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Comparison of the Responses and Trauma Assessment of The Thor-Lx/HIIIr and Hybrid III Denton Legs in Frontal Offset Vehicle Crashes

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Offset Frontal Protection

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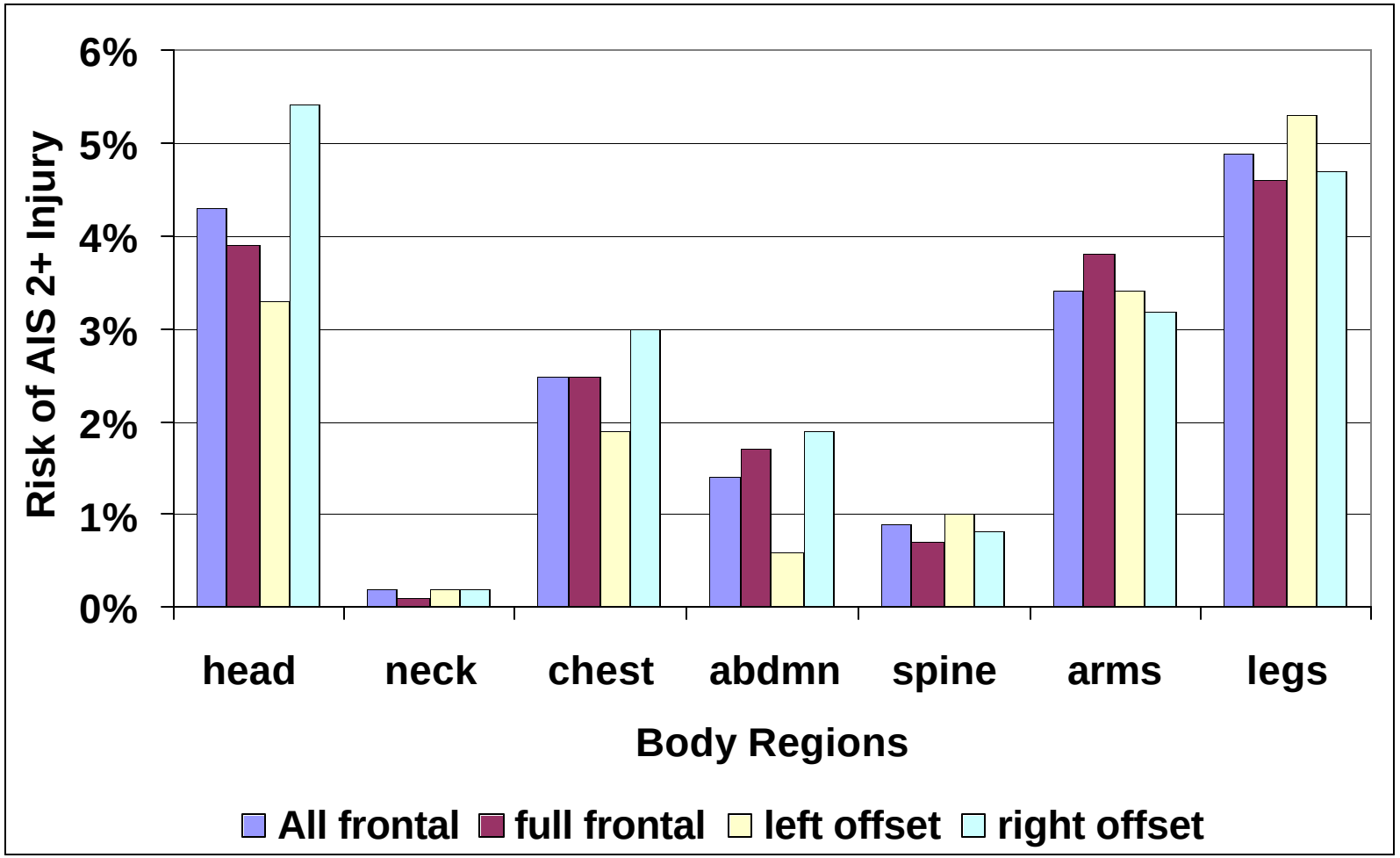
- **Reduce death and injury**
- **Reduce long term impairment, pain and suffering (especially lower extremities)**
- **Reduce costs of recovery and rehabilitation**

