

# The Knee

## Where is the problem?

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# Disclosure

- This presenter, an engineer, occasionally consults with and testifies for plaintiffs in civil actions on snow sport injuries and is remunerated for this
- First cannon of engineering ethics:

***Hold paramount the safety, health, and welfare of the public***

# Boots and bindings

more than skis or course setting

- In the 1970 boots materials changed to polymers
  - Higher and more rigid
    - Favored due to improved transmission of control loads
- Mid-shaft tibia fractures and ankle injuries reduced
  - Protected the ankle
  - Improved interaction with bindings
- Unintended consequence
  - ***Transmission of injurious loads to the knee increased***

***Ski binding design did not evolve appropriately***

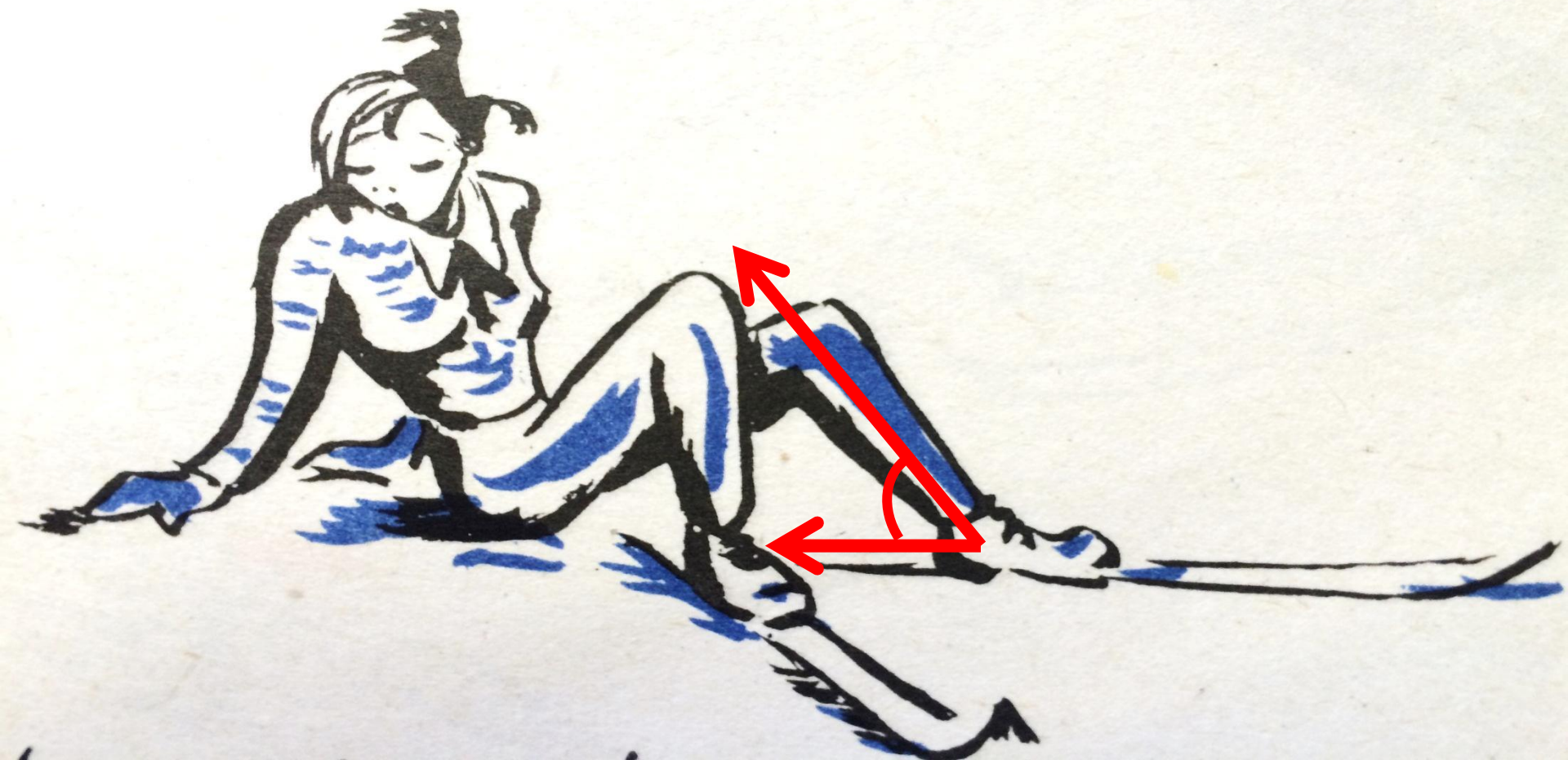
# ACL injuries increased when

boots got much better at transmitting loads between the posterior portion of the lower leg and the tail of the ski



ACL injuries were relatively infrequent through the 1970s

- Boots were softer then so you to sit on the snow



# Misunderstandings

- The binding can limit the transmission of potentially injurious loads to the knee
  - Address inadvertent release
    - Adjustment for elite skiers especially based on strength and quickness as well as weight
  - Separate adjustment for work to release and maximum force
- Roll moment (torque  $rxF$ ) about the ski for edging is not the same as valgus about the knee for loading ACL
  - Critical load is the torque about the knee rather than about the ski
  - Caused by lateral forces on the side of the ski
- Newtonian mechanics explains load transmission
  - more reliably than complex instrumentation

# Conventional two modes of release

Lateral at the heel

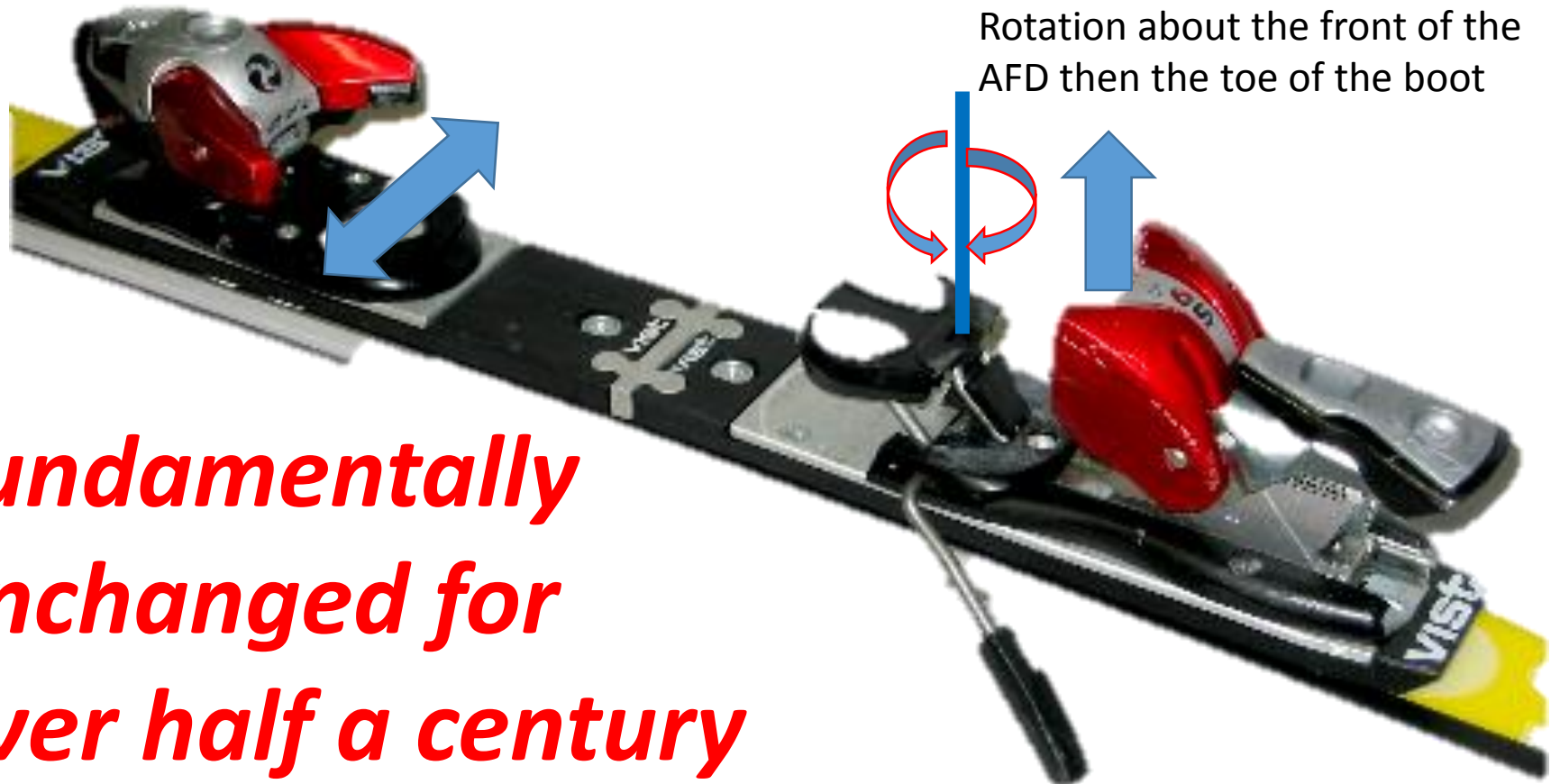
“twist”

