



Monte Carlo Analysis To Study The Influence of Vehicle Design Parameters on Whiplash Associated Disorders

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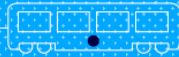
*Crashport
Huntsville, AL, 35806*



Motivation

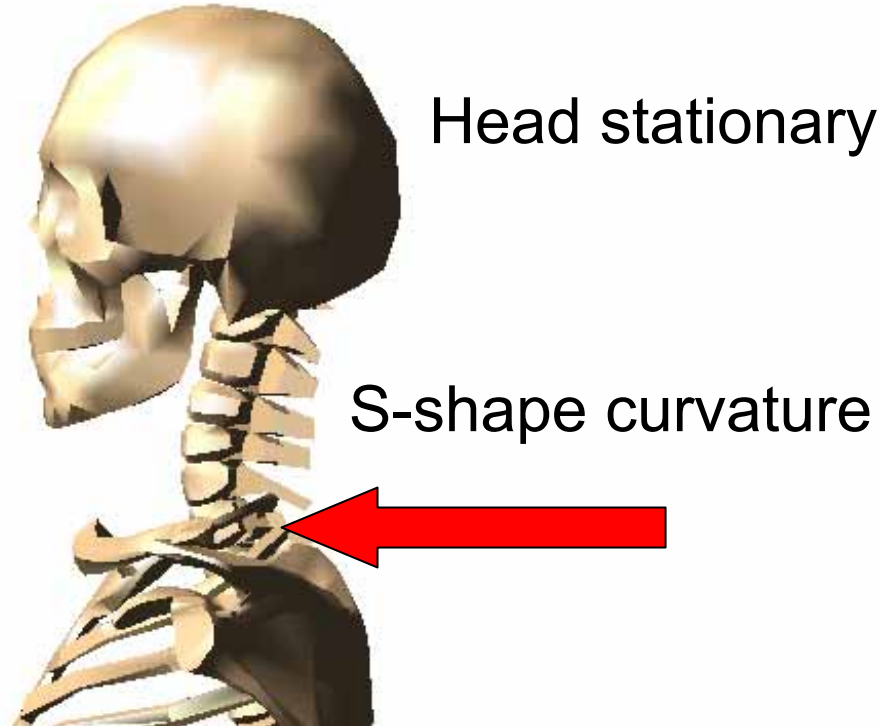
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- Soft Tissue Injuries Present a Large Public Health Problem
 - Whiplash Associated Disorders (WAD)
 - Soft Tissue Injuries
- Simulation Attractive Alternative
 - Parametric analysis of key factors associated with injury
 - Sensitivity analysis, statistical analysis
- The contribution of each design factor to the distinct phases of WAD motion has not been fully explored

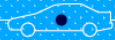


Whiplash Phases: Retraction

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- Proposed Injury Criteria: Neck Injury Criteria (NIC).
- NIC values greater than $15 \text{ m}^2/\text{s}^2$ are believed to be associated with the potential for long-term symptoms.



Whiplash Phases: Extension

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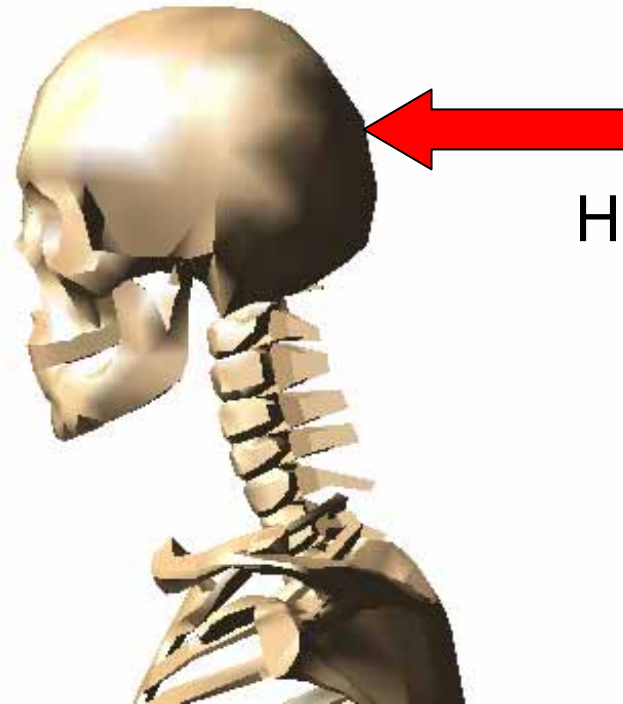


- Proposed Injury Criteria: Extension Moment.
- Extension values exceeding 30.5 Nm are believed to present significant potential for injury.



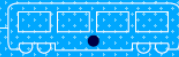
Whiplash Phases: Rebound

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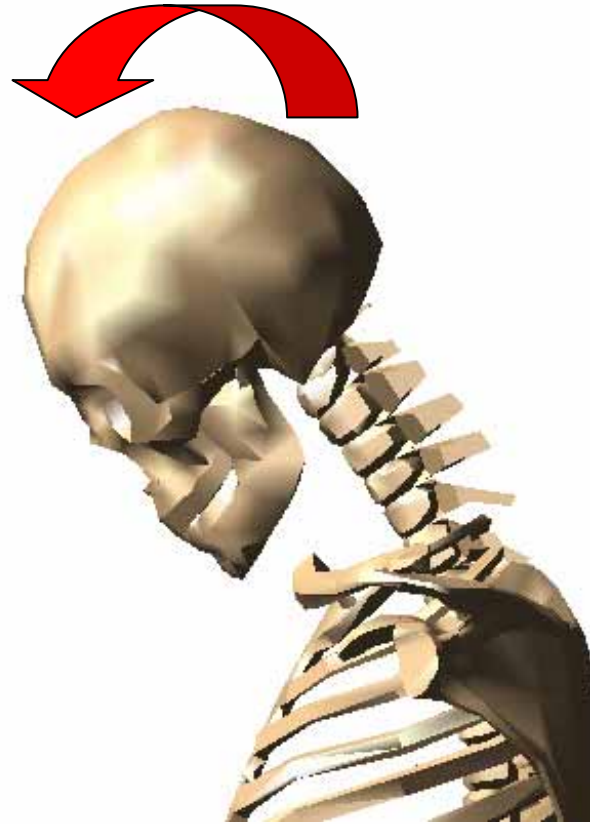
Headrest contact

- Proposed Injury Criteria: N_{km} (combined shear force and moments).
- N_{km} values of 1.0 has been proposed to as a threshold for AIS 1 neck injuries, although other studies suggest that the threshold could be lower.



