Comparison of Effect of Different Approaches on Injury Risk Functions

8th IG GTR9-PH2 meeting, 9-10/Sep/2013, Paris

Japan Automobile Standards Internationalization Center (JASIC)

Comparison of Approaches

Items	BASt	JASIC
Data Source	Nyquist et al. (1985)	Nyquist et al. (1985) Kerrigan et al. (2003a) Kerrigan et al. (2003b) Kerrigan et al. (2004)
Gender	Male	Male and Female
Number of Data	6	19
Treatment of Filtered Data	10% attenuation assumed	Right censored data
Data Scaling	Geometric	Geometric
Standard Length	Tibia Height : 460 mm	Tibia Length : 402 mm Tibia Height : 483 mm
Statistical Method	Normal Distribution	Survival Model with Weibull Distribution
Transfer Function	JASIC function	FlexPLI-Human model correlation function

Comparison of Approaches

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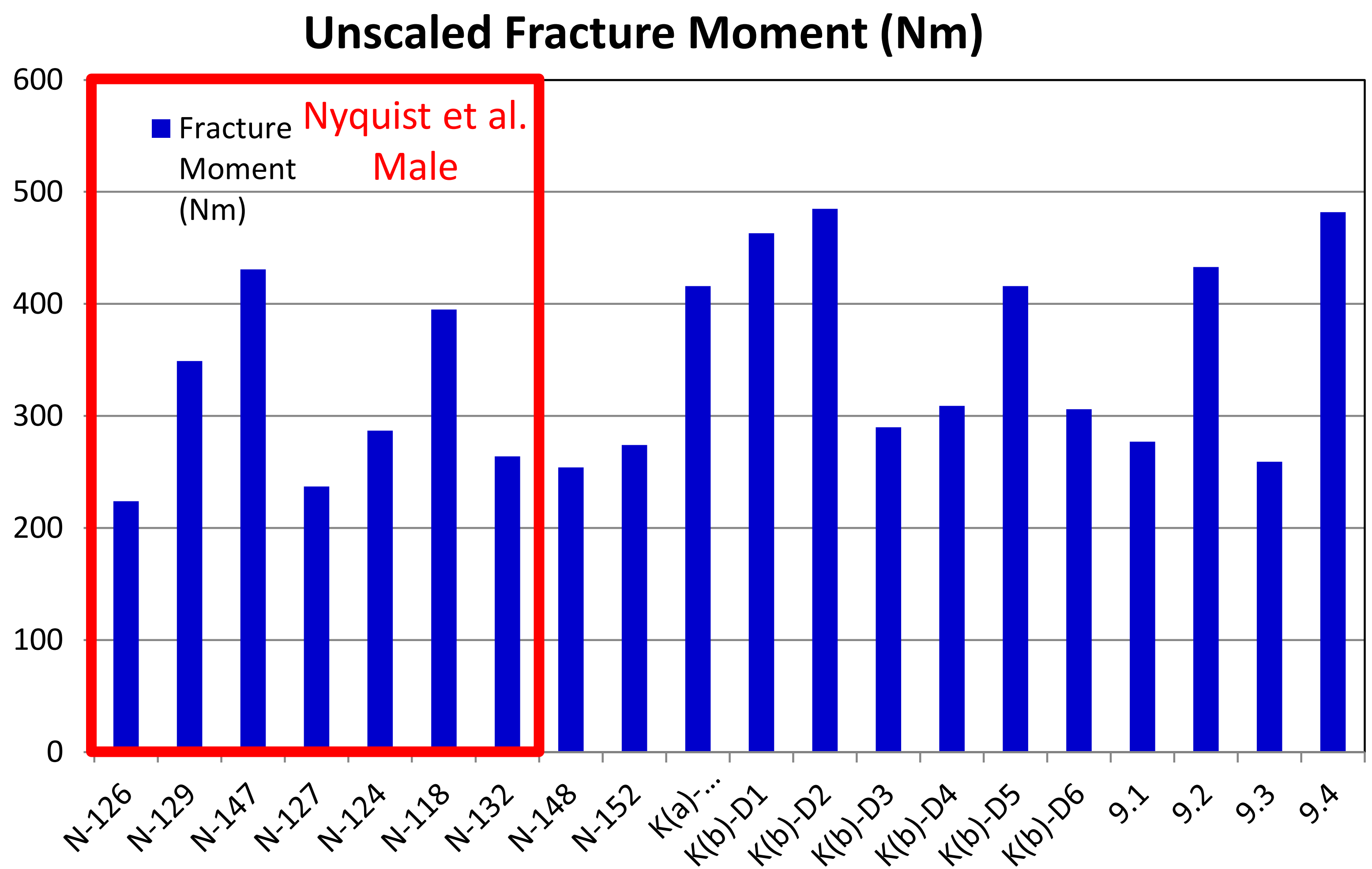
Original Data

Test	Source	Age	Gender	Stature (mm)	Weight (kg)	Anatomical Measurement (mm)	Anatomical Measurement Description	Fracture Moment (Nm)
N-126	Nyquist 1985	58	M	1740	73	480	Tibia Height	224
N-129	Nyquist 1985	57	M	1780	99	500	Tibia Height	349
N-147	Nyquist 1985	57	M	1780	84	405	Tibia Height	431
N-127	Nyquist 1985	56	M	1760	79	465	Tibia Height	237
N-124	Nyquist 1985	64	M	1770	82	490	Tibia Height	287
N-118	Nyquist 1985	54	M	1820	68	520	Tibia Height	395
N-132	Nyquist 1985	57	M	1870	45	445	Tibia Height	264
N-148	Nyquist 1985	57	F	1630	75	420	Tibia Height	254
N-152	Nyquist 1985	51	F	1630	68	430	Tibia Height	274
K(a)-134L	Kerrigan SAE 2003	44	M	1702	73	420	Tibia Length	416
K(b)-D1	Kerrigan NCCM 2003	54	M	1905	88	445	Tibia Length	463
K(b)-D2	Kerrigan NCCM 2003	54	M	1905	88	450	Tibia Length	485
K(b)-D3	Kerrigan NCCM 2003	68	M	1651	51	385	Tibia Length	290
K(b)-D4	Kerrigan NCCM 2003	68	M	1651	51	385	Tibia Length	309
K(b)-D5	Kerrigan NCCM 2003	65	F	1727	60	378	Tibia Length	416
K(b)-D6	Kerrigan NCCM 2003	75	M	1778	65	395	Tibia Length	306
9.1	Kerrigan 2004	66	M	1829	79.8	397	Tibia Length	277
9.2	Kerrigan 2004	69	M	1702	81.6	418	Tibia Length	433
9.3	Kerrigan 2004	62	M	1829	60.8	416	Tibia Length	259
9.4	Kerrigan 2004	54	M	1880	117.9	479	Tibia Length	482

Original Data



- Average fracture moment : Nyquist male only = 312 Nm, Overall = 343 Nm
- Nyquist data are filtered and approx. 10% attenuated (no unfiltered data presented)
- Nyquist male subset might be equivalent to overall dataset in terms of average moment (depending on the validity of 10% attenuation assumption)

Nyquist Data

Question

If Nyquist data involve much more noise than Kerrigan data and data filtering only eliminated spikes, would it be appropriate to interpret filtered and 10% attenuated data as uncensored (exact) data?

tude for the symmetrical loading configuration utilized in these tests. While the initially recorded data were compatible with SAE Channel Class 1000, the results presented herein have been filtered at 100 Hz to smooth the traces and slightly attenuate the short duration spikes. A review of the filtered and unfiltered data suggests that the peak forces were attenuated by about 10 percent by this procedure. We have no evidence regard-