Rotation about the center of the heel

Vertical at the heel

“forward bending”

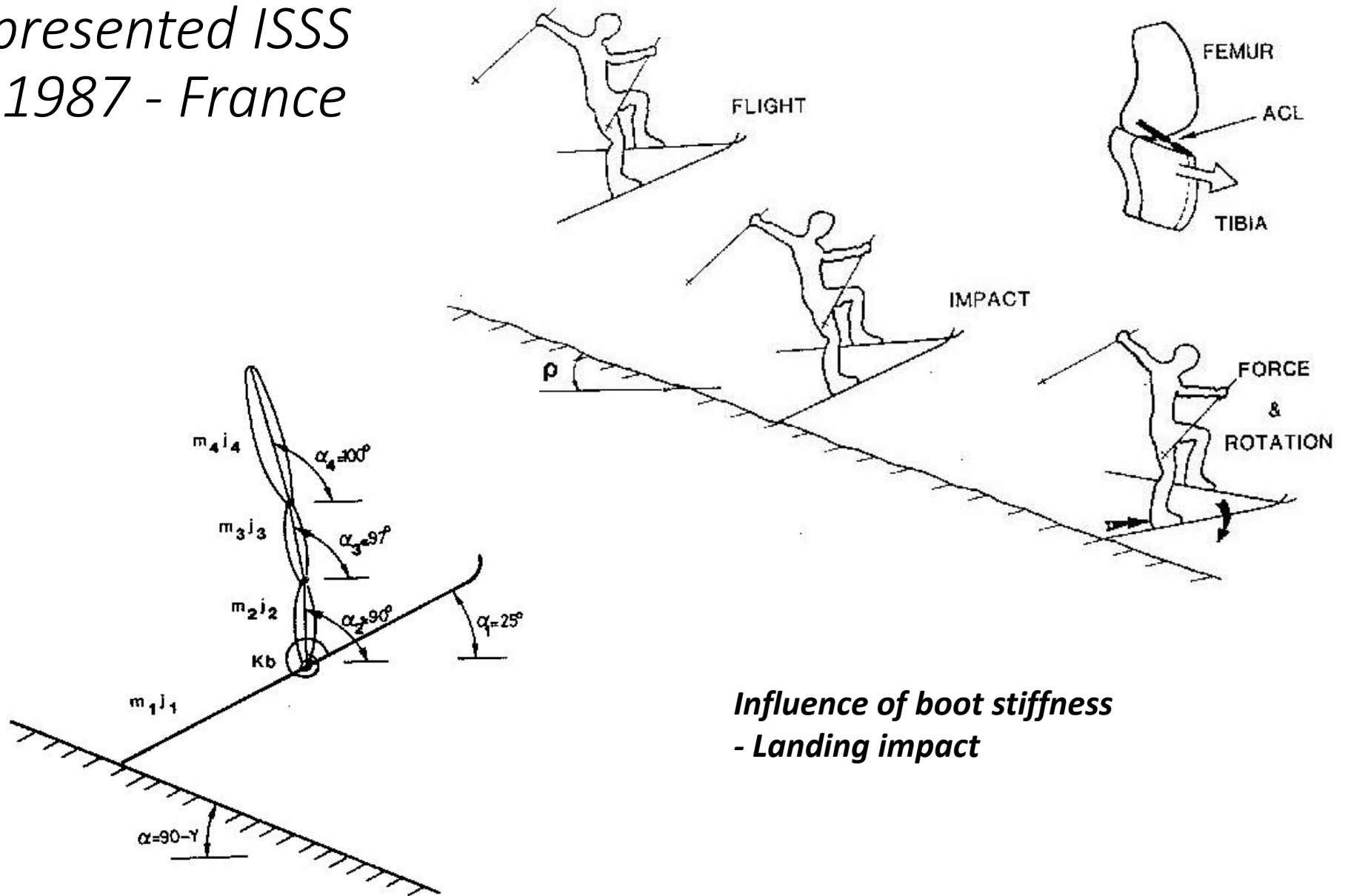
Rotation about the front of the  
AFD then the toe of the boot



***Fundamentally  
unchanged for  
over half a century***

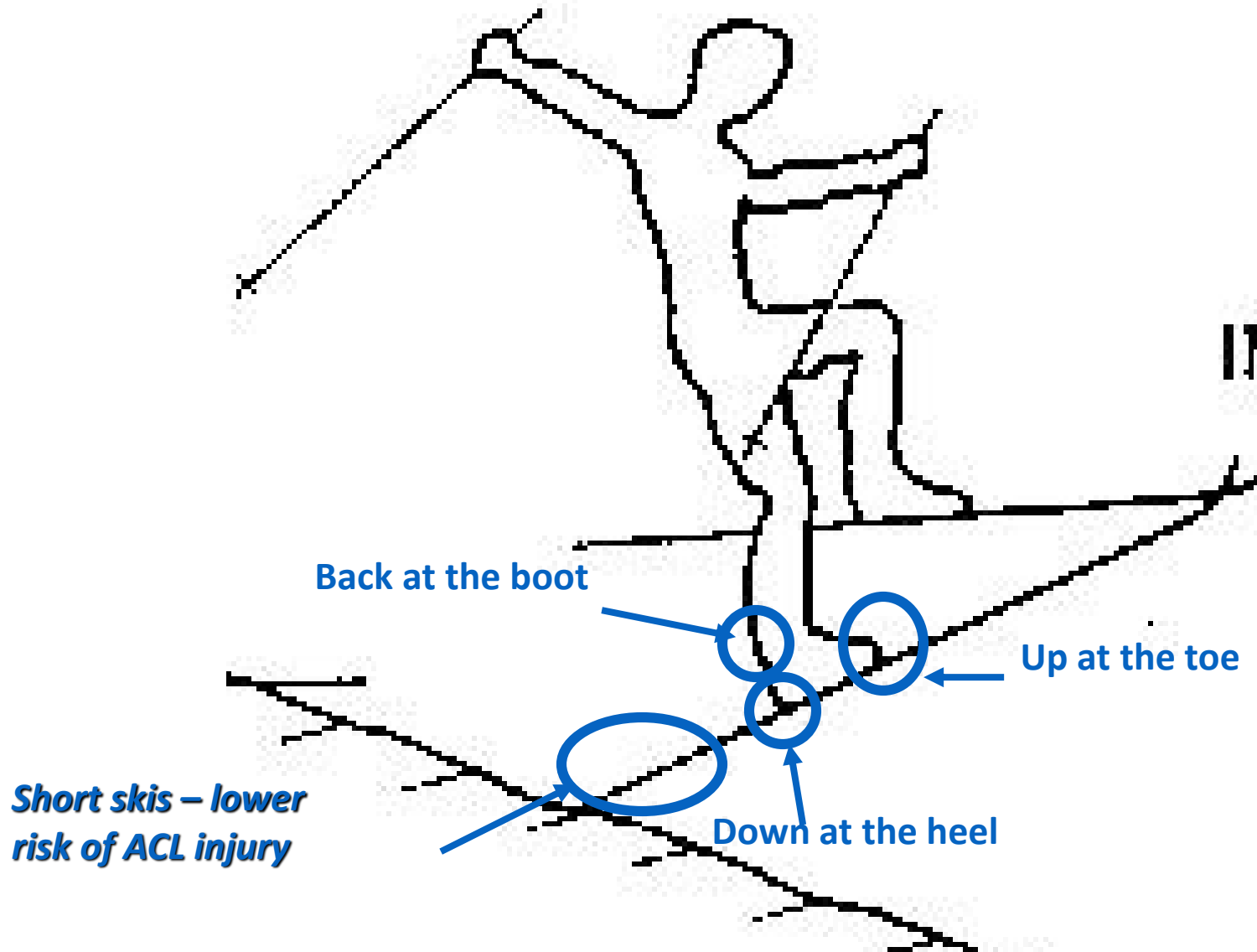
# Bally et al. (1989)