Risk of AIS 2+ Injuries



Lower Extremity Injuries

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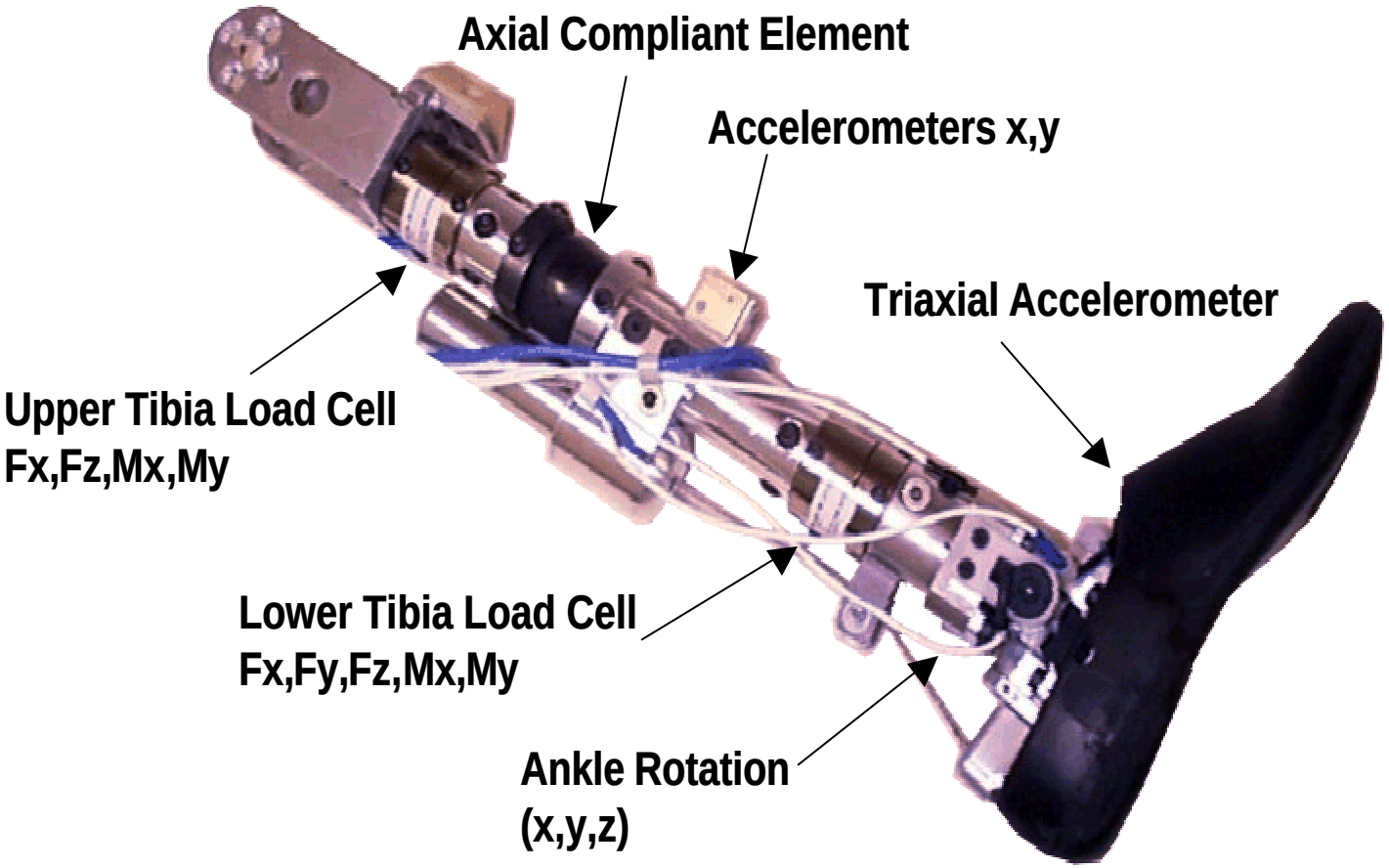
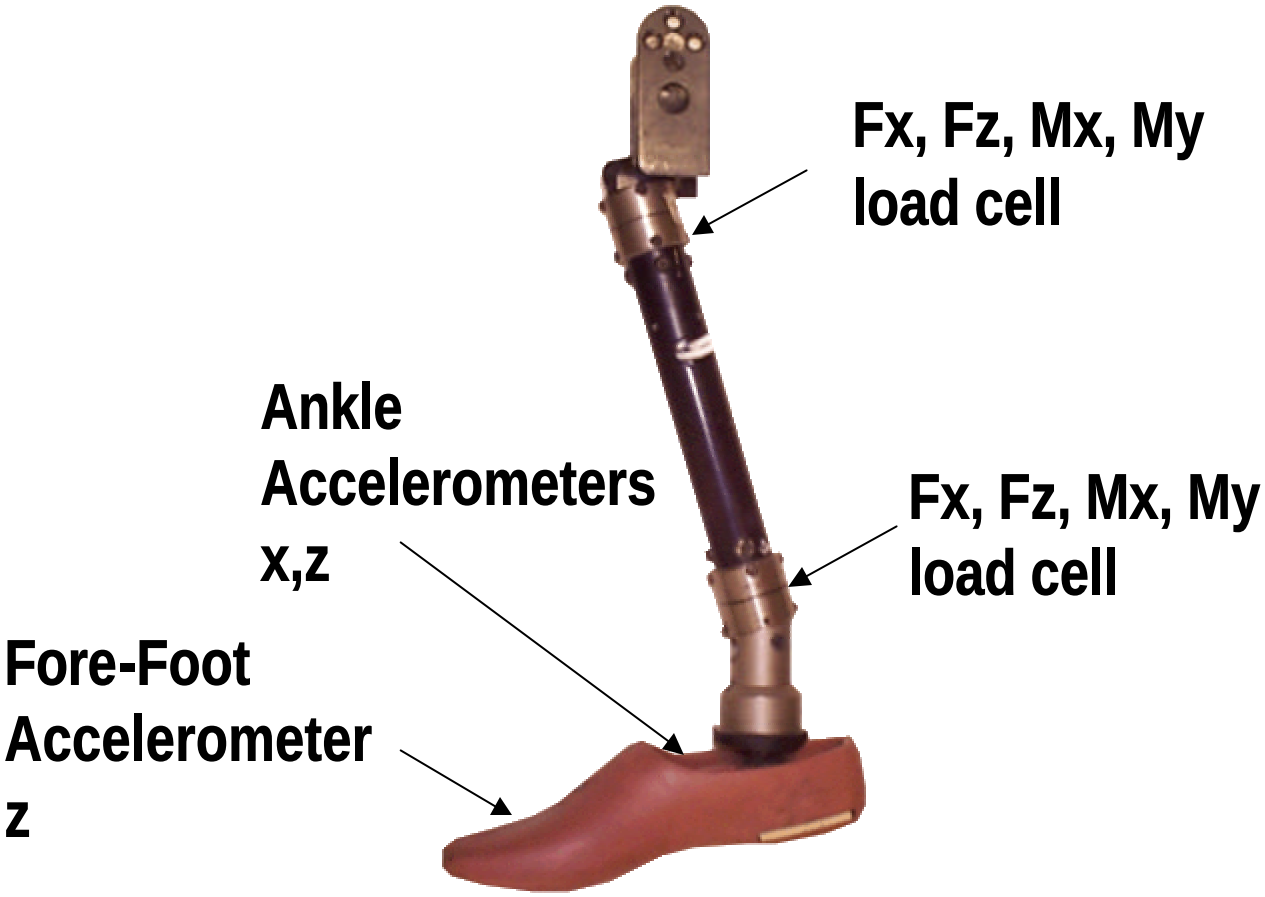
- **NHTSA estimates approximately 84,811 occupants sustain AIS 2 or 3 lower extremity injuries every year in frontal crashes.**
- **Annual Cost estimated at $7 billion.**
- **Two devices available to assess Lower Extremity Injuries**
  - Thor-Lx/HIIIr
  - Denton Leg

