

# Ski Bindings and Mitigation of ACL Rupture.

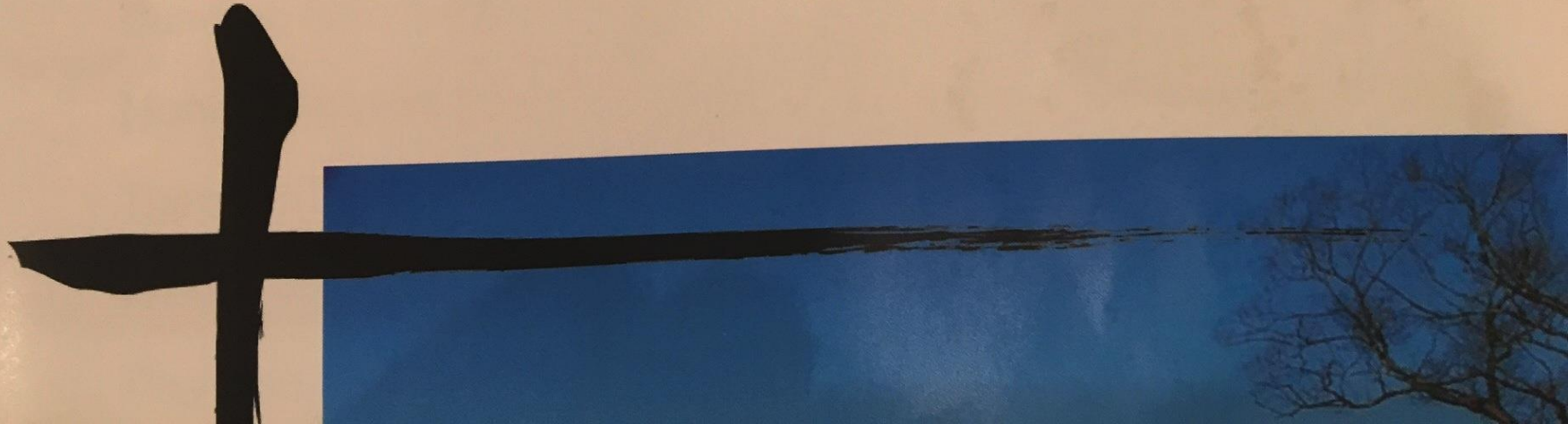
*Rick Howell*  
*Stowe, Vermont USA*



International Society for Snowsports Medicine

**35<sup>th</sup> SITEMSH congress**

Inawashiro, Fukushima, JAPAN, March 13<sup>th</sup> – 17<sup>th</sup> 2016



# Objectives

#1 Determine limits of valgus-related skiing-ACL-rupture.

Slip-Catch

Dynamic Snowplow

Phantom Foot

NOT BIAD

#2 Measure interaction of ski-bindings with ACL-rupture.

2-mode ski-binding

3-mode ski-binding (with additional lateral heel release)



**Tibia Torque**  
**+**  
**Valgus Moment**

**= ACL strain**

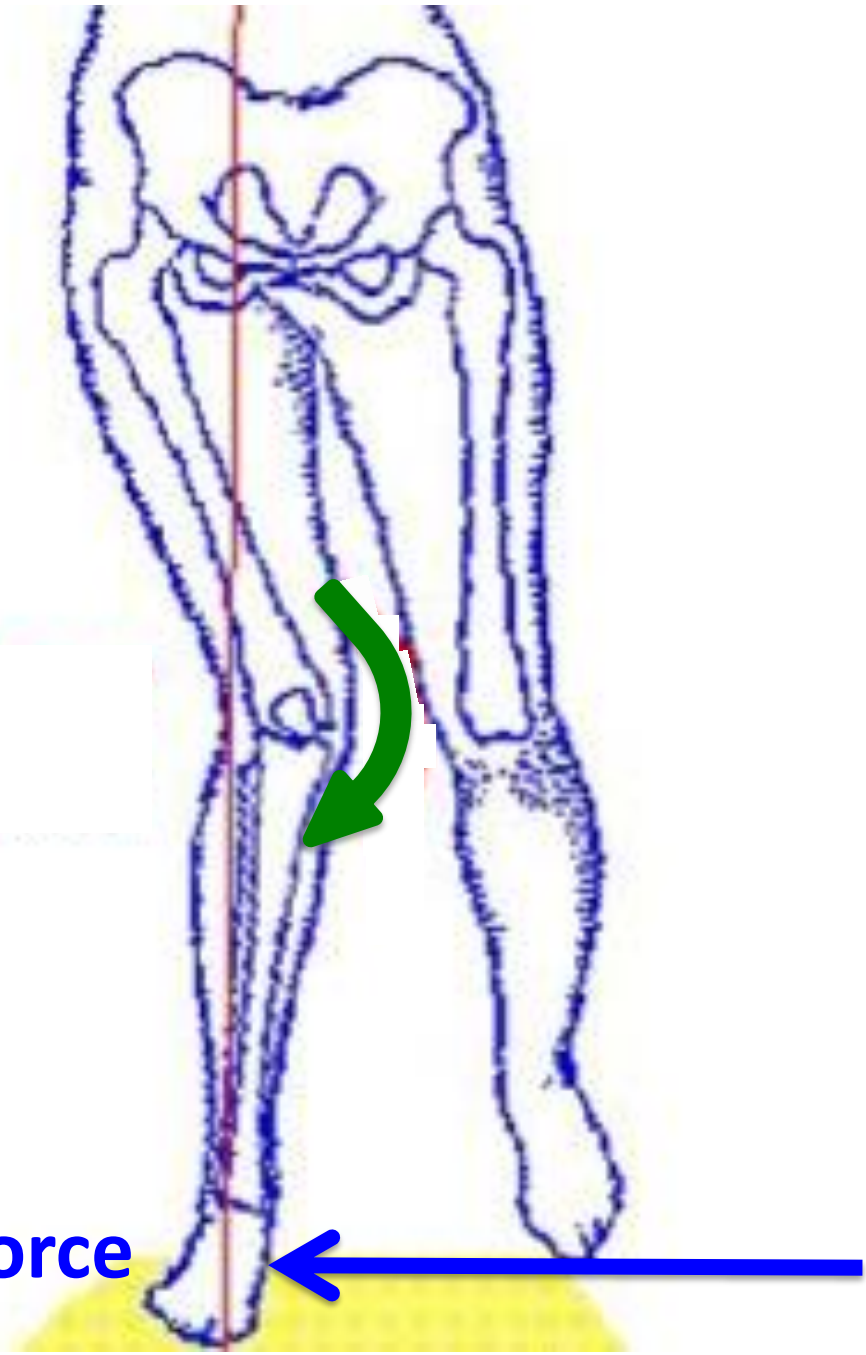


**Tibia Torque**  
**+**  
**Valgus Moment**  
**=**  
**ACL strain**

Shin, C., Chaudhari, A., Andriacchi, T., 2011,  
Valgus plus internal rotation moments increase  
ACL strain more than either alone.  
*Med. Sci. Sports Exerc.*, Vol. 43, No. 8, pp 1484–1491

**Valgus =**

**Abduction Force**



# “Valgus Dominant”

## Skiing ACL Rupture

Ekeland et al. (1987), Norway  
Feagin et al. (1987), USA  
Fischer et al. (1994), Switzerland  
Friden et al. (1995), Sweden  
Freudiger (2003), Switzerland  
Geyer et al. (1991), Germany  
Jarvinene et al. (1994), Finland  
Kennedy et al. (1974), Canada  
Krosshaug et al. (2007b), Norway  
Marshall et al. (1975), USA  
McConkey (1986), Canada  
Ruedl et al. (2009), Austria  
Ruedl et al. (2011), Austria  
Sanchis-Alfonso et al. (2000), Spain

Tecklenburg et al. (2007), Austria  
Urabe et al. (2002), Japan  
Paletta et al. (1992), USA  
Speer et al. (1995), USA  
Aune et al. (1995), Norway  
Aune et al. (1997), Norway  
Bally (1989), Switzerland  
Barone et al. (1999), Germany  
Gerritsen et al. (1996), Austria  
Hame et al. (2002), USA  
Koyanagi et al. (2006), Japan  
Senner et al. (2014), Germany  
St-Onge et al. (2004), Canada  
Yeow et al. (2010), Austria

State-of-the-Art



**Valgus Dominant  
~ 80%**

**100% Conjecture**

VALGUS  
Component  
(Phantom  
Foot, Slip-  
Catch,  
Freudiger's  
Myriad)  
80%

UVM Prof. Robert J. Johnson, MD

Peak  
Valgus

[daNm]

60

40

20

10

2.25 2.38 2.5 2.63 2.75 3.0

Peak Tibia Torque [daNm]

ACL-rupture

0.15 mm/mm<sup>13</sup>

Momersteeg, T., Blankevoort, L., Huiskes, R., 1995, Effect of Variable Relative Insertion Orientation of Human Knee Bone-Ligament-Bone Complexes on Tensile Stiffness. *Journal of Biomechanics*, Vol. 28, pp 745–752.

Shin, C., Chaudhari, A., Andriacchi, T., 2011, Valgus plus internal rotation moments increase ACL strain more than either alone. *Med. Sci. Sports Exerc.*, Vol. 43, No. 8, pp 1484–1491

# Hypothesis

Upon utilization of reorganized  
**tibia-fracture** data  
and  
**ACL-rupture** data ...

... ski-bindings with 3<sup>rd</sup>-mode of lateral heel release  
might reduce **ACL-injury**.