*presented ISSS  
1987 - France*



***Influence of boot stiffness  
- Landing impact***

# Device strategies - BIAD



# Lange Rear Release System 2000

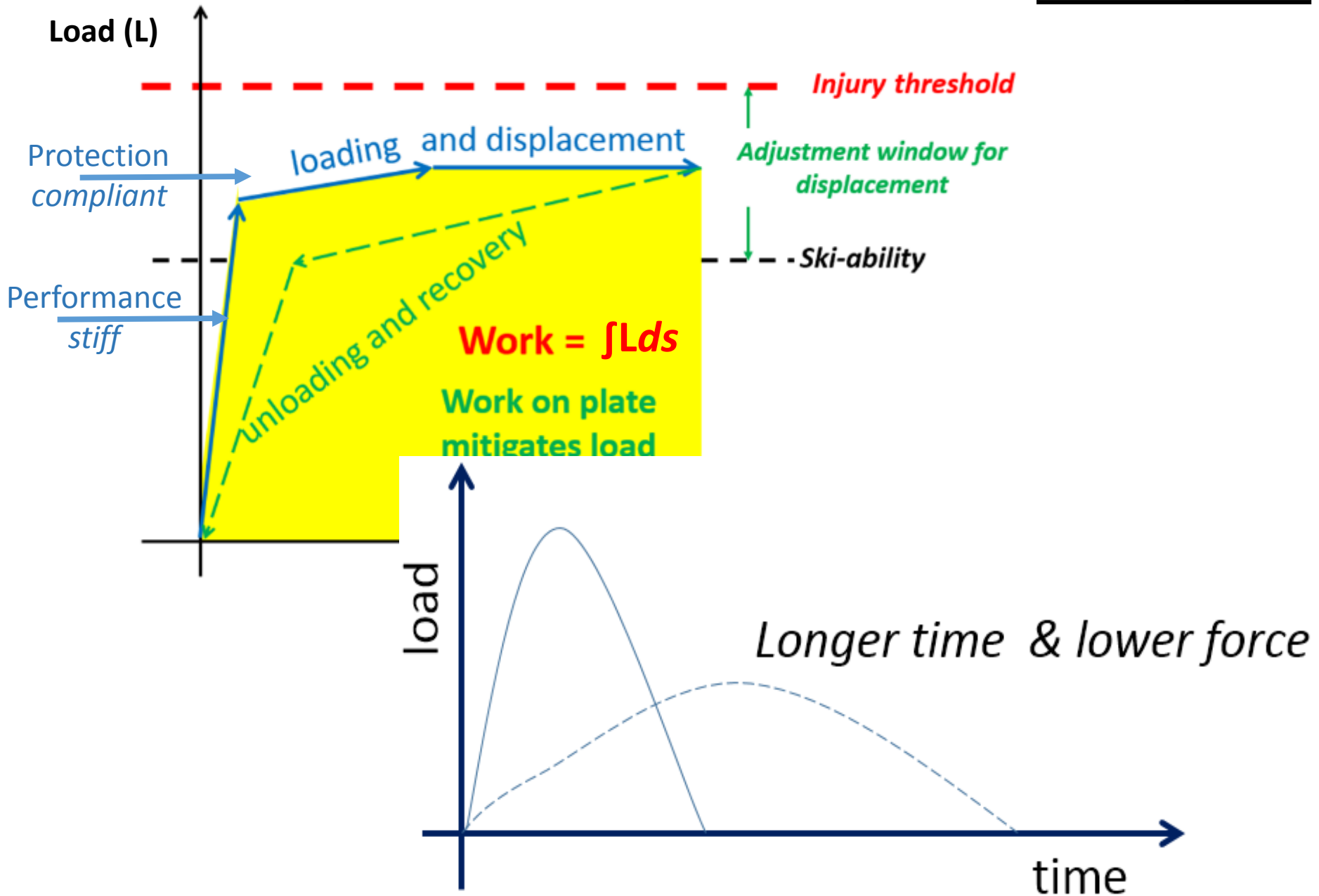
*ISSS 2003  
Young et al.  
and  
Lehner and  
Senner*