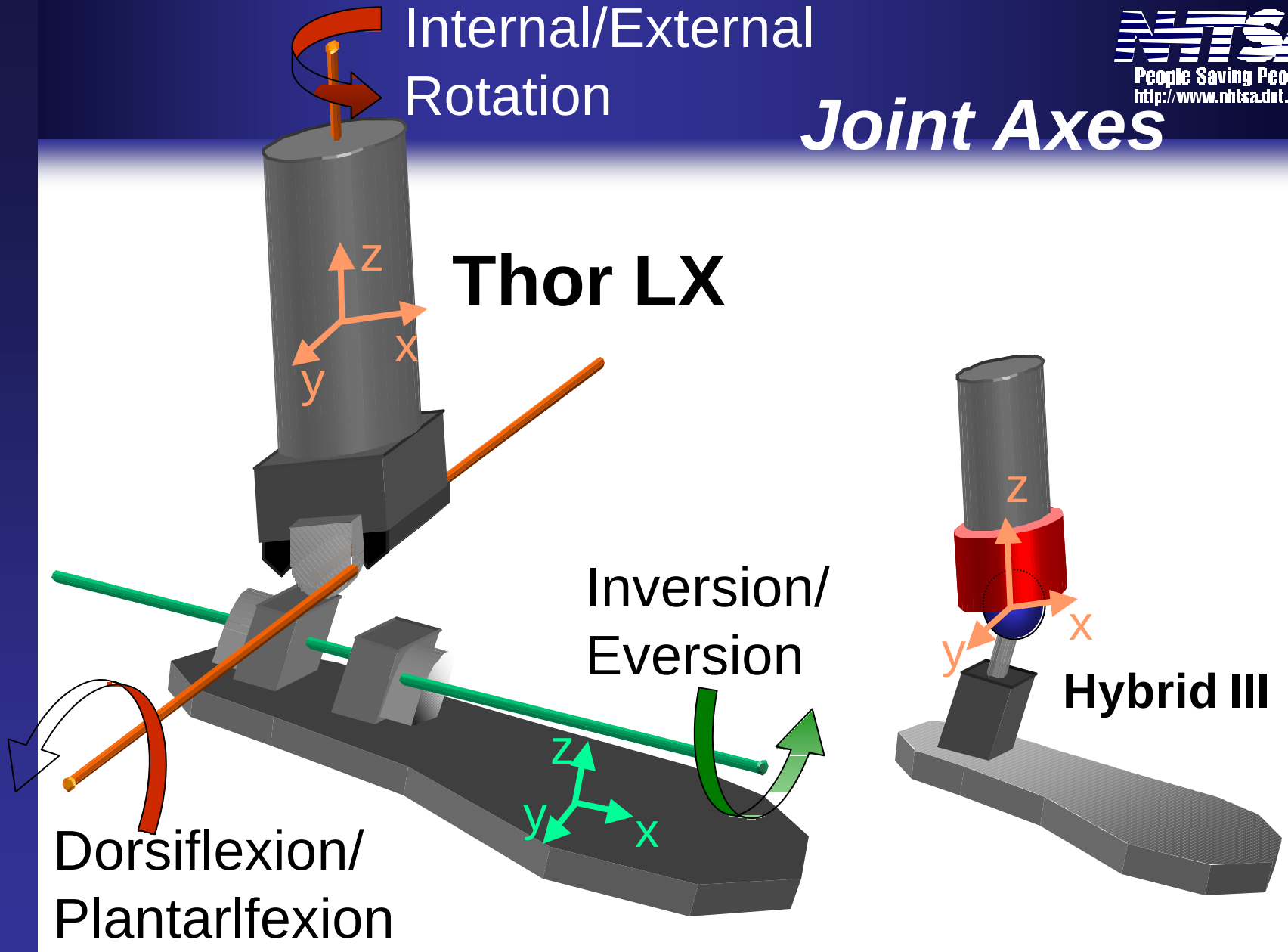
Thor-Lx


Axial Compliant Element
Accelerometers x,y
Triaxial Accelerometer
Upper Tibia Load Cell
Fx,Fz,Mx,My
Lower Tibia Load Cell
Fx,Fy,Fz,Mx,My
Ankle Rotation
(x,y,z)

Denton Leg


Fx, Fz, Mx, My
load cell
Ankle
Accelerometers
x,z
Fx, Fz, Mx, My
load cell
Fore-Foot
Accelerometer
z

Joint Axes



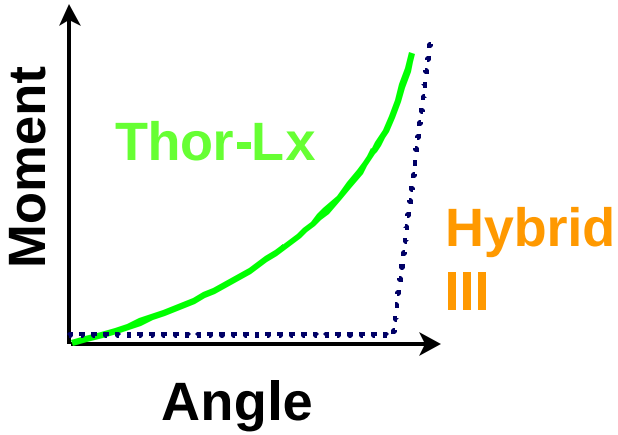
Note: “talus” removed for visualization

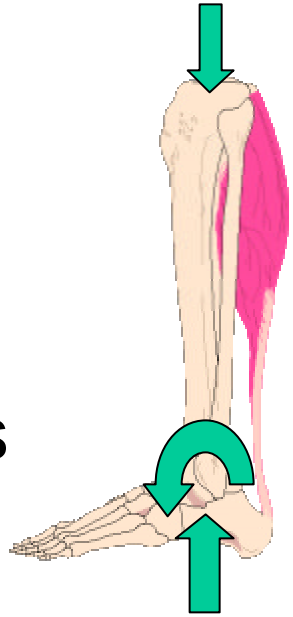
Response Characterstics of the HIII/Denton Leg

- Axial force response stiffer than human.
- Tibia offset induces bending moment upon axial loading
- Inversion/eversion range of motion is small
- Torque-angle characteristics of ankle joint are non-continuous

Response Characteristics of the Thor-Lx/HIIIr

- **Axial loading response similar to human response.**
- **Ankle range of motion is human like**
- **Continuous torque-angle characteristics at ankle joints**
  - Achilles tendon (passive only) increases dorsiflexion stiffness and superimposes axial force on the tibia – as in humans





Injury Criteria for 50th Percentile Male

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Region	Thor-Lx Criteria and Limits	Denton Leg Criteria and Limits
knee-thigh-hip	Femur Fz = 9040 N	Femur Fz = 9070 N
Knee ligament	Knee shear = 15 mm	Knee shear = 15 mm
Tibia Plateau	Upper tibia Fz = 5.6 kN	Upper tibia Fz = 8 kN
Leg Shaft	RTI=F/12+M/240=0.91	TI(corrected)=F/36+M/225=1
Calcaneus, pilon, midfoot	Lower tibia Fz = 5.2 kN	Lower tibia Fz = 8 kN
Ankle /malleolus	Dorsiflexion angle = 35 deg	
	Xversion angle = 35 deg	

