Humanetics Innovative Solutions, Inc.

Flex PLI Weight Tolerance Review

IG GTR9-PH2 9th Meeting

16-17 December 2013

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Introduction

►In the 8th Informal Group meeting it was requested that Humanetics review the ±5.3% total weight tolerance currently in the regulation as it was considered high compared to EEVC leg ±1.5% and could have a bearing on the impact force.

►Documents TEG121 and TEG122 defined mass tolerances based on optional DAS and 24 measurement channels. >5% mass tolerance was applied.

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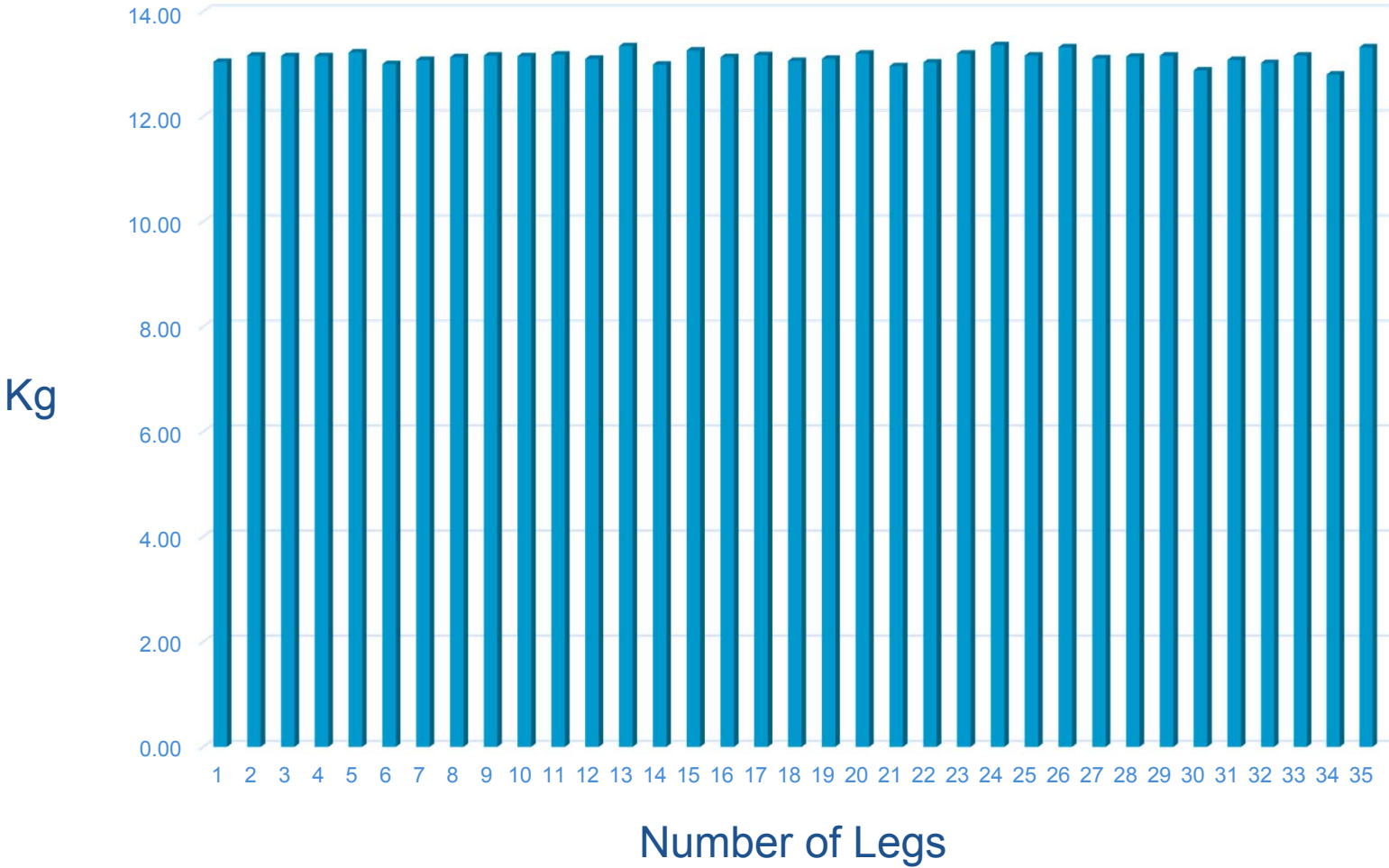Innovative Solutions

