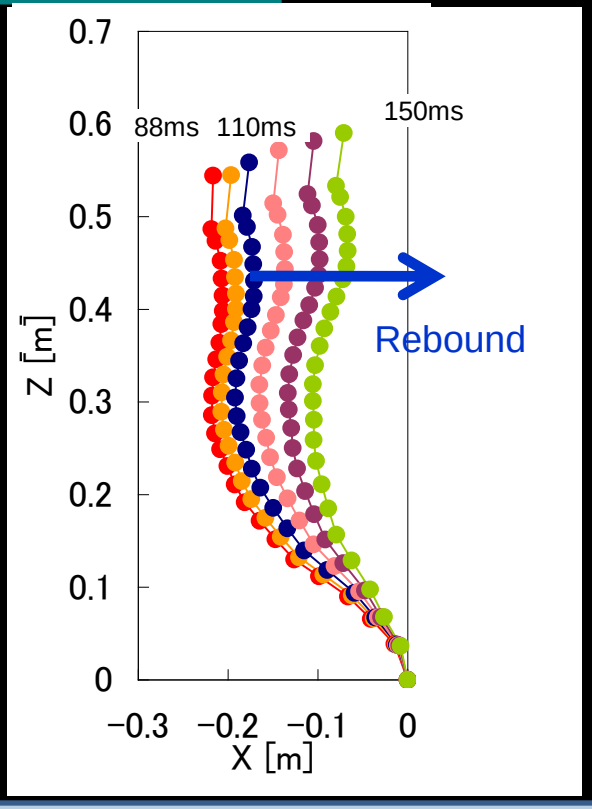
Frontal point of
the upper edge



Occupant behavior —Spine motion





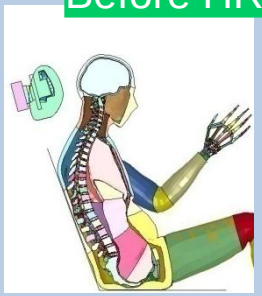


Phase 1
Before HR contact

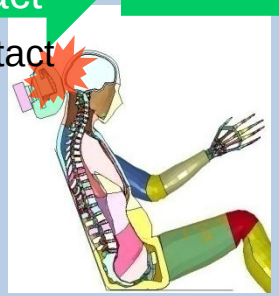
Phase 2

Phase 3

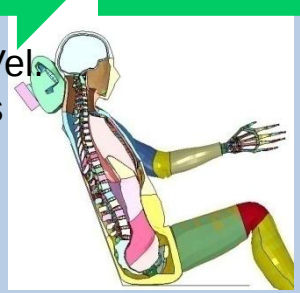
Phase 4
Rebound