Whiplash Phases: Protraction

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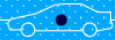
- Proposed Injury Criteria: Flexion Moment.



Objective

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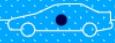
- To study the influence of various design factors on the different design phases (retraction, extension, rebound, protraction)
 - Vehicle Structural Characteristics
 - Headrest Backset
 - Headrest Height
 - Seat Stiffness
 - ...



Outline

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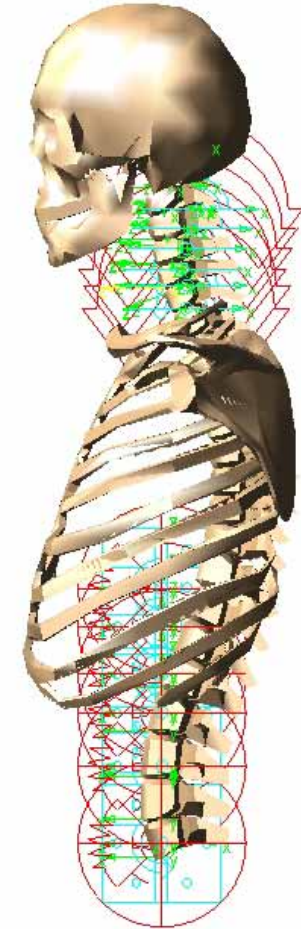
- Motivation ✓
 - Computer Simulation for Injury Assessment
 - Different Phases of Whiplash
- Objective ✓
 - To study the influence of design factors on different phases of WAD motion
- Occupant Model & Validation
- Monte Carlo Simulations
- Conclusions/Ongoing Work



Model Description - OCCUPANT

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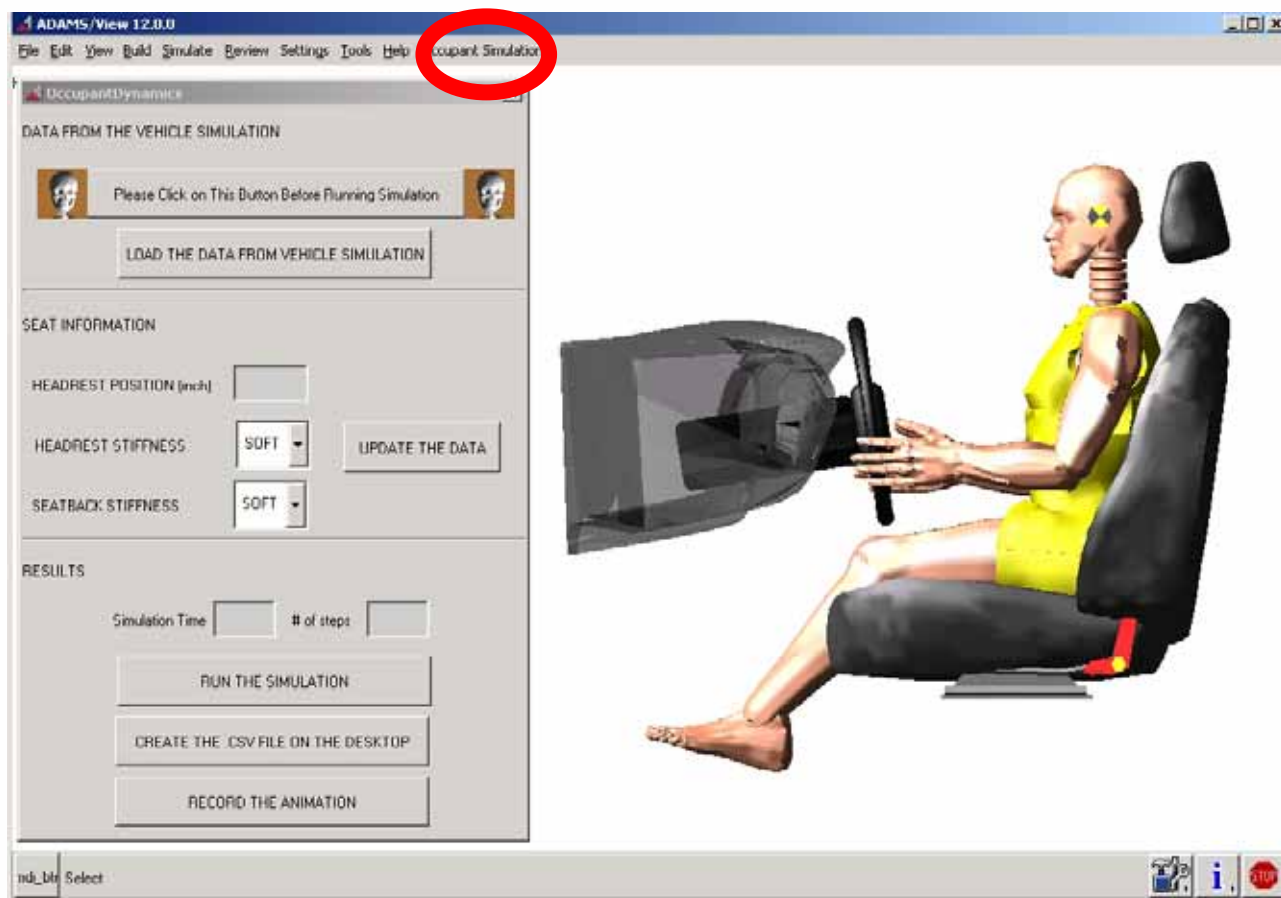
- Constructed in MSC.ADAMS simulation environment
- 7 vertebrae (C1-C7) for cervical spine
- 5 vertebrae (L1-L5) for lumbar spine
- Lumped mass for head, upper torso
- Geometric and inertia data obtained from De Jager, 1996
- Non-linear viscoelastic elements for extension-flexion (non-symmetric) & lateral bending