40% Offset Deformable Barrier Test Setup

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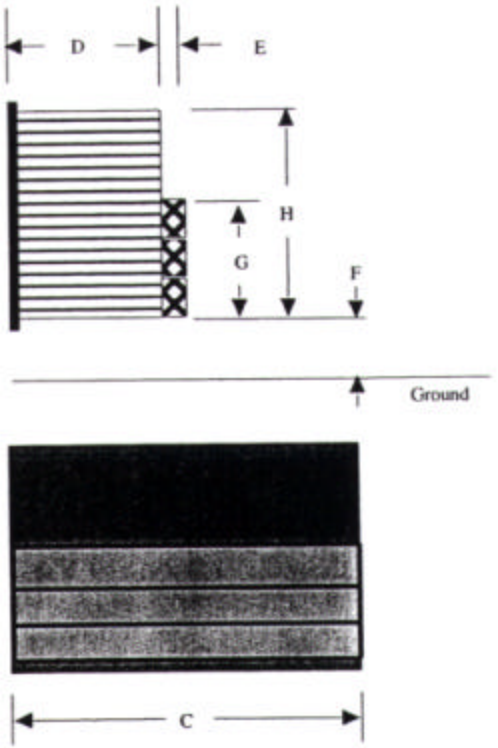

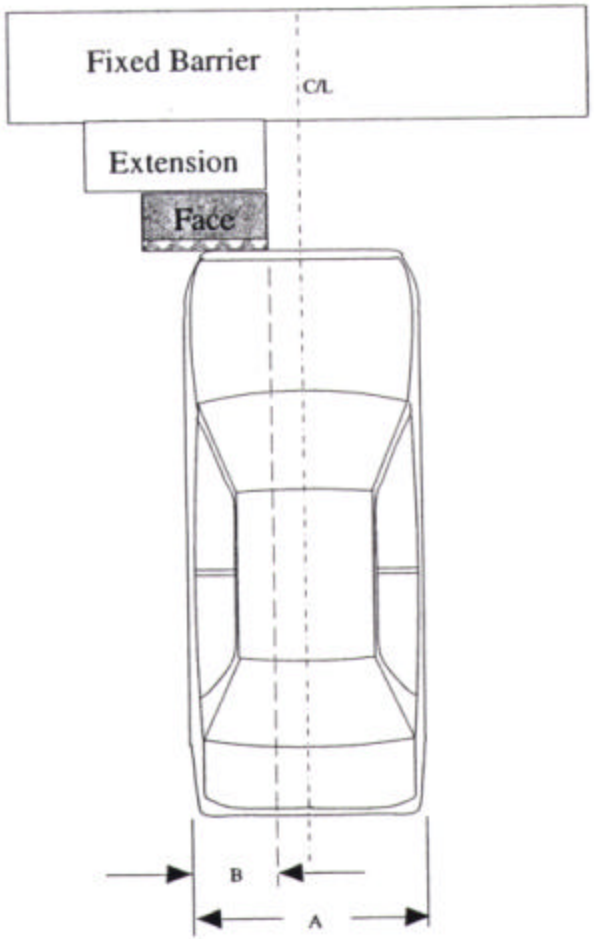

2000 Nissan Quest Thor-Lx

