Player Surface Interaction: Injury and Performance

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Player Surface Interaction

- **Injury**
  - traction
- **Performance**
  - energy

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Sport Surfaces and Injuries

Overuse and acute injuries

- non uniformity
- high stiffness
- minimal surface deformation
- insufficient friction
- excessive friction

⇨ Experimental evidence?

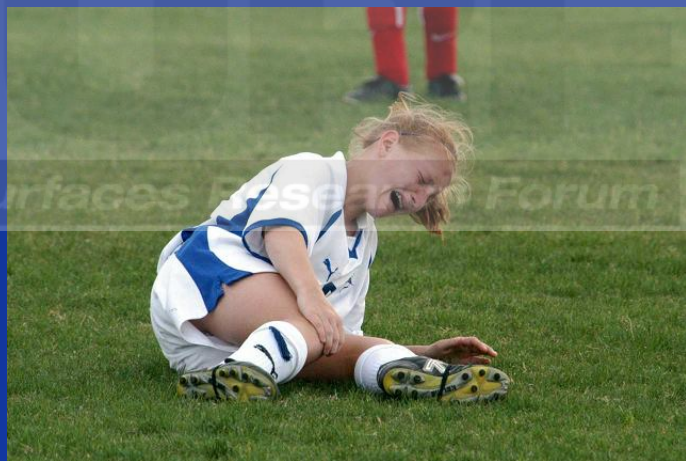
Soccer Injury

- Cutting and dribbling

- 2/3 of ACL injuries non-contact

Andreasson et al., 1986

Ekstrand and Nigg, 1989



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Tennis Injuries

Surface	Frequency of pain [%]	Rel. Frequency of pain [%/hours/week]
Clay	2.2	0.5
Synthetic Sand	3.0	1.6
Synthetic Surface	10.7	3.0
Asphalt	14.5	3.9
Felt Carpet	14.8	4.8
Synthetic Grill	18.0	3.8

Nigg et al., 1980

Traction and Injuries

Torg and Quedenfeld, 1971-1974

- Quantified number and severity of knee and ankle injuries in American Football

- 4 seasons
  first season - 7 stud football shoe
  following seasons - 15 stud soccer shoe

American Football Injury

	Football shoe Injuries/team/game	Soccer shoe Injuries/team/game
Public league		
Knee	0.33	0.14-0.17
Catholic league		
Knee	0.58	0.22-0.24
ankle	0.45	0.23-0.25

Torg and Quedenfeld, 1971

American Football Injury

- Rotational traction
- Release coefficients on grass

Football shoe	.55 ± 0.06
Soccer shoe	.28 ± 0.03

Torg and Quedenfeld, 1974

American Football - Traction

Release Coefficients

0.60

Not safe

0.50

football shoes
0.55 – 0.06 = 0.49

Probably not safe

0.40

Probably safe

soccer shoes
0.28 + 0.03 = 0.31

0.30

Safe

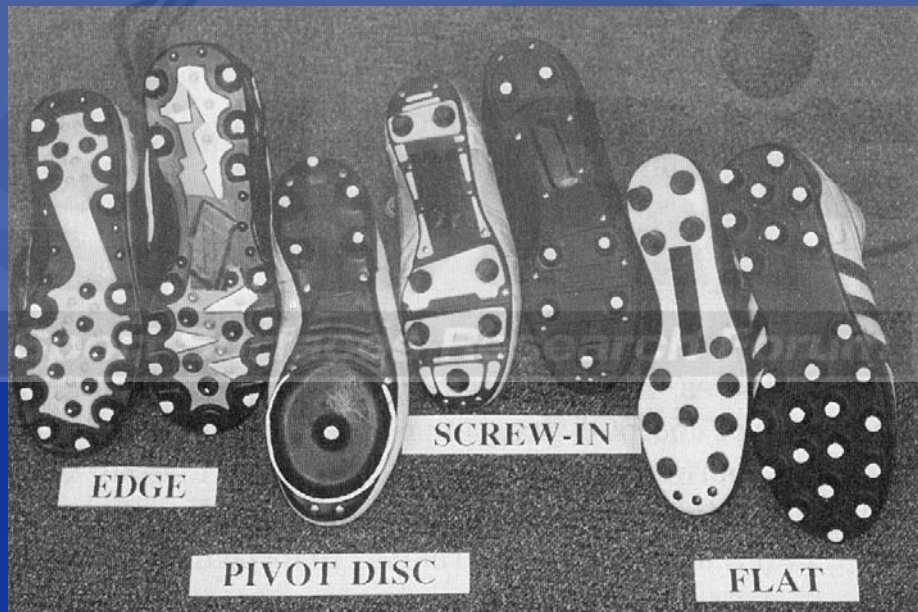
0.20

Torg and Quedenfeld, 1974

Traction and Injury

Lambson et al., 1996

- Quantified ACL injuries in American Football
- 3 seasons Prospective
- 4 shoe conditions



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Traction and Injury

Shoe	ACL Tears	Injury Rate	Art. Turf Torque [Nm]	Nat. Turf Torque [Nm]
Edge	38	0.017	52.0	31.0
Flat	3	0.004	40.0	25.5
Screw in	1	0.015	35.0	24.0
Pivot disk	0	0.000	38.5	21.5

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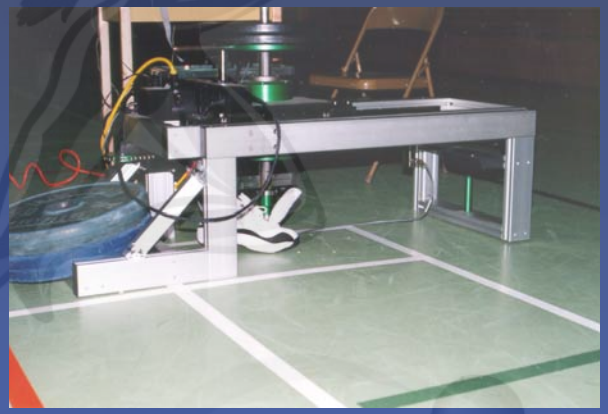
Lambson et al., 1996

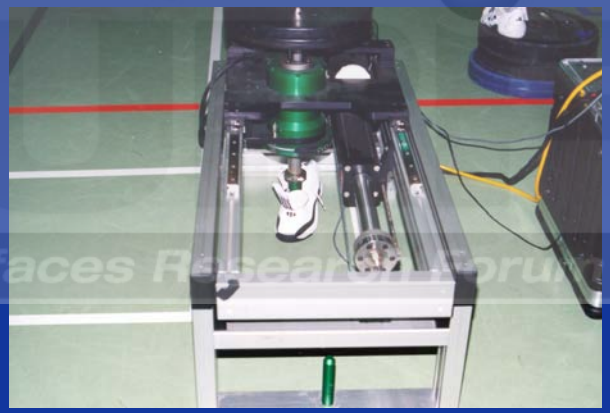
Factors Affecting Traction

Not Coulomb friction

(e.g. Van Gheluwe et al., 1983; Valiant et al., 1985; etc.)



- **Relative velocity**
- **Normal force**
- **Surface contact area**



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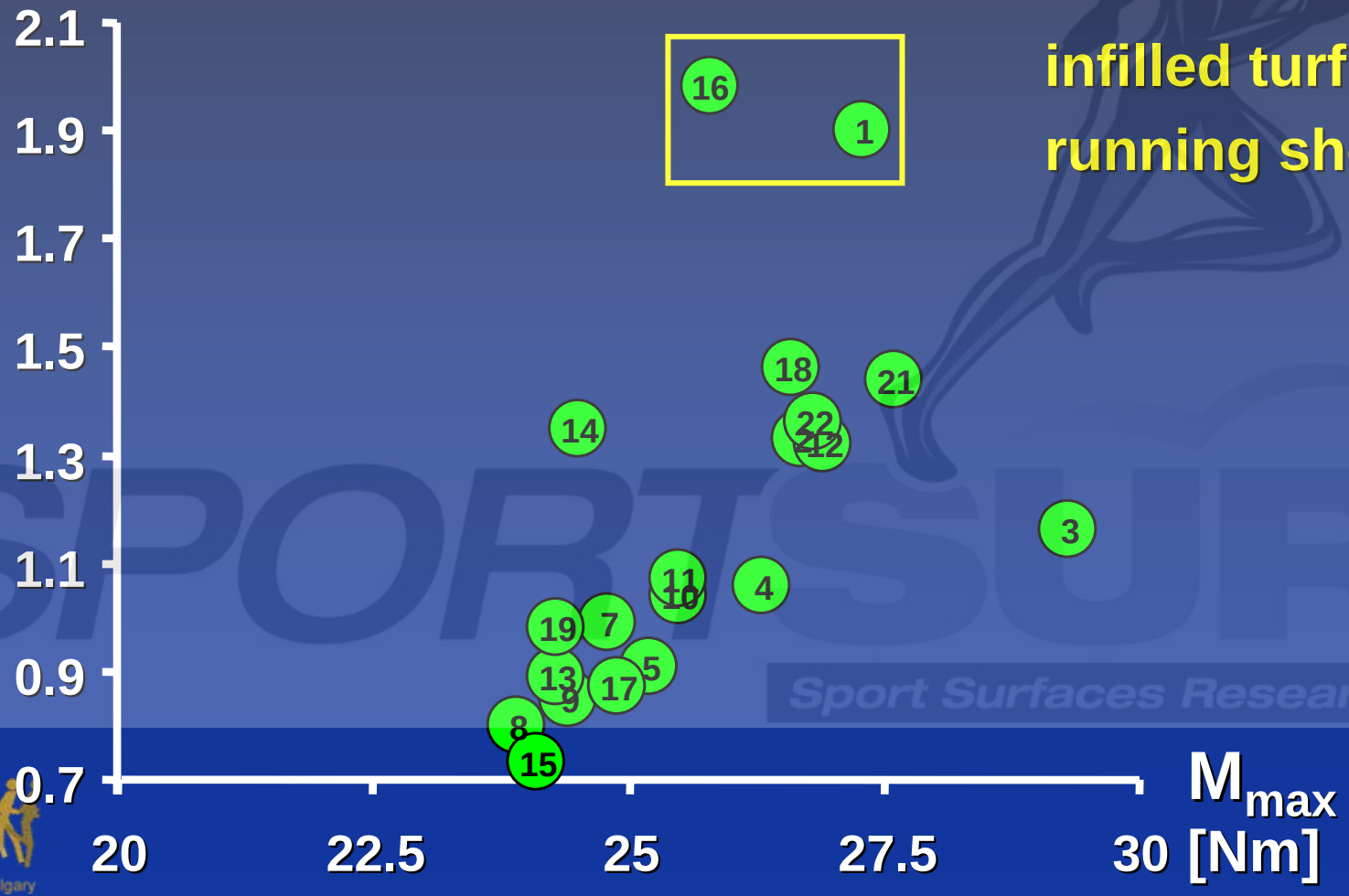
Influence of Surface

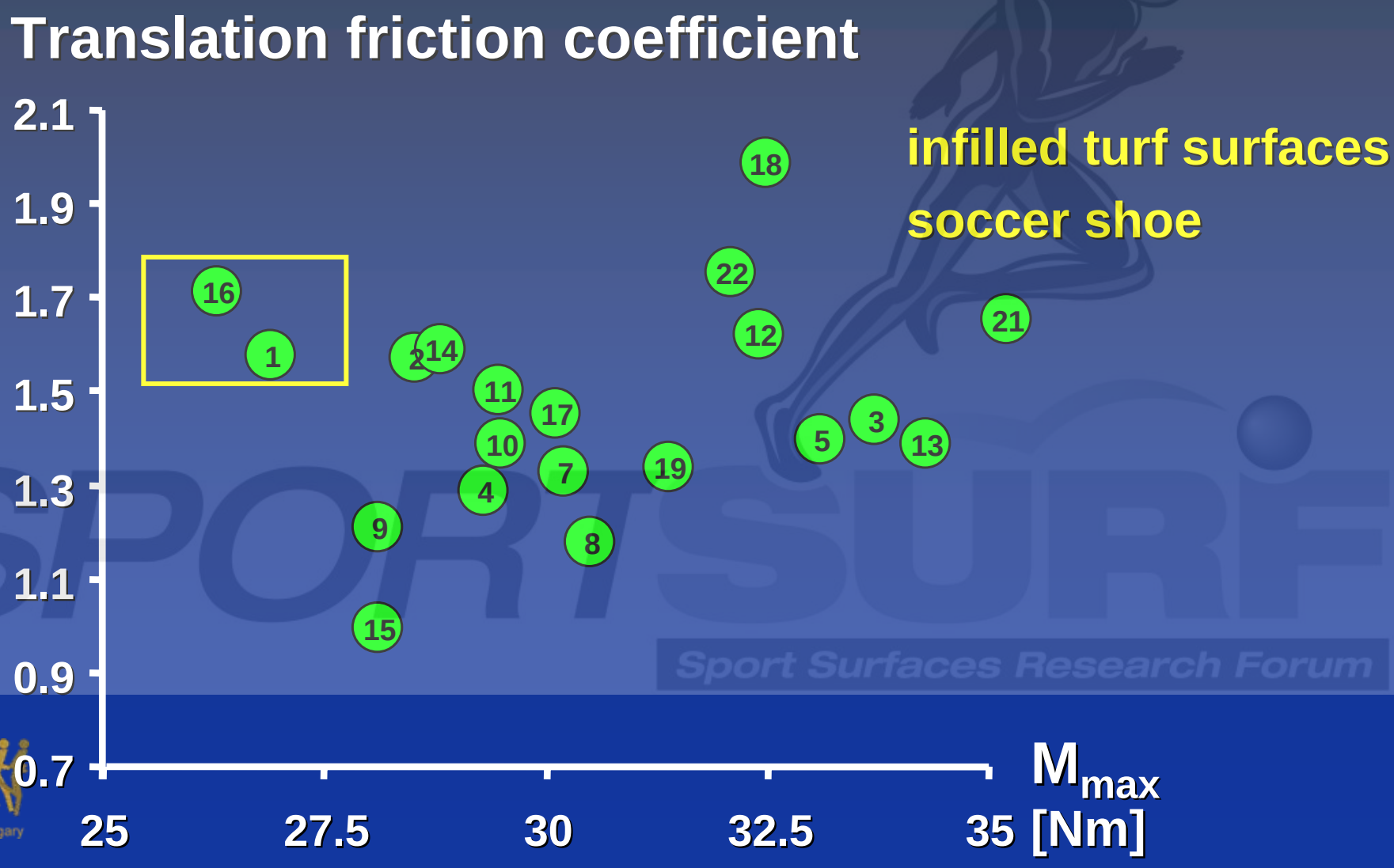
Translation friction coefficient



infilled turf surfaces

running shoe

Influence of Surface



Traction and Internal Loads

Joint loading ultimately plays a functional role in the development of sport injuries.