- Recorded data comparable with SAE Channel Class 1000
- Traces smoothed and spikes attenuated by applying 100 Hz cutoff
- A review of data suggested that peak forces were attenuated by about 10%

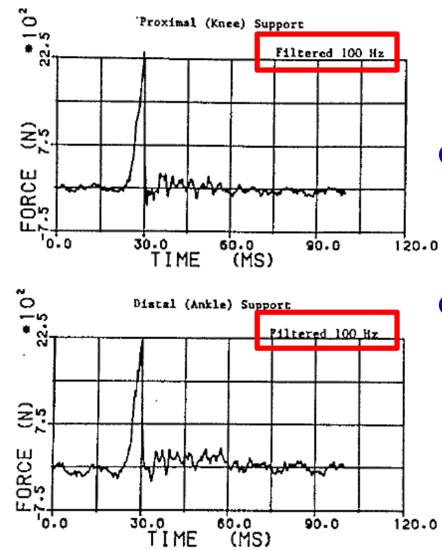
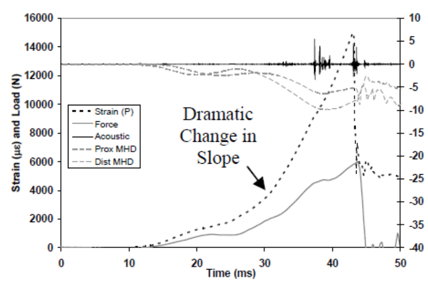
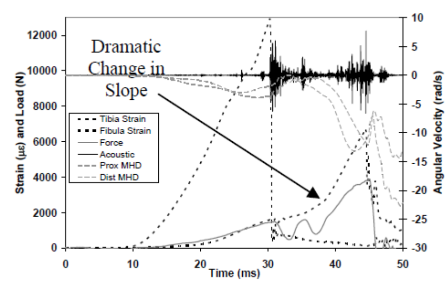


Figure 4. Typical End Restraint Force vs Time Traces. (Test 132, Lateromedial Loading at 3.8 m/s)

- “Filtered 100 Hz”but apparently higher frequency components are present
- If these time histories are unfiltered, then filtering does not seem to be necessary and thus peak values are likely to have dropped by filtering

Reference:
Kerrigan data





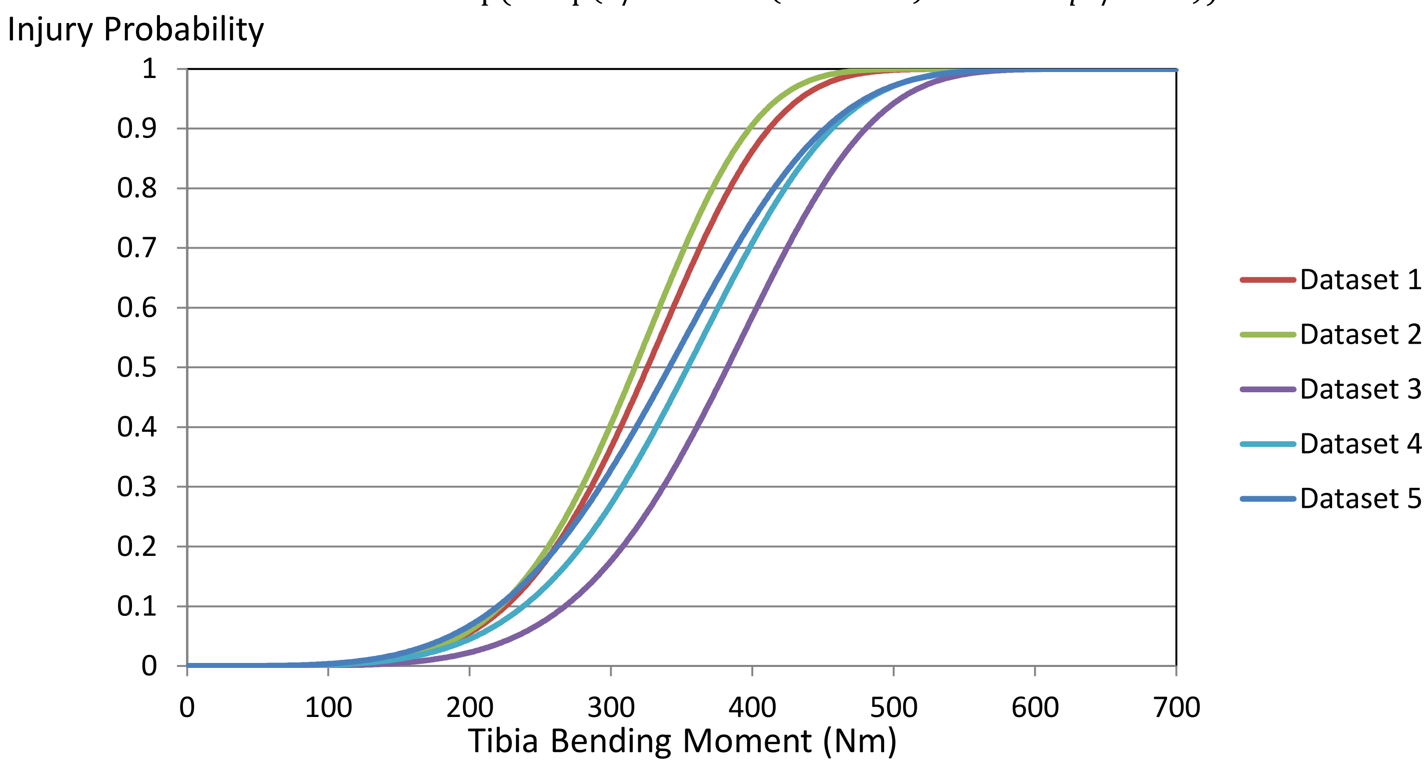
Effect of Dataset

- Unscaled data
- Eliminate N-147 (as performed by both BASt and JASIC) because scaled moment is an outlier
- Survival Model with Weibull Distribution
- Compare four datasets
  - Dataset 1 : Nyquist male only, 10% compensation
  - Dataset 2 : Nyquist all data, 10% compensation
  - Dataset 3 : Kerrigan all data
  - Dataset 4 : Nyquist all data, 10% compensation
    + Kerrigan all data
  - Dataset 5 : Nyquist all data, no compensation
    + Kerrigan all data
- All the data were treated as uncensored data
- Note: 10% compensation may or may not be valid – no way to validate the assumption

Effect of Dataset

	Nyquist	Compensation	Censoring	Kerrigan	Censoring	Intercept	Scale
Dataset 1	male only	10% increase	exact	none	none	5.857595	0.1955334
Dataset 2	all	10% increase	exact	none	none	5.828089	0.1898311
Dataset 3	none	none	none	all	exact	6.015695	0.1898551
Dataset 4	all	10% increase	exact	all	exact	5.947076	0.211052
Dataset 5	all	none	exact	all	exact	5.917936	0.2330465

$$P = 1 - \exp(-\exp(1/Scale * \ln(Tibia\ BM) - Intercept/Scale))$$



- Choice of dataset was found to be a significant contributor to risk functions
- Nyquist male only vs. all data showed relatively small difference