# GEZE SE3 - 1982

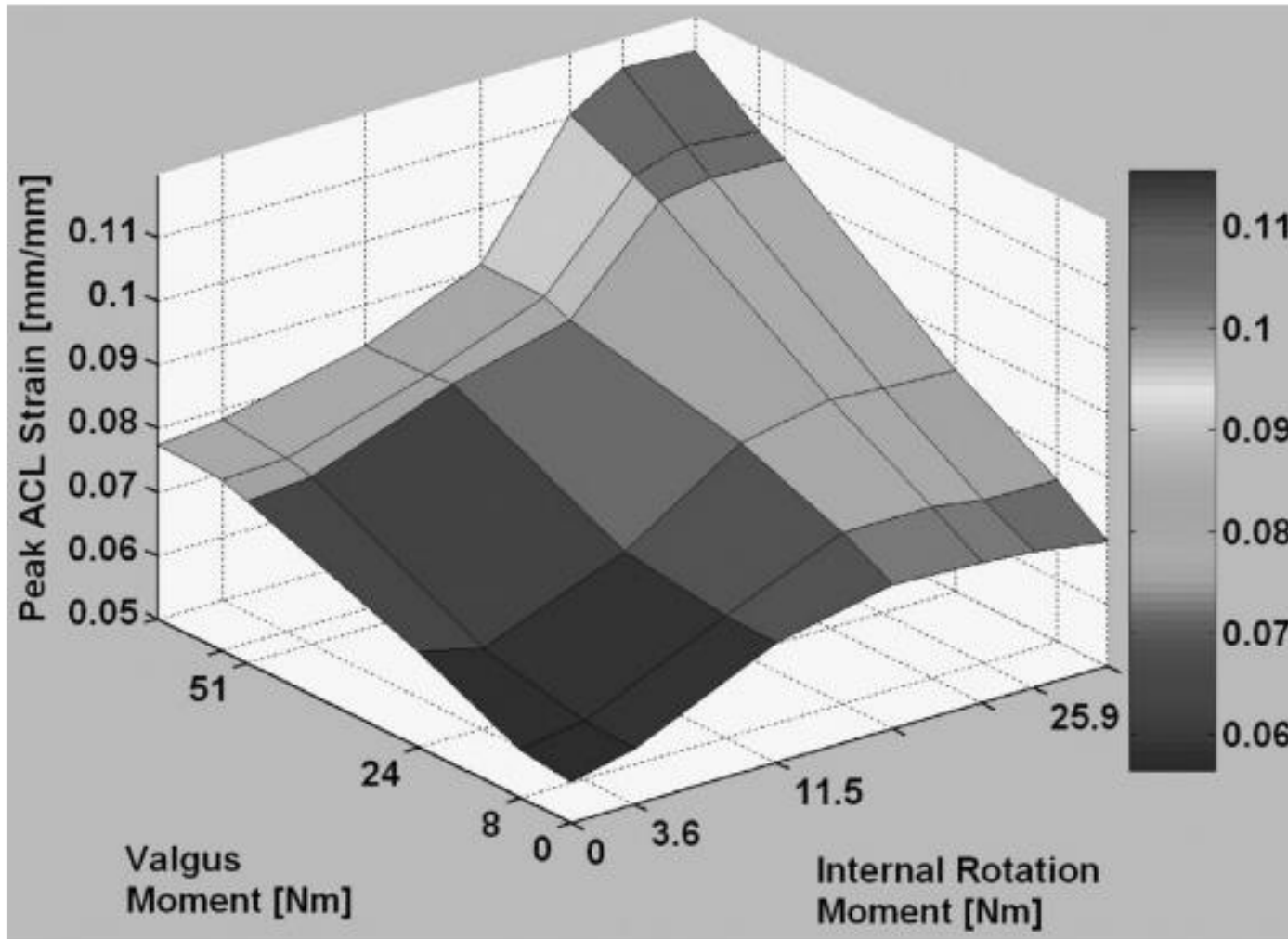


# General Principles



# Combined Valgus + Internal Rotation

*Increases Anterior Cruciate Ligament Strain*



*SHIN , AJIT, and  
ANDRIACCHI (2011)  
Valgus Plus Internal  
Rotation Moments  
Increase Anterior  
Cruciate Ligament  
Strain More Than  
Either Alone  
MEDICINE &  
SCIENCE IN SPORTS  
& EXERCISE*

**FIGURE 3—The estimated peak strain in the anteromedial bundle of the ACL in response to applied valgus and tibial internal rotation**

Torque: cross product of a force and a lever arm  $T = r \times F$

$F$  ski-snow interaction force perpendicular to the side of the ski

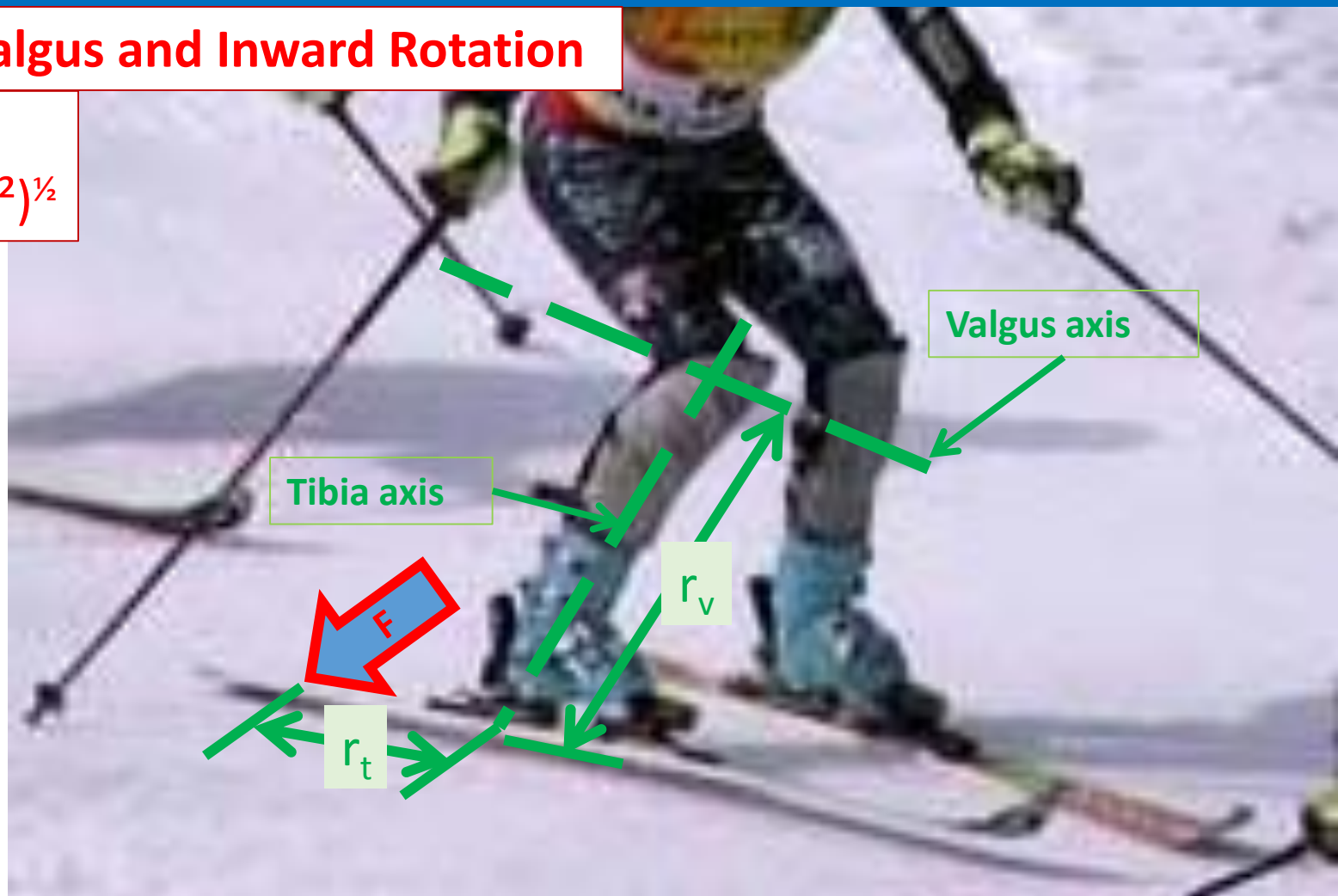
$r_v$  tibia is valgus lever arm  $T_v = r_v \times F$ ,

$r_t$  distance to tibia axis along ski is internal rotation lever arm  $T_t = r_t \times F$