Traction
↓
Joint Loading
↓
Injury

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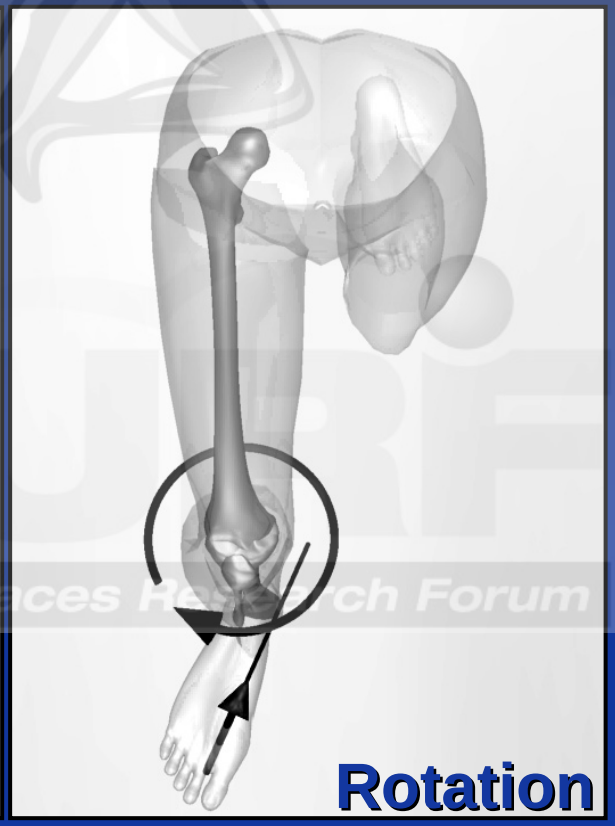
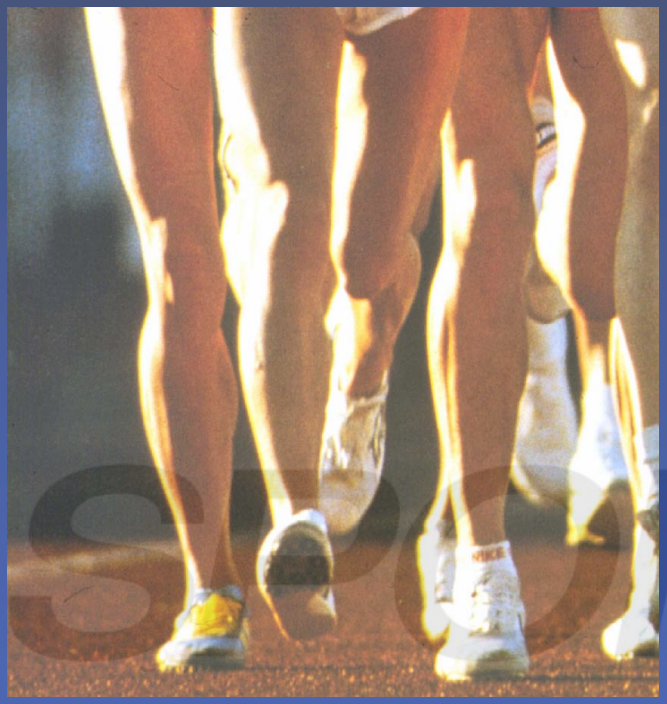
Knee Joint Moments

Sagittal **Frontal** **Transverse**



PFPS Retrospective Study

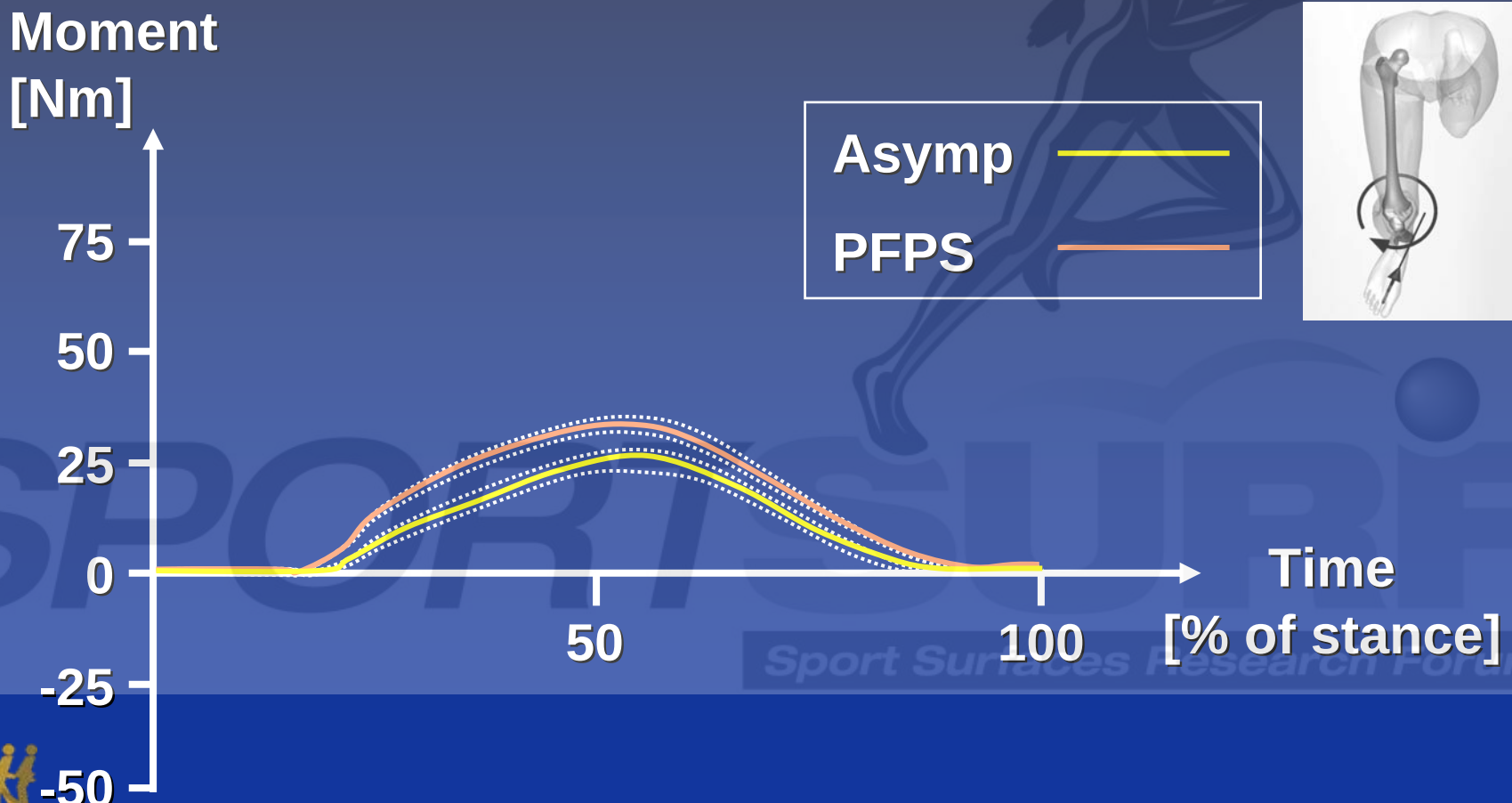


Two groups of runners

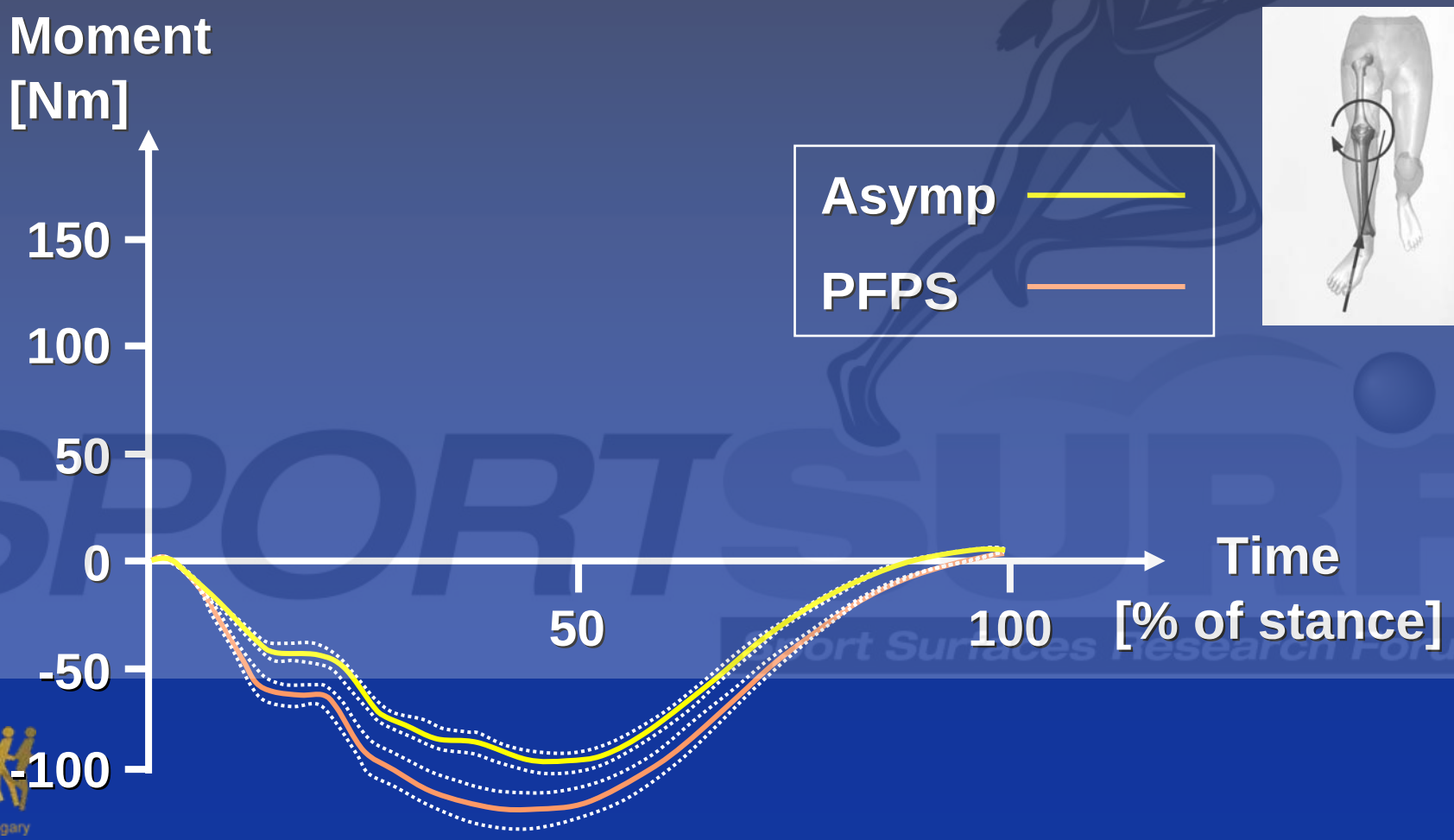
Group 1 (n=20)
positive PFPS diagnosis

Group 2 (n=20)
never diagnosed with PFPS

External Rotation Knee Moment Retrospective



Abduction Knee Moment Retrospective

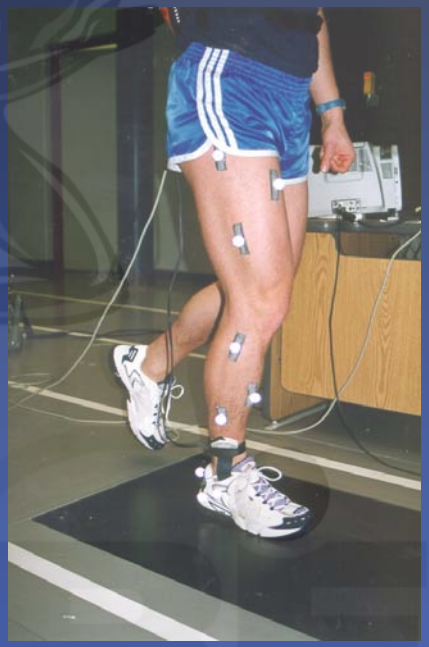


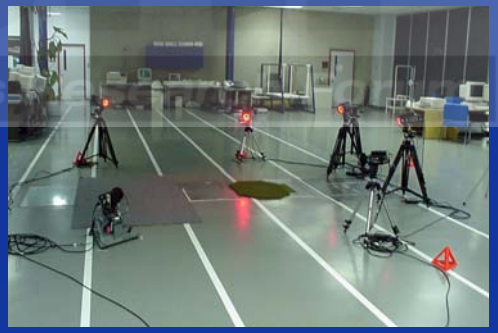
Retrospective PFPS

- Maximal external rotation moments were 8 Nm (22%) higher for injured runners
- Maximal abduction moments were 24 Nm (20%) higher for injured runners

Prospective Running Study

- 145 runners
- Bilateral data collected at beginning of running season
- Shod and barefoot
- Injury data collected over 6 month running season





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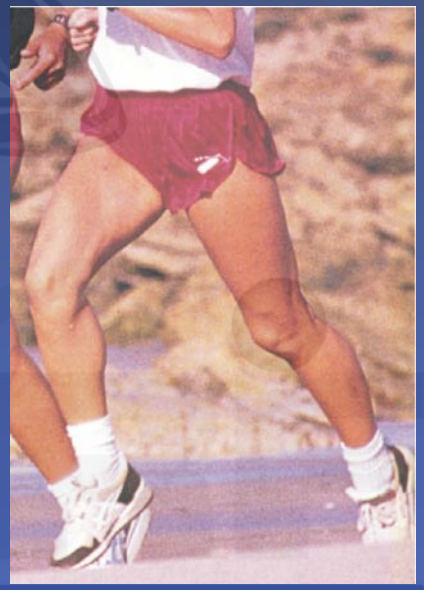
Prospective PFPS

- 6 subjects diagnosed with PFPS
- Physical examination criteria
- None had previous PFPS

Prospective PFPS

- 2 to 1 matched with uninjured subjects
  - gender
  - weekly running distance
  - years of running experience
  - mass