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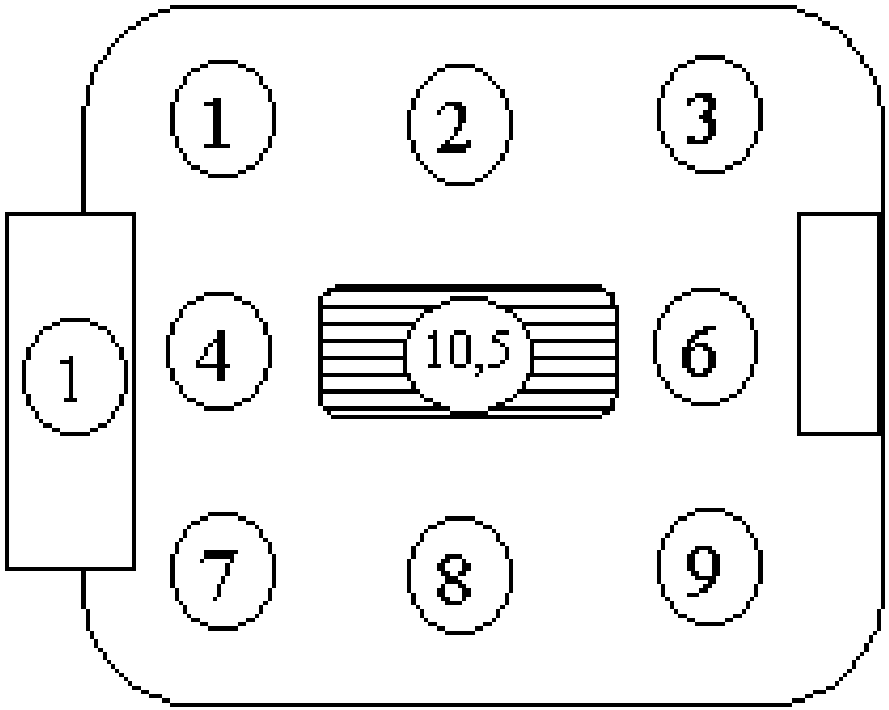
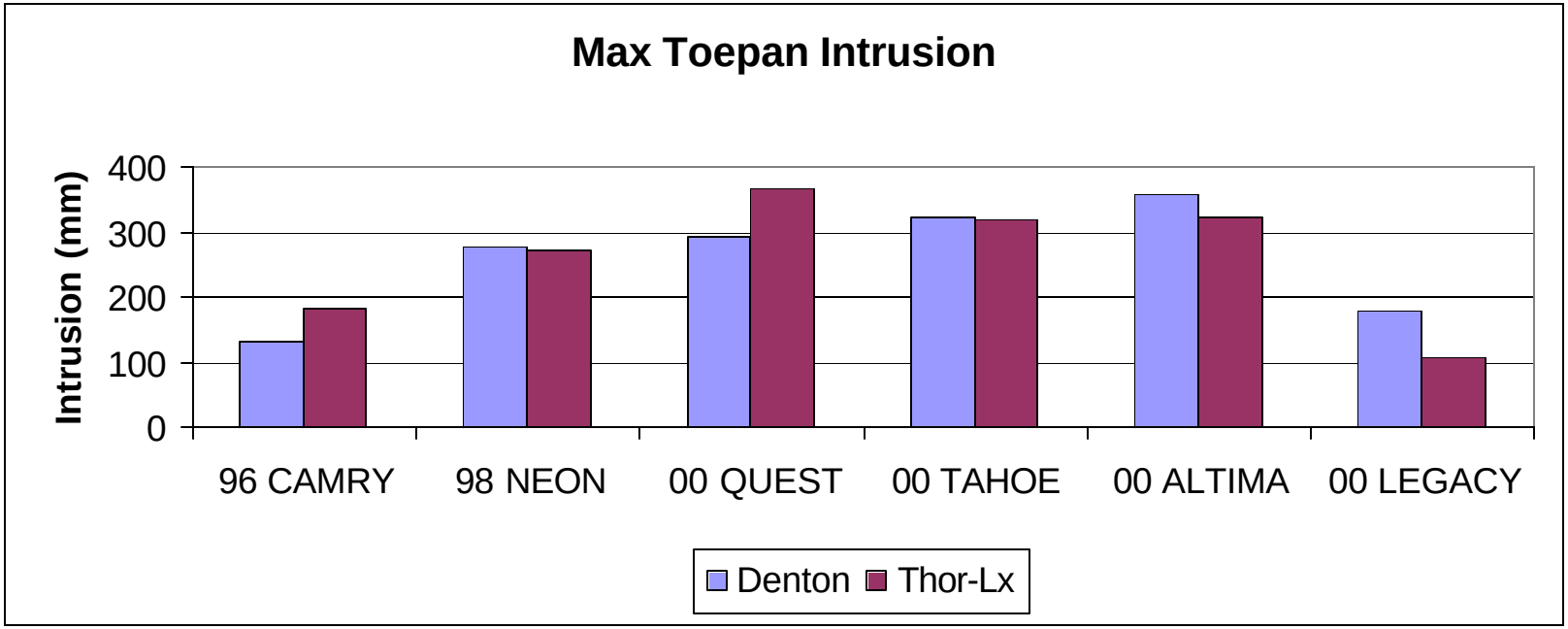
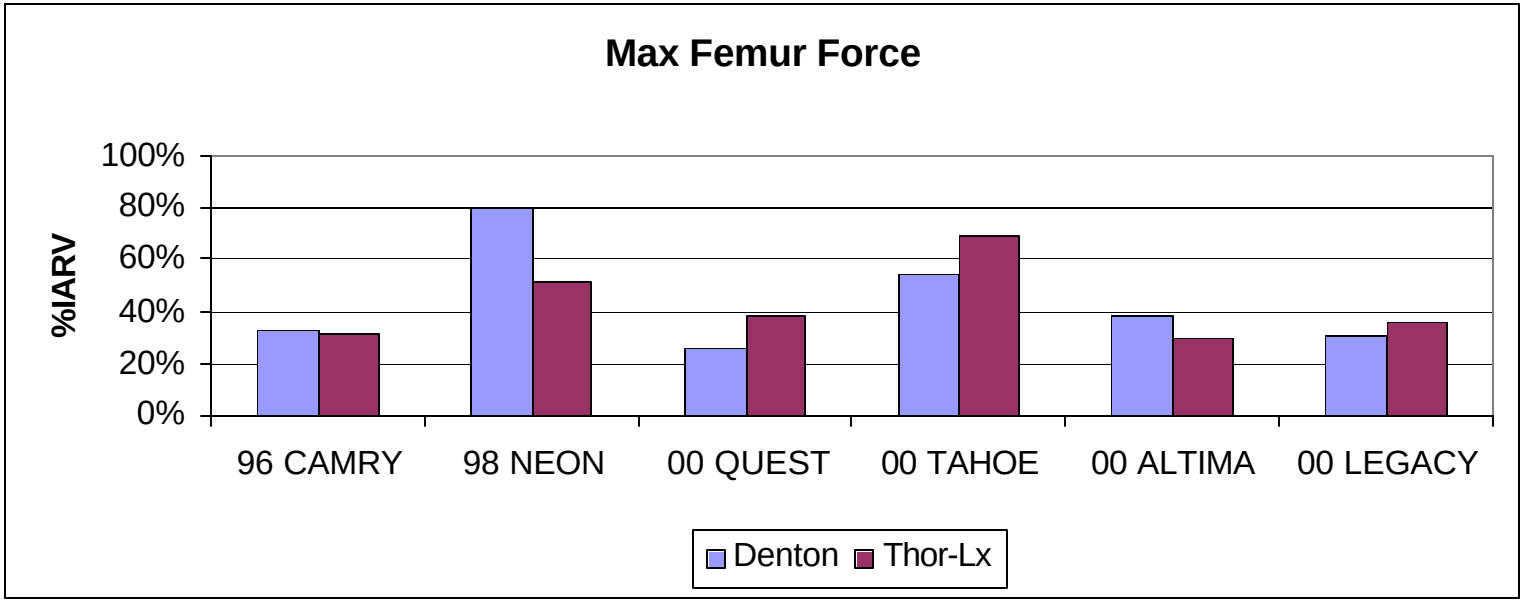
Toepan Intrusion Measurements