Production Weights 35 Legs

Max values
highlighted
red
Min green

Femur assy (Kg)	Tibia Assy (Kg)	Knee Assy (Kg)	Leg assy (Kg)	Flesh (Kg)	Total (Kg)	Channel Count
2.44	2.64	4.30	9.38	3.66	13.04	18 CH DAS
2.44	2.65	4.34	9.43	3.73	13.16	24 CH DAS
2.40	2.61	4.24	9.25	3.90	13.15	12 CH DAS
2.41	2.61	4.24	9.26	3.89	13.15	12 CH DAS
2.39	2.61	4.31	9.31	3.91	13.22	18 CH DAS
2.39	2.62	4.13	9.14	3.86	13.00	12 CH DAS
2.40	2.64	4.20	9.24	3.84	13.08	12 CH DAS
2.41	2.62	4.24	9.27	3.86	13.13	12 CH DAS
2.41	2.65	4.15	9.21	3.95	13.16	12 CH DAS
2.40	2.63	4.40	9.43	3.72	13.15	12 CH DAS
2.41	2.64	4.27	9.32	3.86	13.18	12 CH DAS
2.41	2.66	4.17	9.24	3.86	13.10	12 CH DAS
2.39	2.62	4.49	9.50	3.84	13.34	12 CH DAS
2.39	2.62	4.15	9.16	3.83	12.99	12 CH DAS
2.41	2.66	4.29	9.36	3.90	13.26	12 CH DAS
2.40	2.63	4.29	9.32	3.81	13.13	12 CH DAS
2.40	2.62	4.30	9.32	3.85	13.17	15 CH DAS
2.40	2.65	4.32	9.37	3.69	13.06	12 CH DAS
2.40	2.69	4.30	9.39	3.71	13.10	12 CH DAS
2.44	2.73	4.33	9.50	3.70	13.20	18 CH DAS
2.39	2.61	4.19	9.19	3.77	12.96	12 CH DAS
2.38	2.61	4.24	9.23	3.80	13.03	12 CH DAS
2.43	2.64	4.43	9.50	3.70	13.20	12 CH DAS
2.47	2.69	4.41	9.57	3.79	13.36	21 CH DAS
2.49	2.66	4.31	9.46	3.70	13.16	18 CH DAS
2.43	2.67	4.41	9.51	3.81	13.32	21 CH DAS
2.43	2.61	4.25	9.29	3.82	13.11	12 CH DAS
2.42	2.62	4.26	9.30	3.85	13.14	12 CH DAS
2.43	2.61	4.26	9.30	3.86	13.16	12 CH DAS
2.42	2.62	4.23	9.27	3.61	12.88	12 CH DAS
2.42	2.62	4.29	9.33	3.75	13.08	18 CH DAS
2.45	2.65	4.31	9.41	3.61	13.02	24 CH DAS
2.44	2.65	4.34	9.43	3.73	13.16	24 CH DAS
2.44	2.64	4.12	9.20	3.60	12.80	Off Board
2.50	2.72	4.37	9.59	3.73	13.32	24 CH DAS

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Total Assembly Weight

Leg Total Assembly Weight

Analysis Current and Potential Tolerance

Kg		Femur Assy	Tibia Assy	Knee Assy	Leg Assy	Flesh	Total
Current Specification		2.46	2.64	4.28	9.38	3.82	13.2
Current Range		0.24	0.26	0.42	0.94	0.42	1.4
		Analysis Production Data					
Average (Kg)		2.42	2.64	4.28	9.34	3.79	13.13
Standard Deviation		0.028	0.031	0.087	0.117	0.092	0.120
Coefficient of Variation %		1.20%	1.16%	2.03%	1.25%	2.44%	0.92%
Max		2.50	2.73	4.49	9.59	3.95	13.36
Min		2.38	2.61	4.12	9.14	3.60	12.80
Variation Range in data set		0.12	0.12	0.37	0.45	0.35	0.56
		Preliminary Proposal Av ± 3x SD					
Average + 3x SD		2.50	2.73	4.54	9.69	4.06	13.49
Average - 3x SD		2.34	2.55	4.02	8.99	3.51	12.77
Range		0.17	0.18	0.52	0.70	0.55	0.72
Difference to current range		-0.07	-0.08	0.10	-0.24	0.13	-0.68