- 3-dimensional knee joint moments

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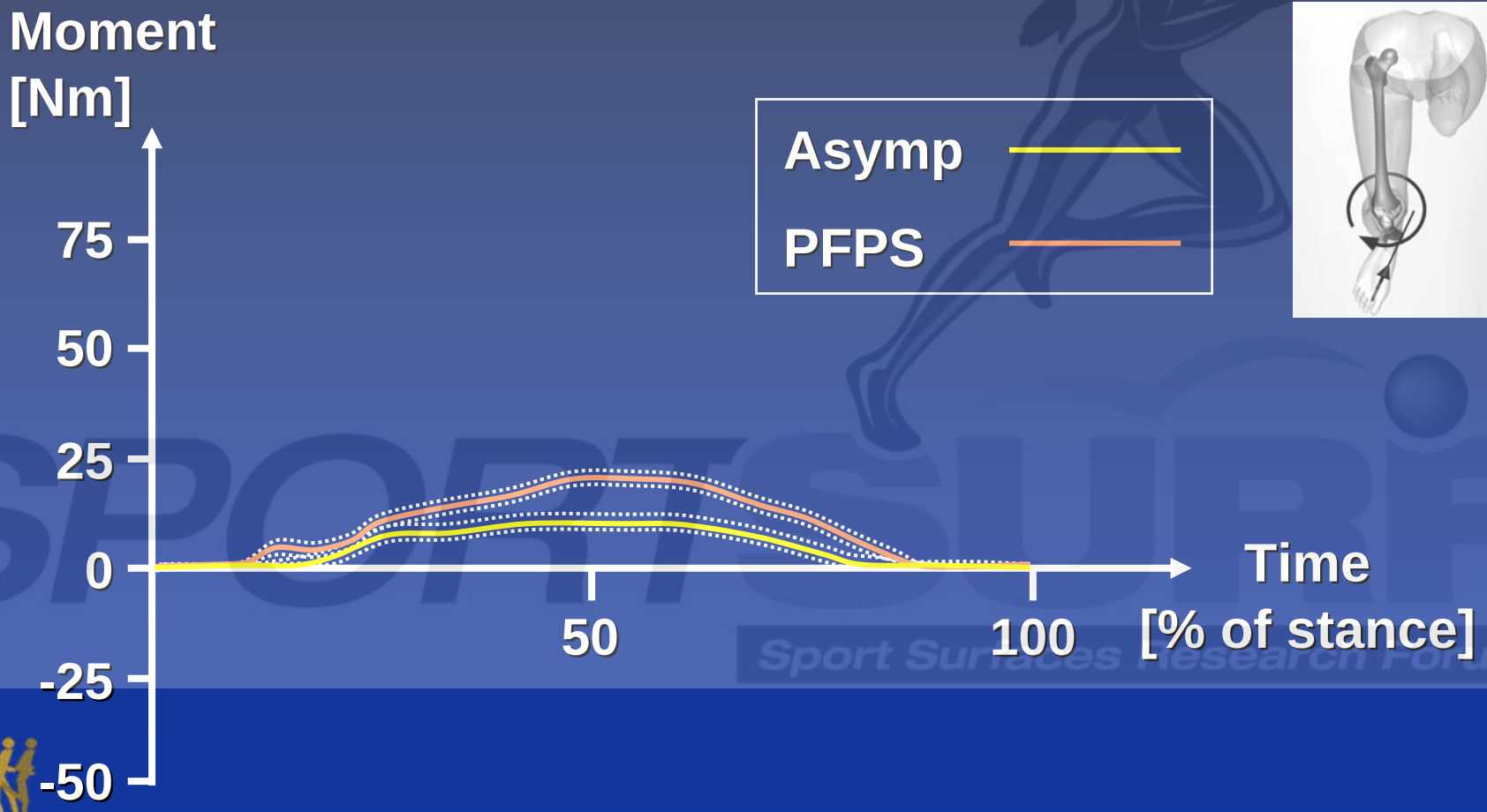
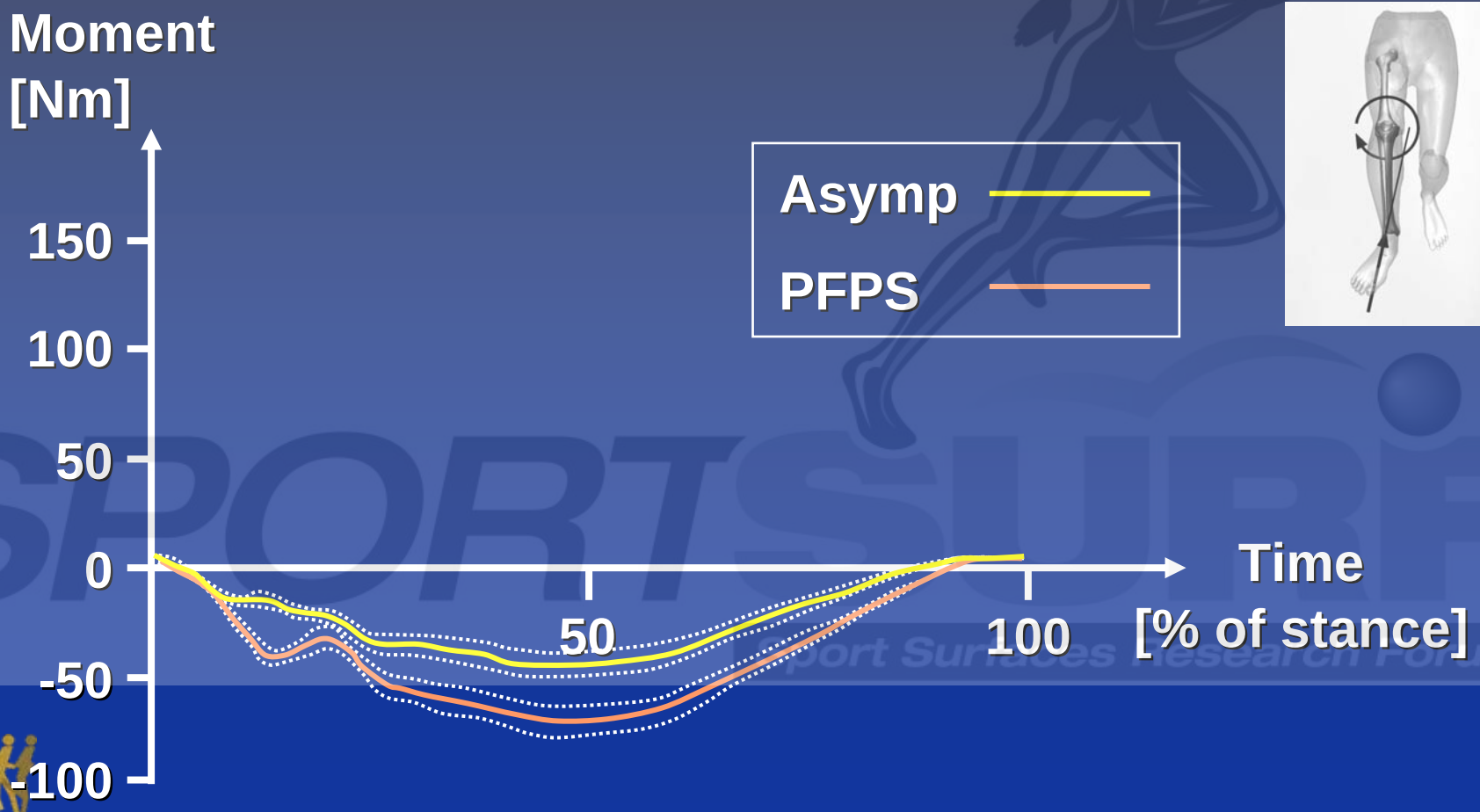
External Rotation Knee Moment Prospective



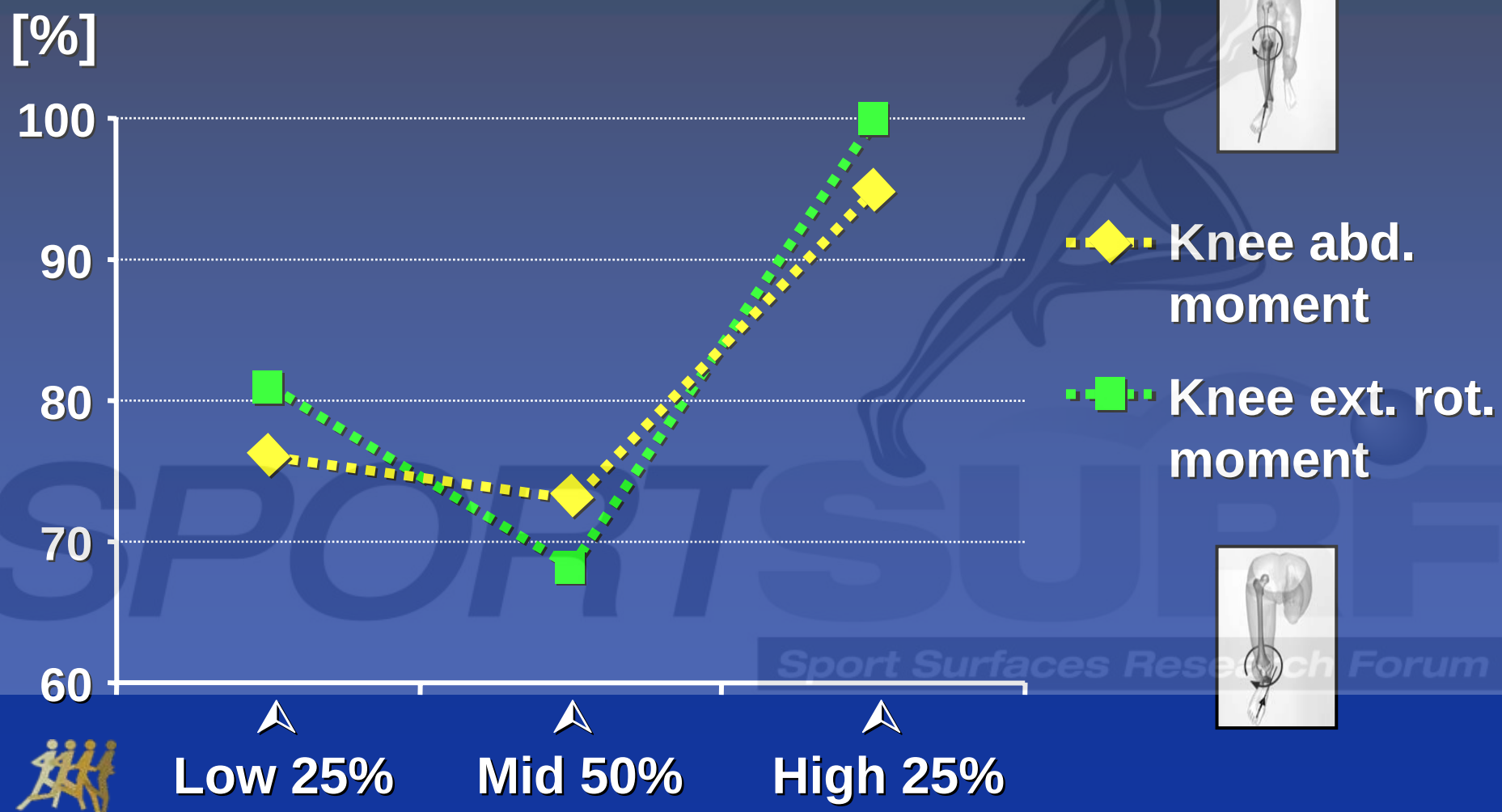
Abduction Knee Moment Prospective



Prospective PFPS

- Maximal external rotation moments were 9 Nm (90%) higher for injured runners
- Maximal abduction moments were 25 Nm (65%) higher for injured runners

Prospective Injury Frequency

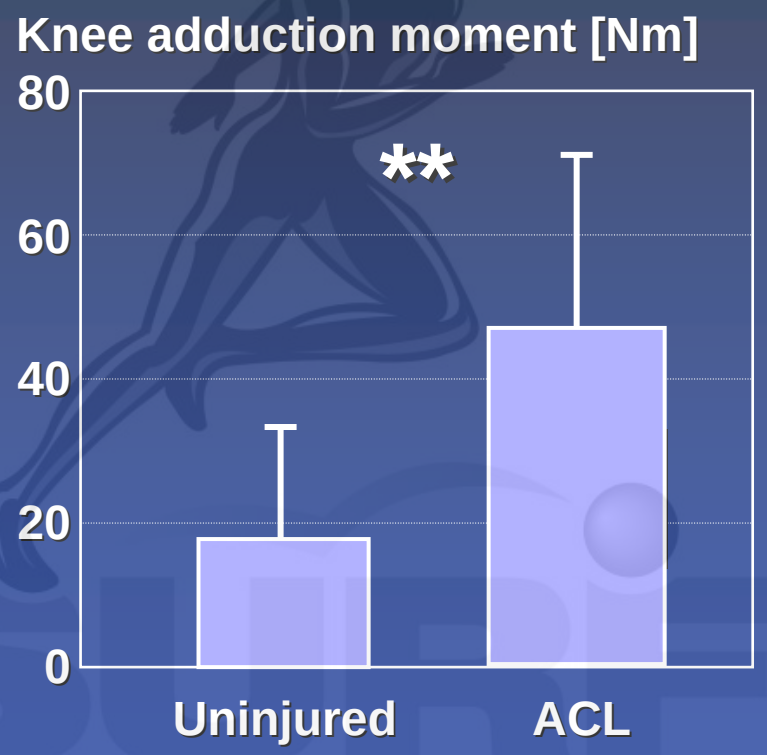


Stefanyshyn et al. (2001)

Knee Moments and Injury

Hewett et al. 2005

- Prospective study
- Female ACL injury
- 205 subjects



Mizuno et al. 2004

- Adduction and rotational moments result in high ACL strain

Sport Surfaces - Joint Moments

- 5 indoor sport surfaces
- 21 subjects

  11 male 10 female
- Three movements

  shuffle, vcut, run shuffle
- Standard court shoe

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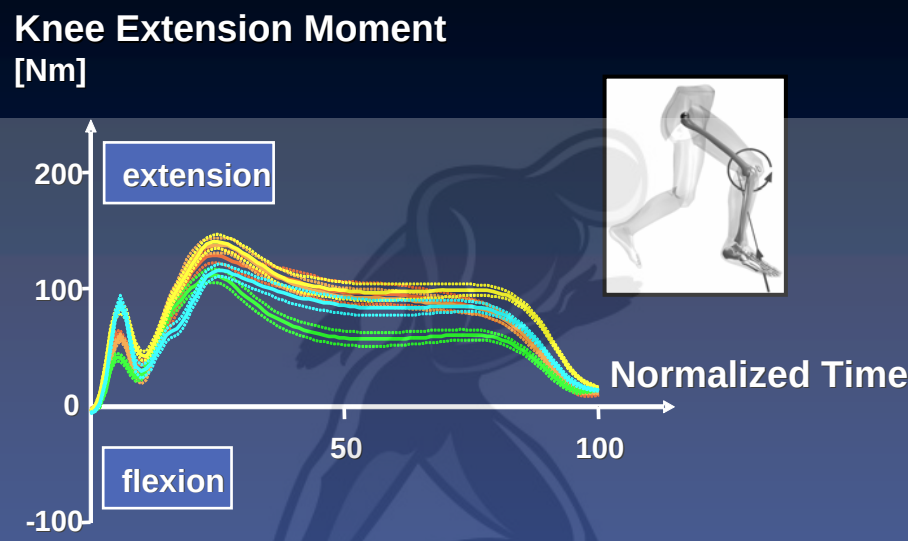
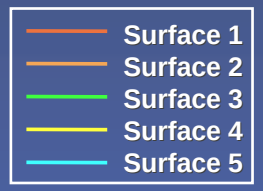
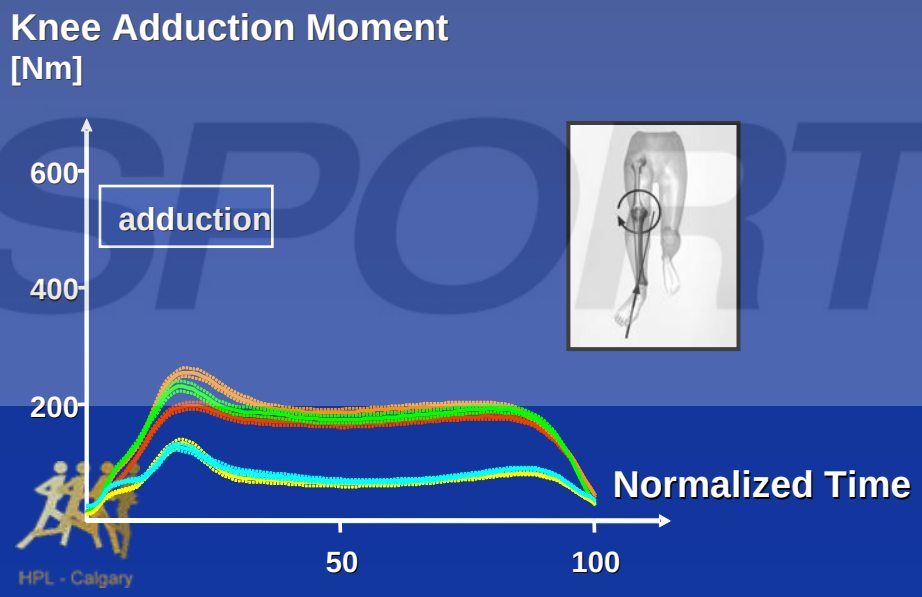
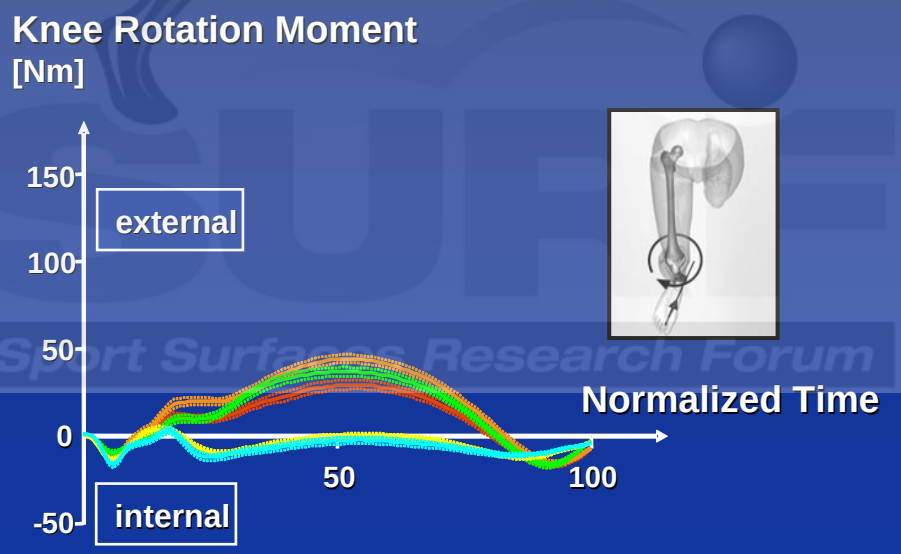
Knee Moments