*This is a biomechanical study.*

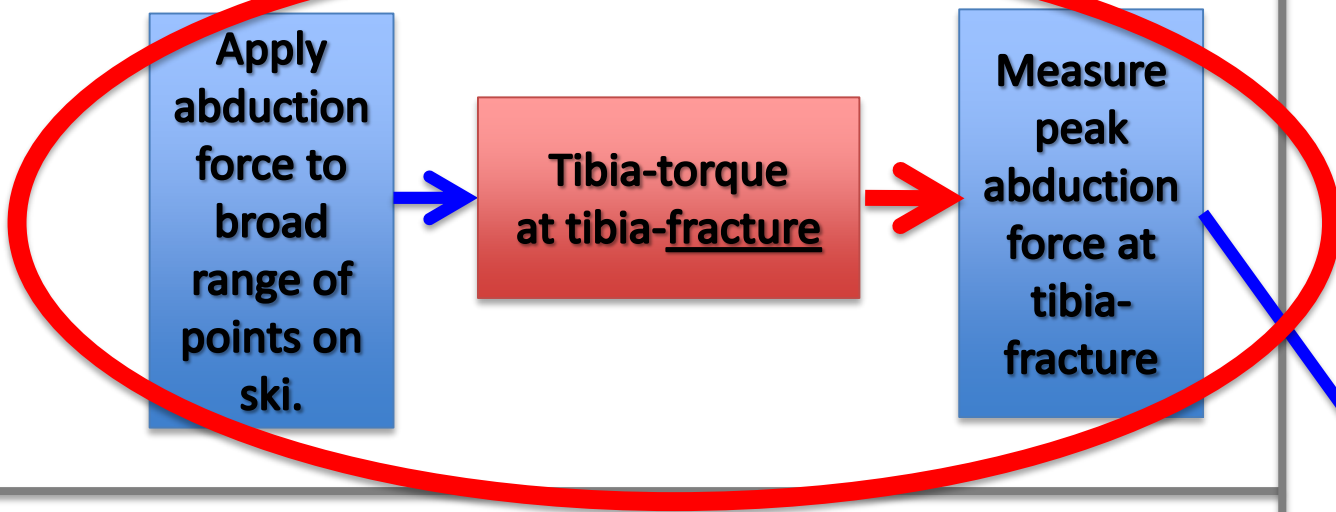
## 2 Goals

Convert 'valgus-moments + tibia-torques' at  
ACL rupture to applied-abduction-forces as a  
function of position of applied-forces into ski.

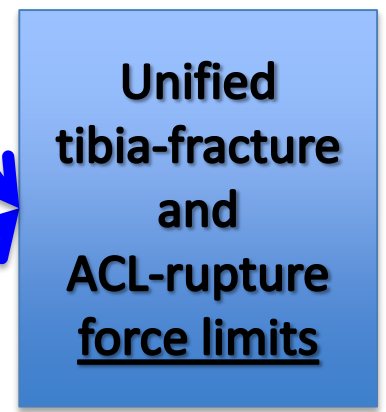
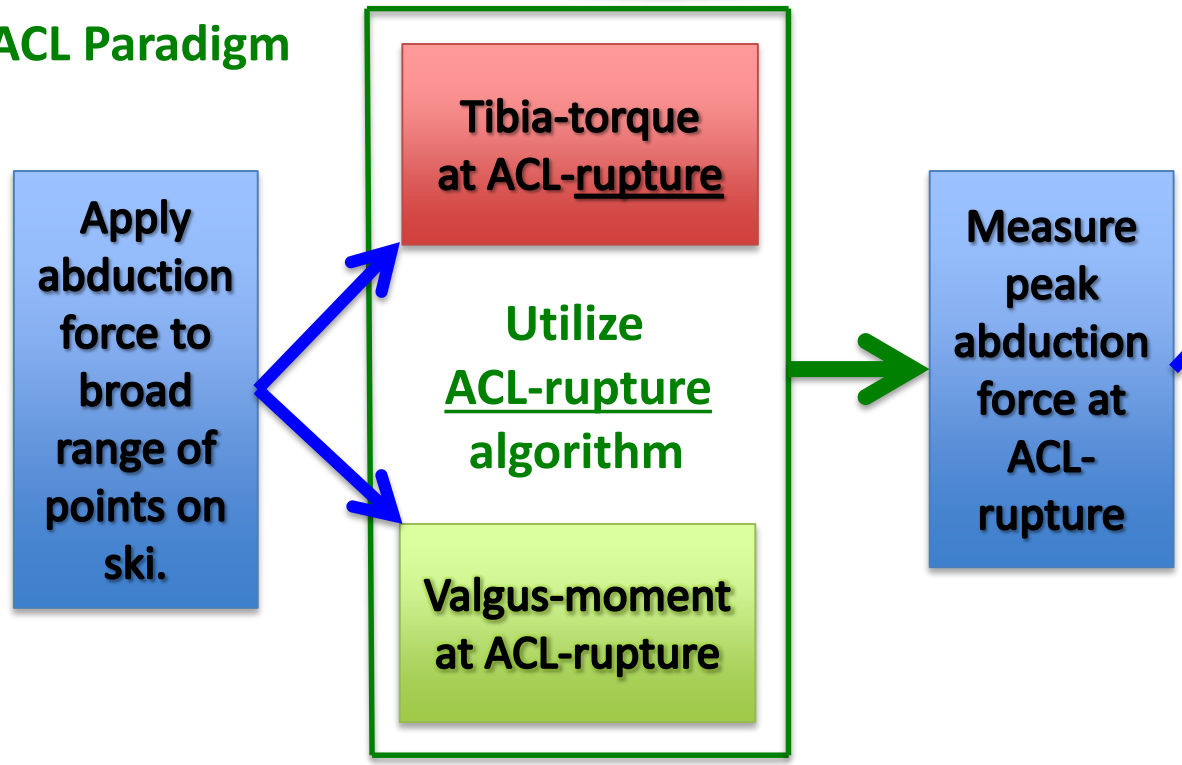
Measure interaction between tibia -torque,  
ACL-rupture, and 2-categories of ski-bindings:  
2-mode bindings  
3-mode bindings