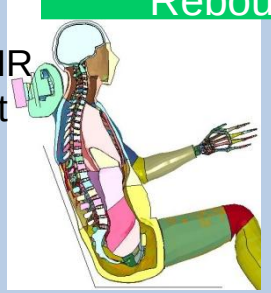
Contact



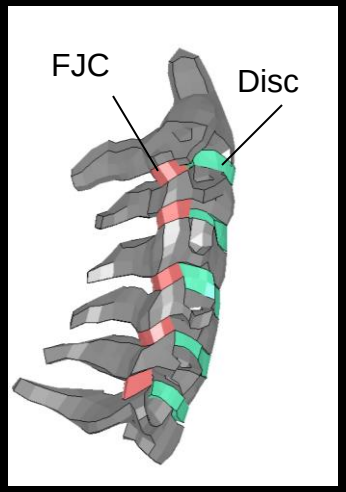
Head Vel.
0m/s

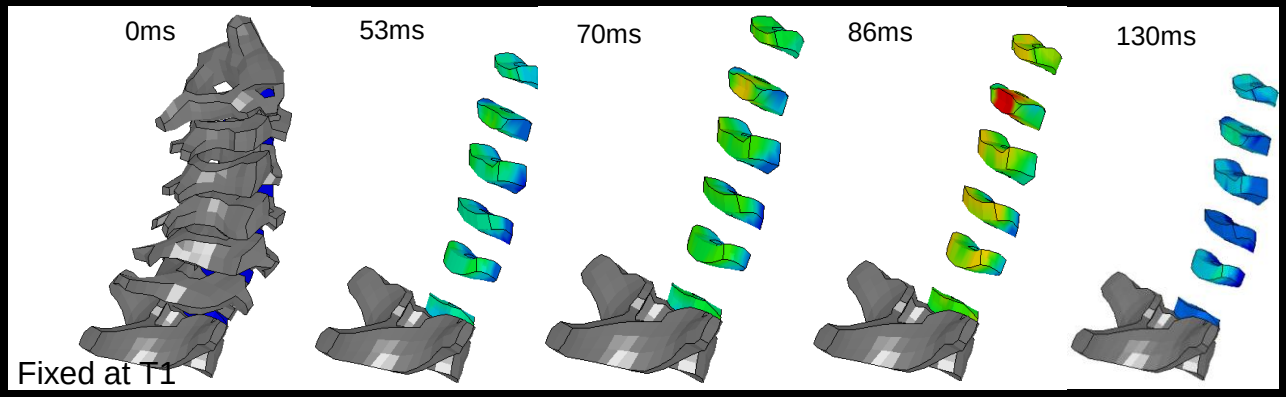


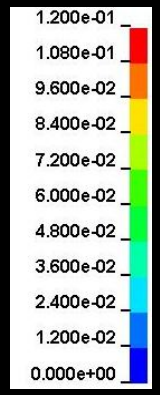
End of HR
contact

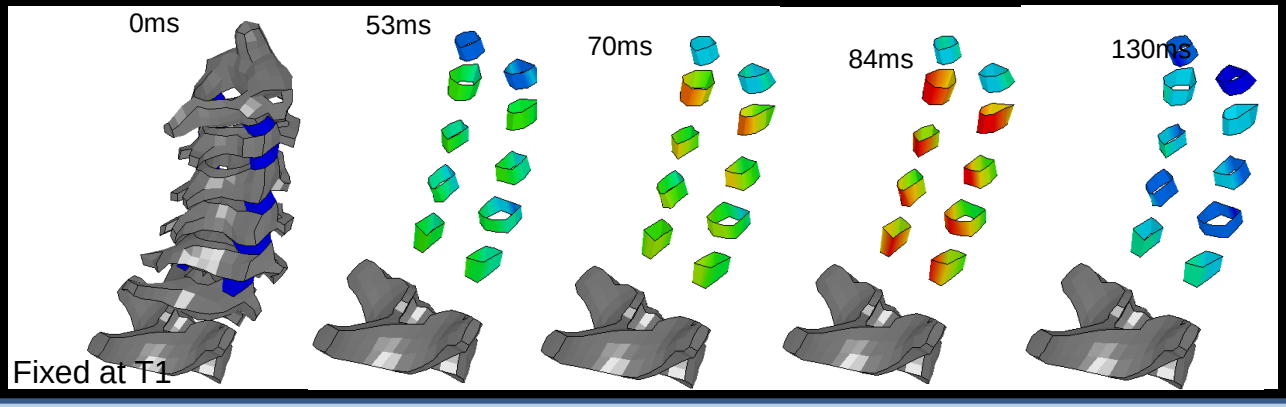


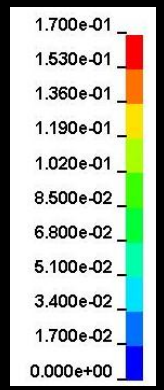
Occupant behavior —Cervical spine motion