Side Shuffle



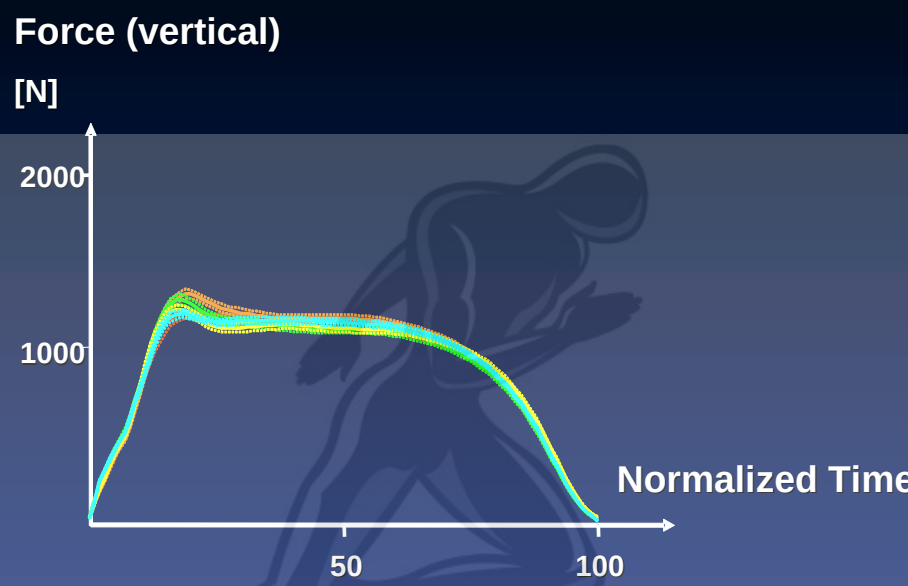


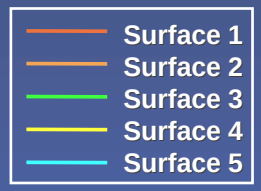


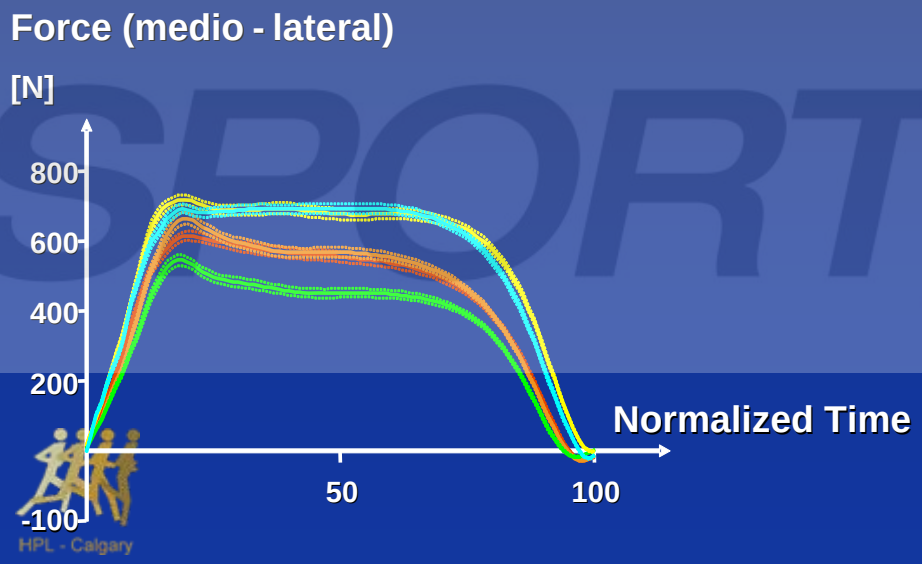


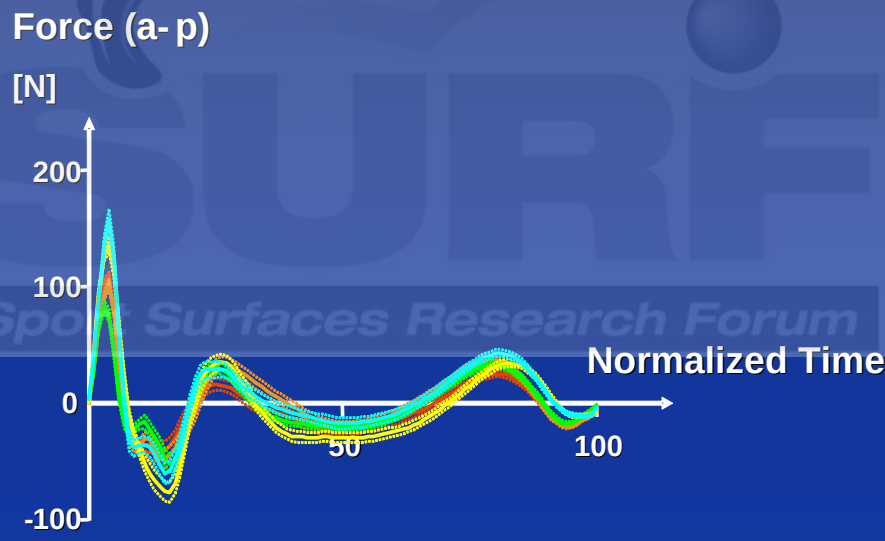
Forces

Side Shuffle

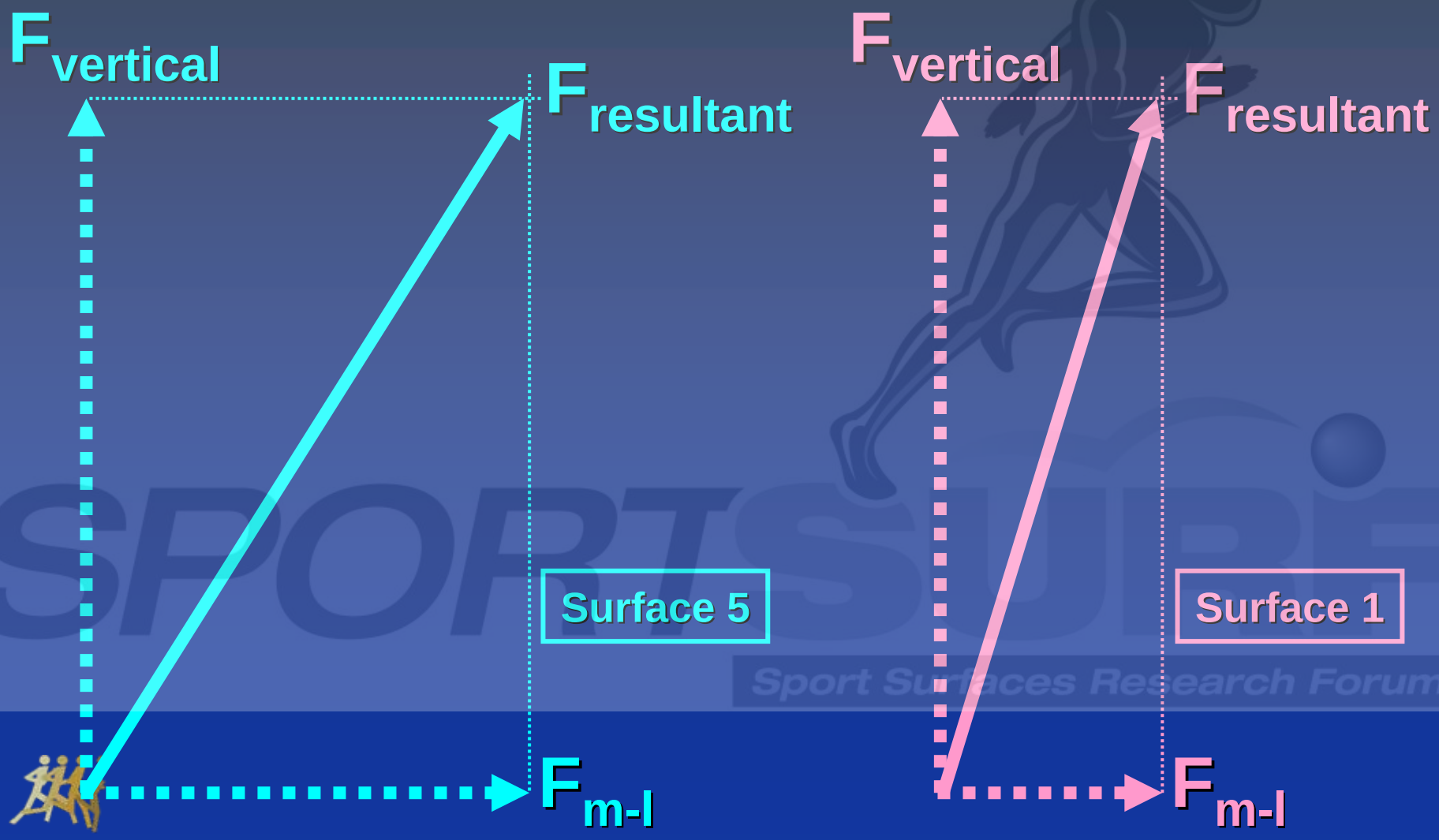


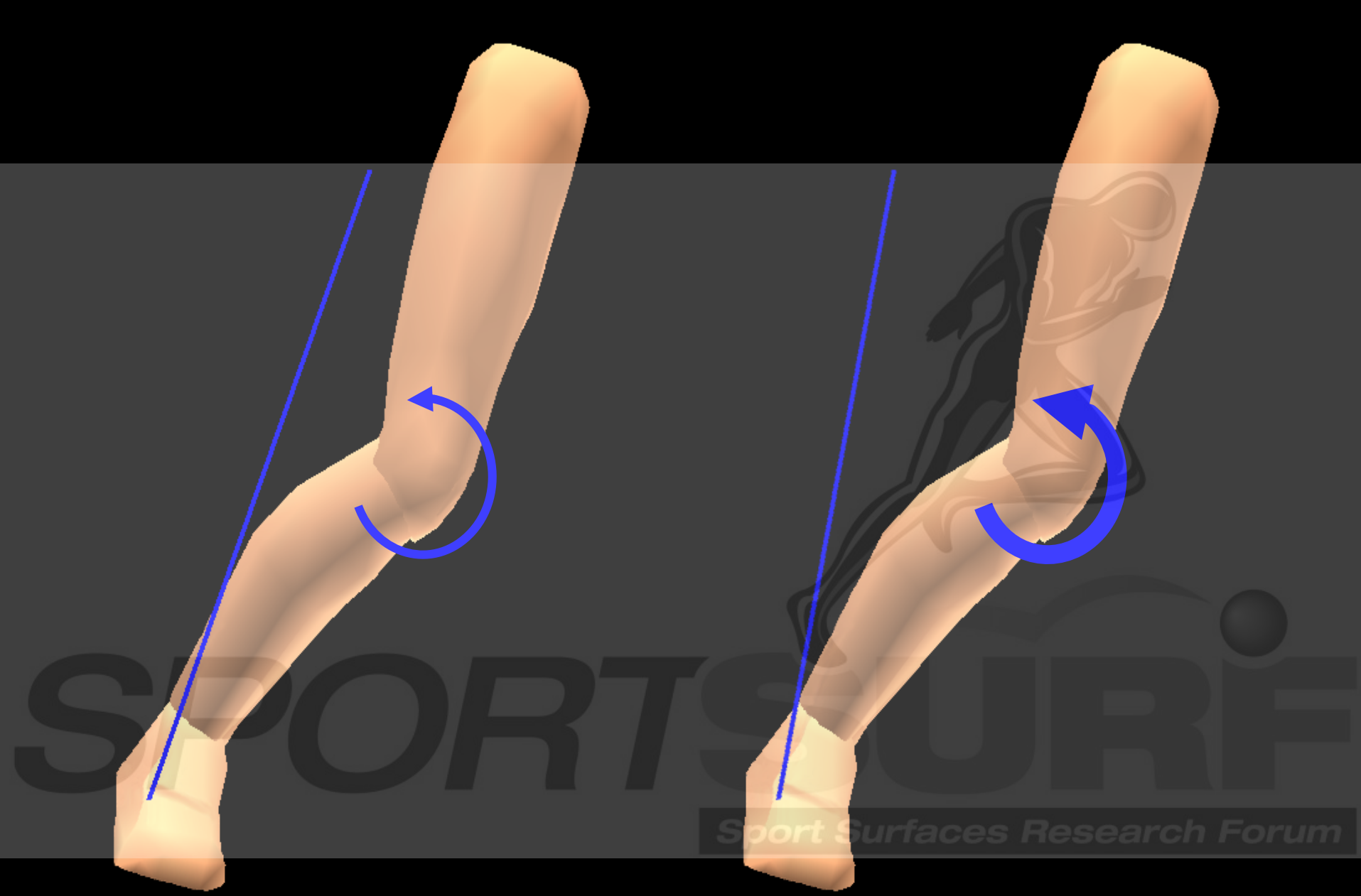




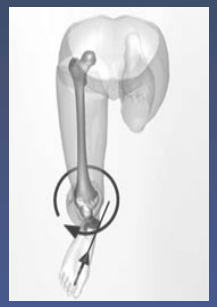


Influence of Surface

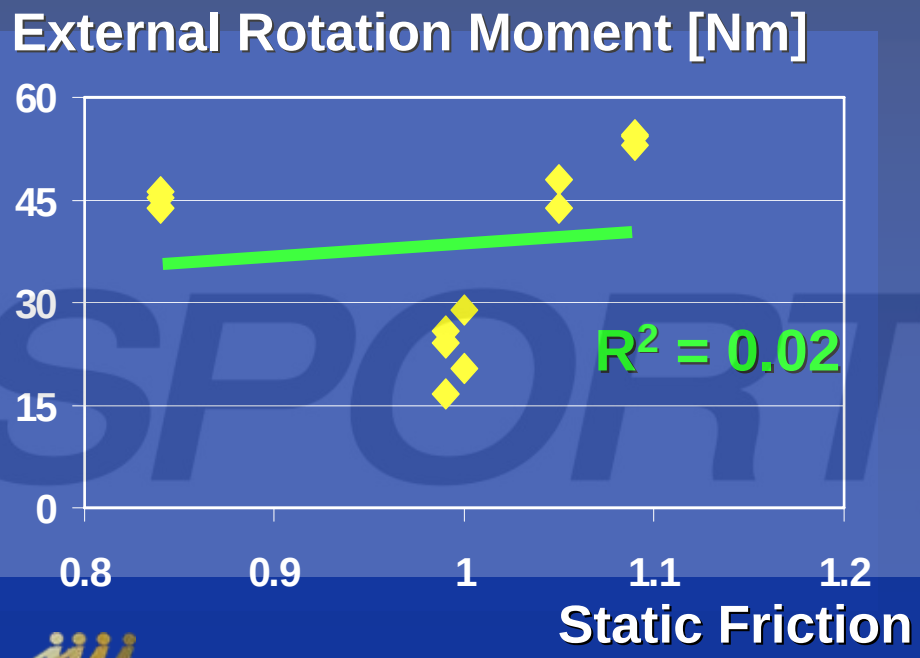


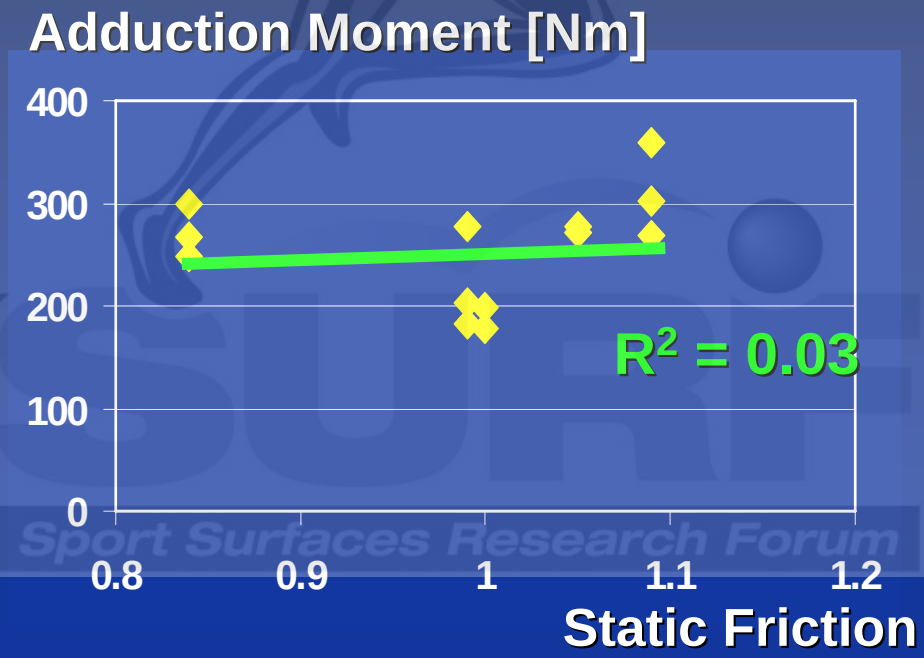

SPORTSURF
Sport Surfaces Research Forum

Translational Friction