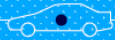




GUI Description - OCCUPANT

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Occupant Animation

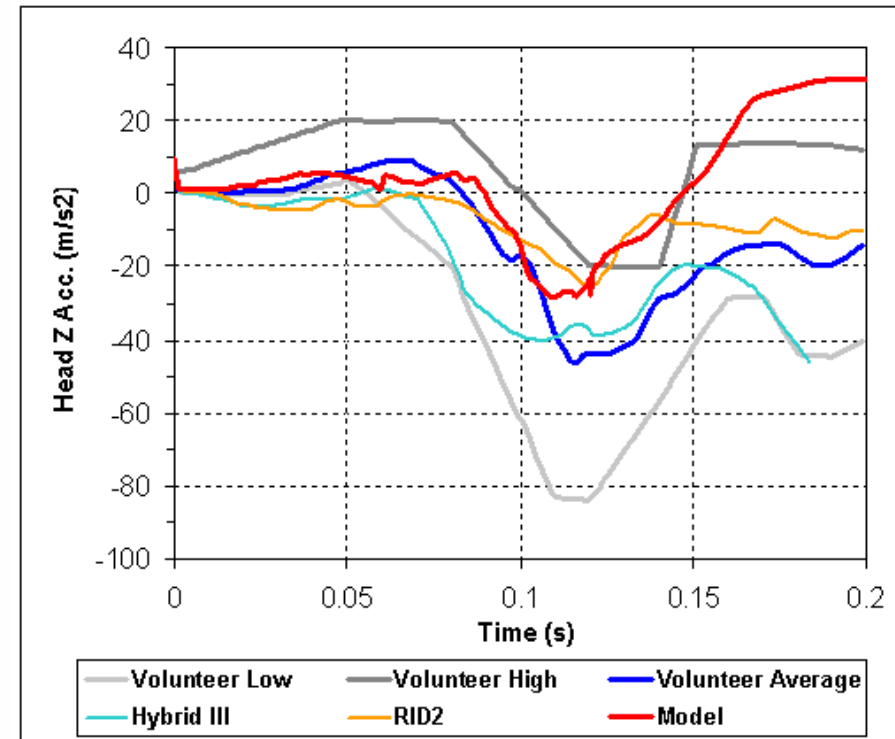
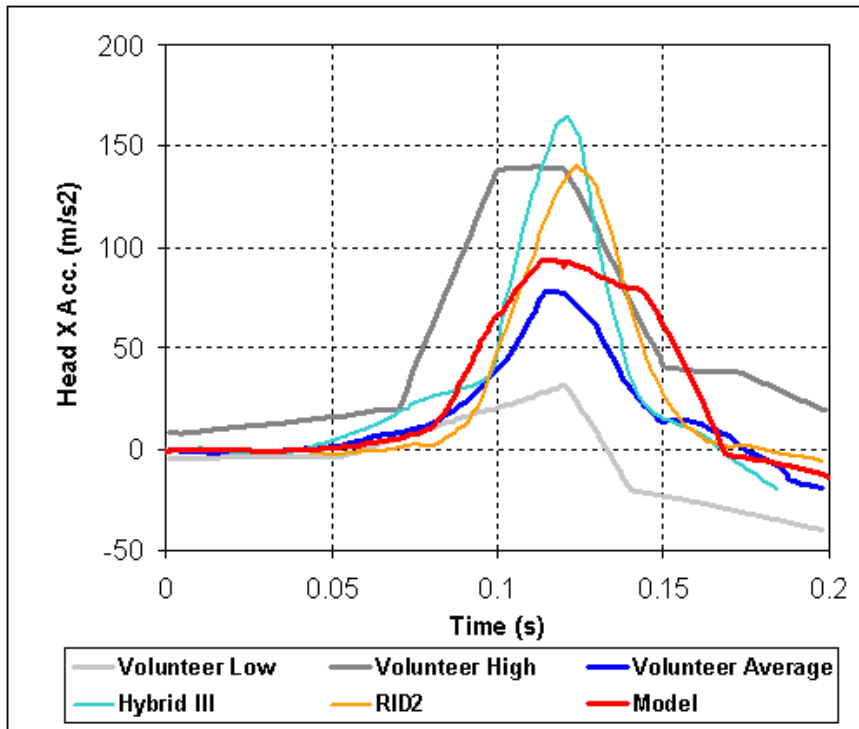
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Validation (Cappon et. al, 1996)