# Method Part-1

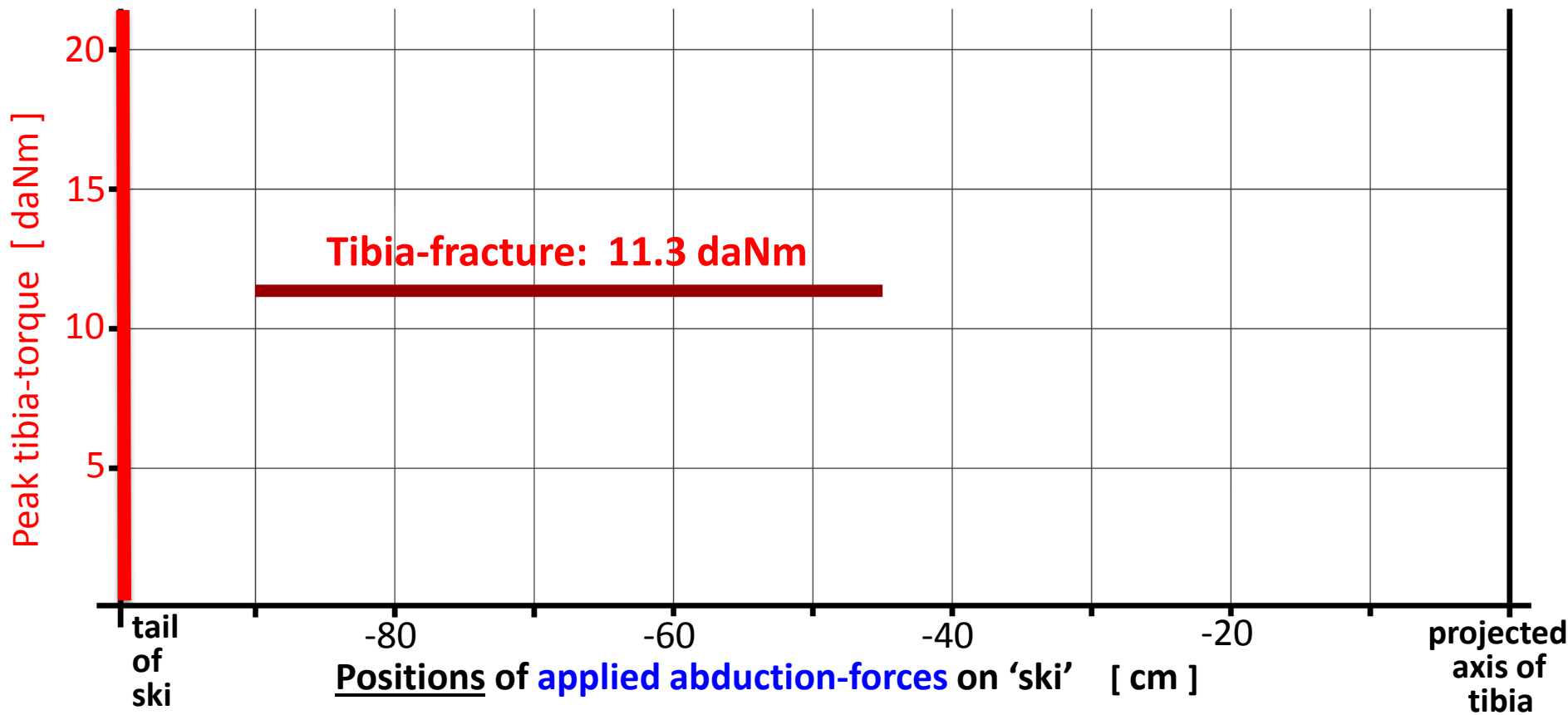
## Tibia Paradigm



## ACL Paradigm

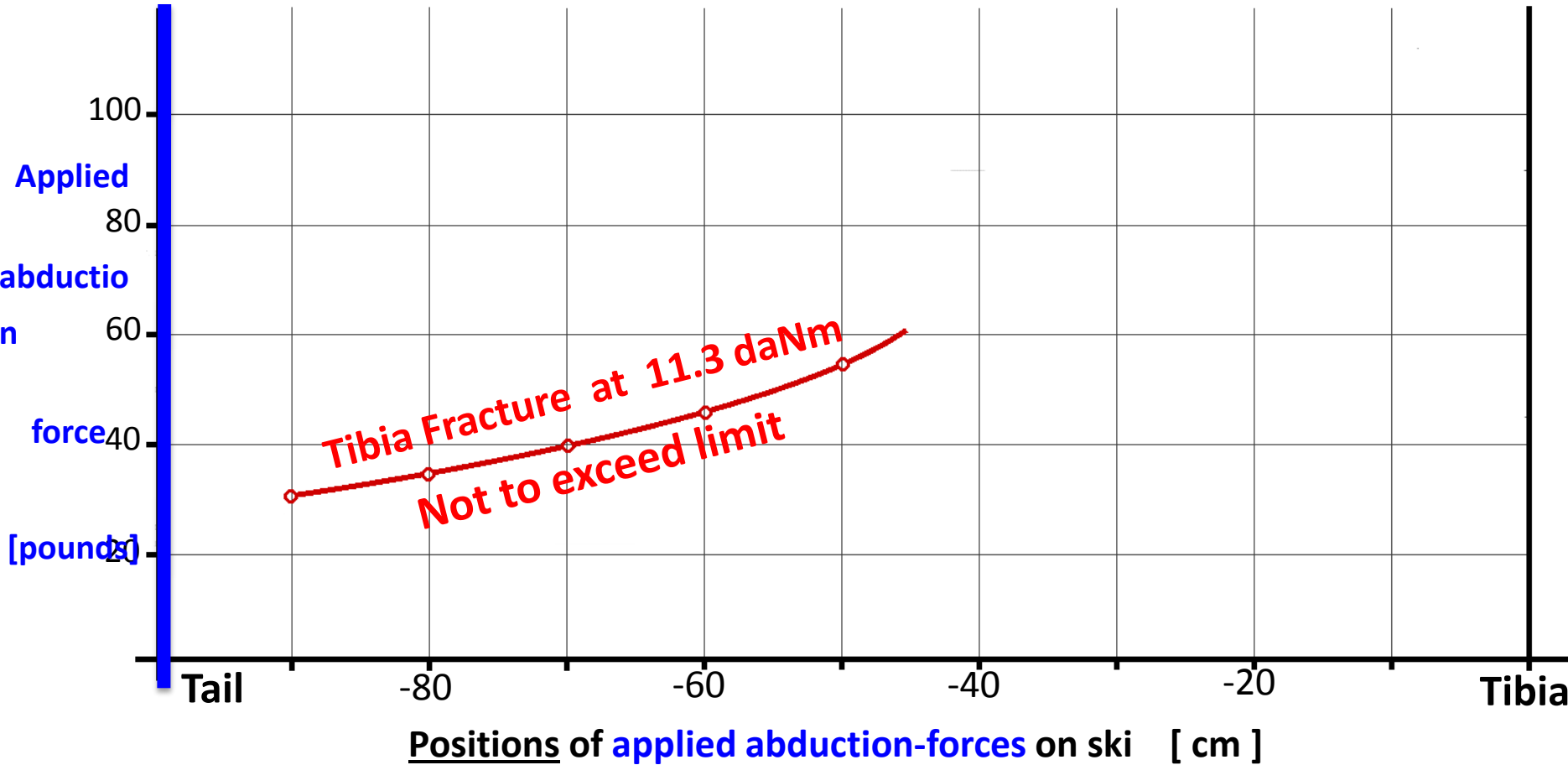


# Tibia fracture, average U.S. male



No ski-binding.

# Peak forces at tibia-fracture

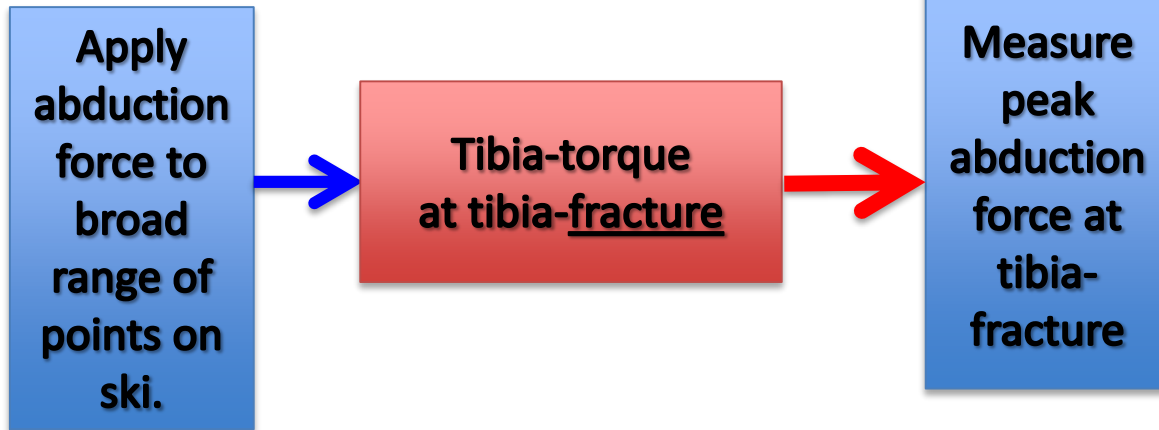


No ski-binding.

## Method, Part-2 — Summary:

- Apply **abduction force** to ski — until combined **tibia-torques** & **valgus-moments** reach ACL-rupture at **0.15 mm/mm of engineering strain** (based on 'Failure-Algorithm') at 5 cm intervals along length of ski.
- Record **peak tibia-torque**, **peak valgus-moment**, **peak abduction-force** at ACL failure as a function of position of applied abduction force.

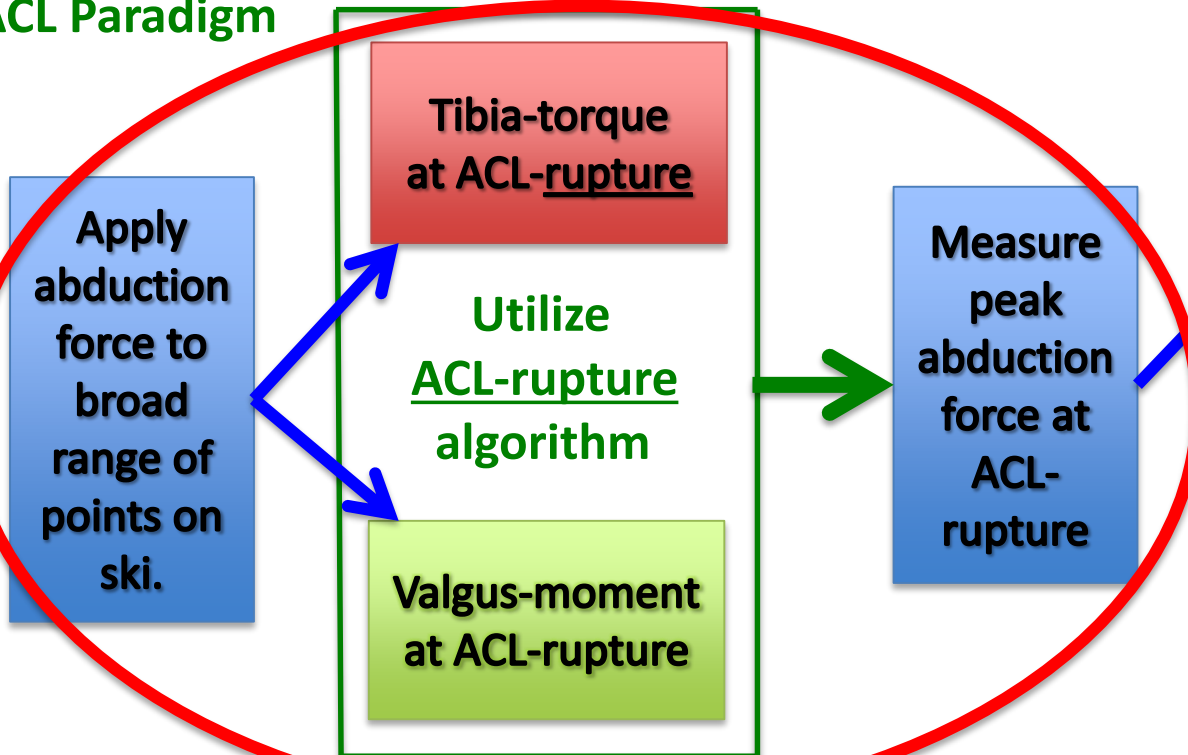
## Tibia Paradigm



## Method Part-2



## ACL Paradigm



# Experimental Parameters

Average U.S. male:

<b>Skier weight:</b>	<b>77 kg</b>
<b>ACL rupture:</b>	<b>0.15 mm/mm</b>
<b>Knee to beam:</b>	<b>55 cm</b>
<b>Knee flexion:</b>	<b>25°</b>
<b>Ankle flexion:</b>	<b>90°</b>
<b>Ski-binding:</b>	<b>None</b>

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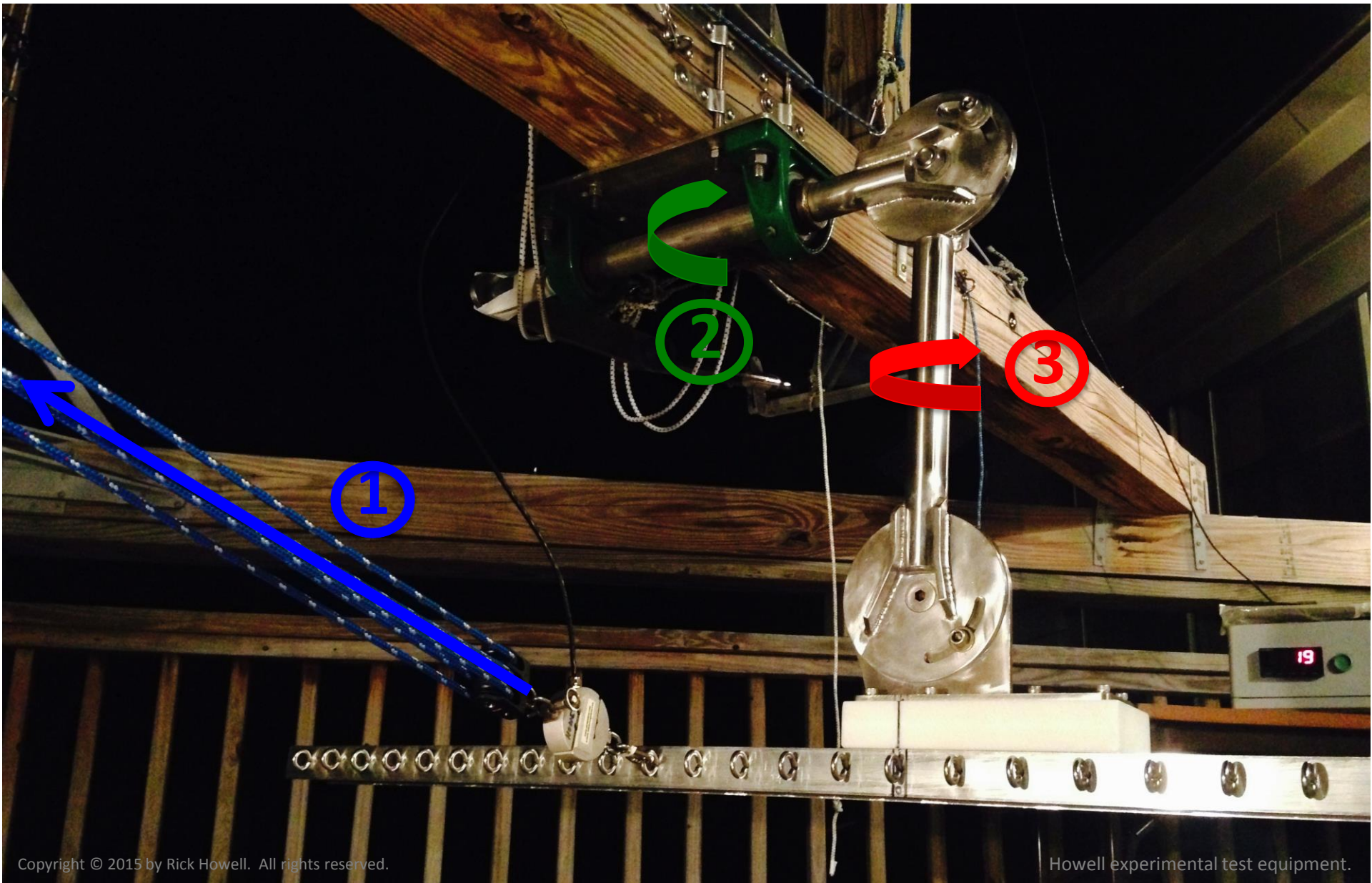
U.S. National Highway Safety Commission: Anthropometric factors, Average U.S. male, 2013.

Momersteeg, T., Blankevoort, L., Huiskes, R., 1995, Effect of variable relative insertion orientation of human knee bone-ligament-bone complexes on tensile stiffness. J Biomech., Vol. 28, pp 745–752.

Alvin R. Tilley, Henry Dreyfus, The Measure of Man and Woman: Human Factors in Design, 2002, Wiley & Sons.

**Apply:** (1) abduction force.

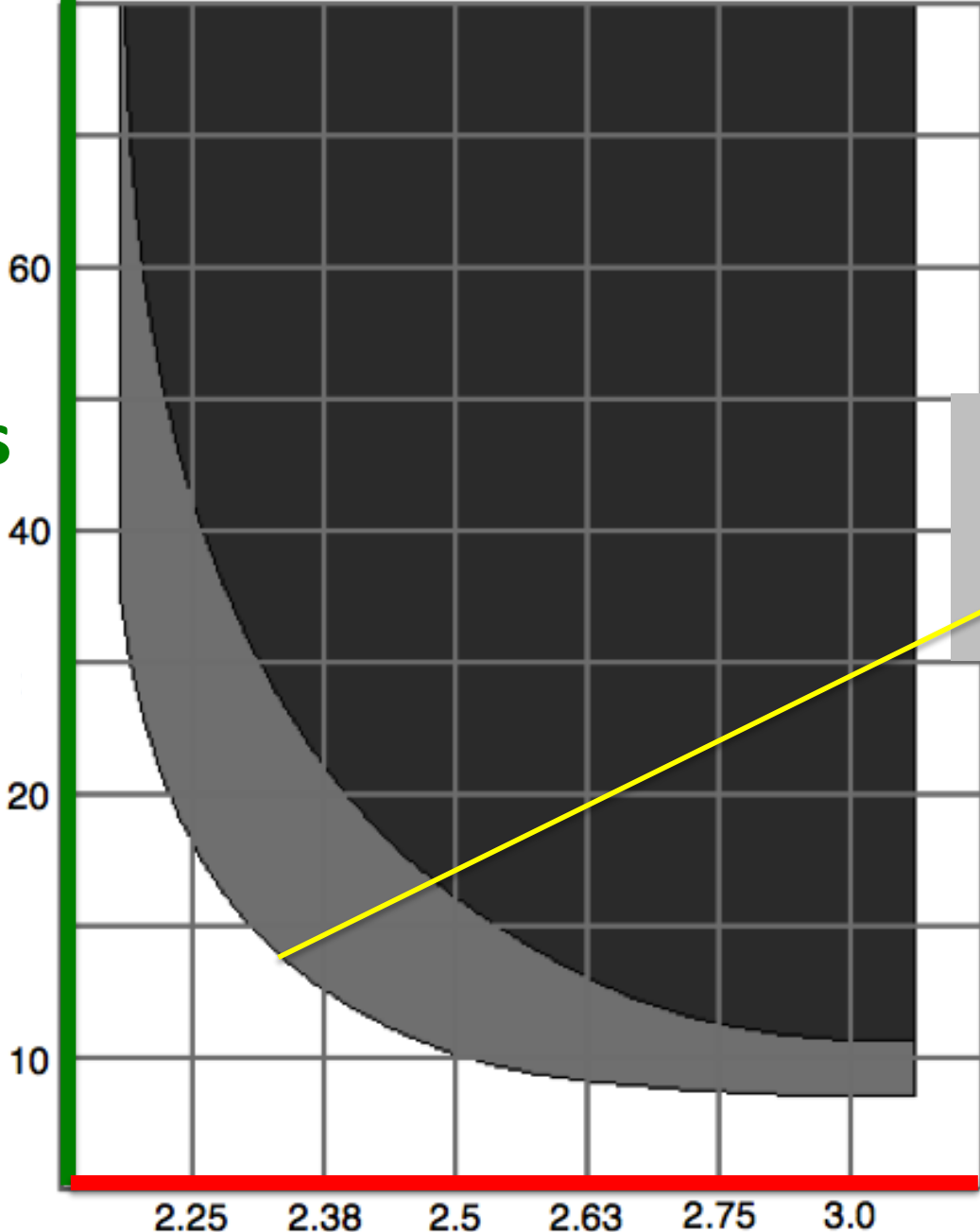
**Measure:** (2) peak Valgus-Moment (3) peak Tibia-Torque  
(4) positions on ski — at ACL Rupture.