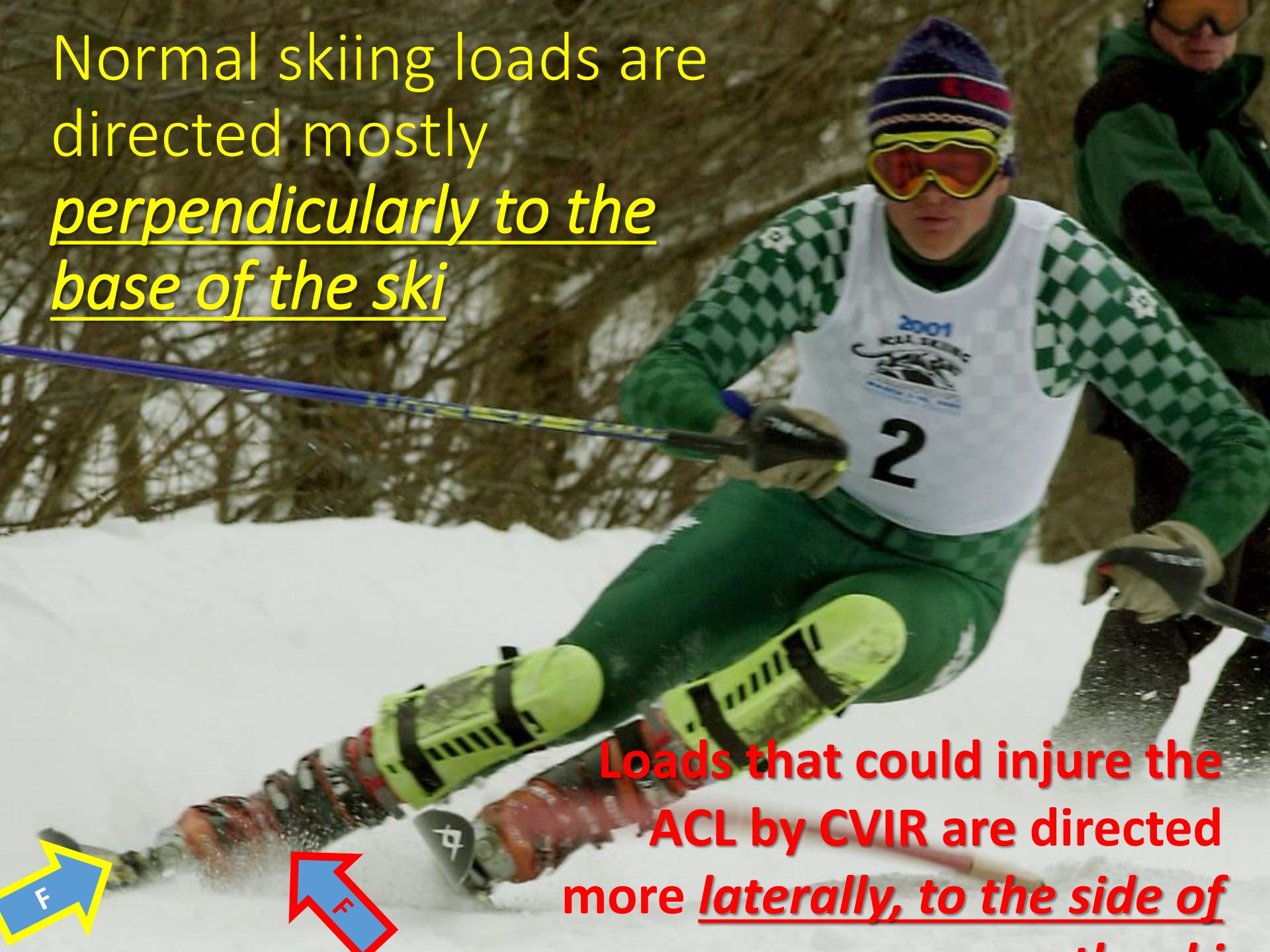
## Combined Valgus and Inward Rotation

### CVIR loading

$$T_{CVIR} \sim (T_t^2 + T_v^2)^{\frac{1}{2}}$$



Normal skiing loads are directed mostly perpendicularly to the base of the ski



Loads that could injure the ACL by CVIR are directed more laterally, to the side of