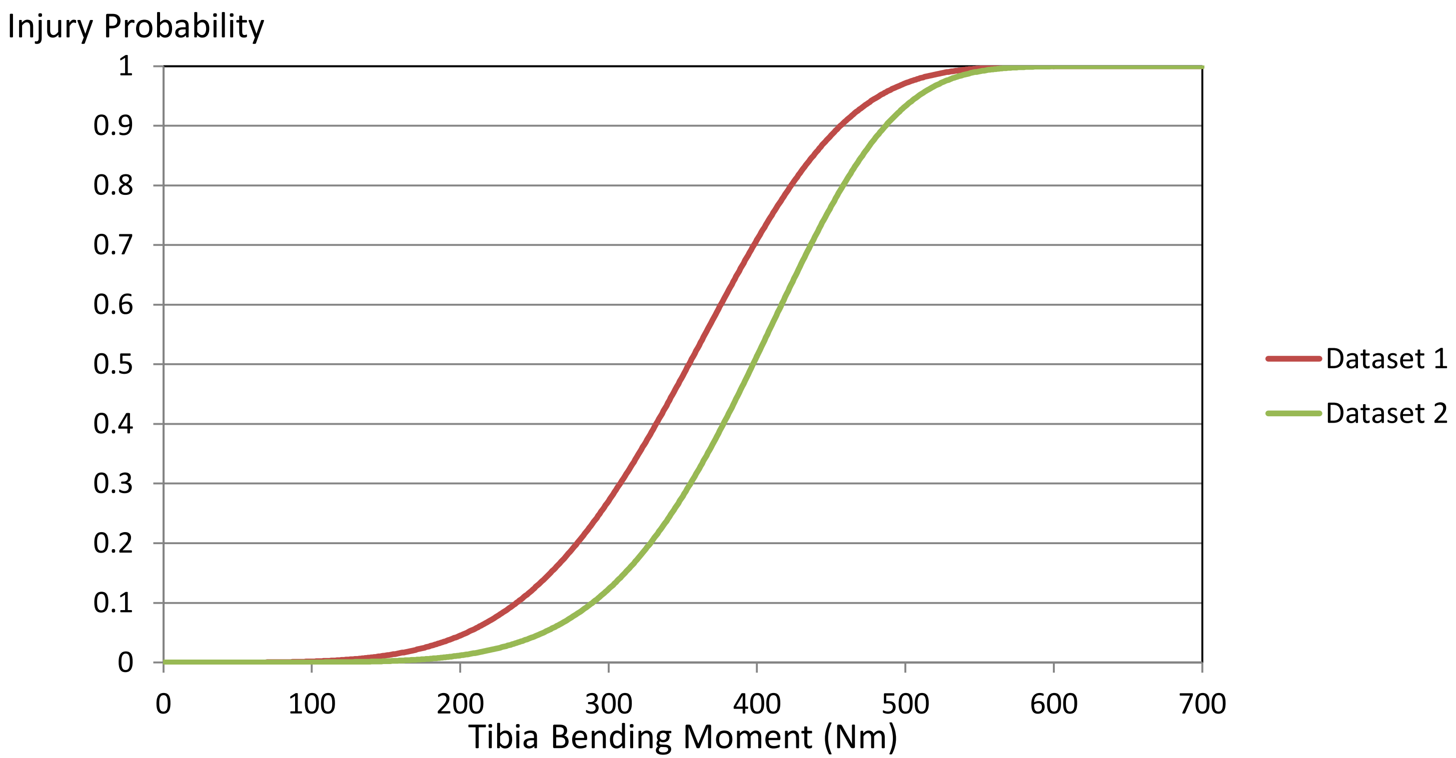
Effect of Censoring

- Unscaled data
- Eliminate N-147 (as performed by both BASt and JASIC) because scaled moment is an outlier
- Survival Model with Weibull Distribution
- Compare two datasets
  - Dataset 1 : Nyquist all data, 10% compensation, uncensored
    + Kerrigan all data, uncensored
  - Dataset 2 : Nyquist all data, no compensation, right censored
    + Kerrigan all data, uncensored
- When uncompensated Nyquist data are used as right censored data, the fact that tibia fracture does not occur up to the filtered (attenuated) peak moment is taken into account in the estimation of a risk function

Effect of Censoring

	Nyquist	Compensation	Censoring	Kerrigan	Censoring	Intercept	Scale
Dataset 1	all	10% increase	exact	all	exact	5.947076	0.211052
Dataset 2	all	none	right censored	all	exact	6.046711	0.1689358

$$P = 1 - \exp(-\exp(1/Scale * \ln(Tibia\ BM) - Intercept/Scale))$$



- Choice of data censoring has a significant impact on injury risk functions
- This suggests that the validity of the assumption of 10% attenuation need to be clarified, if used

Comparison of Approaches

Items	BASt	JASIC
Data Source	Nyquist et al. (1985)	Nyquist et al. (1985) Kerrigan et al. (2003a) Kerrigan et al. (2003b) Kerrigan et al. (2004)
Gender	Male	Male and Female
Number of Data	6	19
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Standard Length	Tibia Height : 460 mm	Tibia Length : 402 mm Tibia Height : 483 mm
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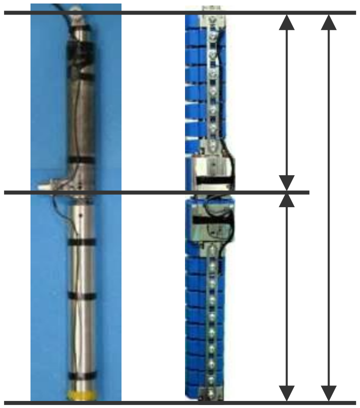
Comparison of Approaches

JASIC



Legform dimensions were determined based on UMTRI anthropometric study

(EEVC, 1994 : Cesari et al., 1994)

UMTRI Data for 50th %ile Male

TABLE 1.4

MID-SIZED MALE STANDARD ANTHROPOMETRY
(Descriptive Statistics, cm or as noted)

Measurement Variable	N	Min.	Max.	Mean	S.D.
Age (years)	25	20.0	61.0	38.1	12.2
Stature	25	171.2	178.6	175.1	2.1
Weight (kg)	25	70.0	83.6	76.7	3.5
Sitting Height (erect)	25	87.2	95.0	91.1	2.3
Buttock-Knee Length	25	55.9	62.6	59.3	2.1
Cervicale Height	25	145.6	153.8	149.8	2.2
Trochanterion Height	25	84.0	95.7	90.5	2.3
Tibiale Height	25	45.0	51.8	48.3	1.9
Head Breadth	25	14.4	16.9	15.8	0.6
Head Length	25	18.8	21.4	19.7	0.7
Head Height	25	21.8	24.9	23.1	0.8
Shoulder Breadth	25	41.3	47.6	44.9	1.7
Biacromial Breadth	25	35.7	43.2	39.5	1.9
Clavicale Length	25	16.6	19.9	18.3	0.9
Suprasternale-Cerv. Dist.	25	11.6	13.8	12.6	0.6
Bispinous Breadth	25	18.7	27.7	22.5	1.9
Acromion-Radiale Length	25	30.8	35.1	32.9	1.2
Shoulder-Elbow Length	25	32.6	38.5	36.5	1.3
Elbow-Hand Length	25	44.5	49.7	47.4	1.3
Radius Length	25	24.8	29.1	26.9	1.1
Hand Breadth	25	7.6	10.2	8.5	0.6
Hand Length	25	17.6	19.5	18.7	0.5
Troch.-to-Lat. Fem. Condyle	25	38.4	46.2	43.5	2.0
Tibia Length	25	36.2	44.3	40.2	2.2
Foot Breadth	25	8.4	10.8	9.6	0.5
Foot Length	25	24.6	27.8	26.4	0.8
Head Circumference	25	53.3	60.9	57.1	1.9
Shoulder Circumference	25	102.3	120.0	111.5	5.3
Chest Circumference (axilla)	25	91.0	104.5	97.3	3.2
Chest Circumference (nipple)	25	89.3	102.5	96.1	3.6
Waist Circumference	25	77.2	94.7	85.9	5.2
Hip Circumference	25	87.3	101.5	94.4	3.1
Upper Arm Circumference (biceps)	25	24.6	35.0	29.9	2.0
Forearm Circumference	25	21.8	28.6	25.4	1.7
Thigh Circumference (mid)	25	45.7	57.3	51.5	3.2
Calf Circumference	25	33.8	39.8	36.7	1.7
Skinfold, Subscapular (mm)	25	10.0	30.0	15.1	4.5
Skinfold, Triceps (mm)	25	4.0	25.0	10.0	6.2
Skinfold, Suprailiac (mm)	25	7.0	37.0	21.1	8.0
Skinfold, Posterior Mid-Calf (mm)	25	3.0	20.0	9.9	5.1