Method  
Part-2

Peak  
Valgus

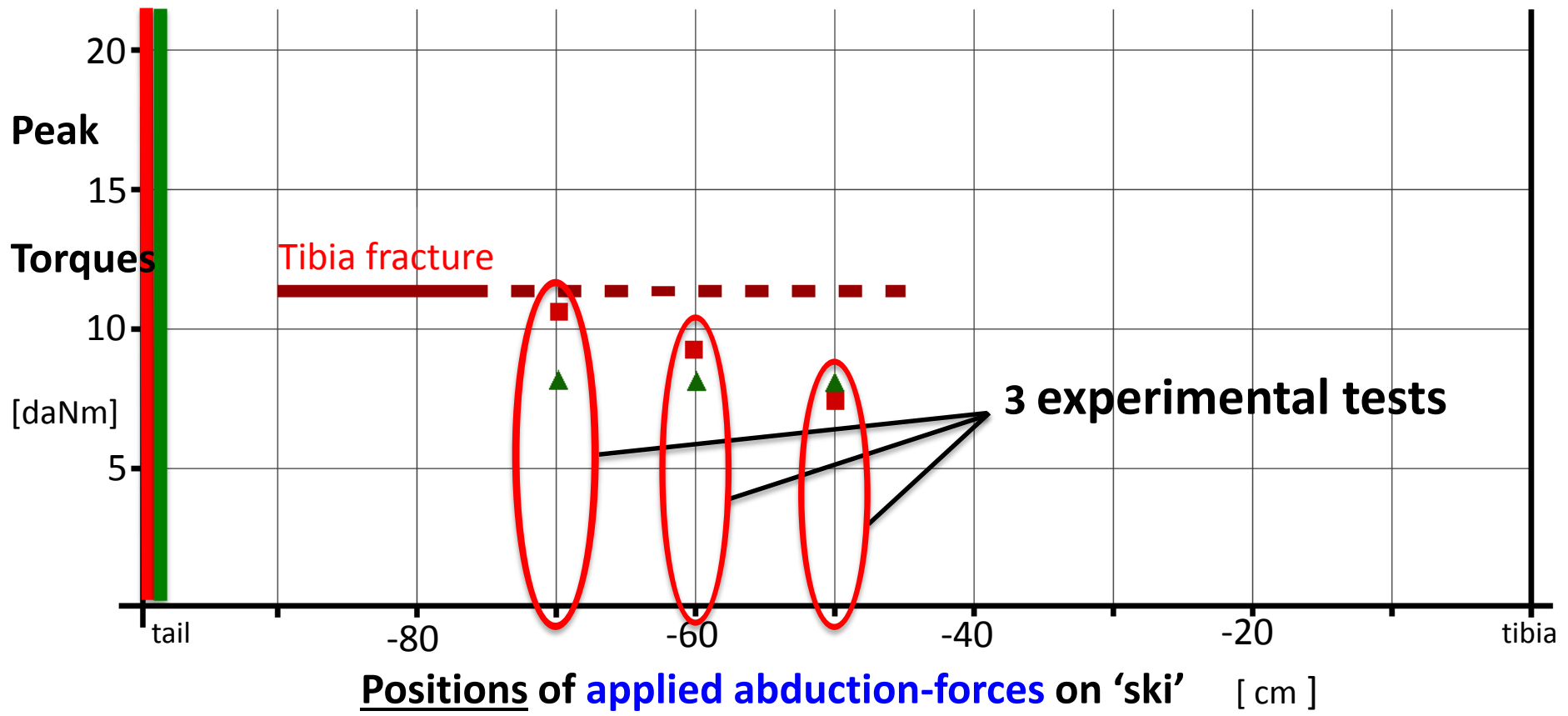
[daNm]



ACL-rupture  
0.15 mm/mm<sup>13</sup>

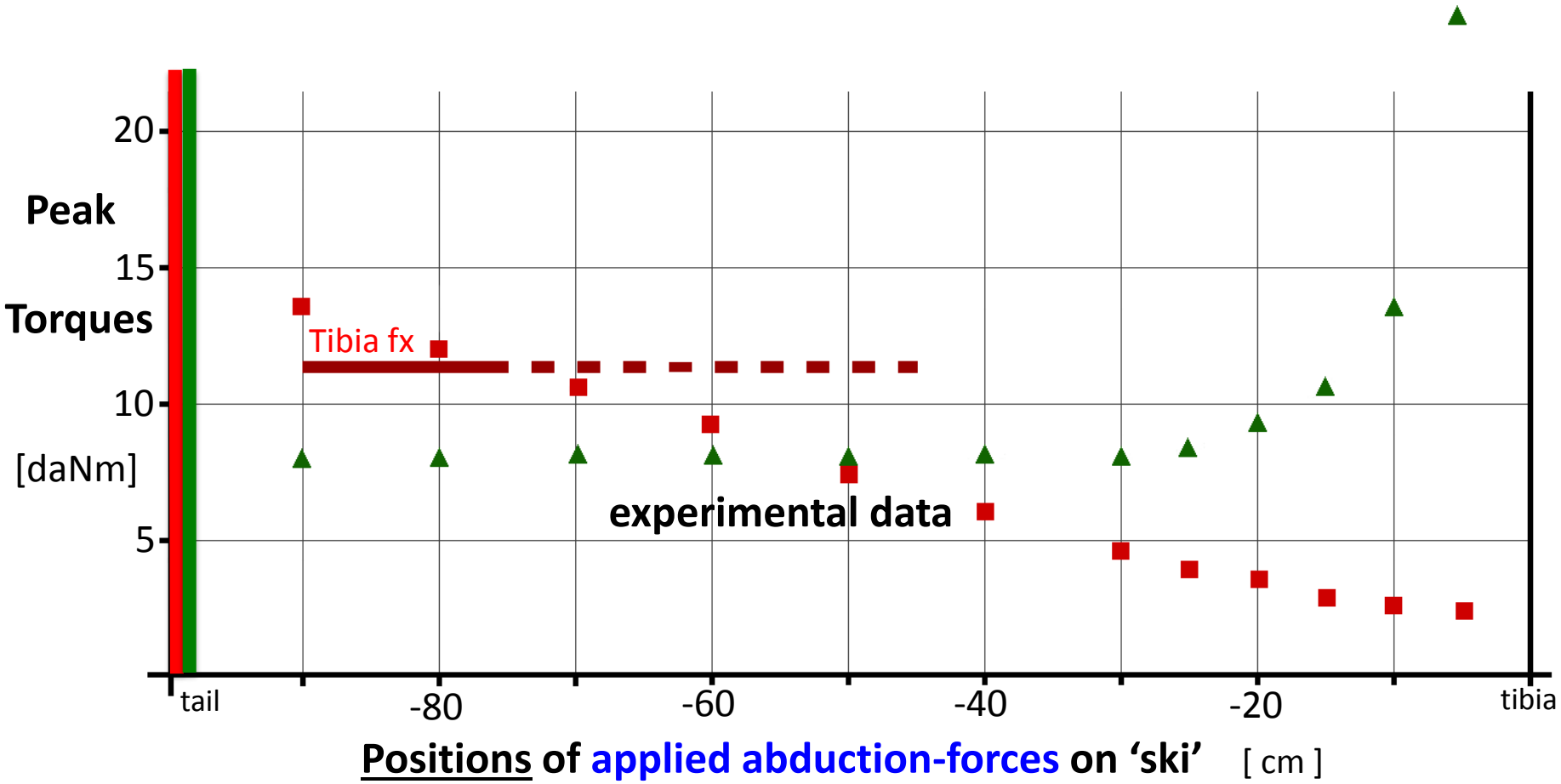
Peak Tibia Torque [daNm]

# Peak **tibia-torques** & **valgus-moments** at ACL-rupture



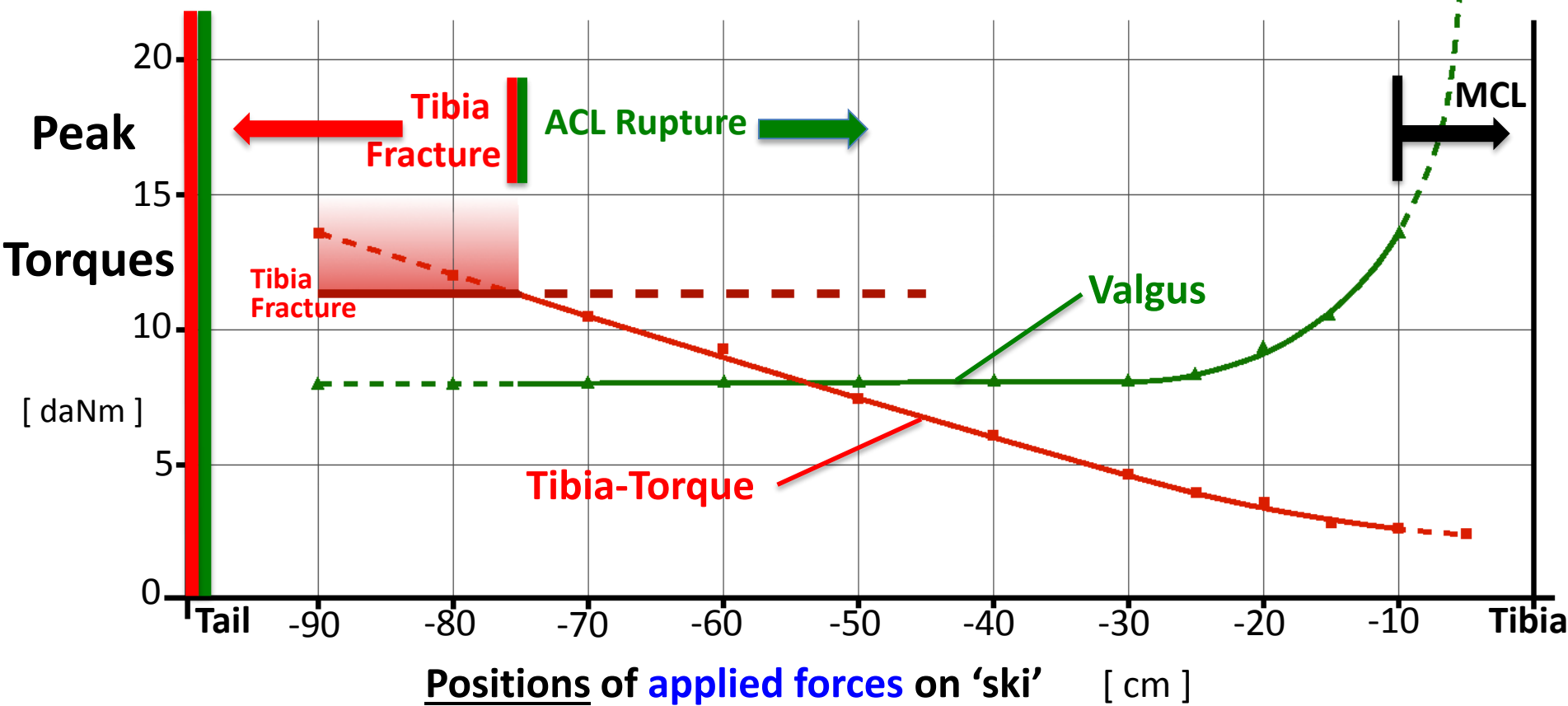
No ski-binding.