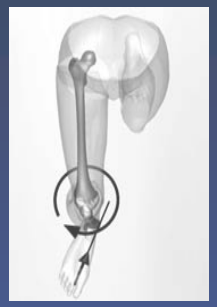


Knee moments



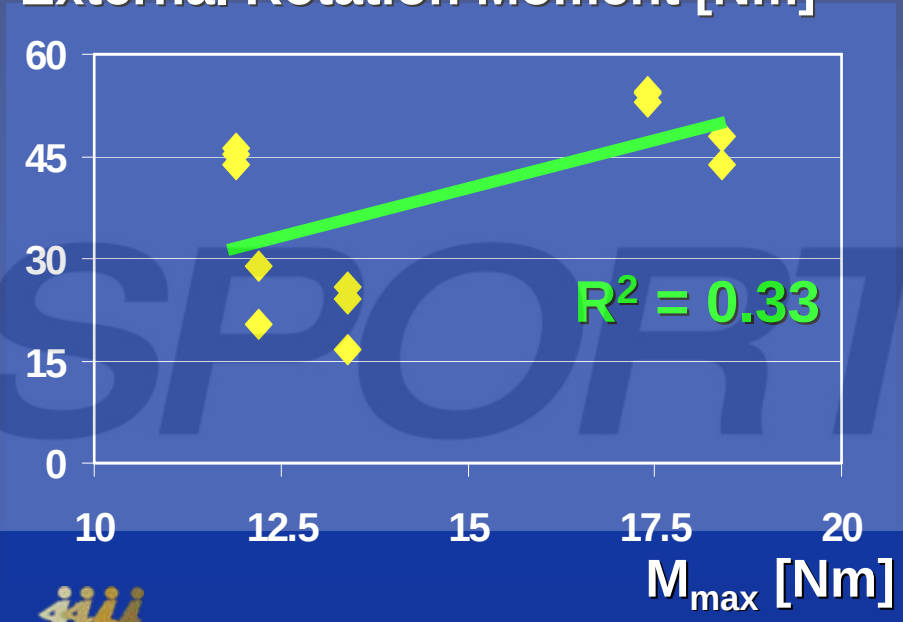


Rotational Friction

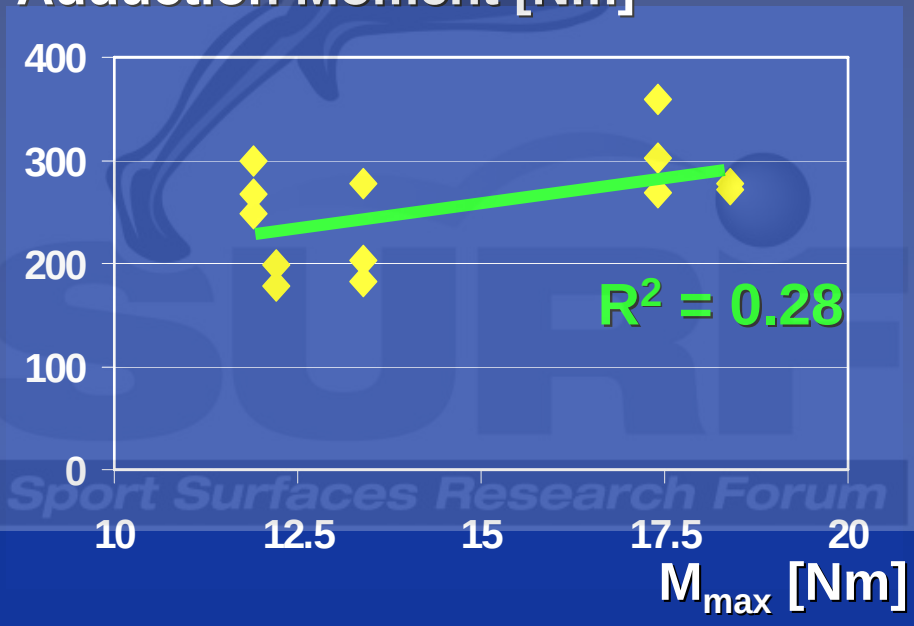


Knee moments

External Rotation Moment [Nm]

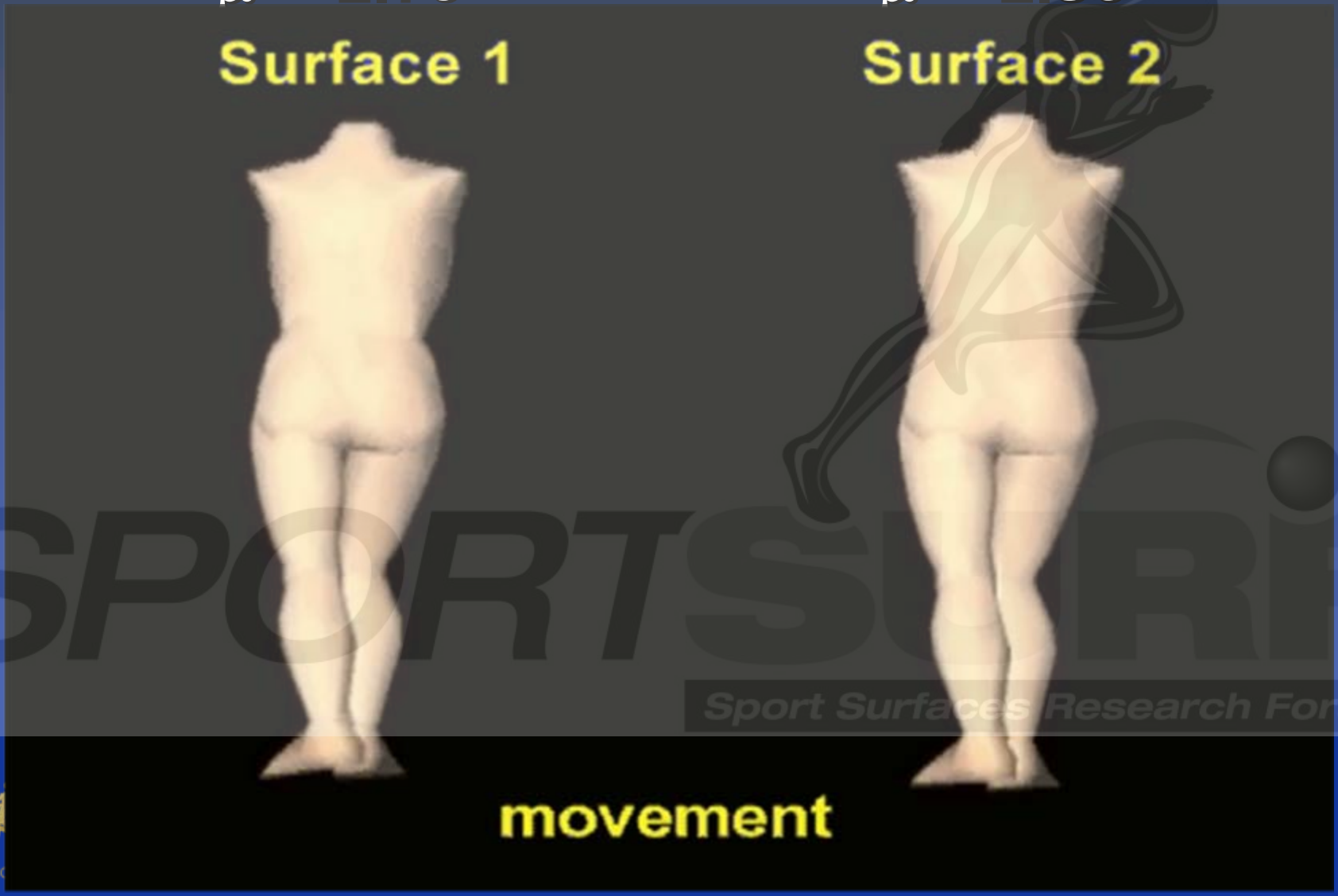


Adduction Moment [Nm]



Higher Friction Lower Friction

$\mu = 1.79$ $\mu = 1.36$



Soccer Shoes

- adidas Nova running
- adidas Copa
- adidas World Cup
- adidas TRX

Methods

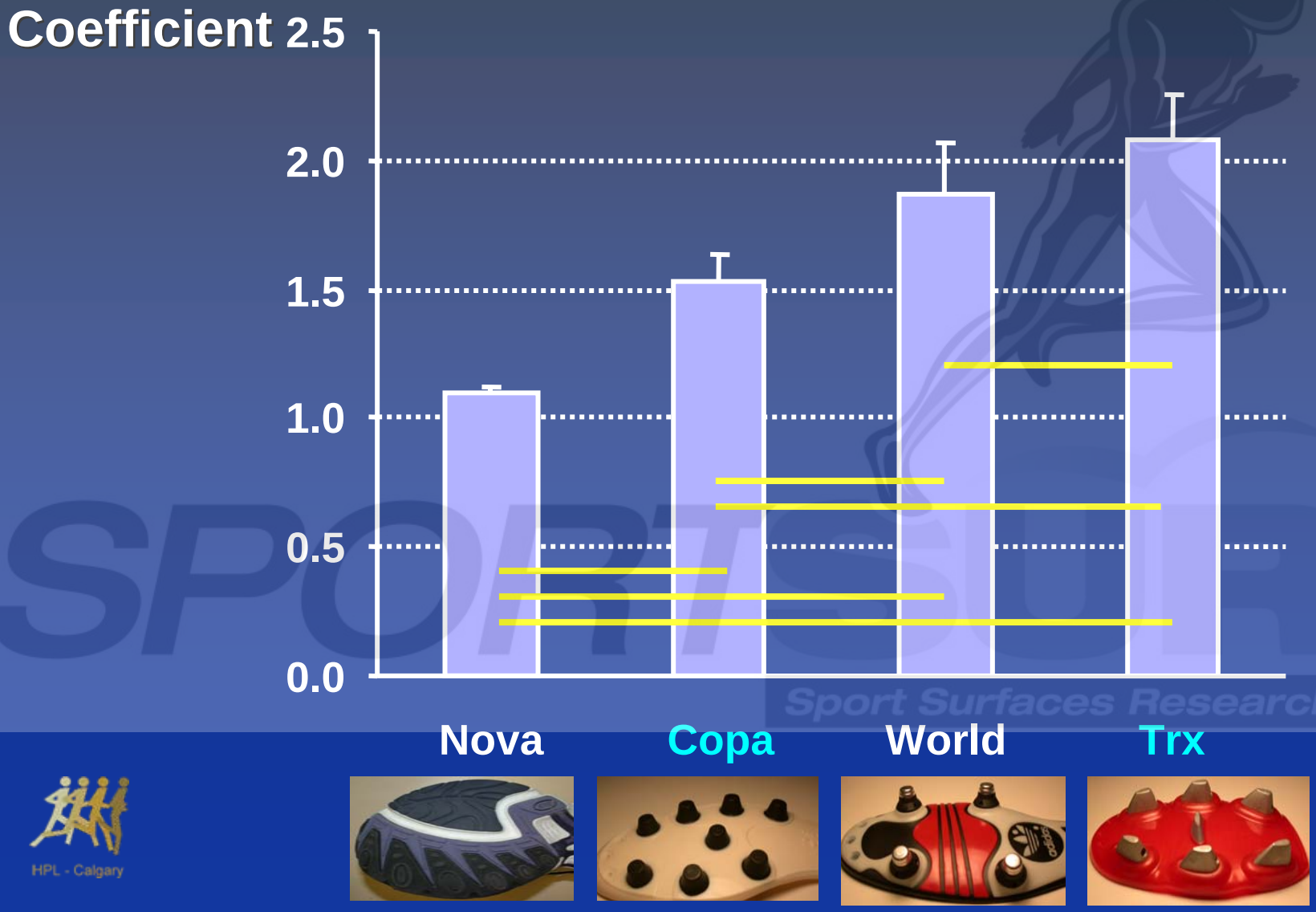
- 12 recreational soccer players
- Two movements