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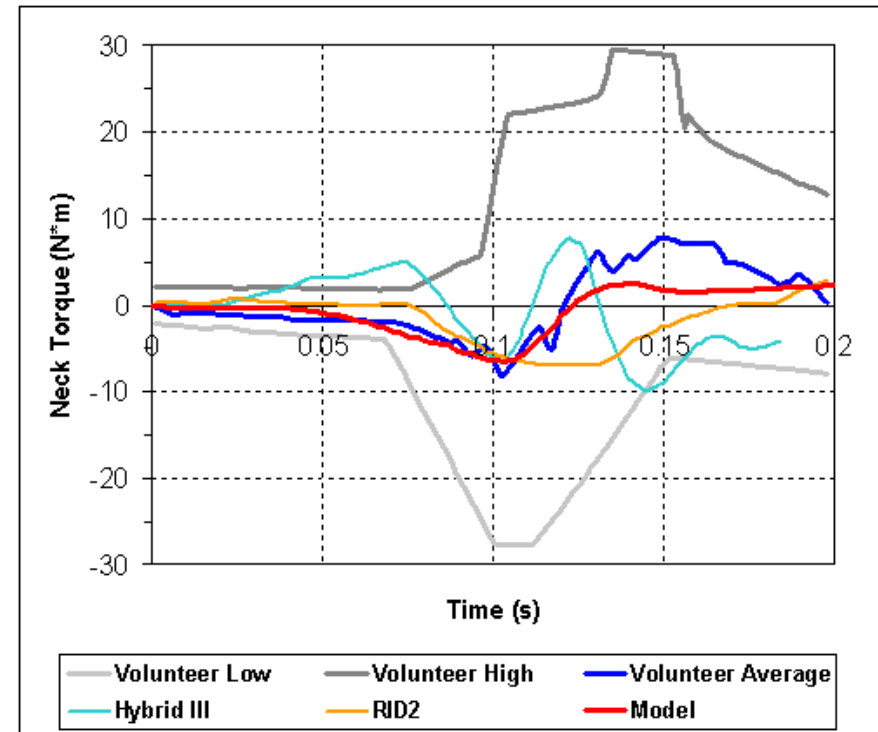
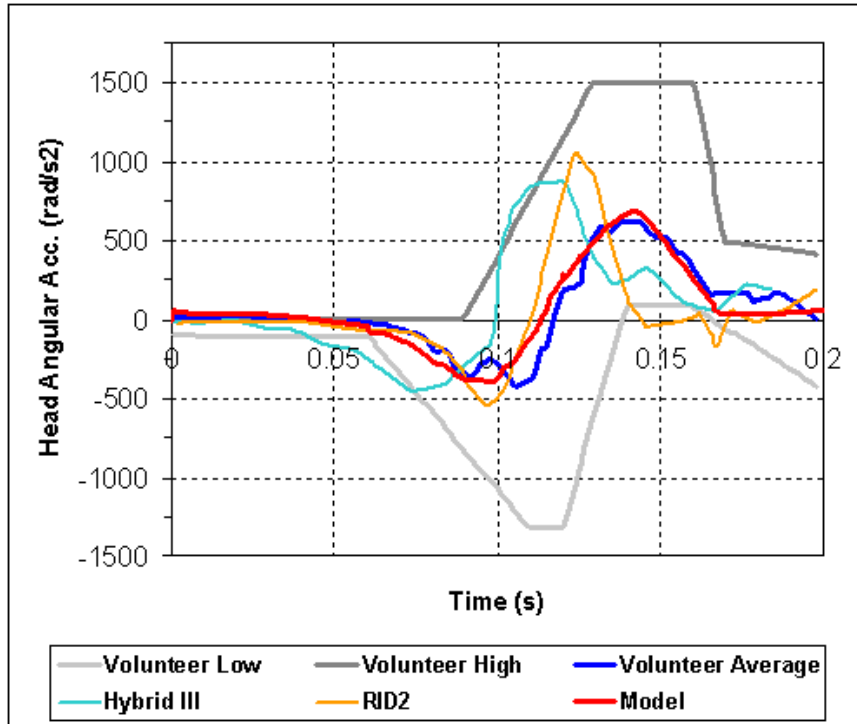


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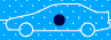


Validation

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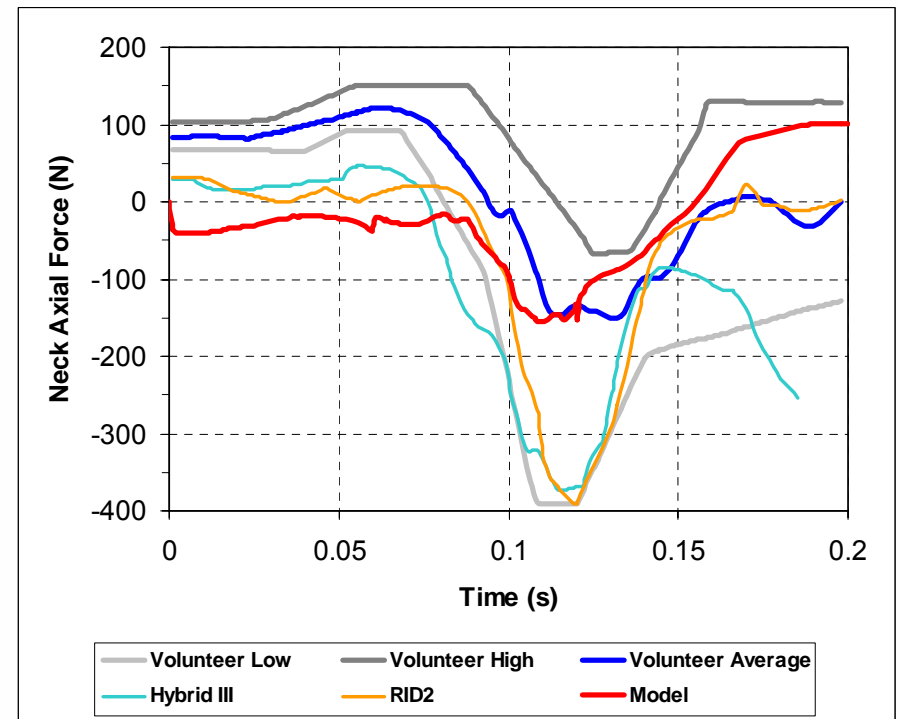
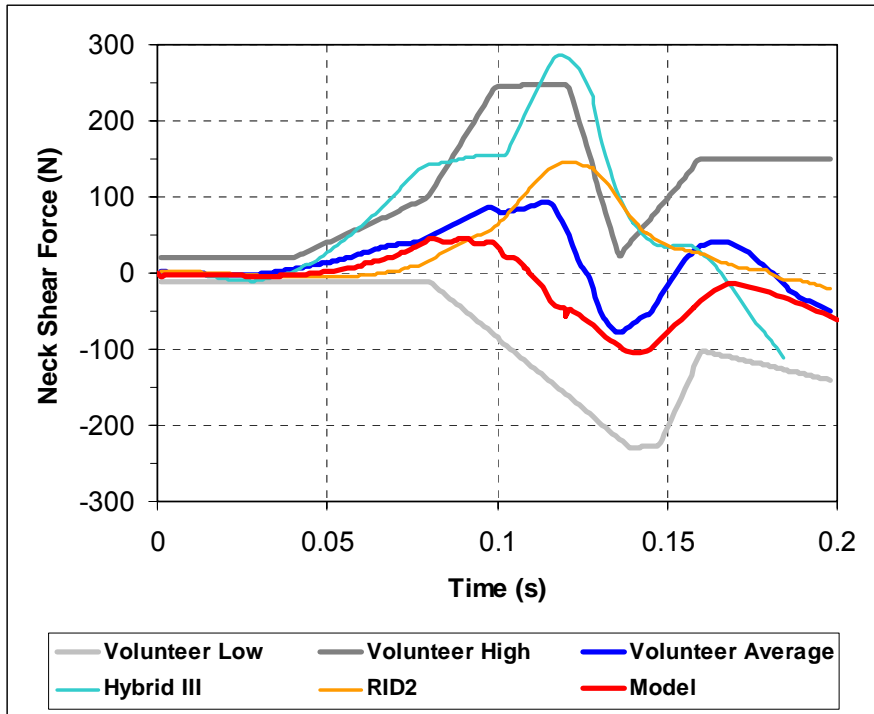