# Peak **tibia-torques** & **valgus-moments** at ACL-rupture



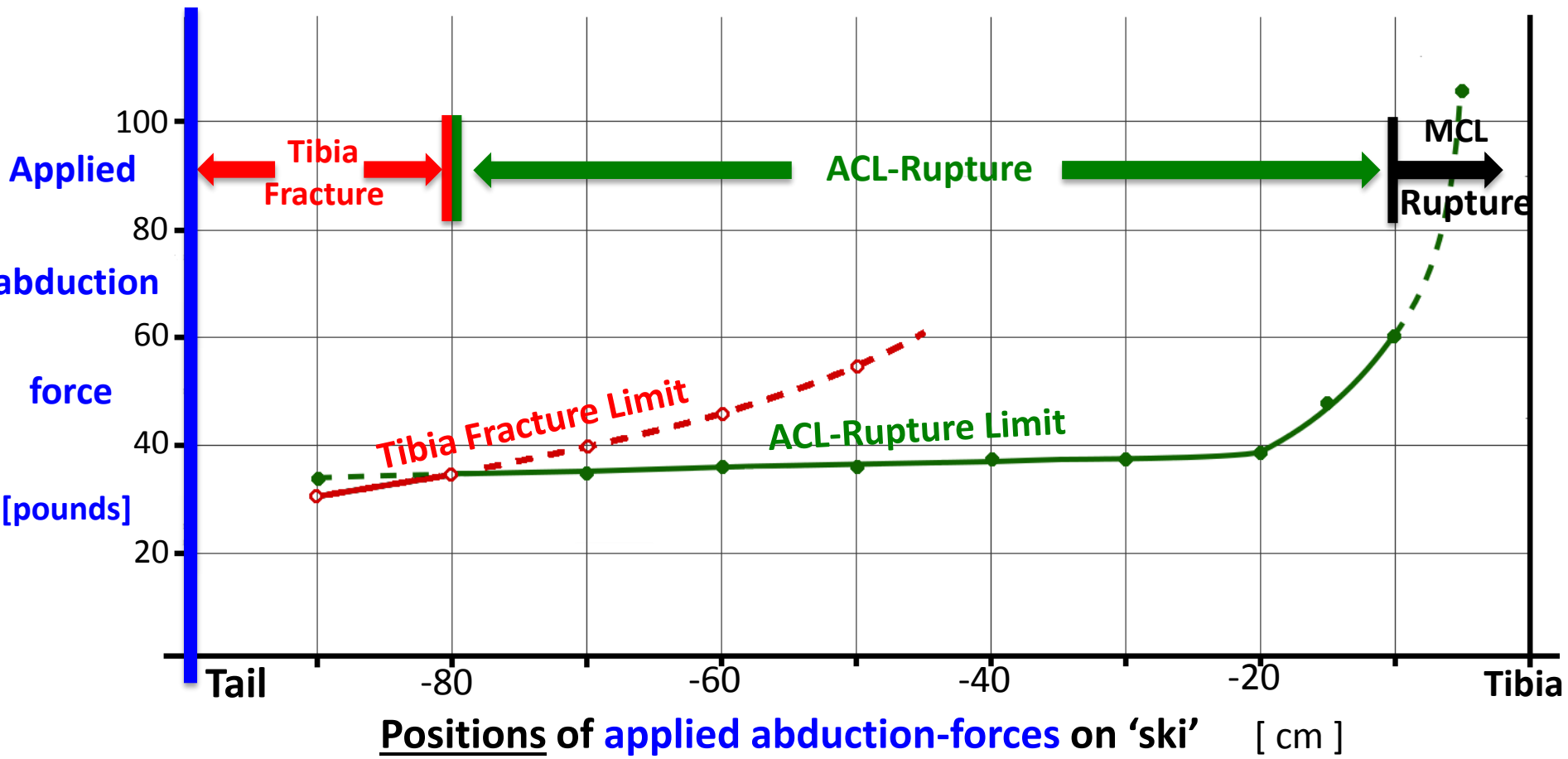
No ski-binding. 12 test-positions.

# Peak tibia-torques & valgus-moments at ACL-rupture



No ski-binding. 3 envelopes. 12 test-positions.

# Peak applied abduction forces at ACL Rupture



No ski-binding.    2 envelopes.    12 test-positions.