High total range in TEG 122e was based on adding up all component tolerances. Statistically simultaneous occurrence is very unlikely, hence much lower total variation in practise. Significant reduction of mass tolerance seems feasible.
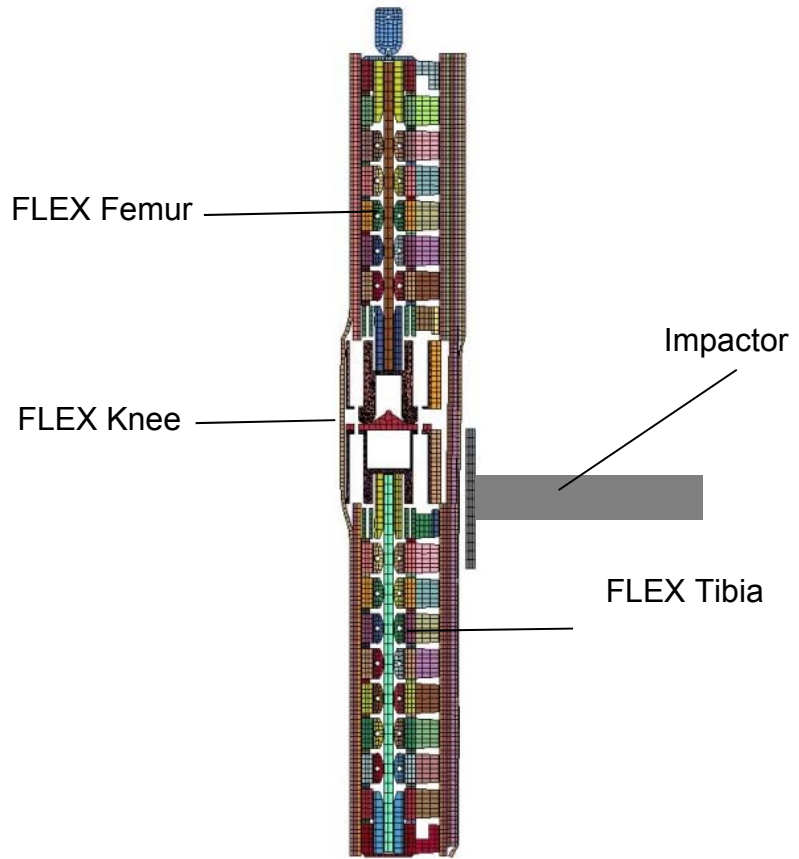
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Weight Tolerance Summary

► The analysis is based on a limited number of production examples that does not include the full DAS and optional sensor variation possible on the leg.

► Therefore Humanetics would like some time to further assess weight variation before proposing a revised tolerance for the regulation.