Load is largely  
perpendicular to  
the ski base



Load is now largely  
perpendicular to  
the side wall just  
behind the binding



Load is  
perpendicular to  
the ski base



Load is  
transitioning from  
the ski base to the  
side wall



Load is  
perpendicular to  
the side wall



Classic phantom foot reaction – uphill hand back and up



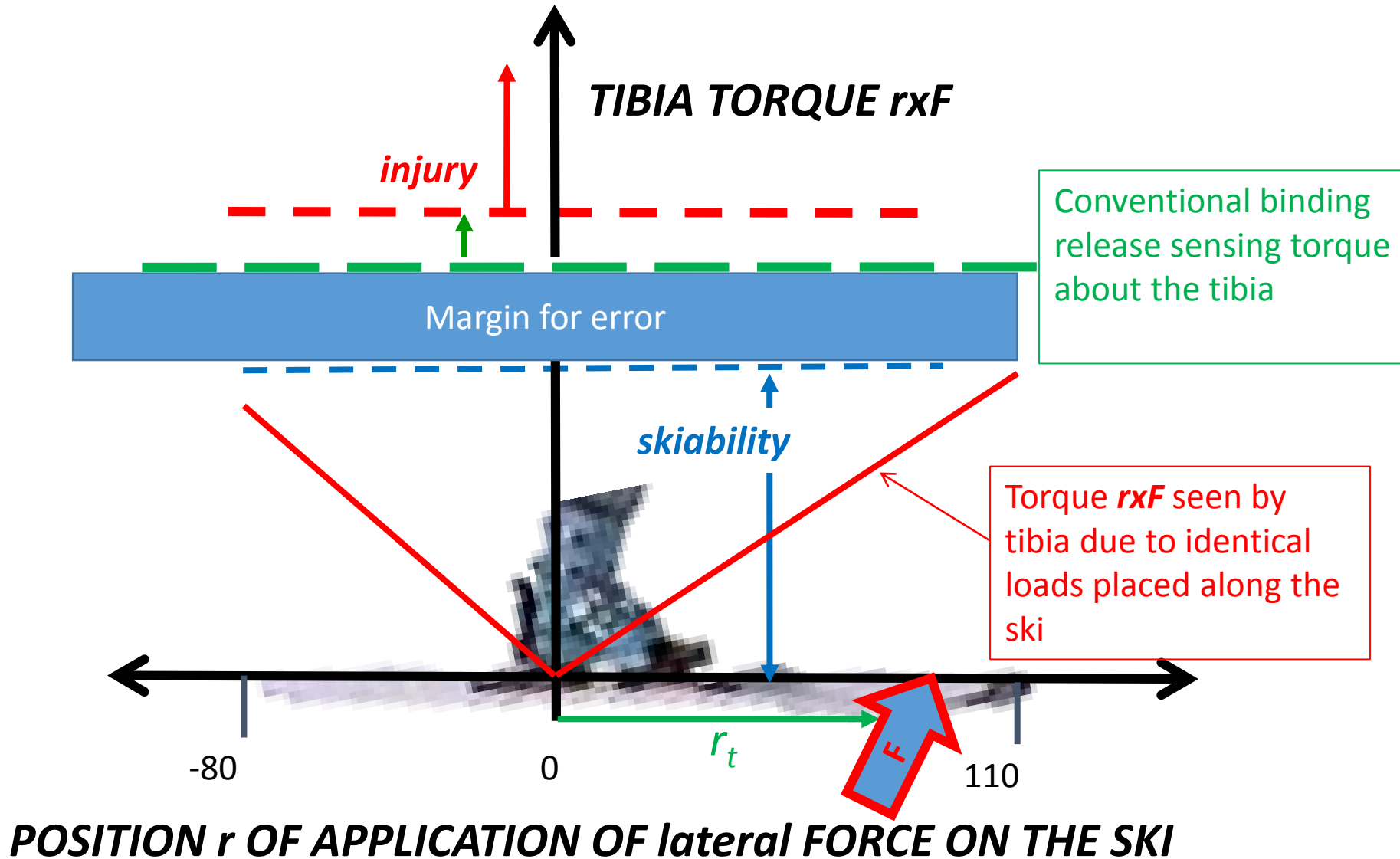
HD ORF eins

Race interrupted

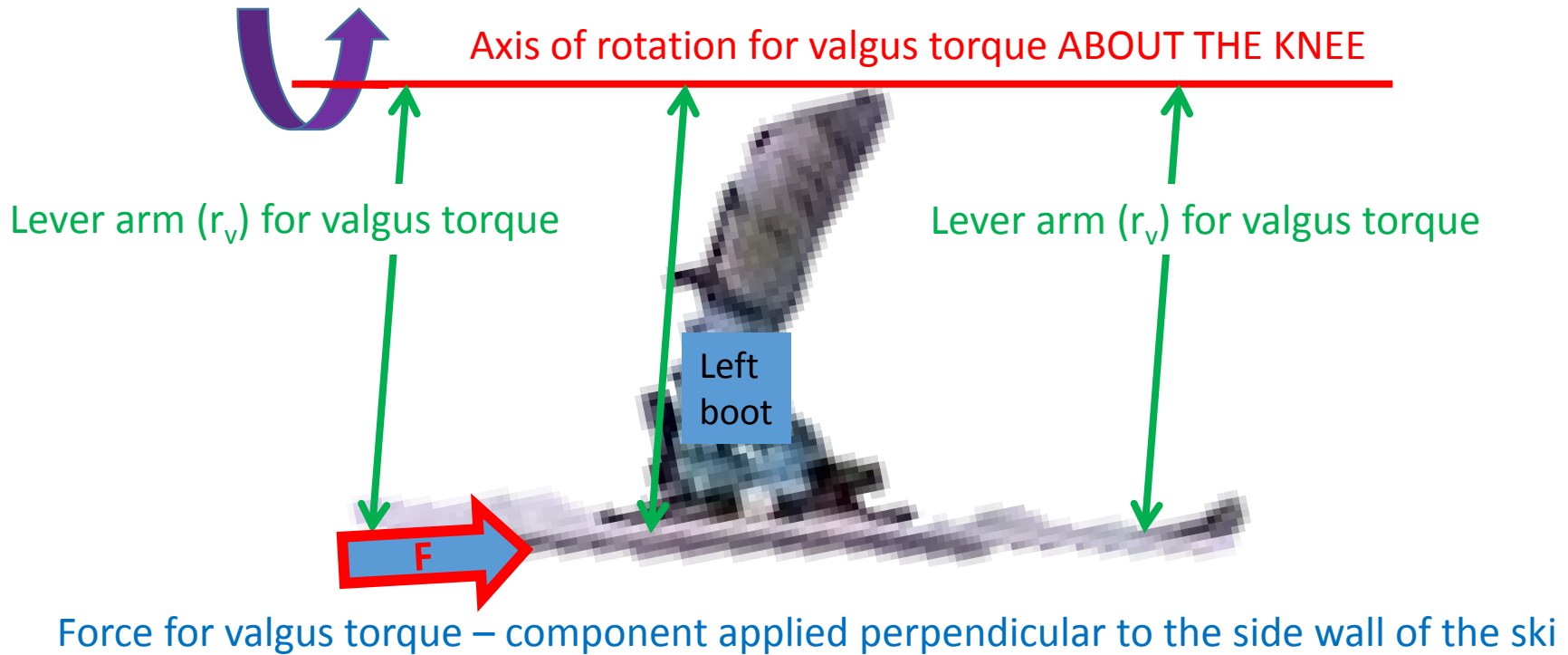
POP!

# Torque about tibia

binding rotation axis coincident with tibia axis



# Consider valgus torque alone



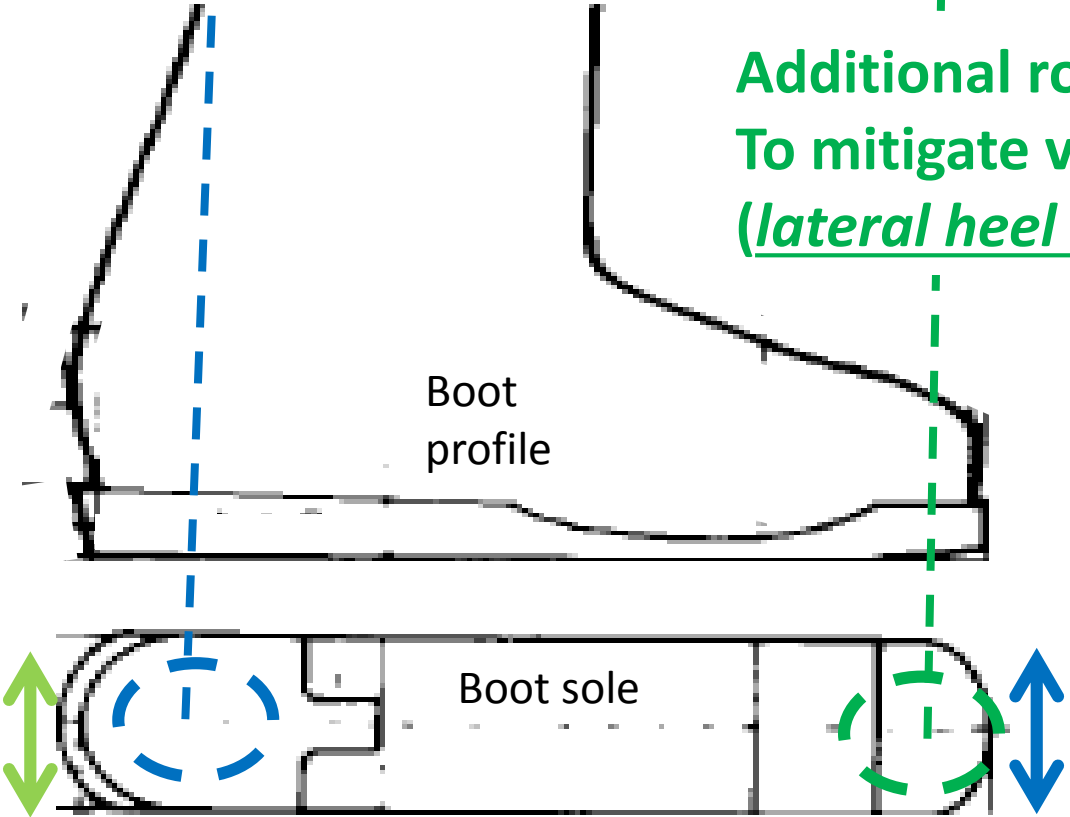
**VALGUS TORQUE (ABOUT THE KNEE) IS NOT THE SAME AS EDGING TORQUE (ABOUT THE SKI)**