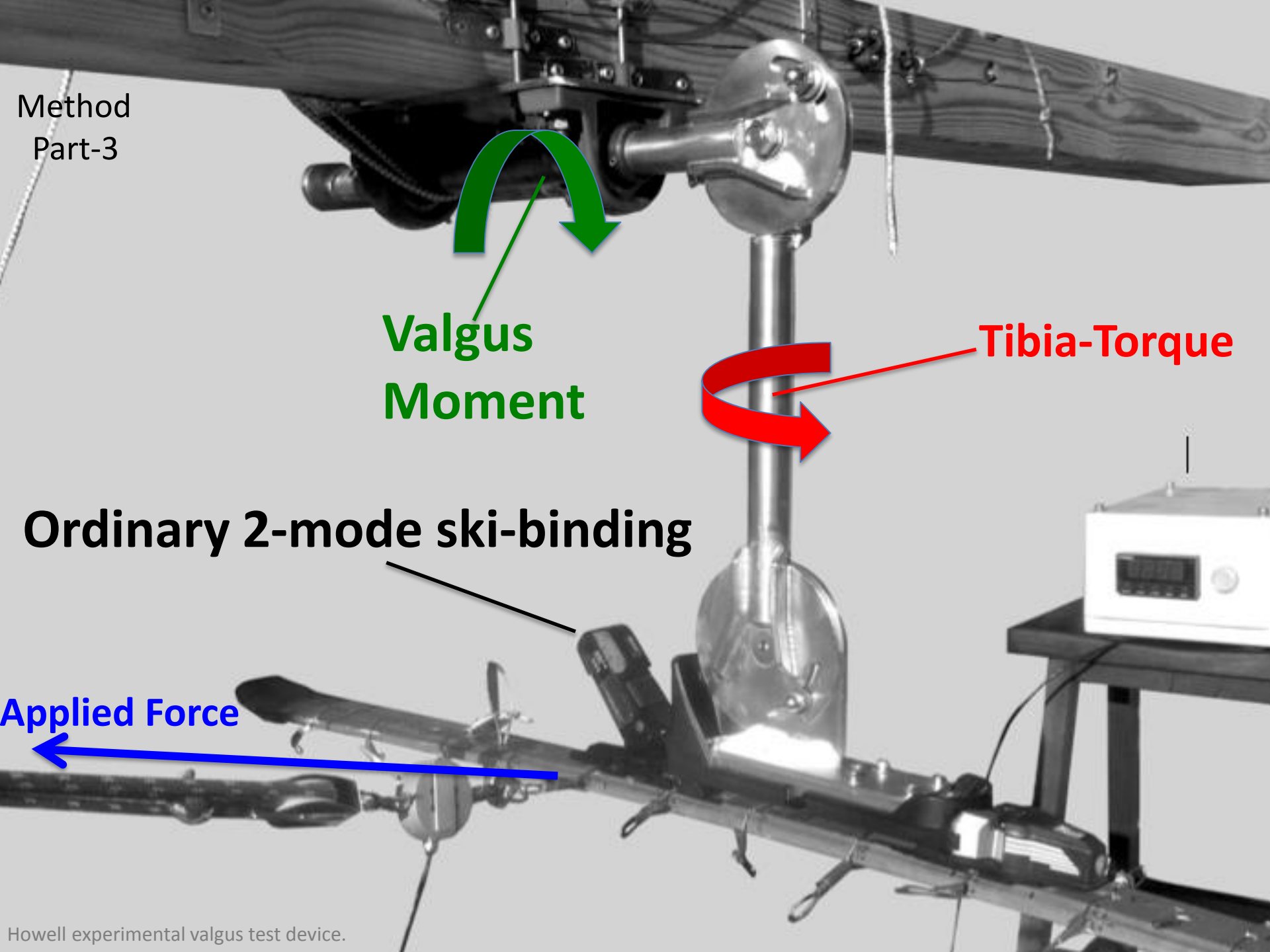
Method  
Part-3

Valgus  
Moment

Tibia-Torque

Ordinary 2-mode ski-binding

Applied Force

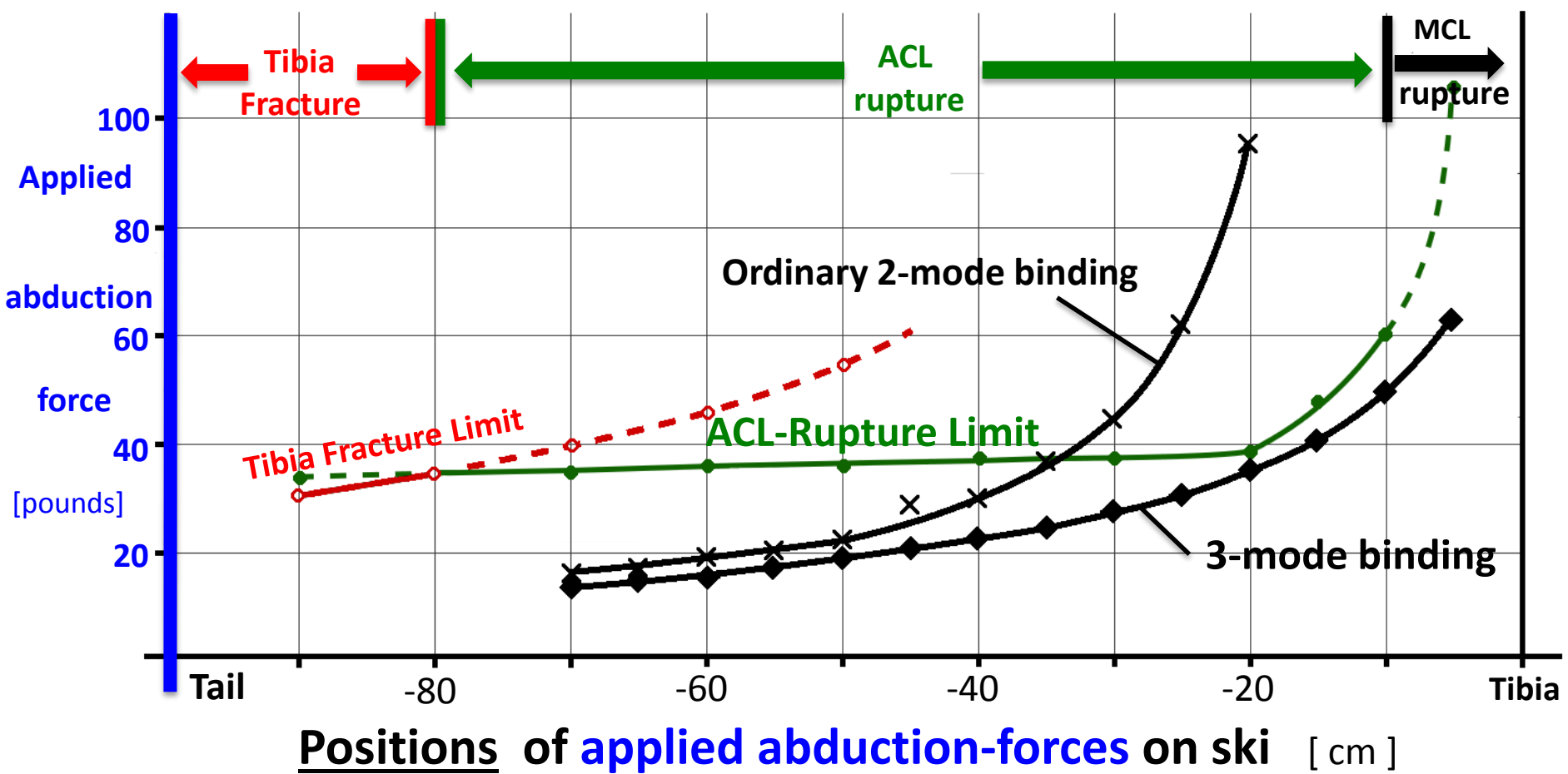


# 3-mode ski-binding.

Additional lateral heel release.



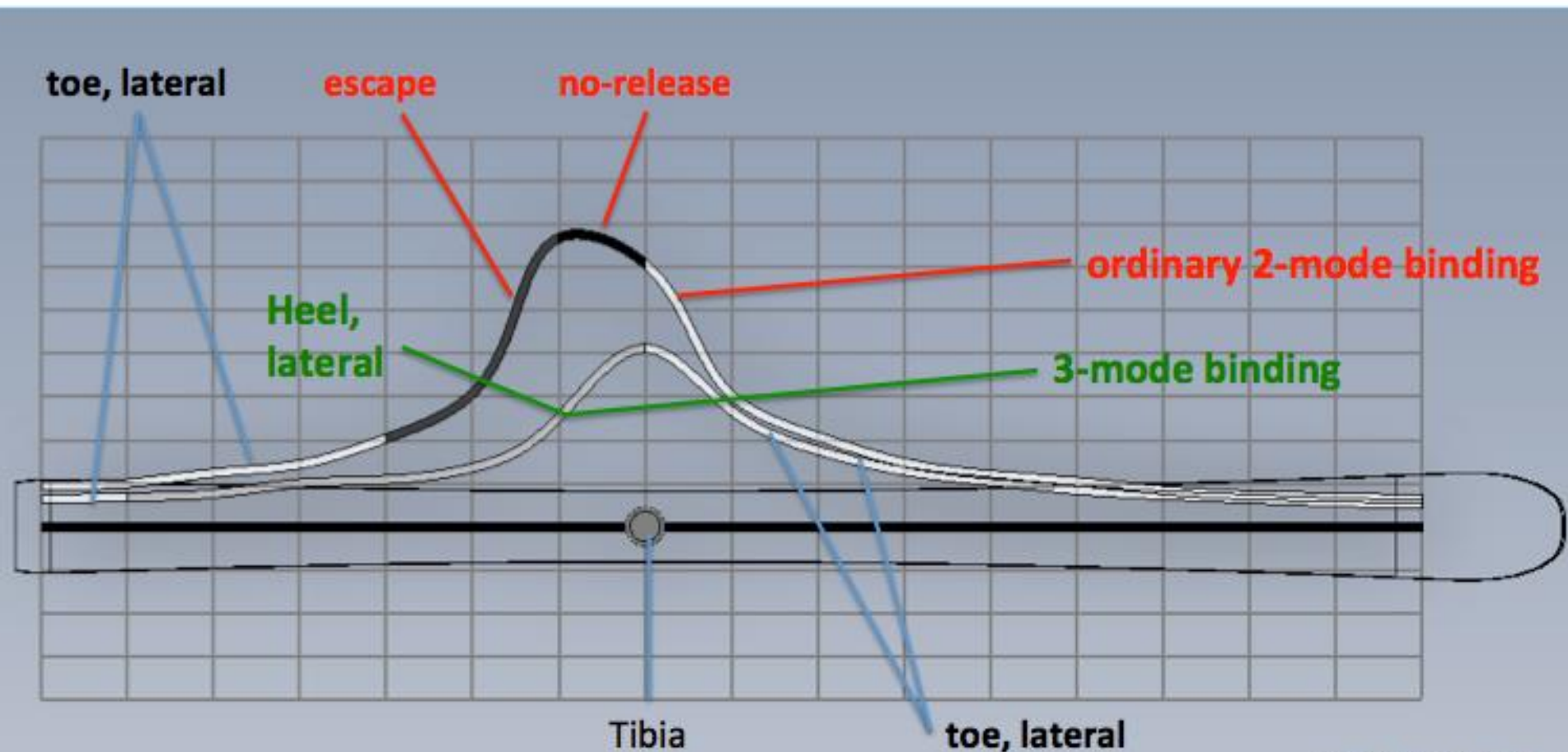
# Peak applied abduction forces at ski-binding release.



16 test-positions

## Modes of release:

- Ordinary 2-mode binding.
- 3-mode binding with lateral heel release.