  running cut, 180° turn
- Infilled artificial turf
- Kinetics and kinematics

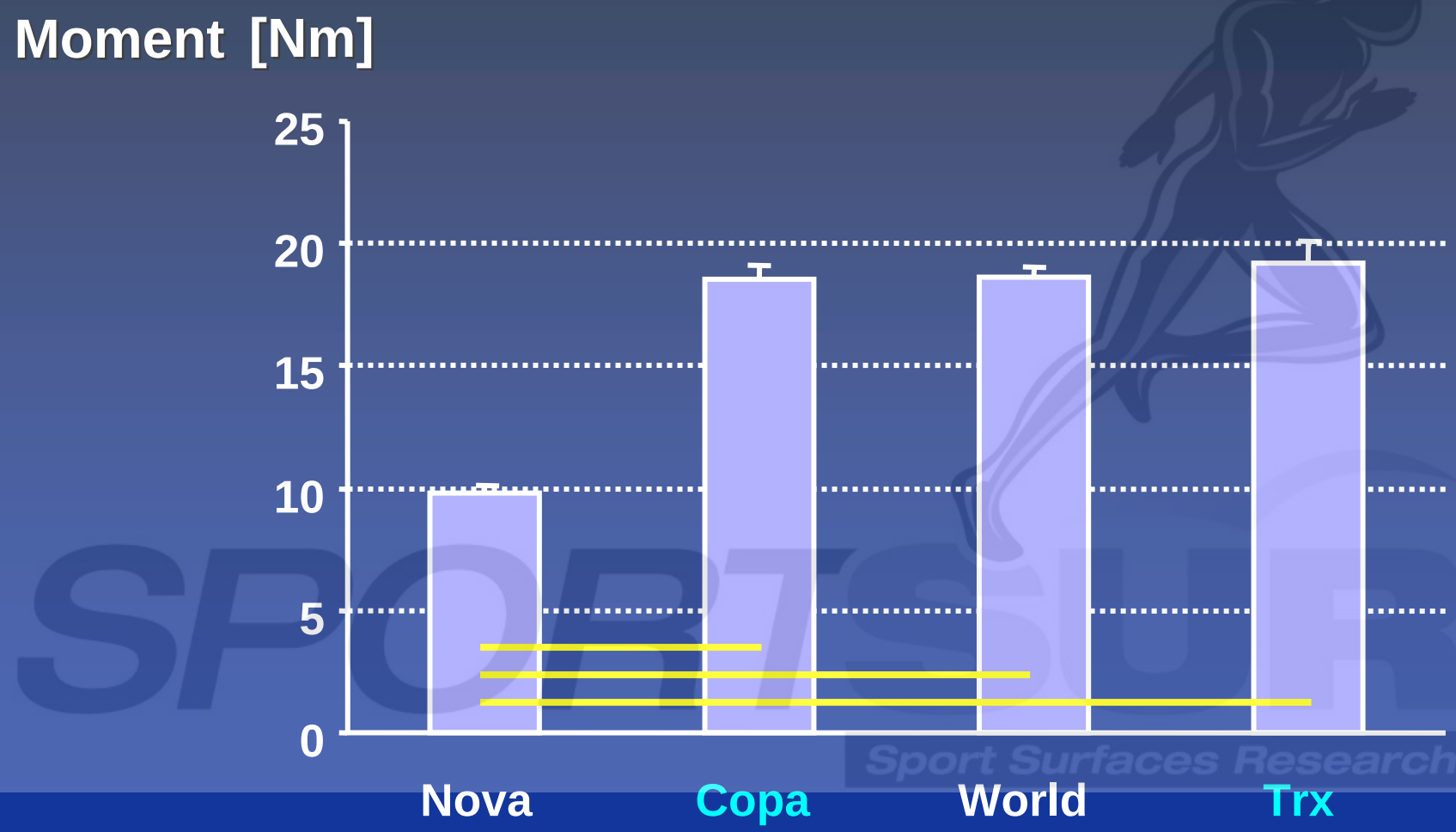
Methods - Traction

6-DOF Stewart platform

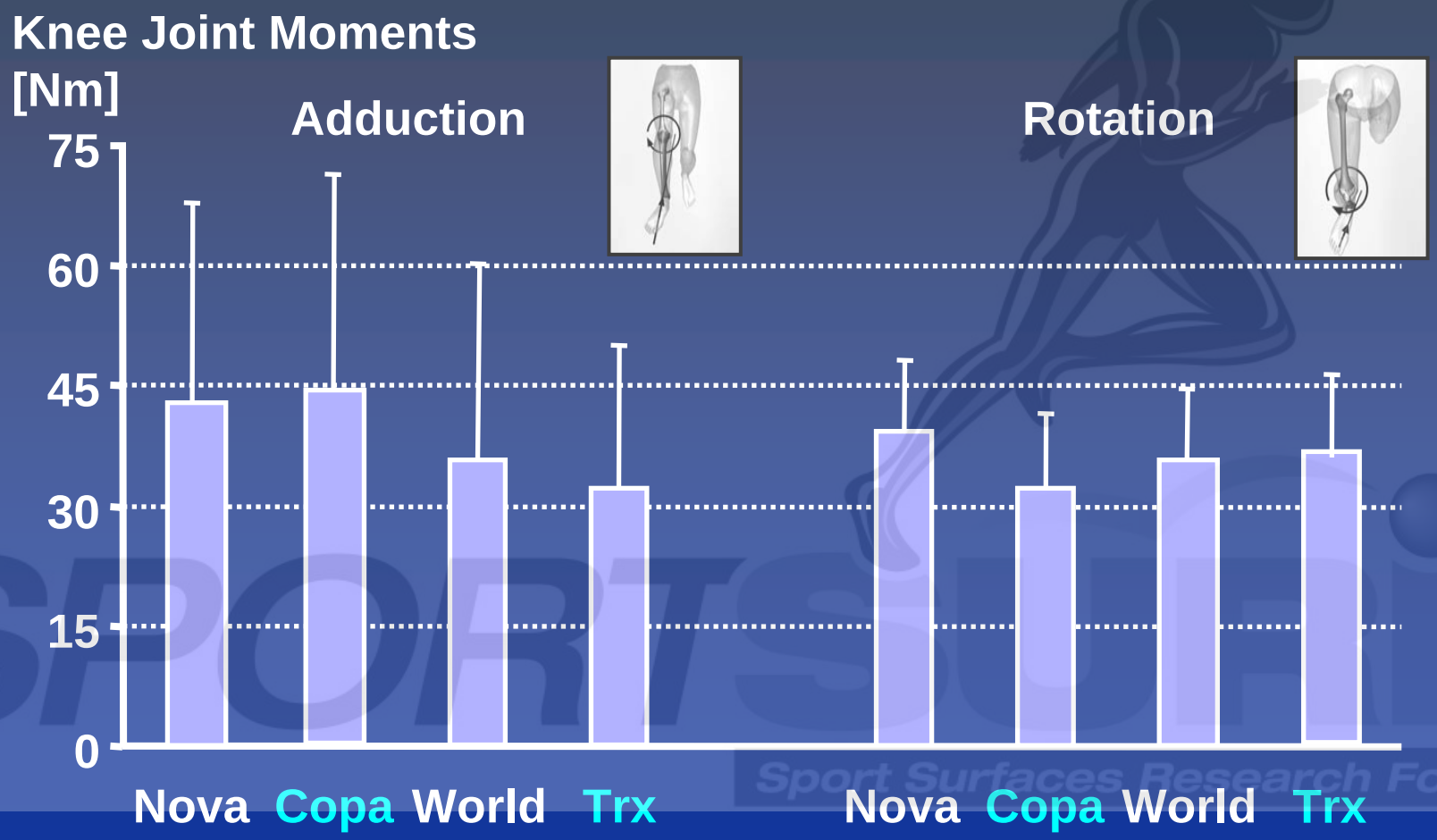
Linear Traction



Rotational Traction

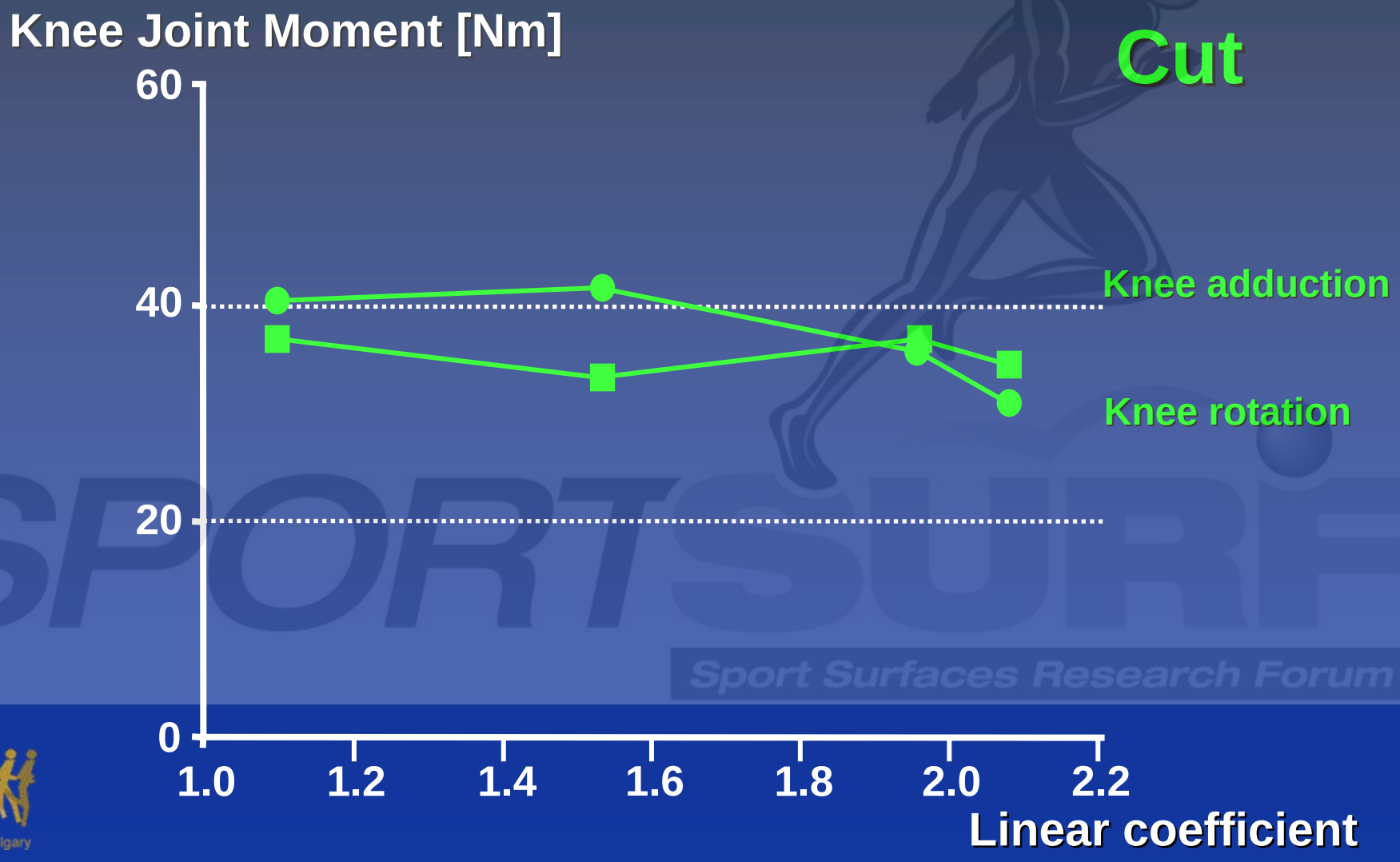


Cut – Knee Joint Moments

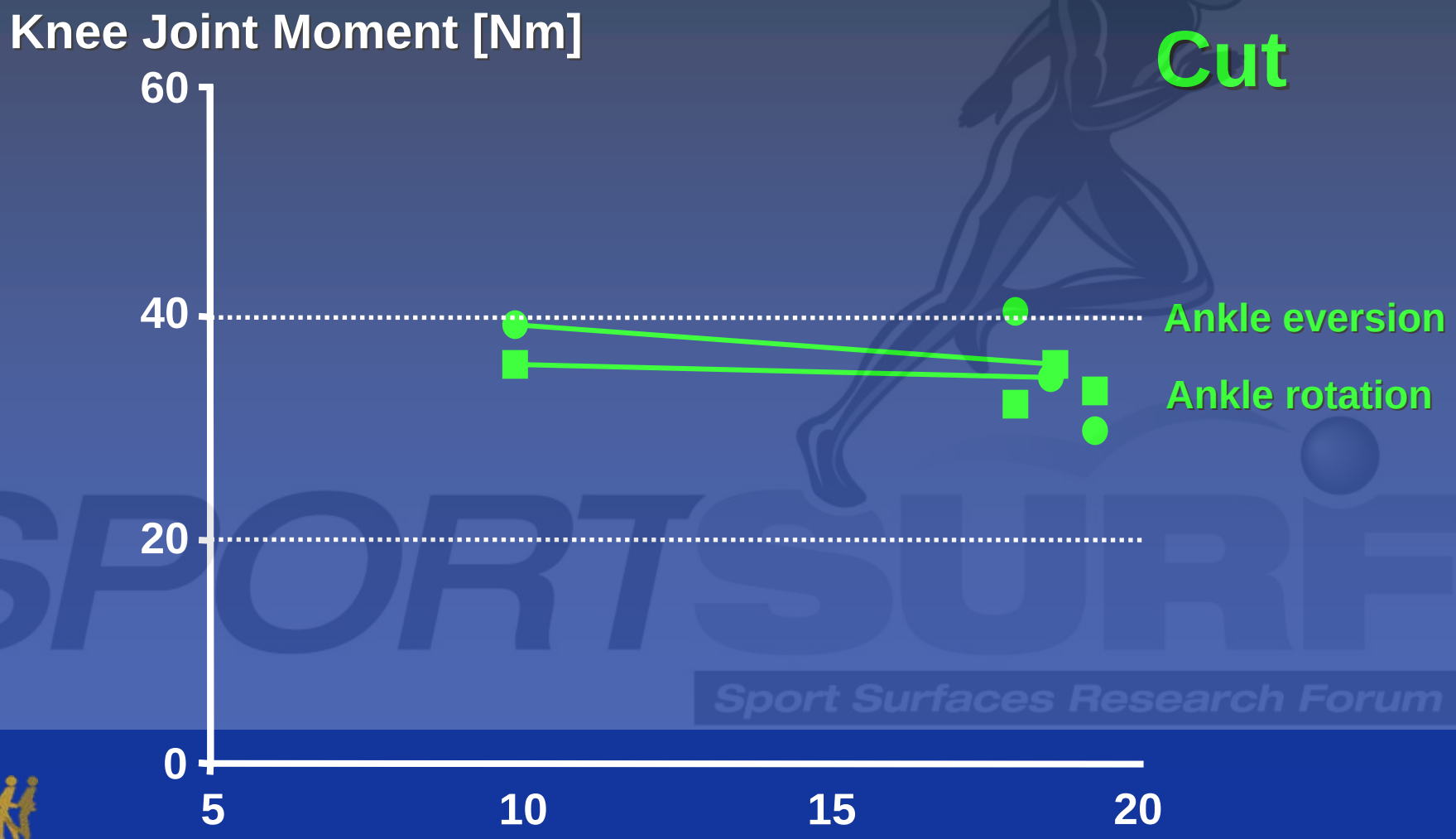




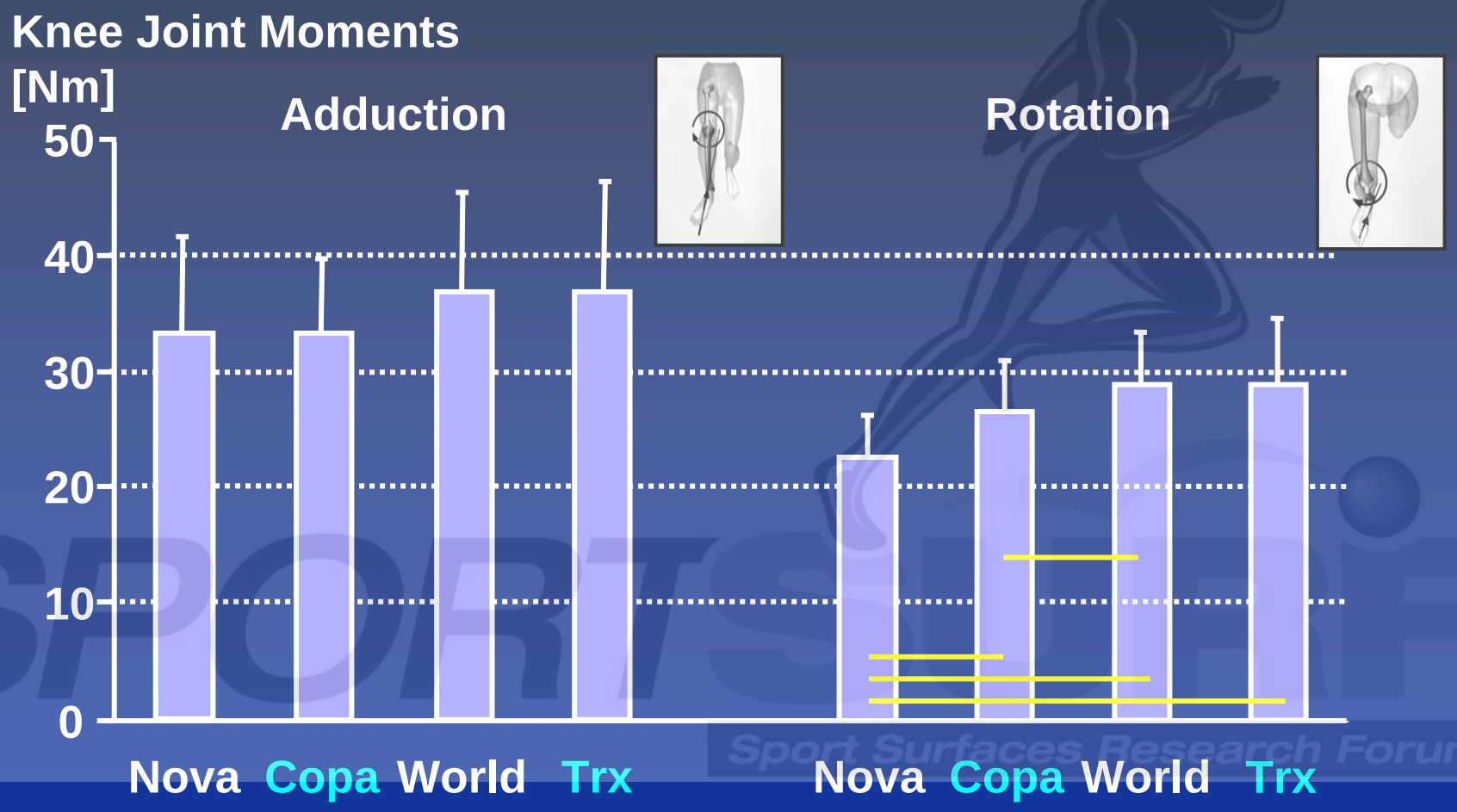

Linear Traction – Knee Moments



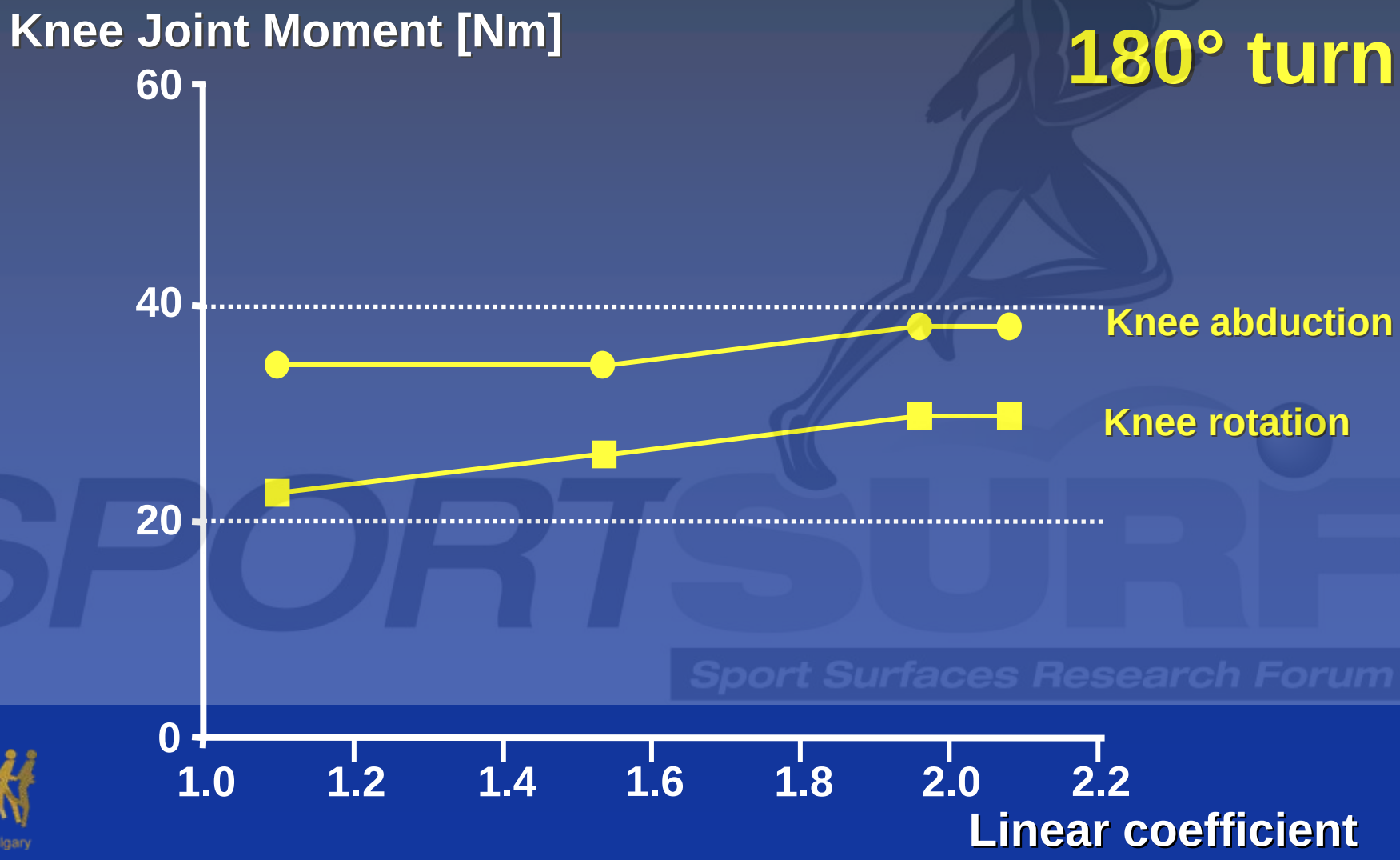
Rotational Traction–Knee Moments



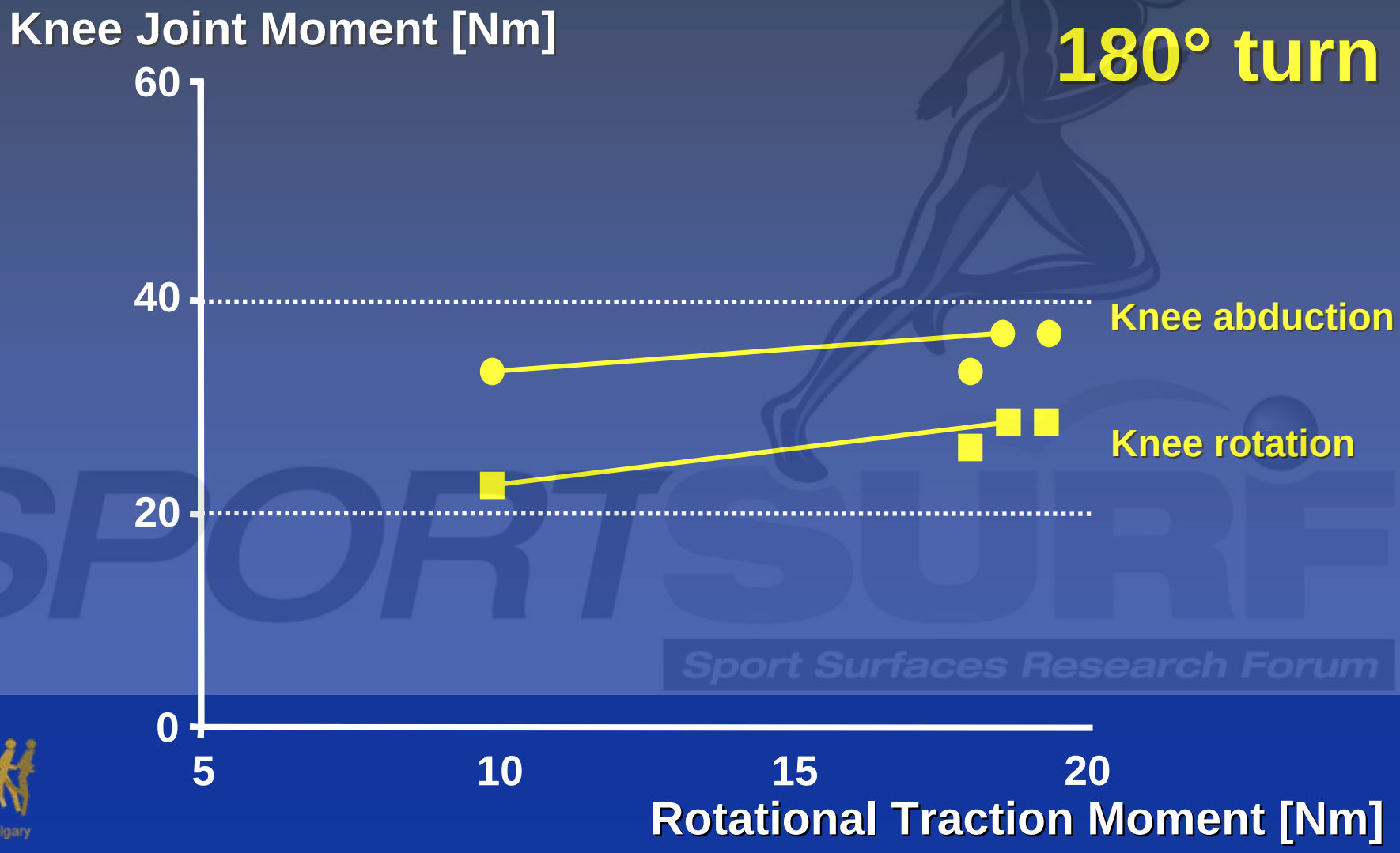
180° Turn – Knee Joint Moments



Linear Traction – Knee Moments



Rotational Traction–Knee Moments



Soccer Cleat Summary

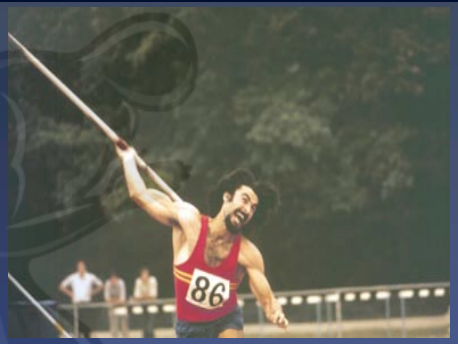
- Cleats only had a significant effect during rotational movement
- Rotational and possibly translational traction seem to affect knee joint moments

Injury Summary

- Traction plays a large roll
  - Rotational and possibly translational
- Influences joint moments