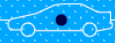
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Validation

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Outline

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- Motivation ✓
 - Computer Simulation for Injury Assessment
 - Different Phases of Whiplash
- Objective ✓
 - Develop Vehicle & Occupant Models/GUIs to Analyze Automotive Impacts
- Occupant Model & Validation ✓
- Monte Carlo Simulations
- Conclusions/Ongoing Work



Variation in Design Parameters

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• Study Effect on Injury Potential for Vehicle Impacts

- Crashpulse Duration
- Headrest Height
- Backset
- Seat Stiffness

- Vehicle Mass
- Seat Angle
- Headrest Stiffness
- Braking
- Friction (occupant-seat)
- Override/underride
- Impact angle

Design Factor	Average	Standard Deviation
Crash Duration (ms)	105	75
Head Restraint Backset (cm)	8.9	5.8
Head Restraint Height (cm)	8.4	4.6
Seat Hinge (Nm/deg)	60	25



Monte Carlo - Implementation

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Dialog-Box Builder: Modifying "OccupantDynamics"

Dialog Box Edit Create Options Preferences

Button "button_5" Attributes: Commands

Single Click Double Click

```

var set var=.Human.dheadrest real=(eval(.Human.inputdata.values[1,.Human.countno]))
var set var=.Human.HRheight real=(eval(.Human.inputdata.values[2,.Human.countno]))
var set var=.Human.Ktorsionspring real=(eval(.Human.inputdata.values[3,.Human.countno]))
var set var=.Human.runnumber integer=(eval(.Human.countno))
var set var=.Human.runnostring string=(eval(.Human.runnumber))

simulation single reset
simulation single trans &
type=auto_select &
end_time= 0.3 &
model_name=Human &
number_of_steps = 100

file text open open=overwrite file=(eval("C:/Documents and Settings/psendur/Desktop/analysisdata"// (eval(.Human.runnostring.string_value))//
for var=.Human.i start=1 inc=1 &
end=(cols(.Human.last_run.AccHeadX.time.values))
file text write format="%6.4f, %6.4f, %6.4f, %6.4f, %6.4f, %6.4f, %6.4f, %6.4f, %6.4f, %6.4f, %6.4f, %6.4f, %6.4f, %6.4f, %6.4f, %6.4f,
values=(.Human.last_run.AccHeadX.time.values[.Human.i]), &
(.Human.last_run.AccHeadX.Q.values[.Human.i]), &
(.Human.last_run.AccHeadY.Q.values[.Human.i]), &