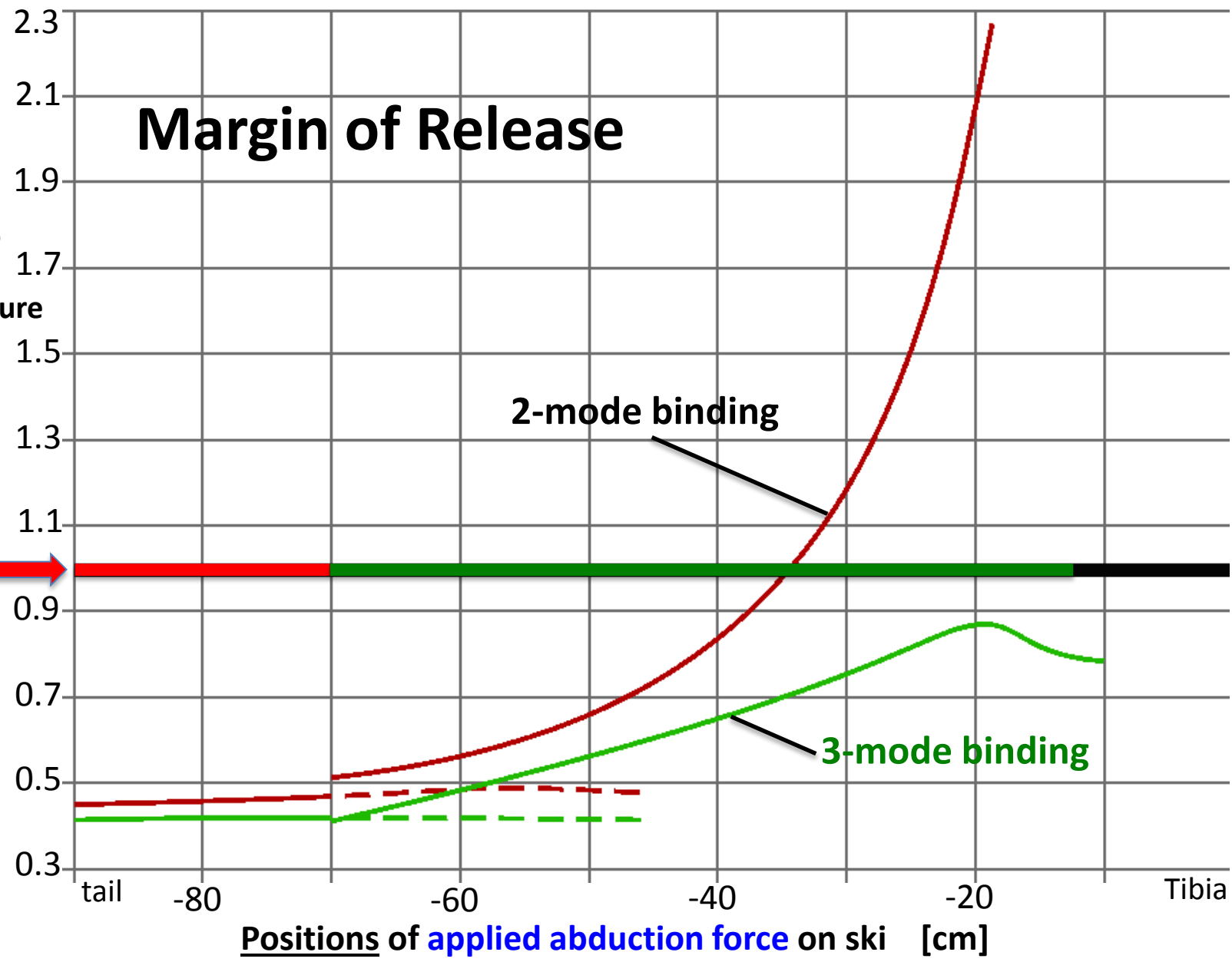


Results  
Parts 1,2,3

# Margin of Release

Ratio:  
binding-release  
to  
ACL & MCL rupture  
&  
tibia-fracture

ACL Rupture  
Tibia Fracture  
MCL Rupture



# Limitations

ACL-failure data is over-applied  
(due to limitations of Andriacchi study).

Need female knee  
(3-times higher risk of ACL-injury than males).

Experimental variation should be reported.

Prospective intervention study is needed for  
proper validation.

# Conclusions

The methods presented in this study might point to a plausible-approach toward investigating the efficacy of **ACL and MCL**-friendly ski bindings — as soon as the method-limitations are resolved.

For the complete study and data:

Rick Howell

President,

Howell Ski Bindings

Stowe, Vermont USA

**<Rick.Howell@HowellSkiBindings.com>**

# Ski Bindings and Mitigation of ACL Rupture.

*Rick Howell*

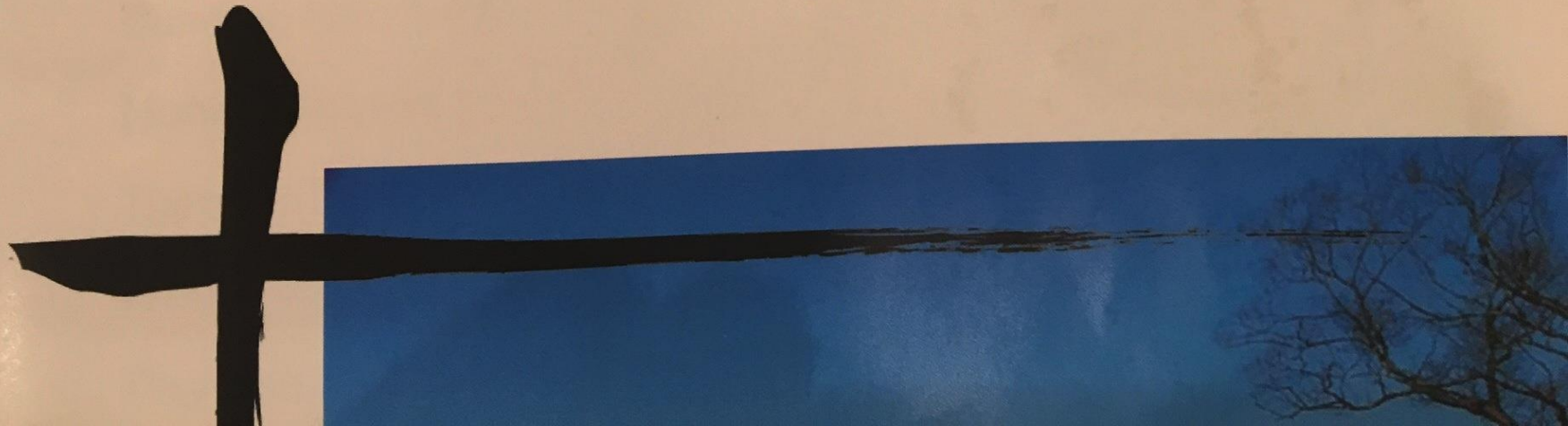
*Howell Ski Bindings Stowe, Vermont USA*



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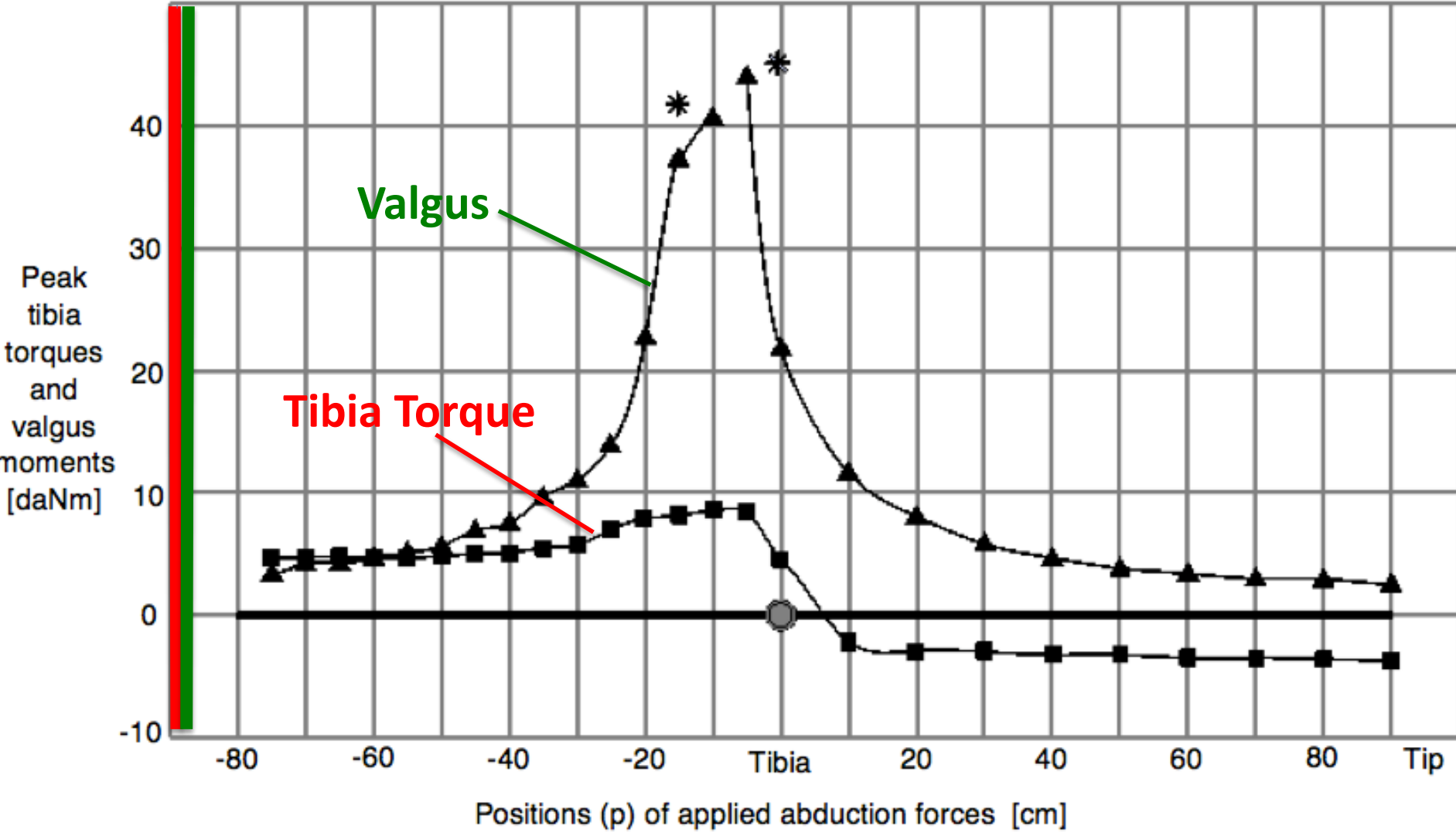


# Appendix

The following two graphs represent peak tibia-torques & peak valgus-moments at ski-binding release, as a function of the incremental positions of the applied abduction-forces along the length of the ski. Ski-binding release is set at 6.0 daNm of 'pure torque' about the long axis of the tibia for both bindings.

Please note: for shorter skis, truncate data at both ends of both envelopes.

# Peak torques at release. Ordinary 2-mode ski-binding.



# Peak torques at release. 3-mode ski-binding.