► This analysis shows the potential to reduce the over all weight tolerance by 48% based on 3x the Standard deviation from the average.
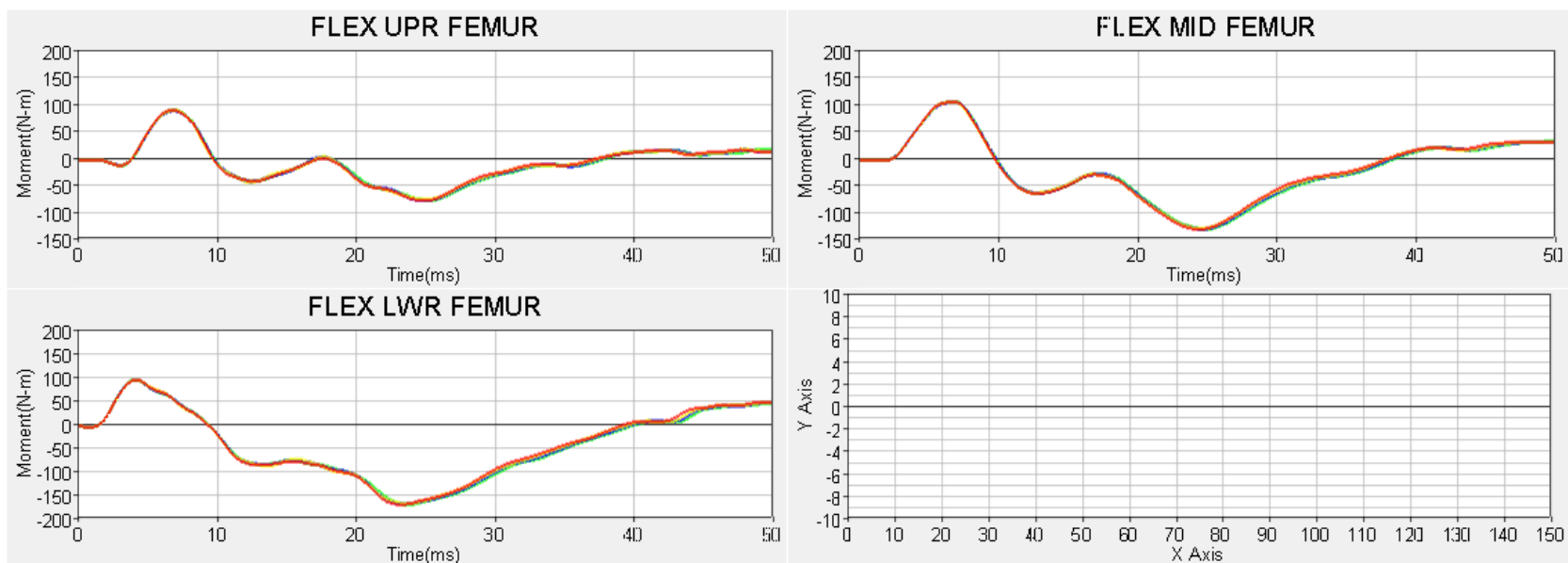
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Simulation Review on Weight Variance

► The actual weight variation was shown to be around ±2.1% in slide 3

► A simulation study was done to look at the affect of +1%, 3% and 5% in weight in an inverse setup with a rigid impactor at 8 m/s.