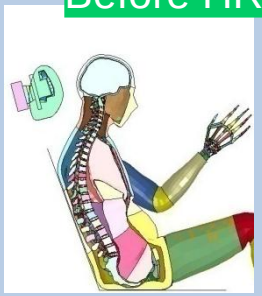






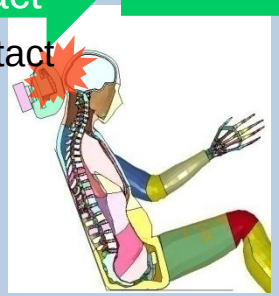


Phase 1
Before HR contact



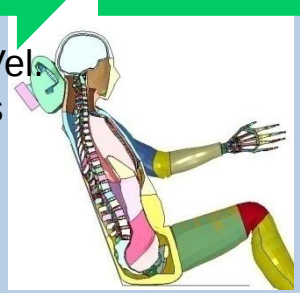
Phase 2

Contact



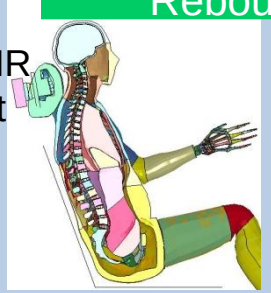
Phase 3

Head Vel.
0m/s

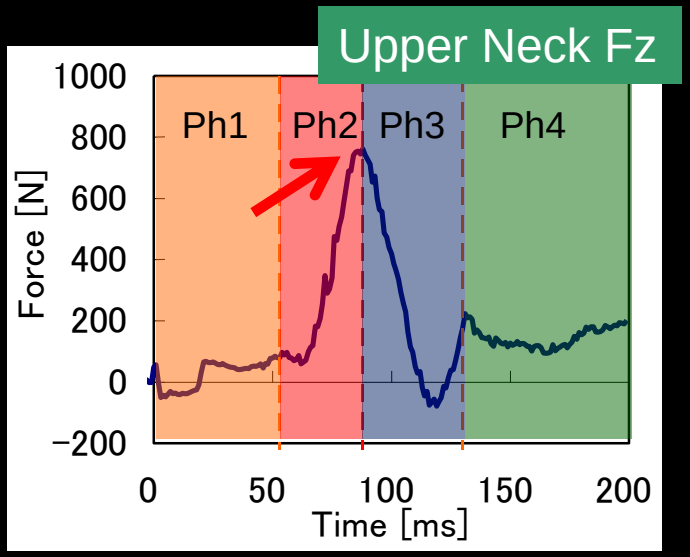


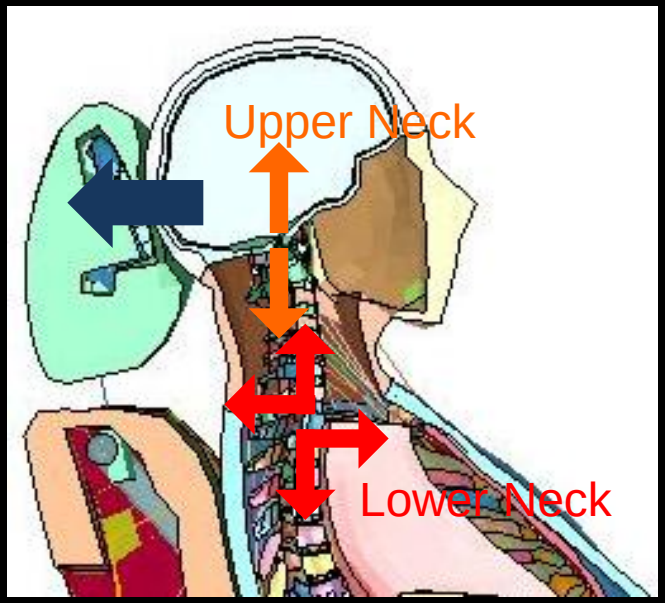
Phase 4
Rebound

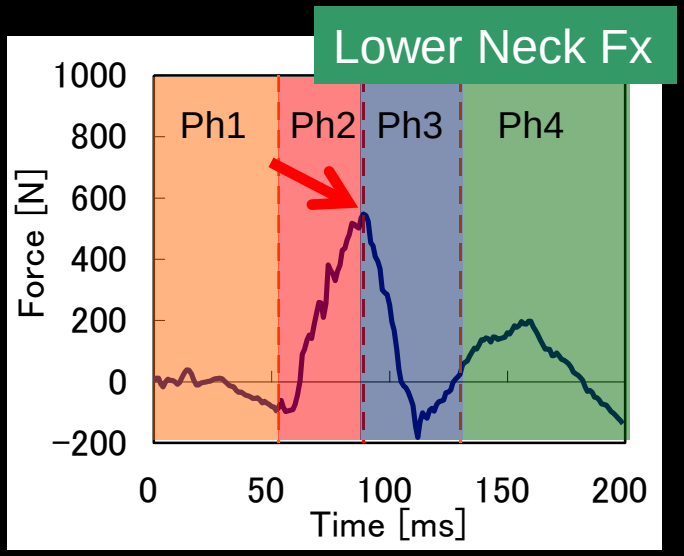
End of HR
contact

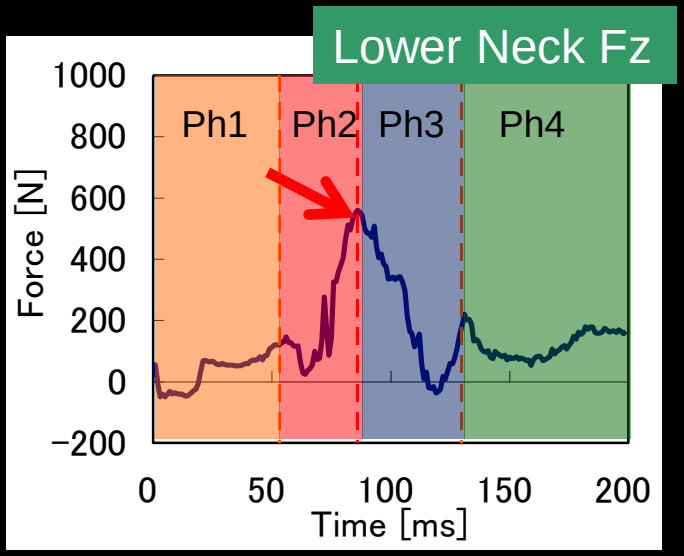


Occupant behavior —Neck force



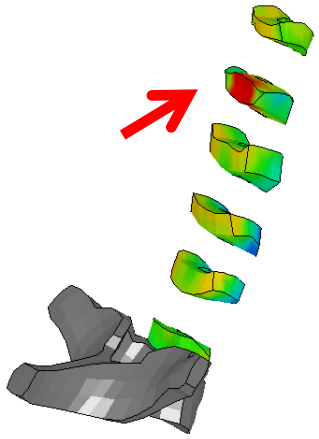


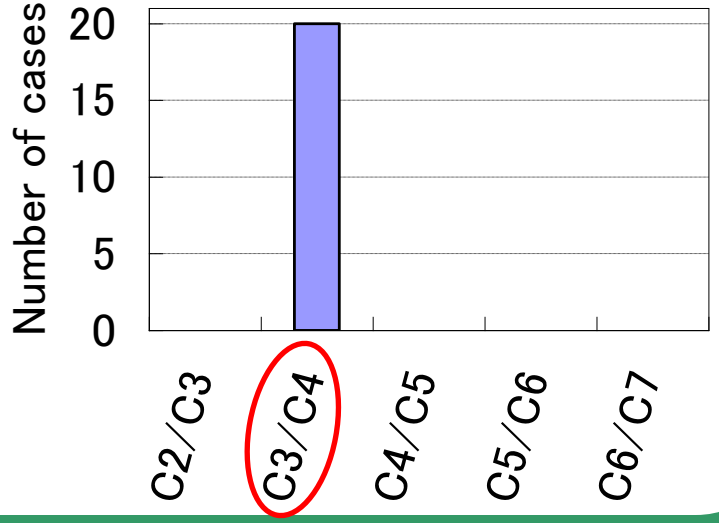