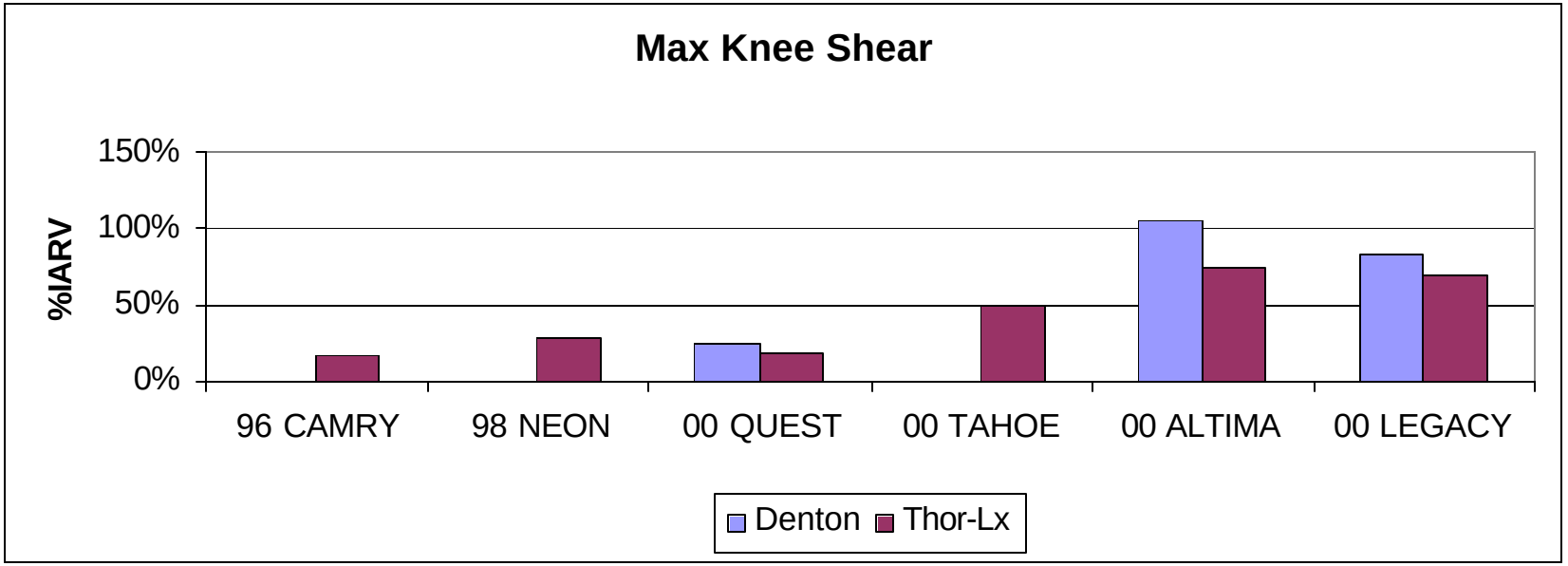
Max Toepan Intrusion



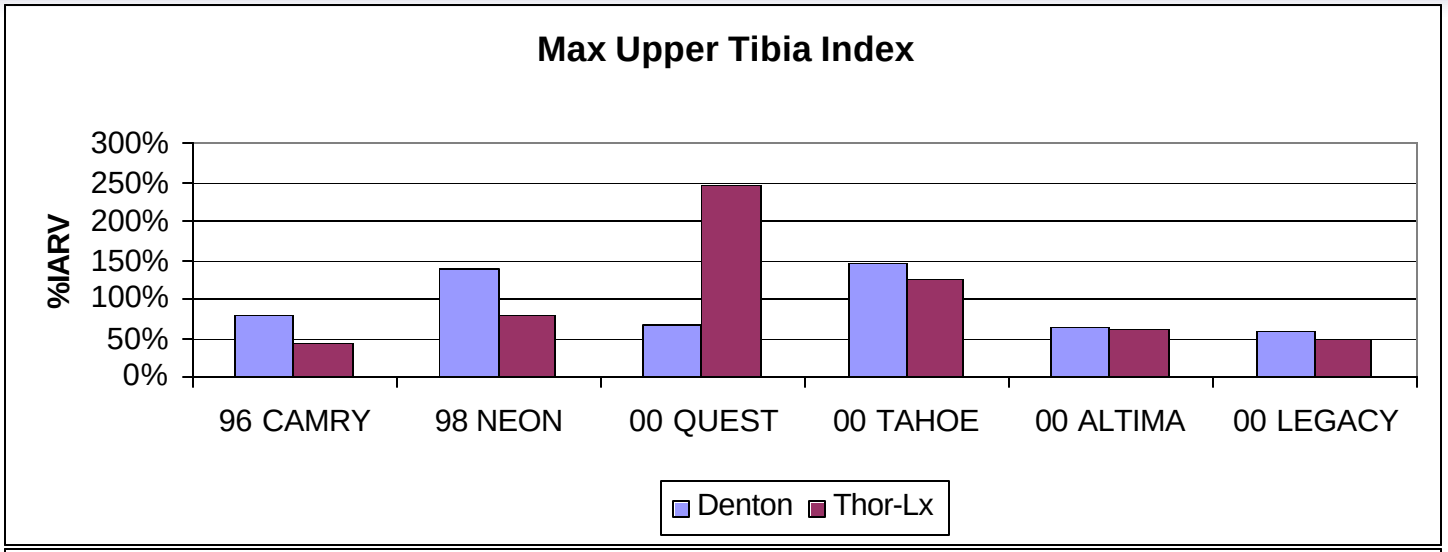
Max Femur Force

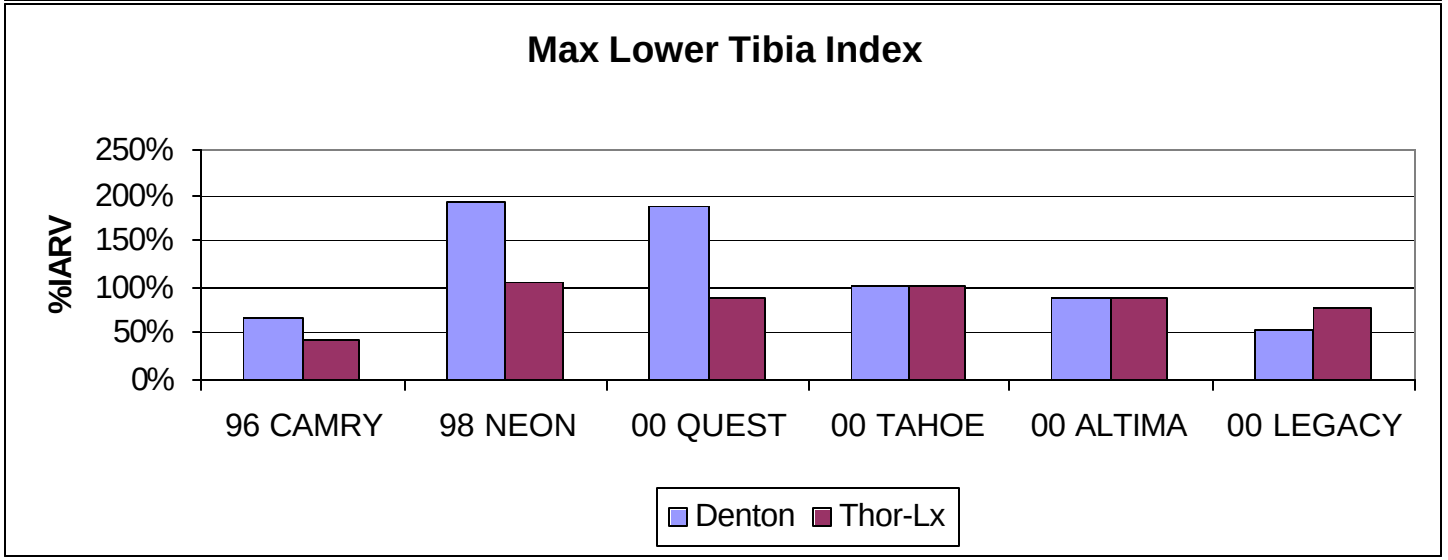


Max Knee Shear

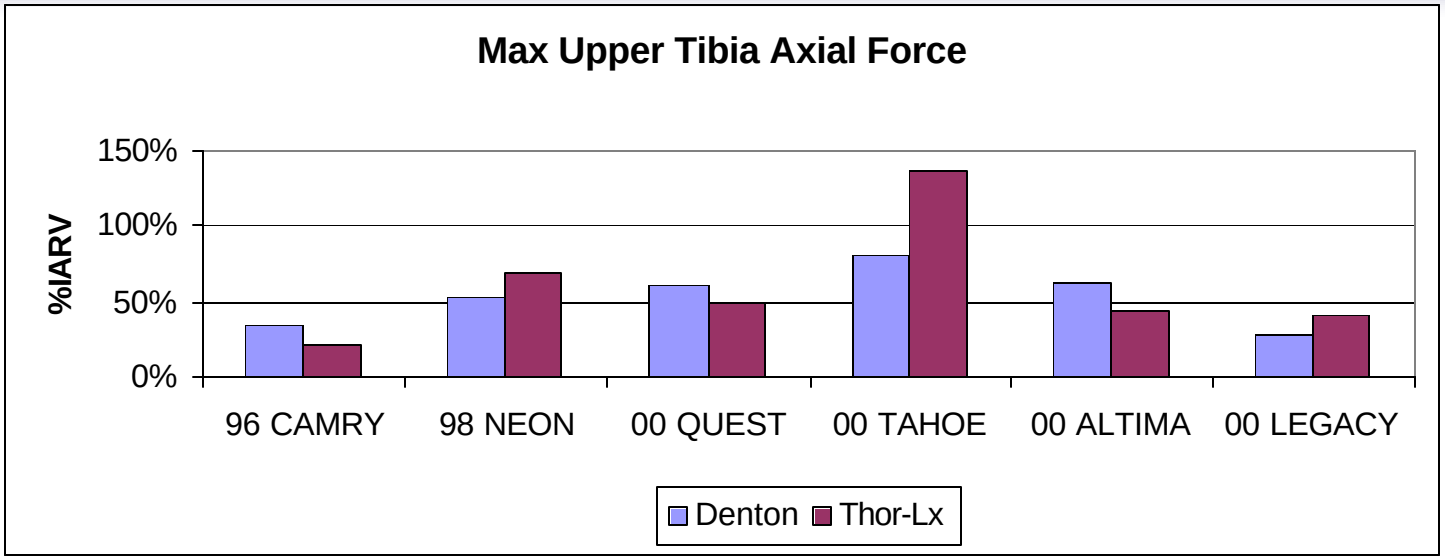


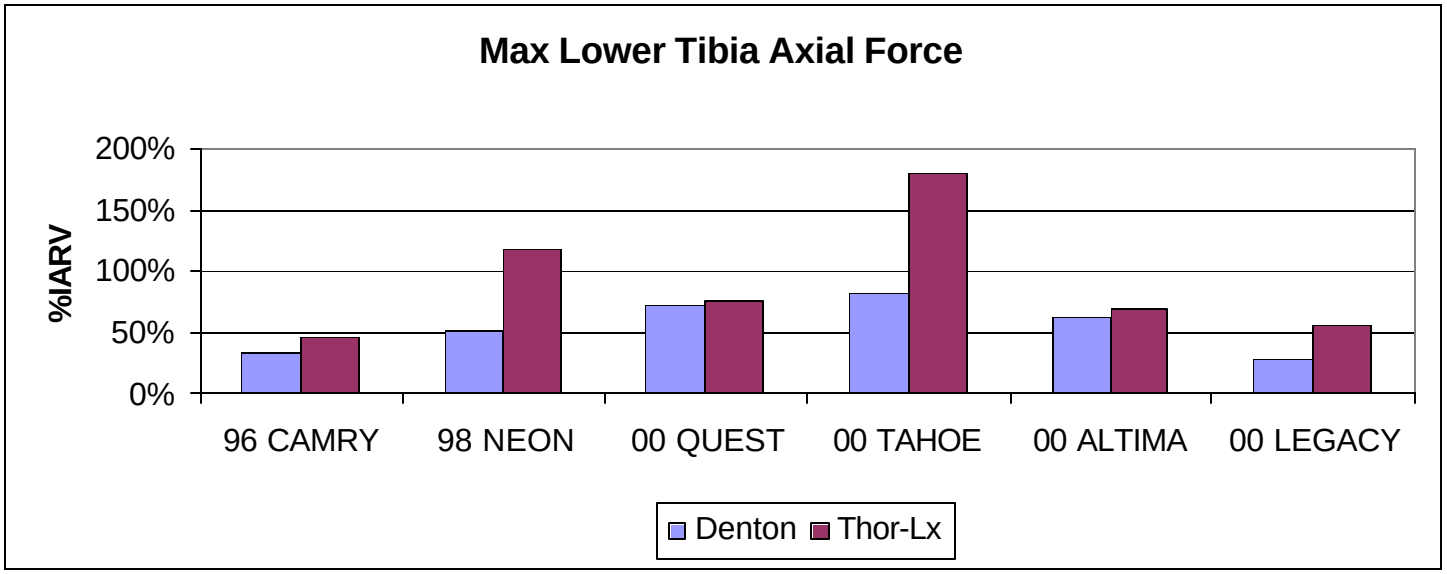
Max Tibia Index



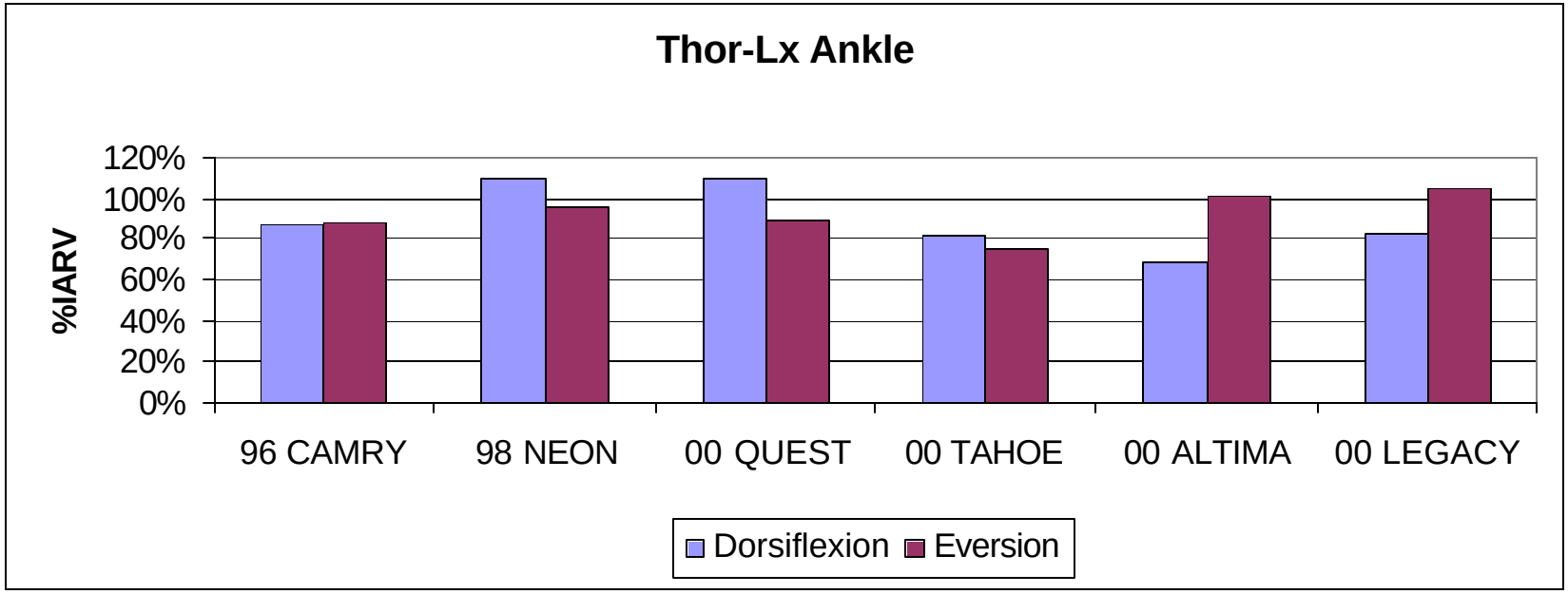


Max Tibia Axial Force





Thor-Lx Ankle



Implications

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- **Thor-Lx/HIIIr predicted higher incidence of foot and ankle injuries than leg shaft fractures. This is in accordance with real world crash data**
- **HIII/Denton leg predicted knee ligament injuries and leg shaft fractures. These constitute only a small percentage of lower limb injuries in real world crashes.**

Injury Criteria for 5th Percentile Female

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Region	Thor-FLx Criteria and Limits	Denton Leg Criteria and Limits
knee-thigh-hip	Femur Fz = 6510 N	Femur Fz = 6186 N
Knee ligament	Knee shear = 13 mm	Knee shear = 12 mm
Tibia Plateau	Upper tibia Fz = 4.0 kN	Upper tibia Fz = 5.1 kN
Leg Shaft	RTI=F/8.6+M/146=0.91	TI(corrected)=F/23+M/115=1
Calcaneus, pilon, midfoot	Lower tibia Fz = 3.8 kN	Lower tibia Fz = 5.1 kN