► Setup was validated in a European model consortium

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Inverse Rigid Impactor

FLEX Femur

FLEX Knee

Impactor

FLEX Tibia

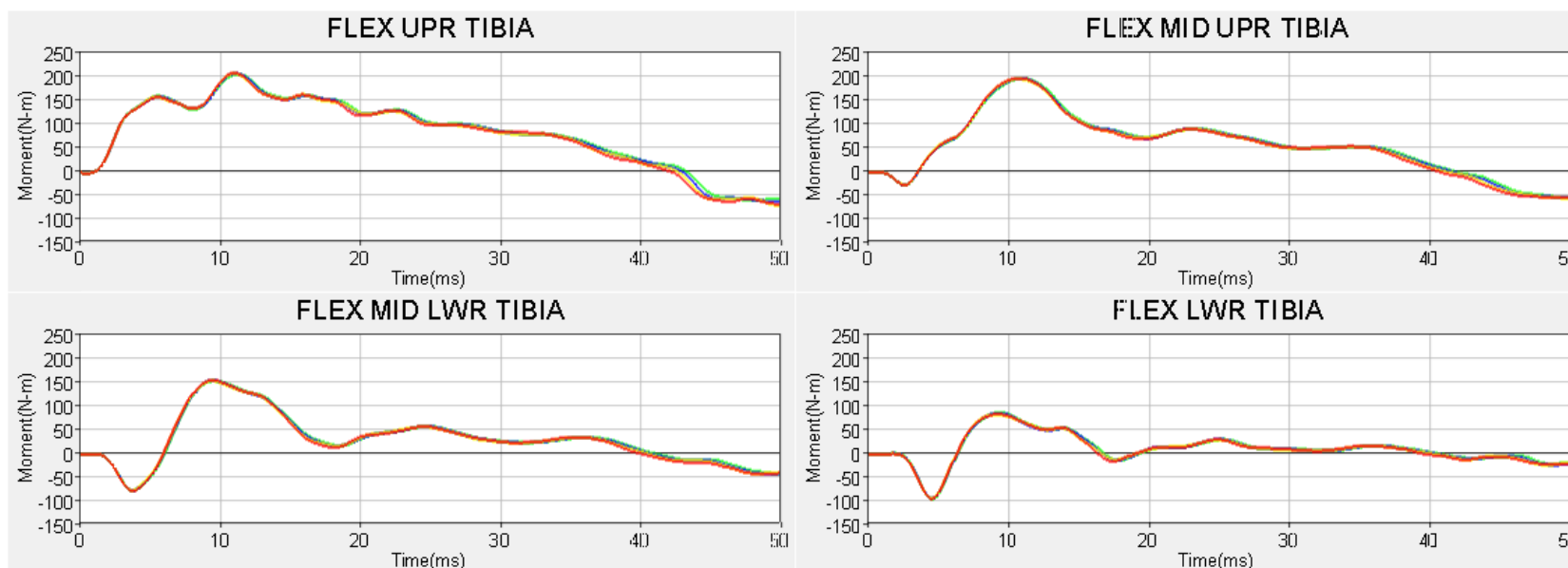# Femur Results Weight Variance

Base model
Total mass increased 1%
Total mass increased 3%
Total mass increased 5%

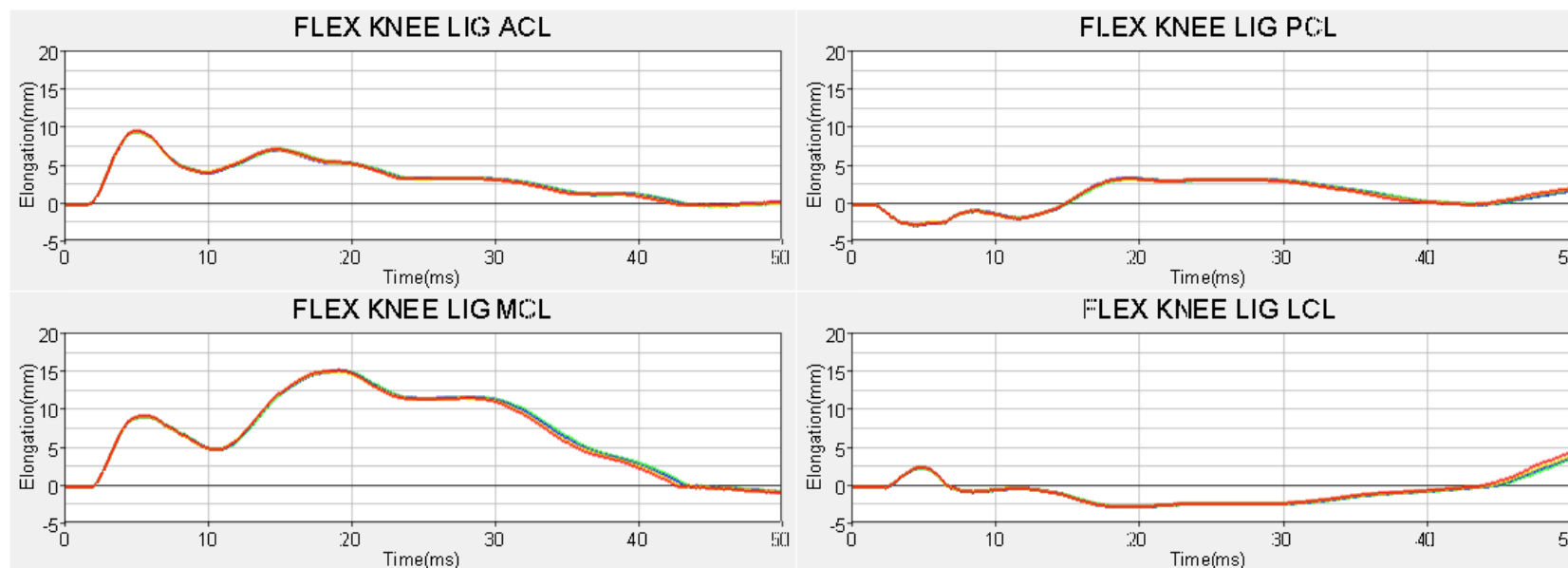* The Mass scaled up for whole flex-pli model and kept the same COG.

Tibia Results Weight Variance

Base model
Total mass increased 1%
Total mass increased 3%
Total mass increased 5%

* The Mass scaled up for whole flex-pli model and kept the same COG.

Ligament Results Weight Variance

Base model
Total mass increased 1%
Total mass increased 3%
Total mass increased 5%

* The Mass scaled up for whole flex-pli model
  and kept the same COG.

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Simulation Summary

▶ The studies showed that in the mass scaling range of +5%, the model performance almost remained the same for both Moments and Knee elongation outputs in an inverse type test (rigid impact method)

▶ The study does not account for varying component assembly weights

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Thank You