Mean

Trochanterion Height	25	84.0	95.7	90.5	2.3
Tibiale Height	25	45.0	51.8	48.3	1.9
Head Breadth	25	14.4	16.9	15.8	0.6

Mean

Troch.-to-Lat. Fem. Condyle	25	38.4	46.2	43.5	2.0
Tibia Length	25	36.2	44.3	40.2	2.2
Foot Breadth	25	8.4	10.8	9.6	0.5

Tibia Height : 483 mm

Tibia Length : 402 mm

Source: Development of Anthropometrically Based Design Specifications for an Advanced Adult Anthropomorphic Dummy Family, Volume 1, UMTRI Report UMTRI-83-53-1, 1983

Geometric Data Scaling

$$M_{scaled} = \lambda_L{}^3 M = (Lref/L)^3 M$$

M : Measured bending moment

M_{scaled} : Scaled bending moment

M : Length scale factor

M_{scaled} : Measured dimension (Tibia Length / Height)

λ_L : Standard dimension (Tibia Length / Height)

- Geometric data scaling
- Standard lengths taken from UMTRI used for determining impactor dimensions

Comparison of Approaches

BASt

GTR9-6-08

BASt threshold determination process

bast

Tibia Bending Moment:

- PMHS (only male) tests from Nyquist (1985):

Test	Source	Gender	Age	Stature (cm)	Body Mass (kg)	Impact Speed (m/s)	Loading Direction	Peak BM at Midspan (CFC 60) [Nm]	Peak BM at Midspan M_{Max} [Nm]	Anatomical Measurement (Heel to Tibial Plateau) L [mm]	Standardized tibia height (DIN 33402-2) L_{ref} [mm]	Scaled Fracture Moment M_{scaled} [Nm]
118	Nyquist et. al.	M	54	182	68	3,5	LM*	395	434,5	520	460	300,8
124	Nyquist et. al.	M	64	177	82	4,2	LM*	287	315,7	490	460	261,2
126	Nyquist et. al.	M	58	174	73	4,2	LM*	224	246,4	480	460	216,9
127	Nyquist et. al.	M	56	176	79	3,7	LM*	237	260,7	465	460	252,4
129	Nyquist et. al.	M	57	178	99	3,7	LM*	349	383,9	500	460	298,9
132	Nyquist et. al.	M	57	187	45	3,8	LM*	264	290,4	445	460	320,8

*: Lateral to Medial

Source: Zander O (TEG 098r1, 2010)

Calculation of scaled fracture moments: $M_{scaled}=[(L_{ref}/L)^3]*M_{max}$

L_{ref}: standardized tibia height for scaling Nyquist data = 460 cm, taken from DIN 33402-2 for 18-65 yrs old male

Oliver Zander March 19th-20th, 2013 Slide No. 5

- The scaling method used by JASIC was also used by BASt
- Standard length taken from DIN 33402-2, which allowed the use of Nyquist data only

Effect of Data Scaling

Geometric Data Scaling

$$M_{scaled} = \lambda_L{}^3 M = (Lref/L)^3 M$$

M : Measured bending moment
M_{scaled} : Scaled bending moment
M : Length scale factor
M_{scaled} : Measured dimension (Tibia Length / Height)
λ_L : Standard dimension (Tibia Length / Height)

Anthropometric Measurements

- Nyquist study : Tibia Height
- Kerrigan study : Tibia Length

Estimated dimensions

Ahthropometric Database	Tibia Height (mm)	Tibia Length (mm)	Note
UMTRI[1]	483	402	Database based on which impactor dimensions were determined
DIN[2]	460	382.9	Tibia Length estimated using the ratio from UMTRI study
CAESAR[3]	491.6	409.2	Tibia Height: average of right (491.42) and left (491.77) Tibia Length estimated using the ratio from UMTRI study
ANSUR[4]	503.9	419.4	Tibia Length estimated using the ratio from UMTRI study
Diffrient et al.[5]	500	411	

References

(1) L. W. Schneider et al., "Development of Anthropometrically Based Design Specifications for an Advanced Adult Anthropomorphic Dummy Family" (1983)
(2) DIN 33402-2 (GTR9-6-08)
(3) C. R. Harrison et al., "CAESAR: Summary Statistics for the Adult Population (Ages 18-65) of the United States of America", AFRL-HE-WP-TR-2002-0170 (2002)
(4) C. C. Gordon et al., "1998 Amthropometric Survey of U.S. Army Personnel: Methods and Summary Statistics" (1989)
(5) N. Diffrient et al., "Humanscale", The MIT Press (1993)