- Surfaces have large influence
- Rotational movements important
- Needs to be studied further

Energy

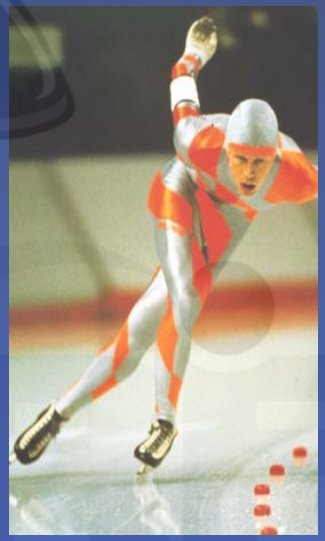
The ability to do work.



More work ⇨ throw farther

⇨ skate faster

⇨ jump higher



Energy ⇨ Work ⇨ Performance

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Energy and Performance

- Maximize energy return
- Minimize energy lost
- Optimize muscular output

Nigg and Segesser, 1992; Nigg, 2000

Energy and Performance

- Maximize energy return
- Minimize energy lost
- Optimize muscular output

Nigg and Segesser, 1992; Nigg, 2000

Maximizing Energy Return

Energy transfer in sports

body → foot → shoe → surface

and eventually

surface → shoe → foot → body

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Energy Return

$$E_{returned} = E_{input} - E_{lost}$$

Energy Input

$$W_{athlete} = \int \vec{F} \circ d\vec{r} = \Delta E_{surface}$$

deformation

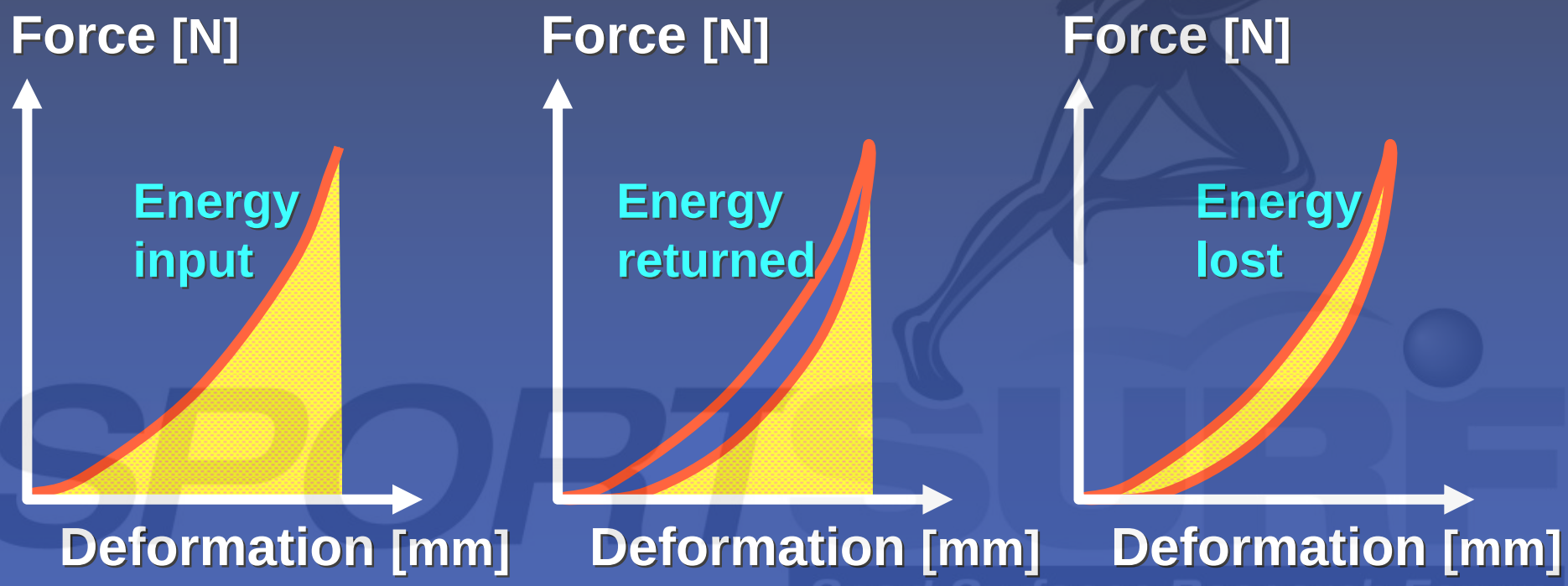
$$E_{surface} = \tfrac{1}{2}\, k\, x^2$$