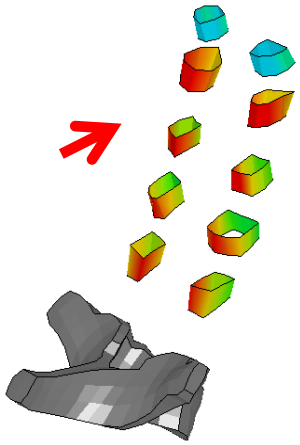
Vertebra level at the maximum strain

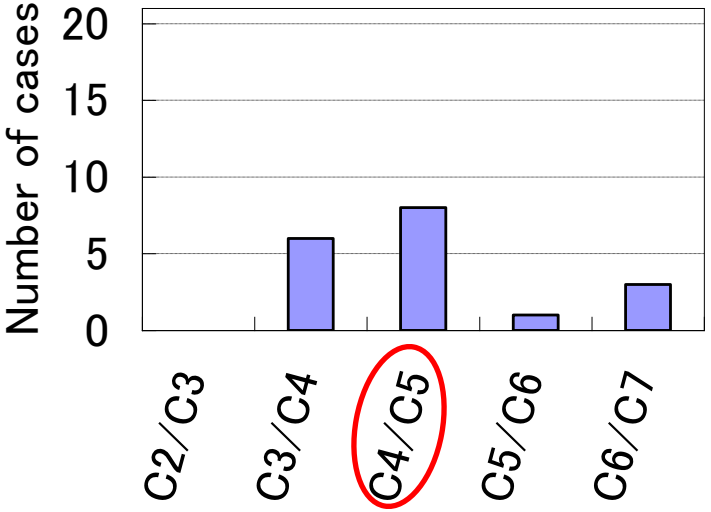
Disc





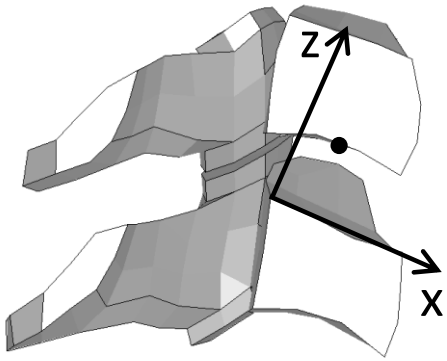
Facet Joint Capsule

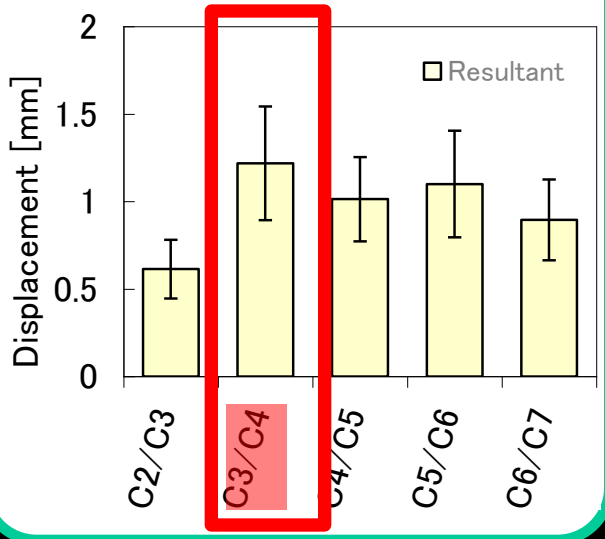




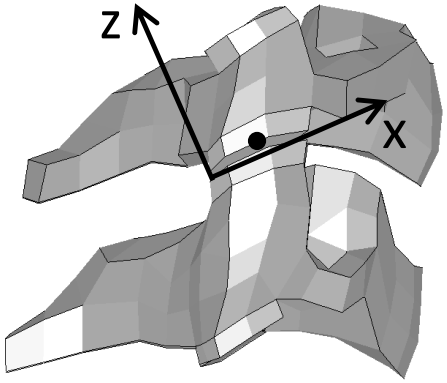
Vertebral motion

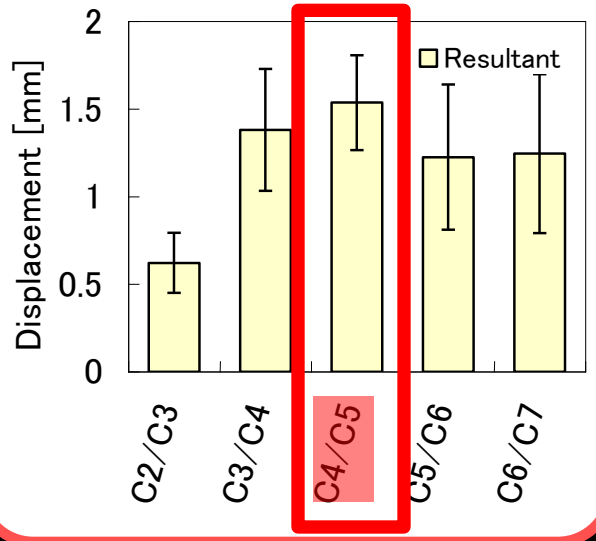
Displacement -Disc



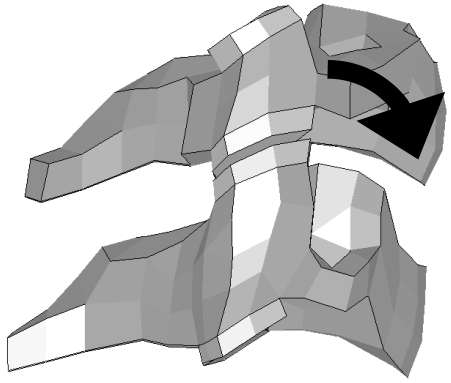


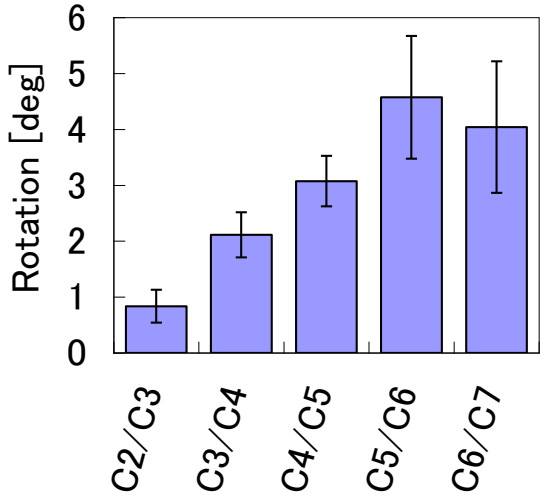
Displacement -FJ





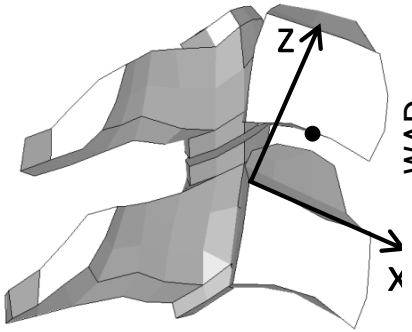
Relative Rotation

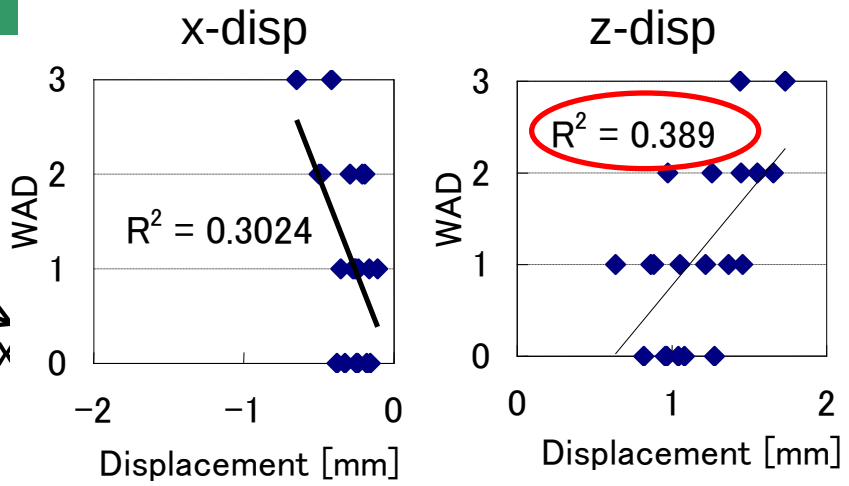