Effect of Data Scaling

Test	Source	Age	Gender	Stature (mm)	Weight (kg)	Anatomical Measurement (mm)	Anatomical Measurement Description	Unscaled Fracture Moment (Nm)	UMTRI Scaled Moment (Nm)	DIN Scaled Moment (Nm)	CAESAR Scaled Moment (Nm)	ANSUR Scaled Moment (Nm)	Diffrient Scaled Moment (Nm)	M50 Scaled Moment (Nm)
N-126	Nyquist 1985	58	M	1740	73	480	Tibia Height	224	228.2	197.2	240.6	259.2	253.2	228.3
N-129	Nyquist 1985	57	M	1780	99	500	Tibia Height	349	314.6	271.8	331.7	357.2	349.0	332.2
N-127	Nyquist 1985	56	M	1760	79	465	Tibia Height	237	265.6	229.4	280.0	301.6	294.6	233.4
N-124	Nyquist 1985	64	M	1770	82	490	Tibia Height	287	274.9	237.4	289.8	312.1	304.9	277.9
N-118	Nyquist 1985	54	M	1820	68	520	Tibia Height	395	316.5	273.4	333.7	359.4	351.2	351.8
N-132	Nyquist 1985	57	M	1870	45	445	Tibia Height	264	337.6	291.6	355.9	383.3	374.5	216.7
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N-152	Nyquist 1985	51	F	1630	68	430	Tibia Height	274	388.3	335.4	409.4	440.9	430.8	339.7
K(a)-134L	Kerrigan SAE 2003	44	M	1702	73	420	Tibia Length	416	364.8	315.1	384.6	414.2	389.8	453.0
K(b)-D1	Kerrigan NCCM 2003	54	M	1905	88	445	Tibia Length	463	341.3	294.9	359.9	387.6	364.8	359.5
K(b)-D2	Kerrigan NCCM 2003	54	M	1905	88	450	Tibia Length	485	345.8	298.7	364.6	392.6	369.5	376.6
K(b)-D3	Kerrigan NCCM 2003	68	M	1651	51	385	Tibia Length	290	330.1	285.2	348.1	374.9	352.8	346.0
K(b)-D4	Kerrigan NCCM 2003	68	M	1651	51	385	Tibia Length	309	351.8	303.9	370.9	399.4	375.9	368.6
K(b)-D5	Kerrigan NCCM 2003	65	F	1727	60	378	Tibia Length	416	500.4	432.2	527.6	568.2	534.7	433.6
K(b)-D6	Kerrigan NCCM 2003	75	M	1778	65	395	Tibia Length	306	322.6	278.6	340.1	366.3	344.7	292.3
9.1	Kerrigan 2004	66	M	1829	79.8	397	Tibia Length	277	287.6	248.4	303.2	326.6	307.4	243.1
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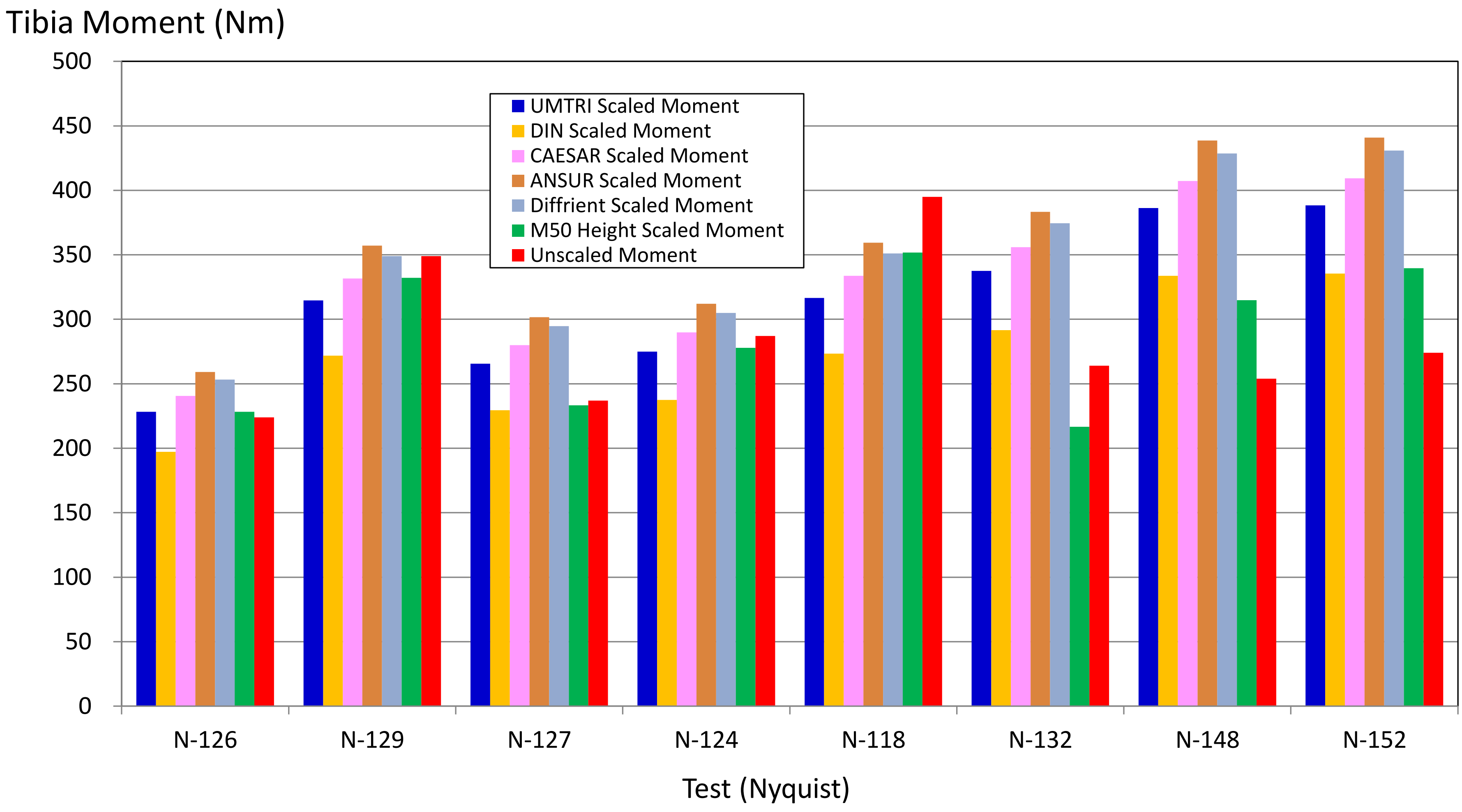
9.3	Kerrigan 2004	62	M	1829	60.8	416	Tibia Length	259	233.7	201.9	246.4	265.4	249.8	227.3
9.4	Kerrigan 2004	54	M	1880	117.9	479	Tibia Length	482	284.9	246.1	300.4	323.5	304.5	389.4

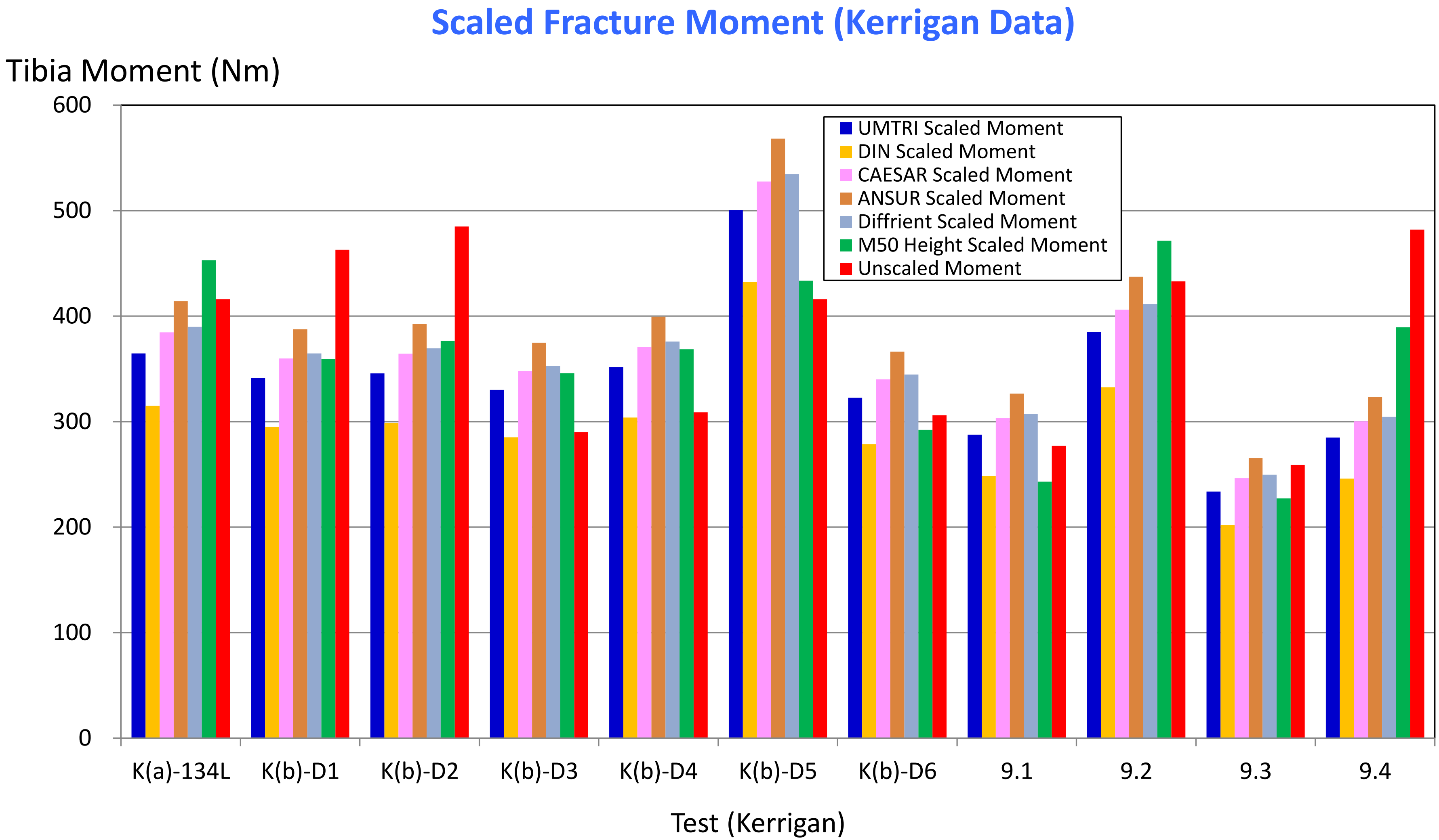
M50 Scaled Moment : Fracture moment scaled to American Male 50th %ile height taken from UMTRI (175.1 cm)