Ankle /malleolus	Dorsiflexion angle = 35 deg	
	Xversion angle = 35 deg	

Injury Assessment Using the 5th Denton Leg

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	Injury limit	Camry (60 km/h)		Altima (60 km/h)		Neon (60 km/h)		Legacy (60 km/h)		Quest (60 km/h)	
		left	right	left	right	left	right	left	right	left	right
Femur Fz (N)	6186 N	3147.4	1830.513	3804	2535	4170	1563	3721	2942	2964.2	2744.87
Knee Shear (mm)	12 mm	ND	ND	1.27	2.28	NA	NA	0.76	0.84	0.045	0.009
Upper TI	1	0.033	0.626	0.55	0.76	0.81	**2.09**	0.57	0.43	0.556	**1.096**
Lower TI	1	0.149	**1.845**	0.89	**2.13**	**3.34**	**2.45**	0.86	0.78	0.757	**1.977**
tibia Fz (N)	5104 N	97.71	2210.84	1706	3858	2274	3506	1674	2368	1076.3	3700.86

Injury Assessment Using Thor-Flx/HIIIr

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	Injury limit	Camry (60 km/h)		Altima (64 km/h)		Neon (60 km/h)		Legacy (64 km/h)		Quest (60 km/h)	
		left	right	left	right	left	right	left	right	left	right
Femur Fz (N)	6510 N	3050.8	2042.09	4582.9	2498	3152.2	1509.47	2935.6	2926.068	3237.8	3291.03
Knee Shear (mm)	13 mm	1.068	0.99	1.972	3.776	3.476	1.311	1.55	1.469	0.469	3.541