**VALGUS TORQUE DOES NOT DIMINISH AS THE TIBIAL AXIS IS APPROACHED**

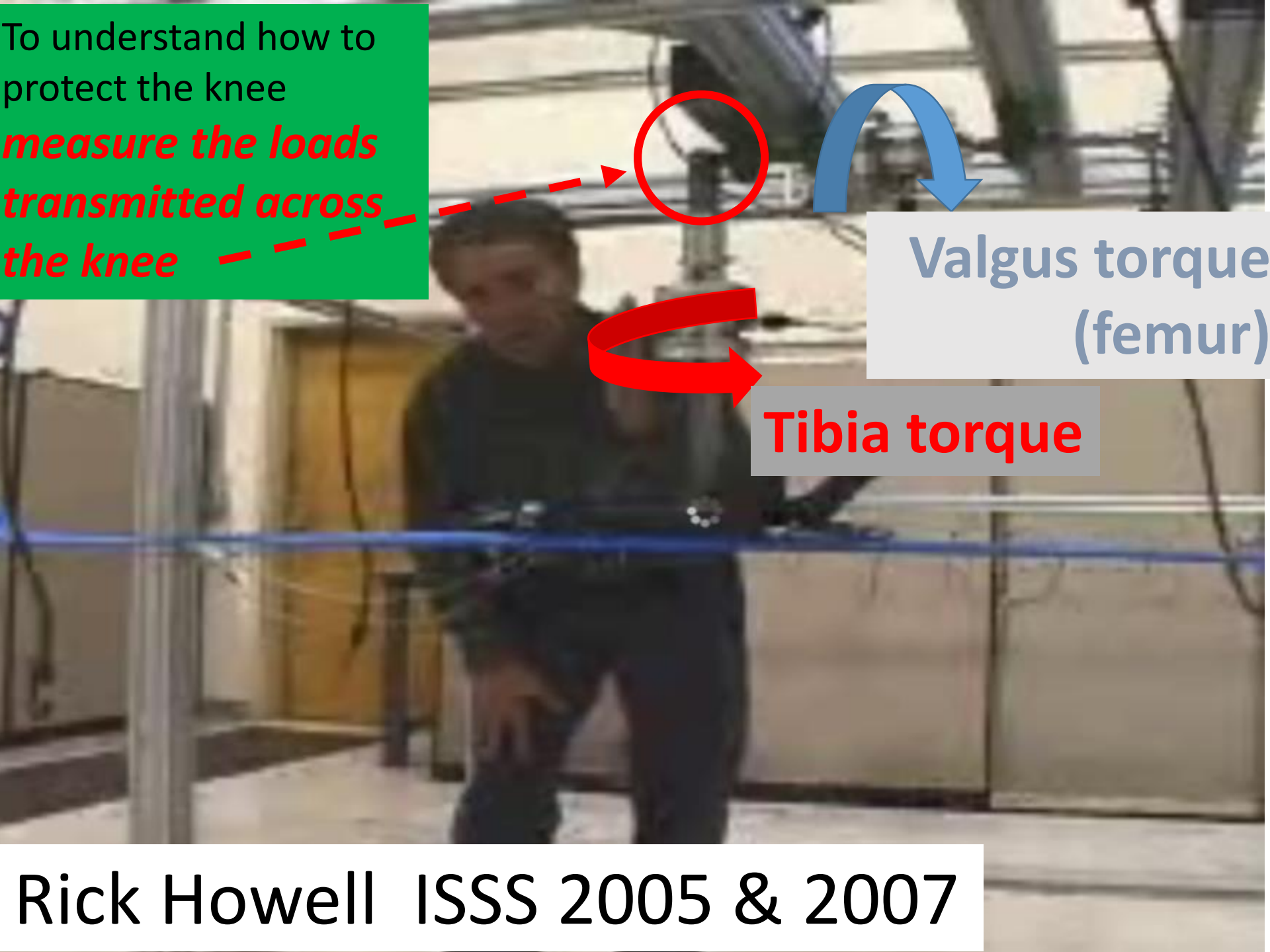
# Binding rotation axes

Conventional rotation axis  
Aligned approximately  
with tibia shaft  
*(lateral toe release)*

Additional rotation axis  
To mitigate valgus loads  
*(lateral heel release)*



To understand how to protect the knee  
*measure the loads transmitted across the knee*



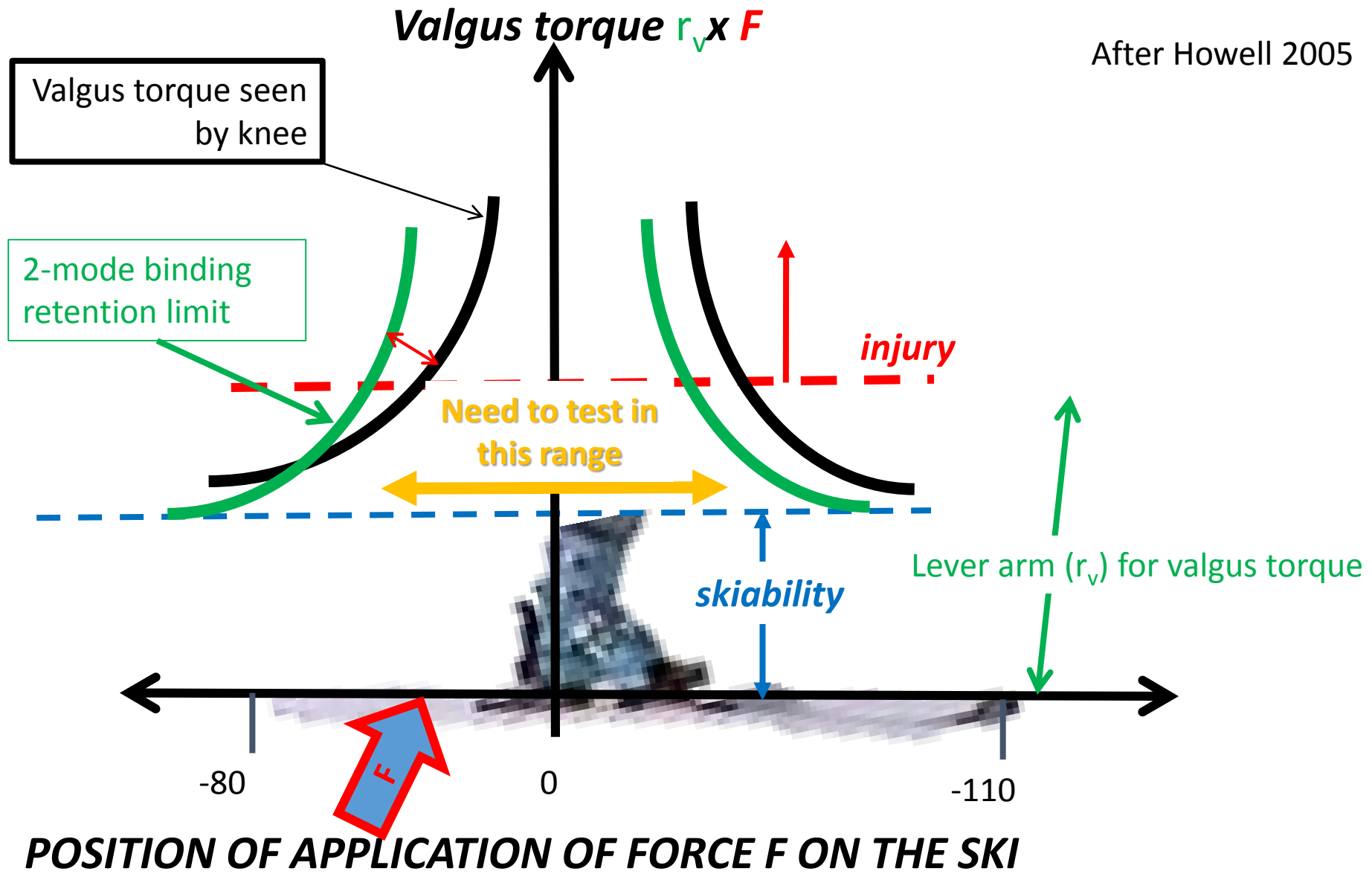
Valgus torque  
(femur)