Effect of Data Scaling

Scaled Fracture Moment (Nyquist Data)



Effect of Data Scaling



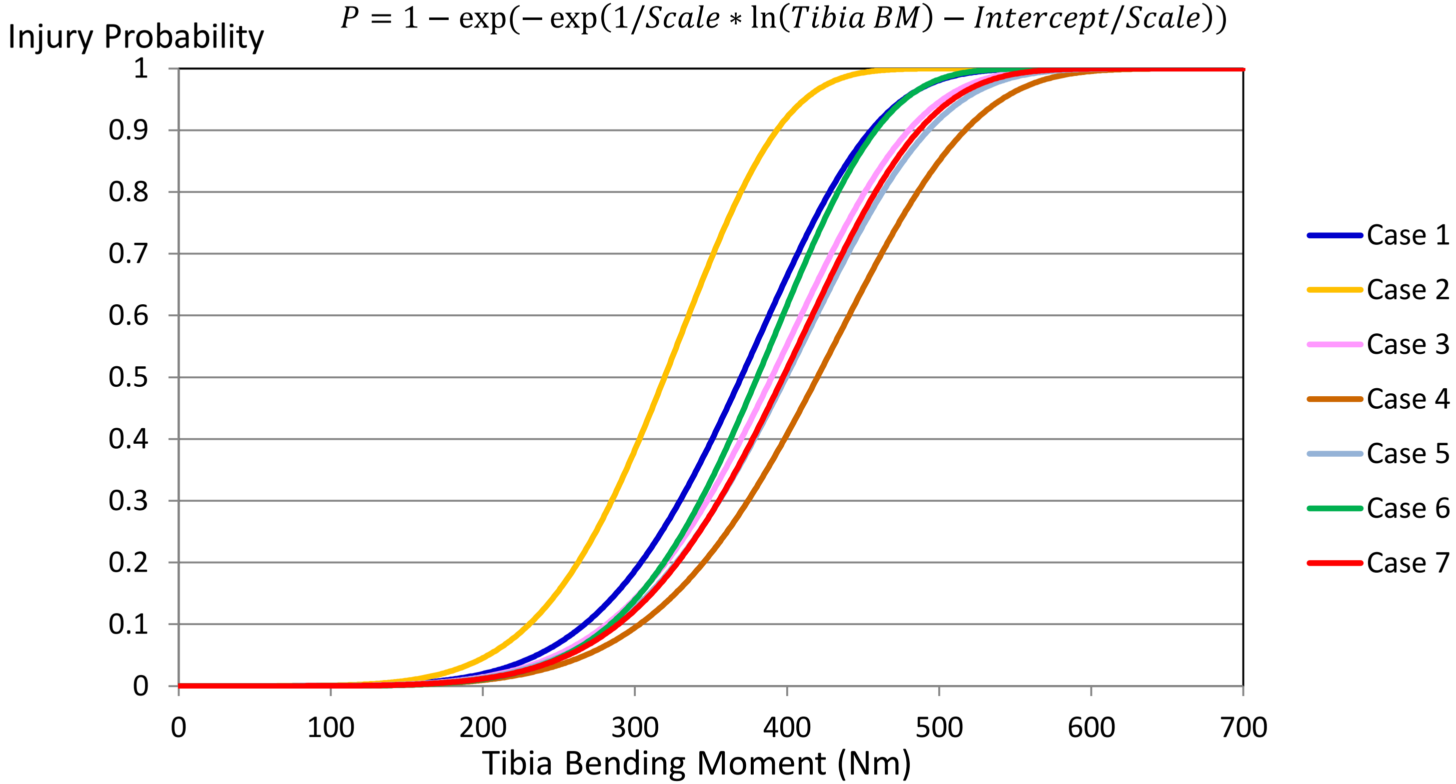
Effect of Data Scaling

- All data from Nyquist and Kerrigan used
- Eliminate N-147 (as performed by both BASt and JASIC)
- Survival Model with Weibull Distribution
- Nyquist uncompensated data incorporated as right censored data – no 10% compensation
- Compare seven cases with different data scaling
  - Case 1 : Scaled using standard lengths from UMTRI
  - Case 2 : Scaled using standard Tibia Height from DIN (Tibia Length estimated using the ratio from UMTRI)
  - Case 3 : Scaled using standard Tibia Height from CAESAR (Tibia Length estimated using the ratio from UMTRI)
  - Case 4 : Scaled using standard Tibia Height from ANSUR (Tibia Length estimated using the ratio from UMTRI)
  - Case 5 : Scaled using standard lengths from Diffrient et al.
  - Case 6 : Scaled using 50th %ile male height from UMTRI (175.1 cm)
  - Case 7 : Unscaled

Effect of Data Scaling

	Nyquist	Compensation	Censoring	Kerrigan	Censoring	Scaling	Intercept	Scale
Case 1	all	none	right censored	all	exact	UMTRI	5.976499	0.1731729
Case 2	all	none	right censored	all	exact	DIN	5.830053	0.1731261
Case 3	all	none	right censored	all	exact	CAESAR	6.029413	0.1731751
Case 4	all	none	right censored	all	exact	ANSUR	6.103549	0.1731674
Case 5	all	none	right censored	all	exact	Diffrient	6.053993	0.1753228
Case 6	all	none	right censored	all	exact	Height	5.998048	0.1551238
Case 7	all	none	right censored	all	exact	Unscaled	6.046711	0.1689358

$$P = 1 - \exp(-\exp(1/Scale * \ln(Tibia\ BM) - Intercept/Scale))$$



- Data scaling has a significant impact on the risk functions
- DIN and ANSUR scaled moments provide worst and best case scenarios
- Risk function from UMTRI scaled moment used by JASIC is in the middle

Comparison of Approaches

Items	BASt	JASIC
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Transfer Function	JASIC function	FlexPLI-Human model correlation function