Upper RTI	0.91	0.33	0.42	0.34	0.82	0.73	0.82	0.38	0.28	0.792	0.624
Upper Tibia Fz (N)	4000 N	655.36	995.39	940	2930.04	2425.6	2137.93	1545.9	1067.97	1448	2555.15
Lower RTI	0.91	0.35	ND	0.56	**1.55**	0.84	**0.96**	0.51	0.58	0.717	0.826
Lower tibia Fz (N)	3750 N	1793.3	2213.49	2470.4	**5519.34**	**4086.6**	**3790.6**	3006.4	2497.98	2894.2	3628.3
Xversion (deg)	35 deg.	11.4	-22.5	-27.9	**37.1**	28.4	-10	14.4	34.74	-27.55	-10.71
Dorsiflexion (deg)	35 deg	**39.1**	**35.4**	**41.7**	**35.8**	**44**	**35.3**	34.74	28.04	**39.65**	**37.42**

Implications

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- **Thor-Flx/HIIIr predicted higher incidence of foot and ankle injuries than leg shaft fractures. This is in accordance with real world crash data**
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Conclusions

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- **Both 50th and 5th HIII/Denton and Thor-Lx/HIIIr were durable in crash tests**
- **Foot rotation measurements provide insight into the interaction of the feet with intruding toe pan.**
- **Injury assessment with 50th and 5th Thor-Lx/HIIIr is in accordance with injury distribution seen in real world crashes**