Tibia torque

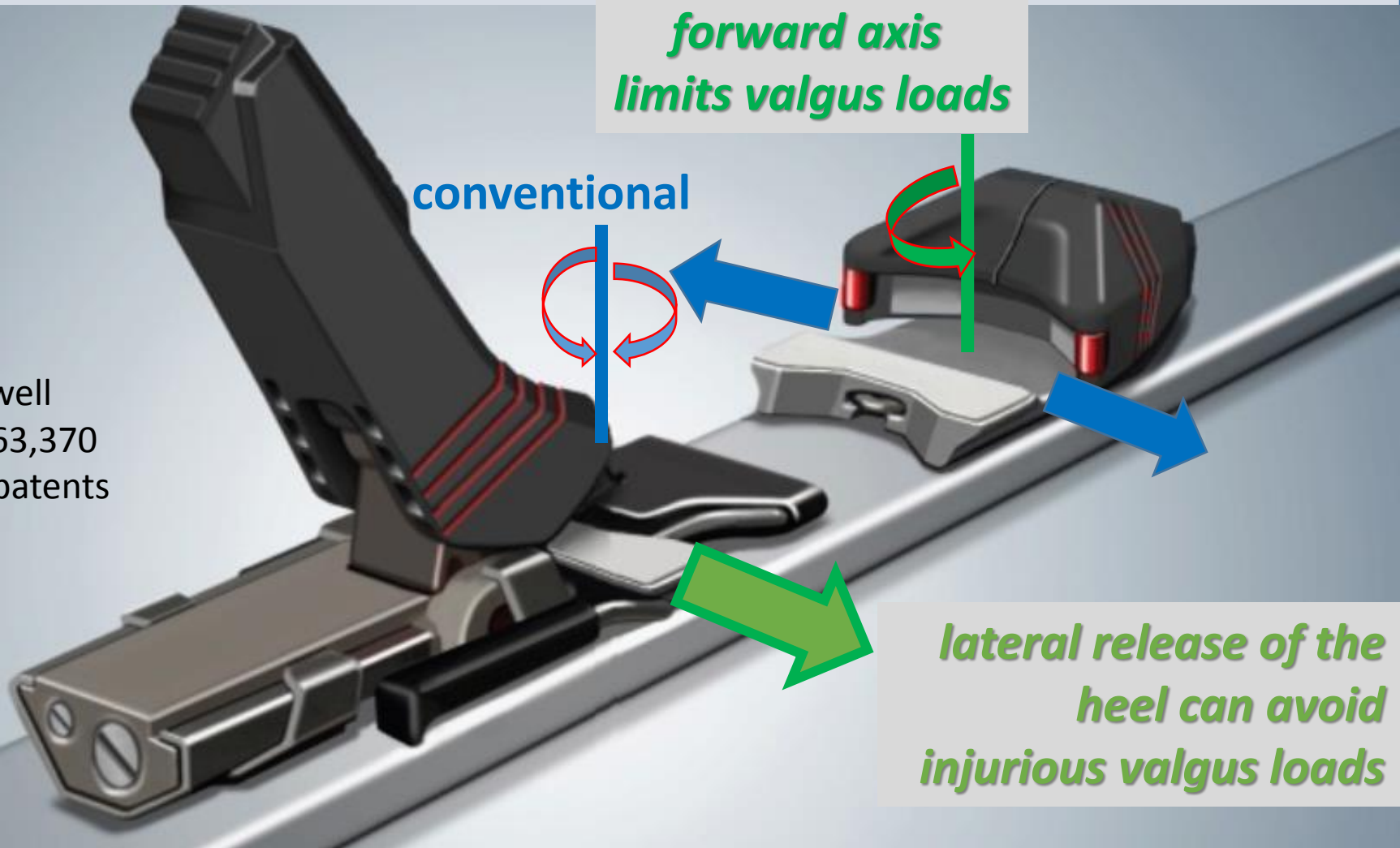
Rick Howell ISSS 2005 & 2007

# Valgus torque

After Howell 2005



# ACL protection two pivots for lateral release

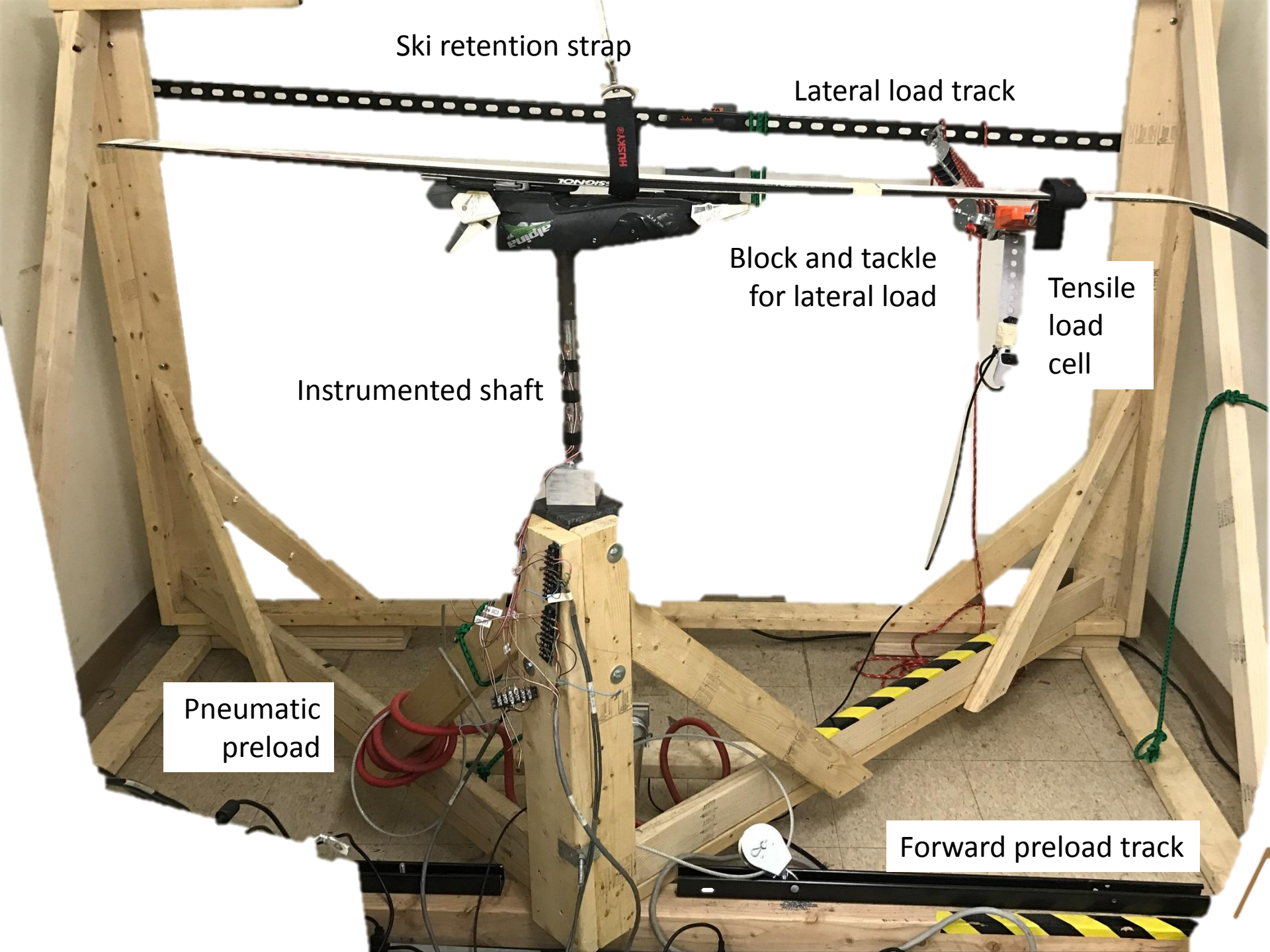


*forward axis  
limits valgus loads*

conventional

Rick Howell  
U.S. 9,463,370  
foreign patents  
pending

*lateral release of the  
heel can avoid  
injurious valgus loads*



Ski retention strap

Lateral load track

Block and tackle  
for lateral load

Tensile  
load  
cell

Instrumented shaft

Pneumatic  
preload

Forward preload track

Thank you very much  
for your attention!