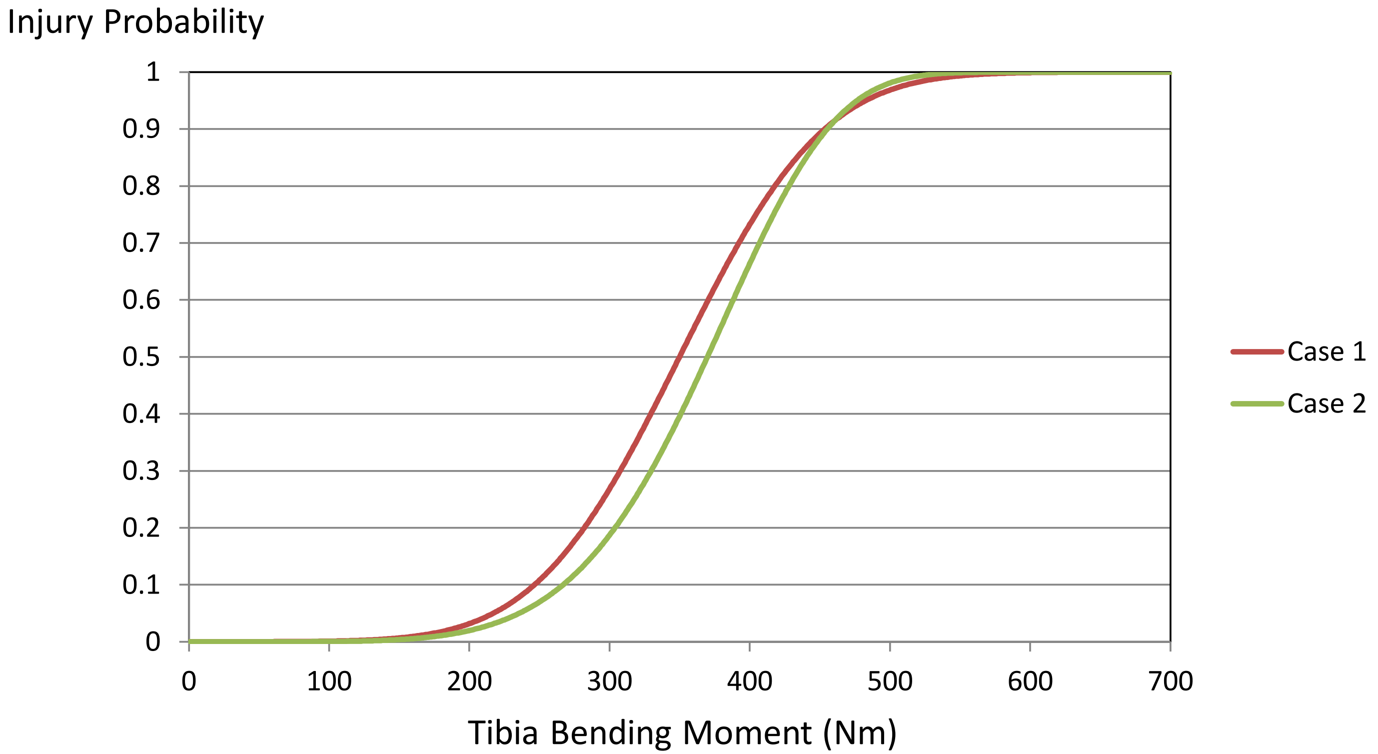
Effect of Statistical Method

- All data from Nyquist and Kerrigan used without scaling
- Eliminate N-147 (as performed by both BASt and JASIC) because scaled moment is an outlier
- 10% compensation was applied to Nyquist data because Normal Distribution method accepts uncensored data only
- Compare two cases with different statistical method
  - Case 1 : Normal distribution
  - Case 2 : Survival Model with Weibull distribution

Effect of Statistical Method

	Nyquist	Compensation	Censoring	Kerrigan	Censoring	Scaling	Statistical Method	Intercept	Scale
Case 1	all	10% increase	exact	all	exact	Unscaled	Normal Distribution	-	-
Case 2	all	10% increase	exact	all	exact	Unscaled	Weibull Survival	5.976499	0.1731729

$$P = 1 - \exp(-\exp(1/Scale * \ln(Tibia\ BM) - Intercept/Scale))$$



- Not very significant effect on risk functions
- Normal distribution method provided slightly more stringent function

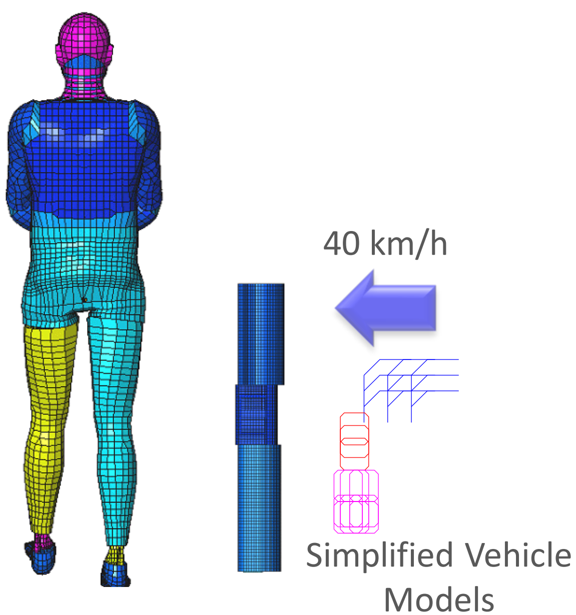
Comparison of Approaches

Items	BASt	JASIC
Data Source	Nyquist et al. (1985)	Nyquist et al. (1985) Kerrigan et al. (2003a) Kerrigan et al. (2003b) Kerrigan et al. (2004)
Gender	Male	Male and Female
Number of Data	6	19
Treatment of Filtered Data	10% attenuation assumed	Right censored data
Data Scaling	Geometric	Geometric
Standard Length	Tibia Height : 460 mm	Tibia Length : 402 mm Tibia Height : 483 mm
Statistical Method	Normal Distribution	Survival Model with Weibull Distribution
Transfer Function	JASIC function	FlexPLI-Human model correlation function

Transfer Function

JAMA-JARI Correlation Analysis (TEG-096 (2009))

Impact Simulations

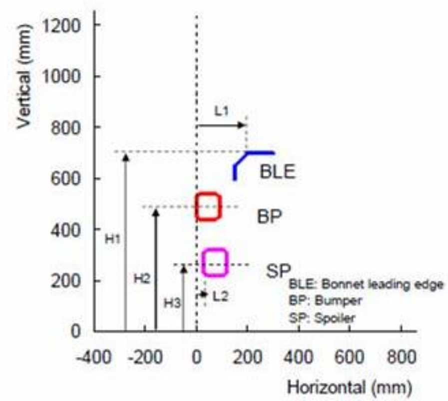


Simplified Vehicle Model Parameters

Simplified Car Model Parameters

Parameter	Unit	Level 1	Level 2	Level 3
K1 (BLE stiffness*)	mm	0.4	0.6	
K2 (BP stiffness**)	JC***	0.7	0.8	1.0
K3 (SP stiffness**)	JC***	0.6	0.8	1.0
H1 (BLE height)	mm	650	700	750
H2 (BP height)	mm	450	490	530
H3 (SP height)	mm	250	270	350
L1 (BLE lead)	mm	125	200	275
L2 (SP lead)	mm	-20	0	30

* Stiffness is changed by steel plate thickness.
** Stiffness is changed by joint characteristics.
*** JC: Joint characteristics
\# BLE: Bonnet leading edge, BP: Bumper, SP: Spoiler



Combinations of Parameters (18 Cases)