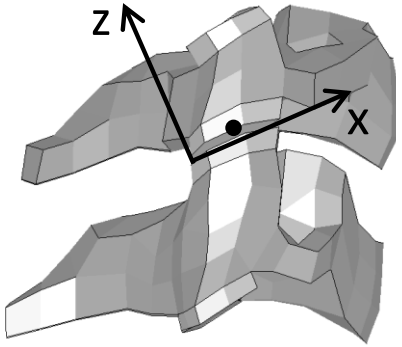
Vertebral motion and injury severity

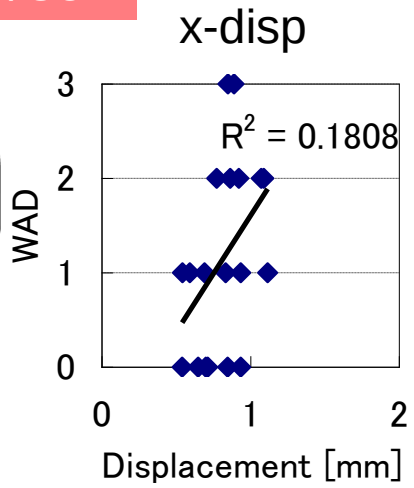
Disc C3/C4

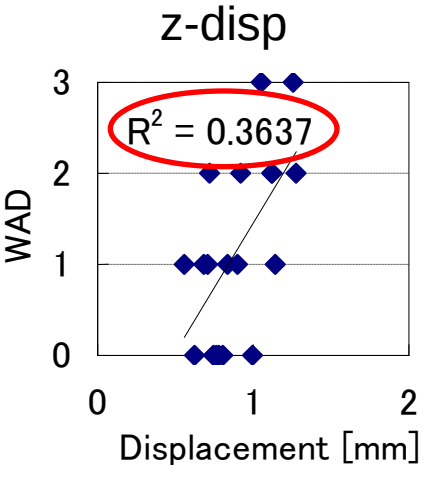




Facet Joint C4/C5







Classification of WAD
(Whiplash-associated disorders)

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

Limitations

- The accident reconstruction simulations were carried out with ideal HR and seat positions for the occupants.
- The seat FE model was modeled on only one type of mass production seat.
- The accident cases were collected from only one type of mass production car for the seat modeling.
- The use of an Human FE Model to calculate the strains may also be a limitation concerning the accuracy of these calculations that are of course dependent on the quality of the validation of the model.

Parametric studies would be needed to generalized our results.
- Positioning
- Seat and car types

Conclusions

- A human FE model for rear-end impacts was validated against PMHS test data at ΔV16km/h. The human FE model could reconstruct the whole body and cervical vertebral motions of PMHS.
- By using the human FE model, the relationship between the strain of intervertebral soft tissue and occupant motion was analyzed. When the strain became maximal, the head sank at its deepest point into the HR and the neck was affected by tensile and shear forces.
- The stretch motion of cervical vertebrae due to the interaction between the head and HR influences the strain of cervical soft tissue. This is an important factor in analysing the relationship between the head-neck motion and HR during rear-end collisions.

Acknowledgement

The Japan Automobile Manufacturers Association, Inc.

Thank you for your attention.