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(.Human.last_run.ForceOCZ.Q.values[.Human.i]), &
(.Human.last_run.ForceMomentFLXEXT.Q.values[.Human.i]), &
(.Human.last_run.ForceMomentLateralBending.Q.values[.Human.i]), &

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LHS_Monte_Carlo_Analysis

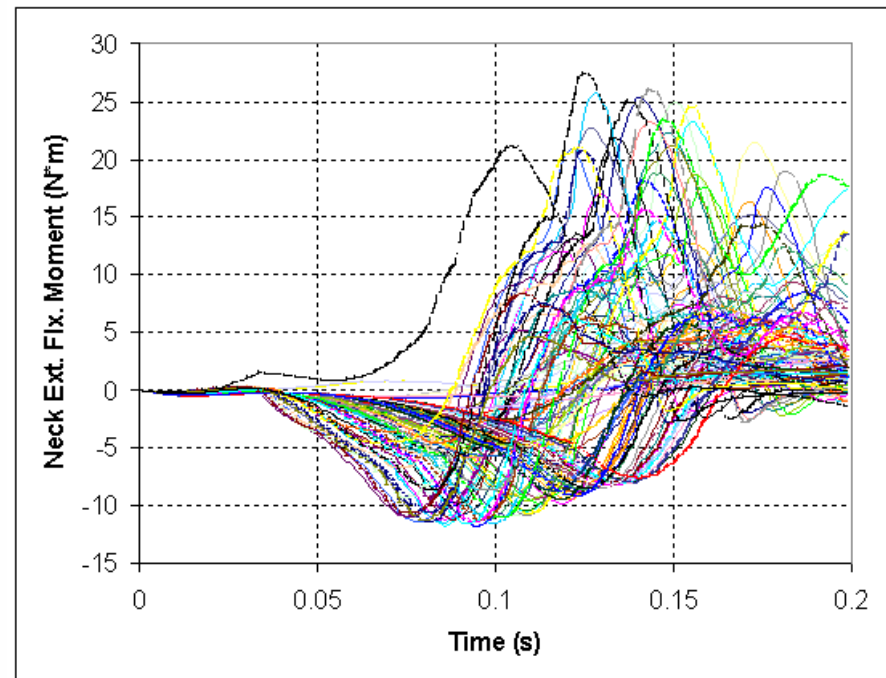
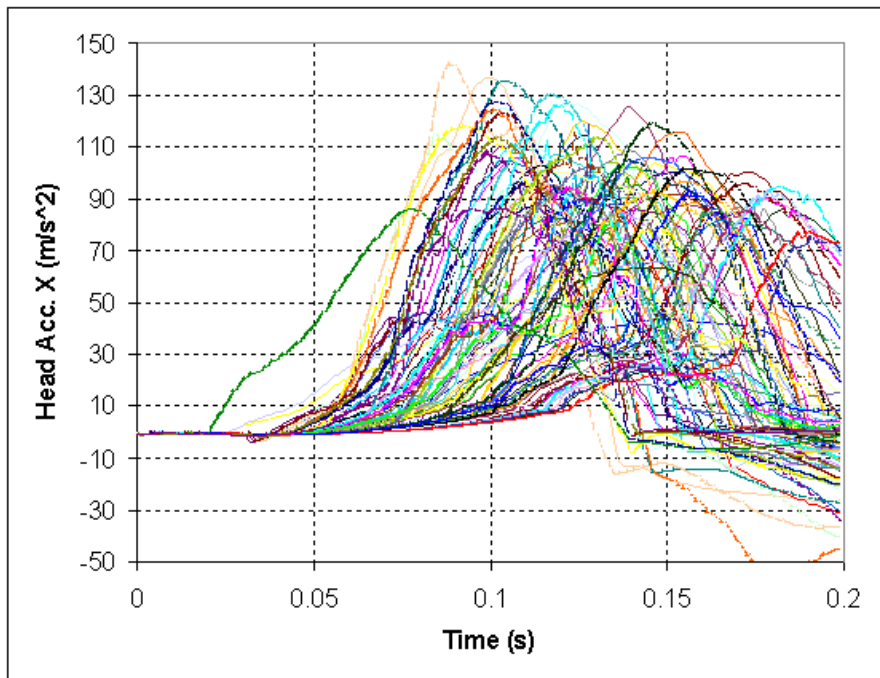
Apply Reset

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Monte Carlo Results

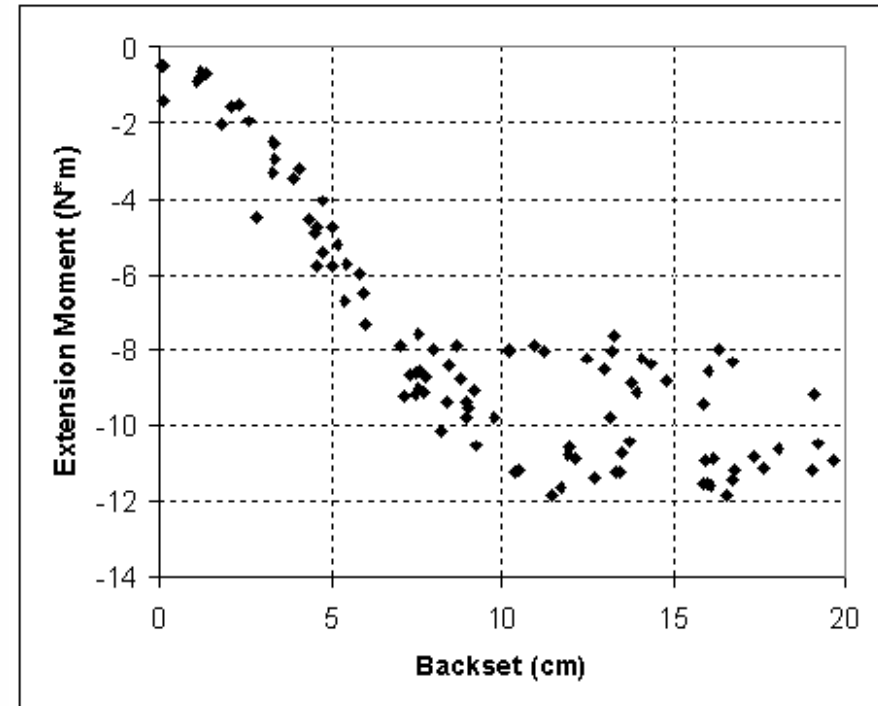
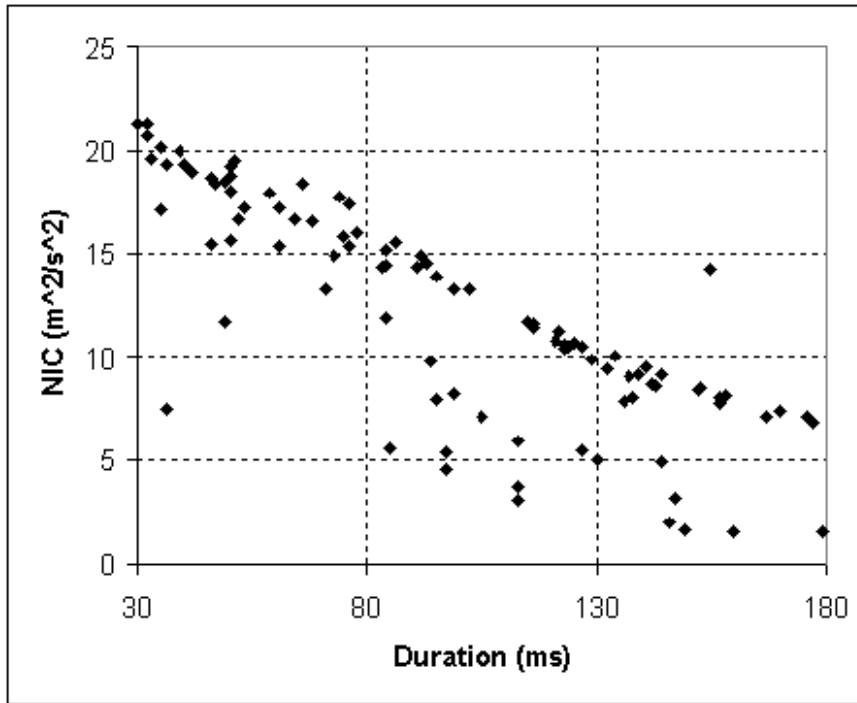
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Scatter Plots

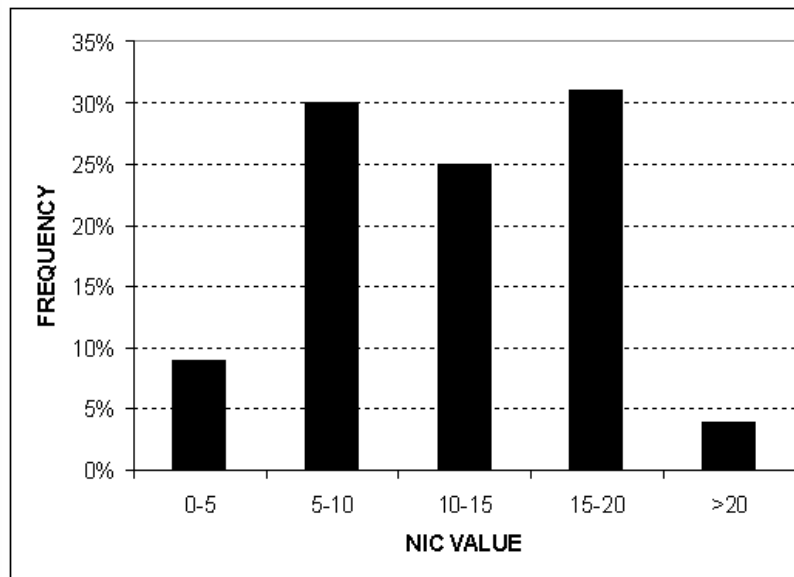
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Results

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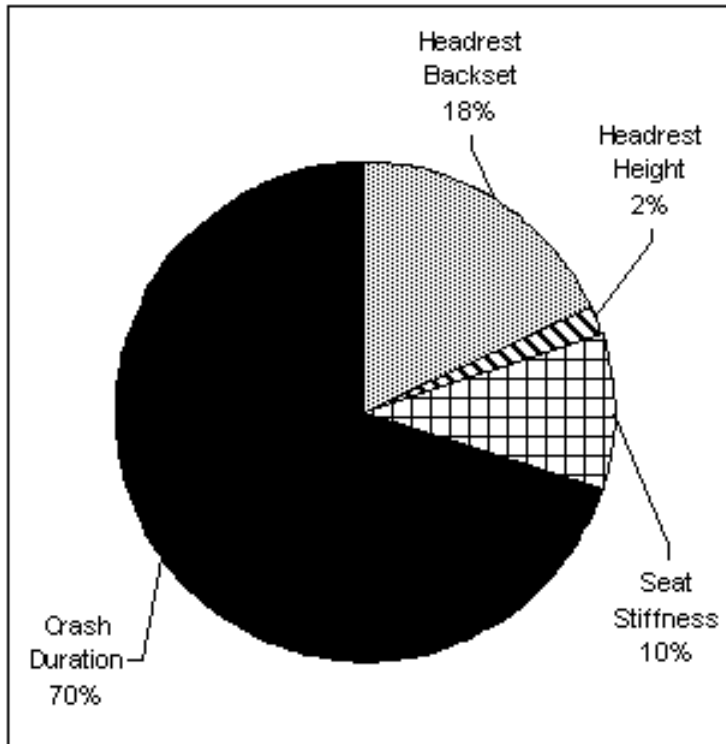


Injury Measure	Low	High	Average
NIC (m^2/s^2)	1.53	21.22	12.17
N_{km}	0.11	0.58	0.37
Flexion Moment (Nm)	2.52	27.44	11.08
Extension Moment (Nm)	0.50	11.8	7.68
Tension (N)	1	500	151
Compression (N)	39	372	149

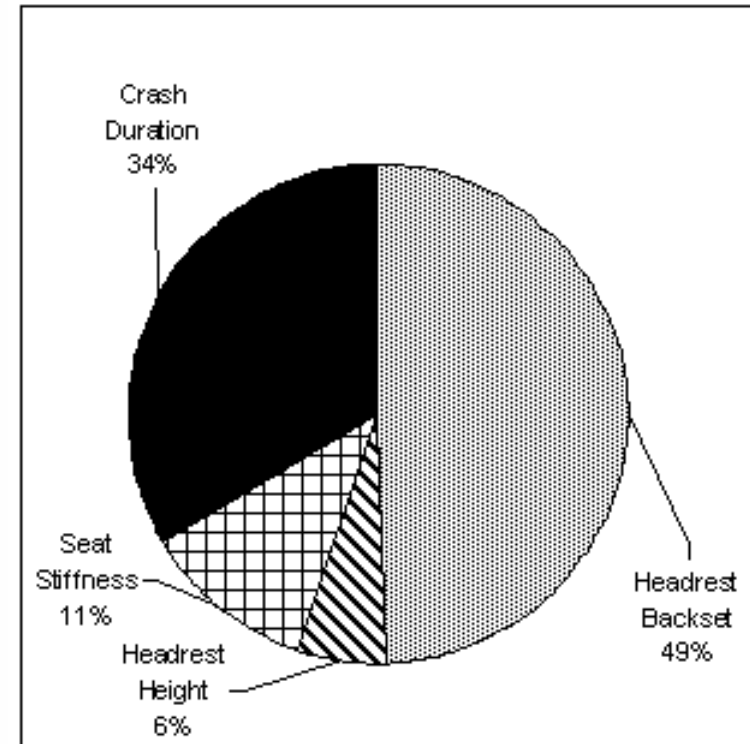


Sensitivity Results

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Retraction Phase