Simplified Car model specifications

Simplified Car Model ID	K1 (BLE stiffness*) mm	K2 (BP stiffness**) JC***	K3 (SP stiffness**) JC***	H1 (BLE height) mm	H2 (BP height) mm	H3 (SP height) mm	L1 (BLE lead) mm	L2 (SP lead) mm
S1	0.4	0.7	0.6	650	450	250	125	-20
S2	0.4	0.7	0.8	700	490	270	200	0
S3	0.4	0.7	1.0	750	530	350	275	30
S4	0.4	0.8	0.6	650	490	270	275	30
S5	0.4	0.8	0.8	700	530	350	125	-20
S6	0.4	0.8	1.0	750	450	250	200	0
S7	0.4	1.0	0.6	700	450	350	200	30
S8	0.4	1.0	0.8	750	490	250	275	-20
S9	0.4	1.0	1.0	650	530	270	125	0
S10	0.6	0.7	0.6	750	530	270	200	-20
S11	0.6	0.7	0.8	650	450	350	275	0
S12	0.6	0.7	1.0	700	490	250	125	30
S13	0.6	0.8	0.6	700	530	250	275	0
S14	0.6	0.8	0.8	750	450	270	125	30
S15	0.6	0.8	1.0	650	490	350	200	-20
S16	0.6	1.0	0.6	750	490	350	125	0
S17	0.6	1.0	0.8	650	530	250	200	30
S18	0.6	1.0	1.0	700	450	270	275	-20

* Stiffness is changed by steel plate thickness.
** Stiffness is changed by joint characteristics.
*** JC: Joint characteristics
\# BLE: Bonnet leading edge, BP: Bumper, SP: Spoiler

Based on L18 orthogonal table

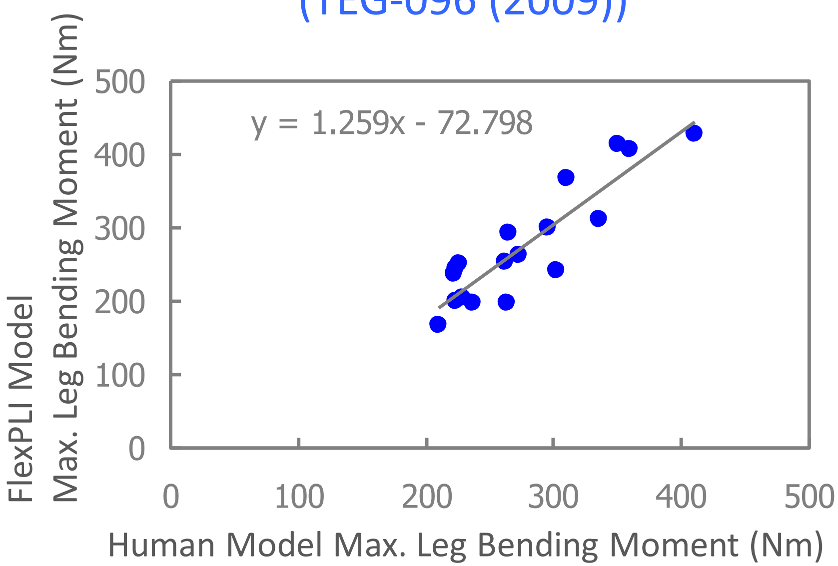
Convert human injury probability functions to FlexPLI functions using the results of the correlation analysis

Transfer Function

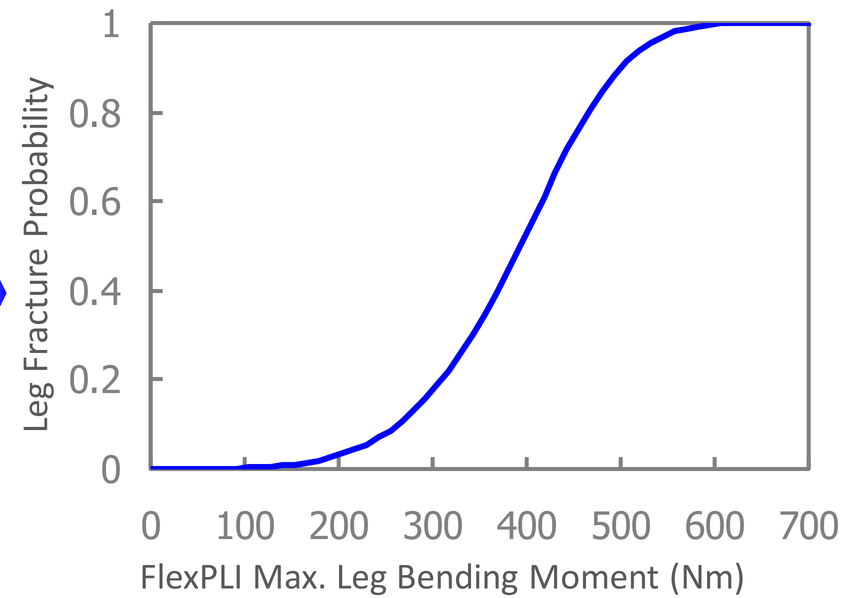
JASIC

Results of Correlation Analysis

(TEG-096 (2009))



Injury Probability Function



$$M_{FlexPLI} = 1.259 \cdot M_{Human} - 72.798$$

M_{Human}: Human model max leg bending moment Nm)

$M_{Flex-GTR}$: FlexPLI model max leg bending moment Nm)

Linear correlation function was used to convert human risk function to that of the FlexPLI

Transfer Function

BASt

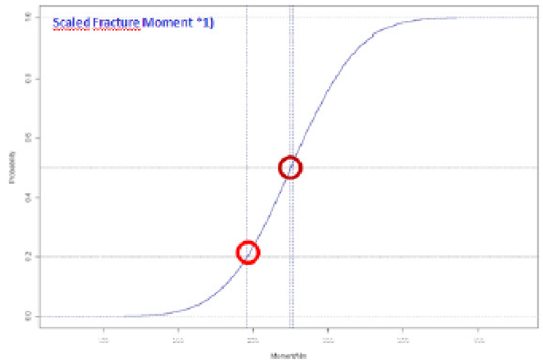
GTR9-6-08

BASt threshold determination process

bast

Tibia Bending Moment:

- Development of injury risk function using Gaussian distribution
- Proposed bending moment threshold for 50% risk of human tibia bone fracture: 275,2 Nm (20% injury risk: 245,6 Nm)
- Assumptions (TEG-048):
  $BM_{human\ tibia} = BM_{human\ tibia\ model}$
  $BM_{Flex\text{-}GTR\ model} = BM_{Flex\text{-}GTR}$
- Calculation of $BM_{Flex\text{-}GTR}$ according to formula:
  $BM_{Flex\text{-}GTR}$ = 1,259 * 275,2 Nm - 72,798 = 273,7 Nm
- Calculation of mean value of nine inverse tests (SN01, SN02, SN03) with reproducible test results acc. to ISO/TC22/SC12/WG5Doc N751 (CV's < 5%) and consideration of reproducibility corridor [0,9*MV*1,1]: 246,3 Nm < MV < 301,1 Nm



*1): according to formula M[illegible]=[(L[illegible]/L)³]*M[illegible] under consideration of DIN standardized tibia heights

Source: Pastor C. (2009)

- Proposal for Tibia BM („lower performance limit“): 302 Nm

Oliver Zander | March 19th-20th, 2013 | Slide No. 6

- BASt used the transfer function developed by JASIC
- Both approaches used the same transfer function

Summary

- Choice of dataset, handling of filtered data and data scaling were found to be significant contributors to injury risk functions
- Effect of the choice of statistical method was found to be less significant
  - ✓ Note: Use of normal distribution accepts uncensored (exact) data only
- With regard to data scaling, fracture moments scaled using DIN and ANSUR standard length were found to provide "worst" and "best" case scenarios
- Fracture moment scaled using UMTRI standard lengths (JASIC approach) provided a risk function in the middle of the "worst" and "best" case functions