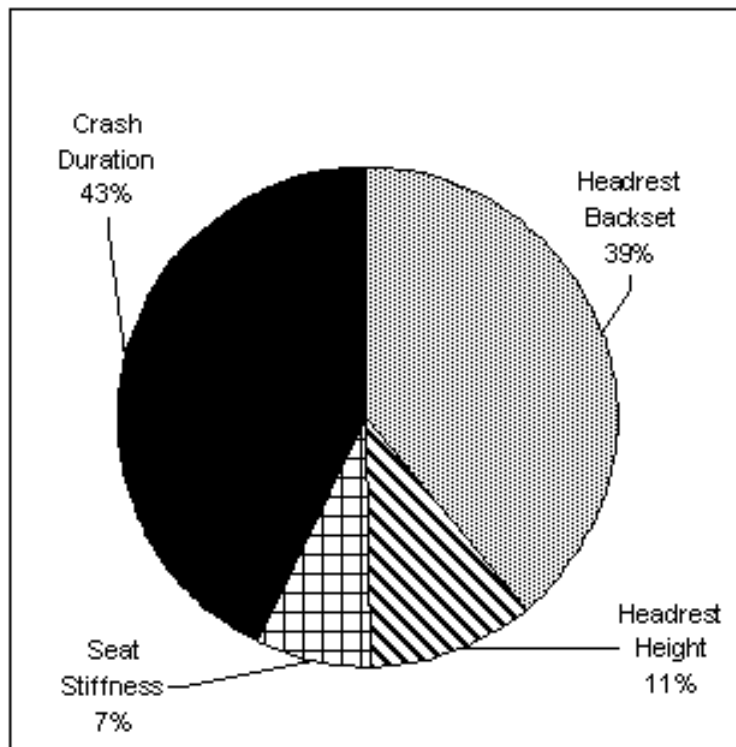


Extension Phase

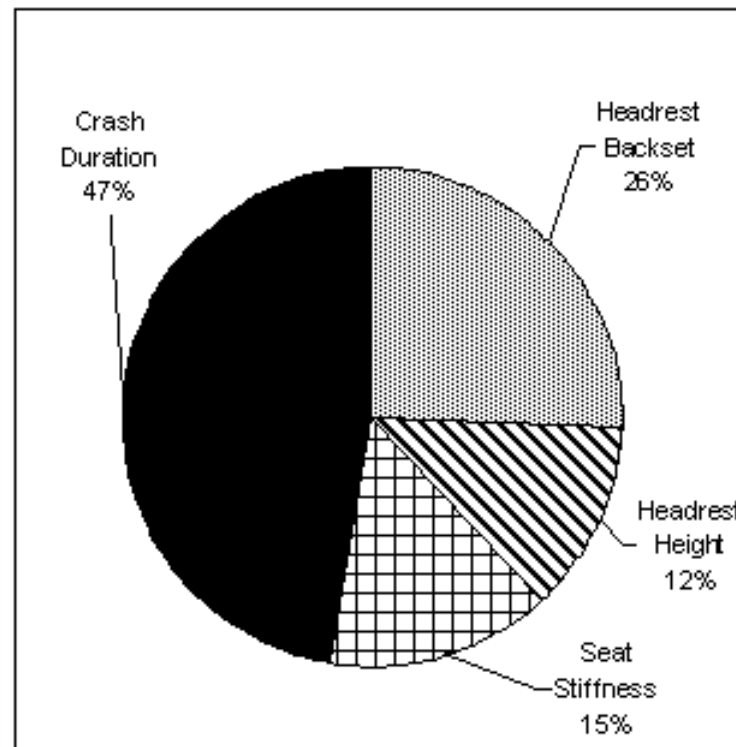


Sensitivity Results

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Rebound Phase

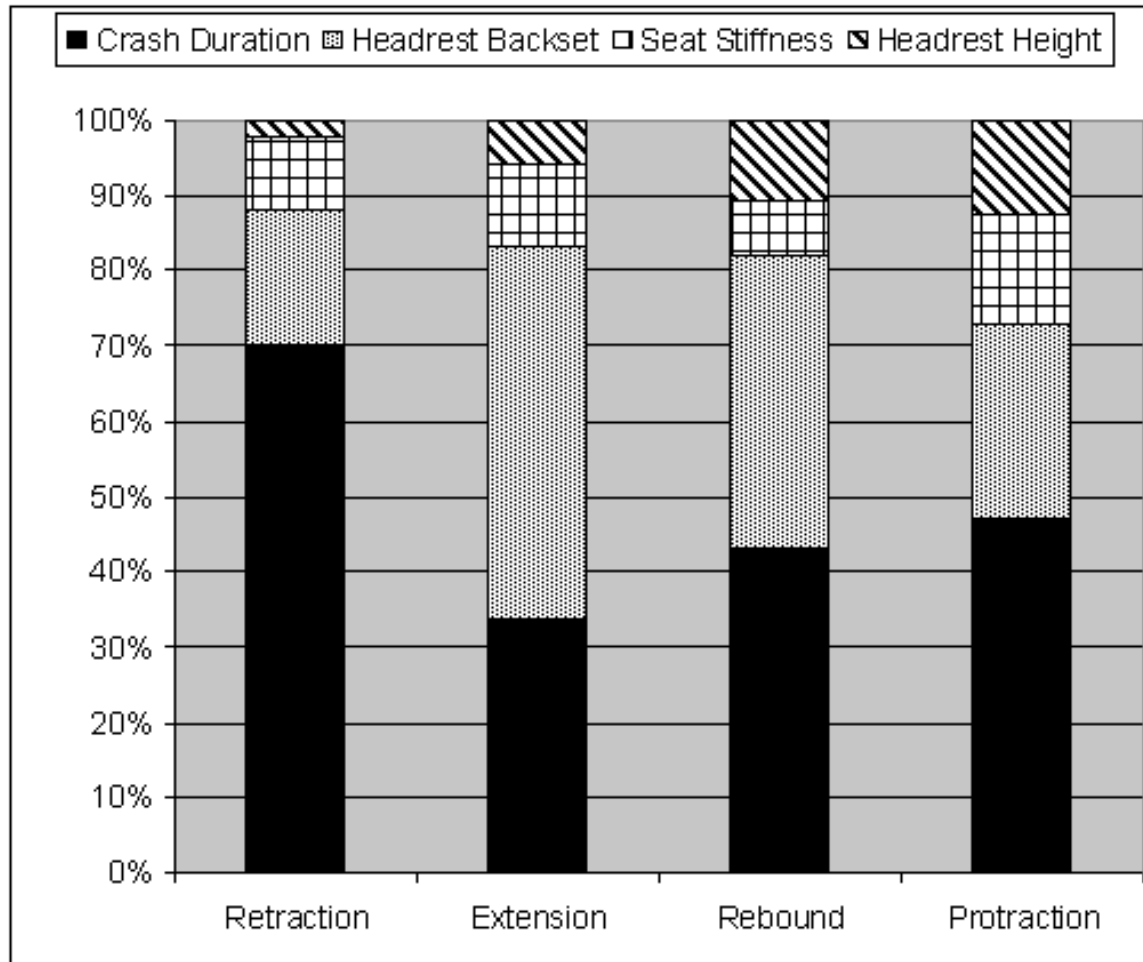


Protraction Phase



Summary: Design Factors

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Conclusions

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- Vehicle design plays an important role in protection of the occupant from whiplash injury
- Different design factors may have different levels of influence on the phases of the whiplash motion
- Relationship between design factors and injury measures for different phases of whiplash make the vehicle design quite challenging
- It is important to look at the vehicle as a system in designing and rating vehicles for WAD
- Models Show Good Correlation With Testing
- Given the strong influence of bumper design on WAD potential, test agencies should consider incorporating vehicle specific crashpulses into the sled testing
- Computer simulation should be considered as a supplement to physical crash testing for assessing whiplash performance