stiffness

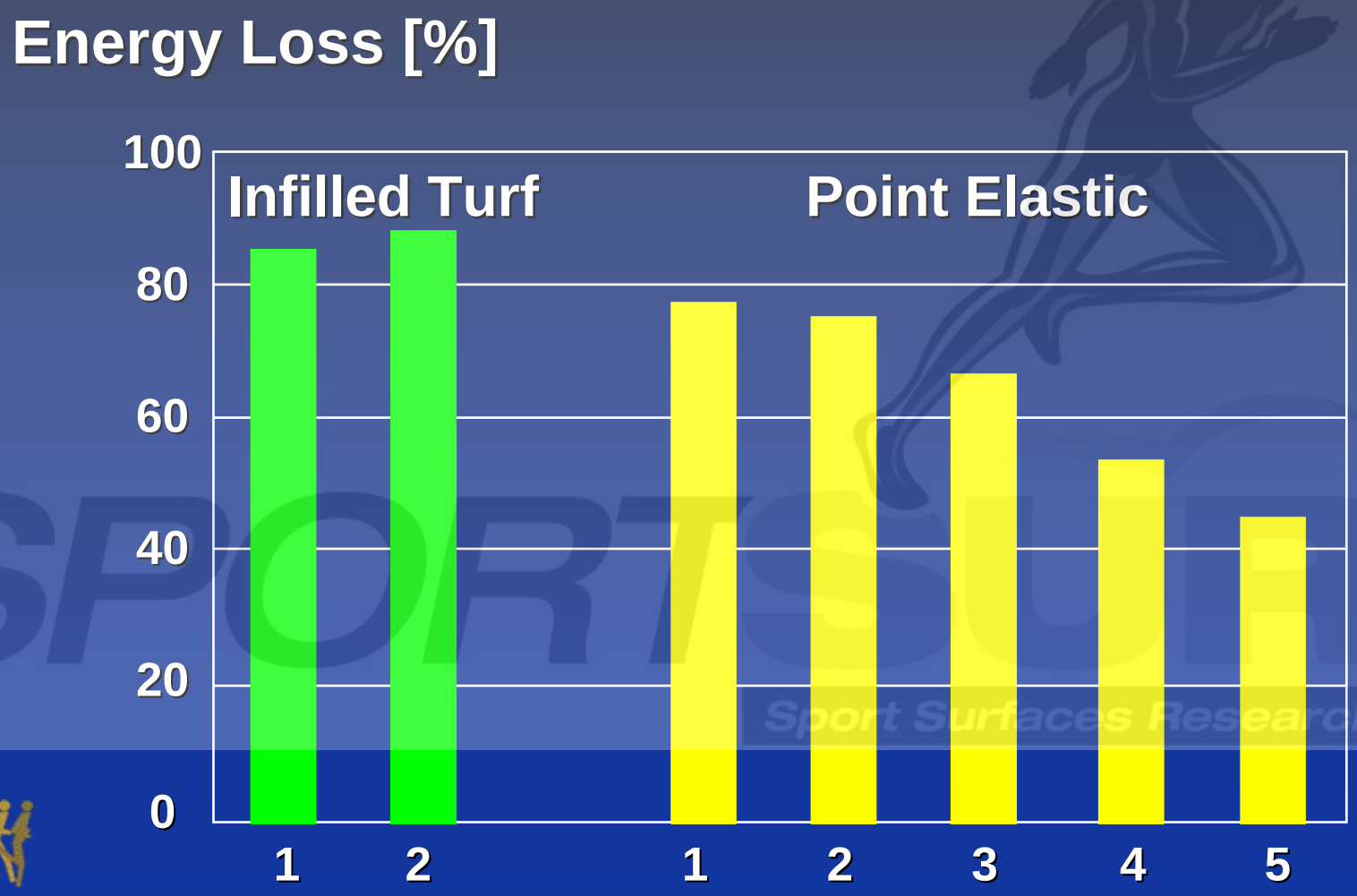
Energy Input

Surface	Approx Stiffness [N/m]	Deform [m]	Energy [J]
Tumbling floor	50000	0.100	250
Gymnastic floor	120000	0.050	150
Running track	240000	0.010	12
Gymnasium floor	400000	0.005	5

Energy Lost



Energy Lost - Surfaces

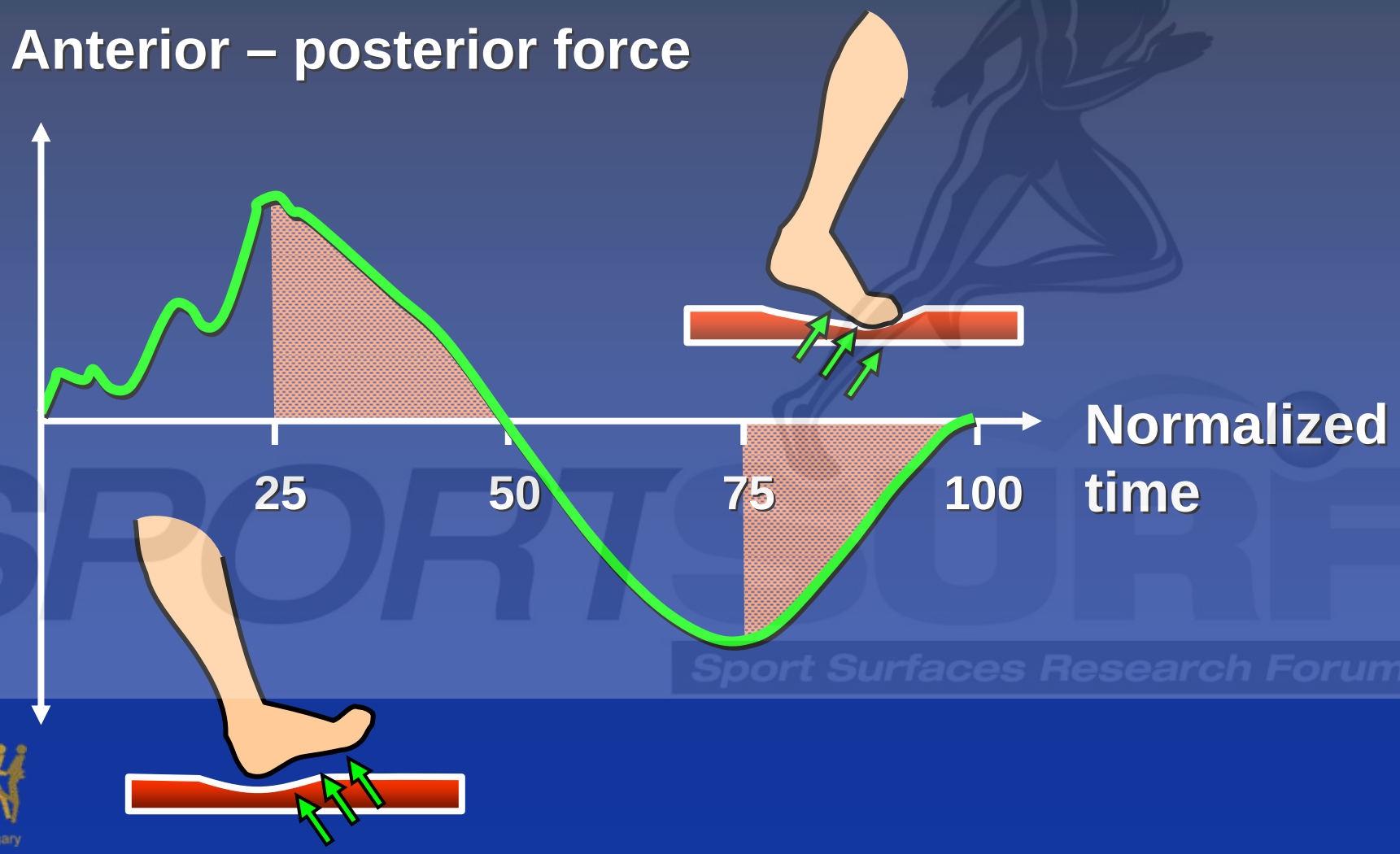


Criteria for Energy Return

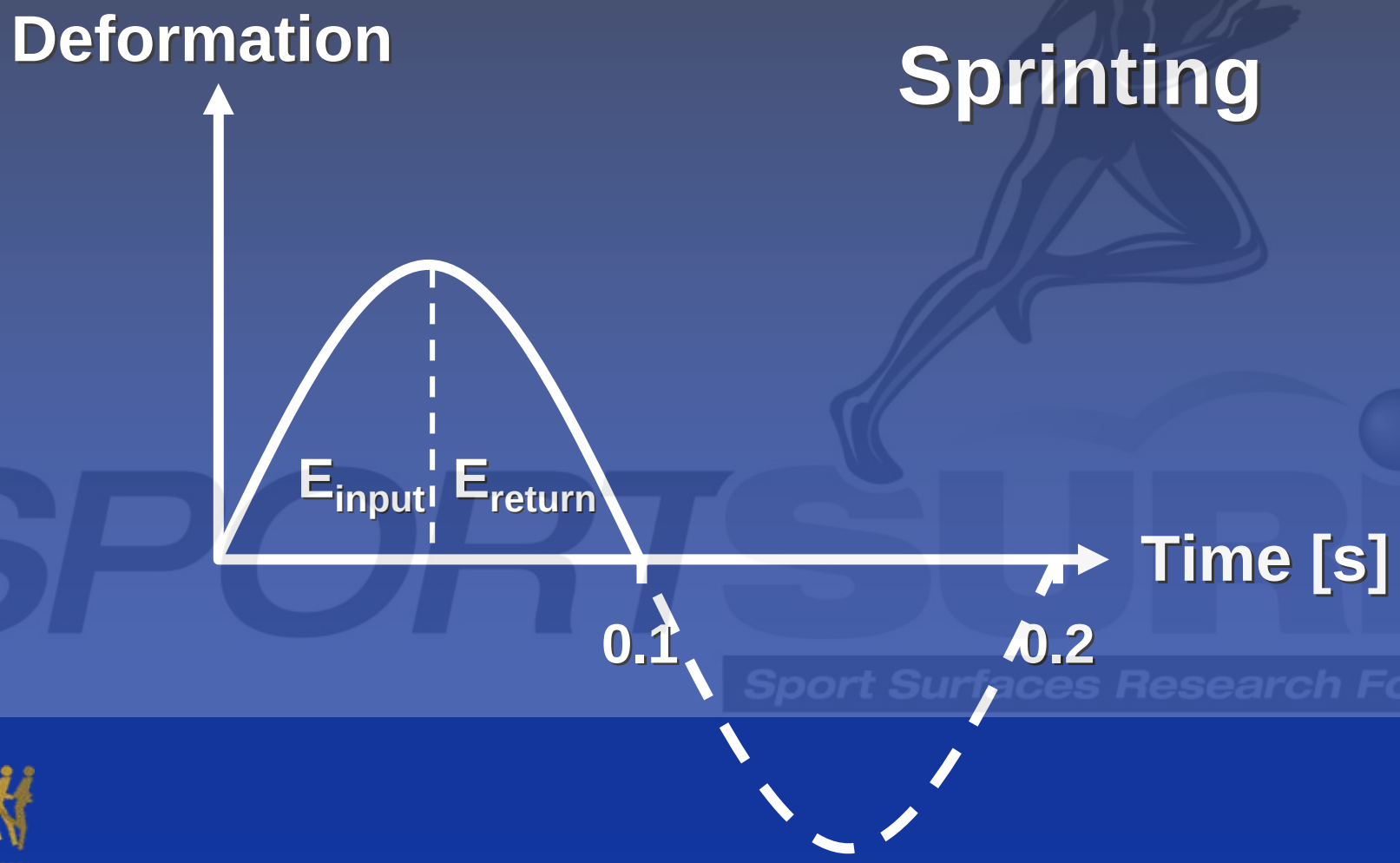
- Large enough to influence performance
- Returned at the
  - right location
  - in the proper direction
  - at the appropriate time
  - with the right frequency

Nigg and Segesser, 1988

Right Location and Direction

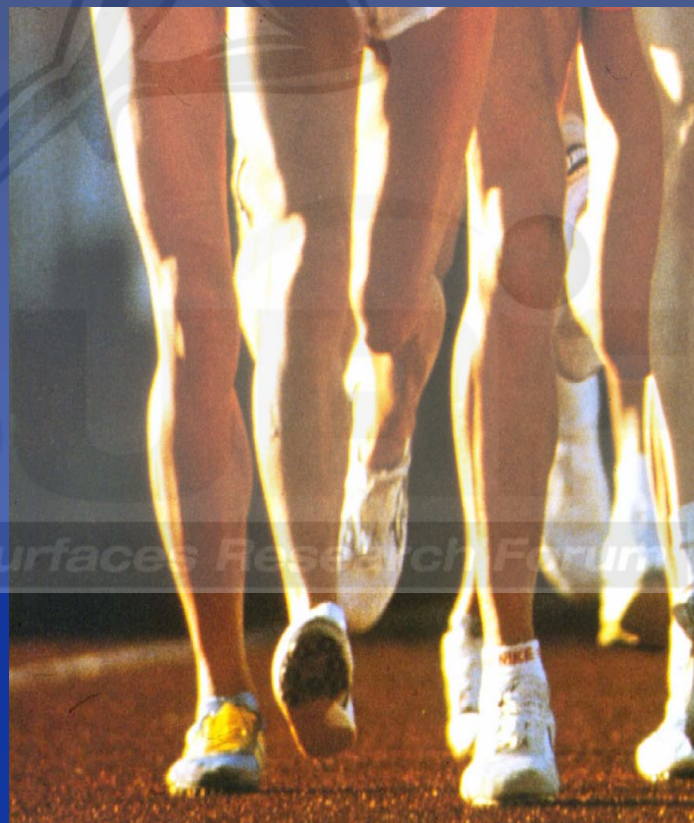


Right Frequency



Tuned Indoor Track

- McMahon and Greene 1978, 1979
- Optimal stiffness
  - dependent on runner's
  - lower leg stiffness
- Increased performance
  - 2-3%



Outdoor tracks?

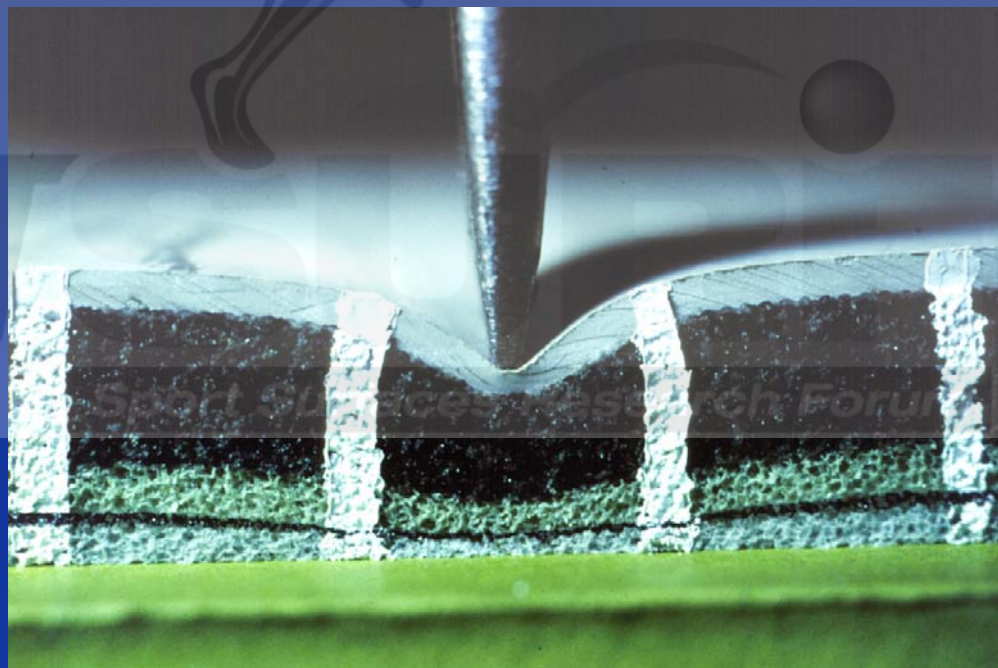
Current Outdoor Track Surfaces

Given subsurface

Solid - thin

Homogeneous

Isotropic



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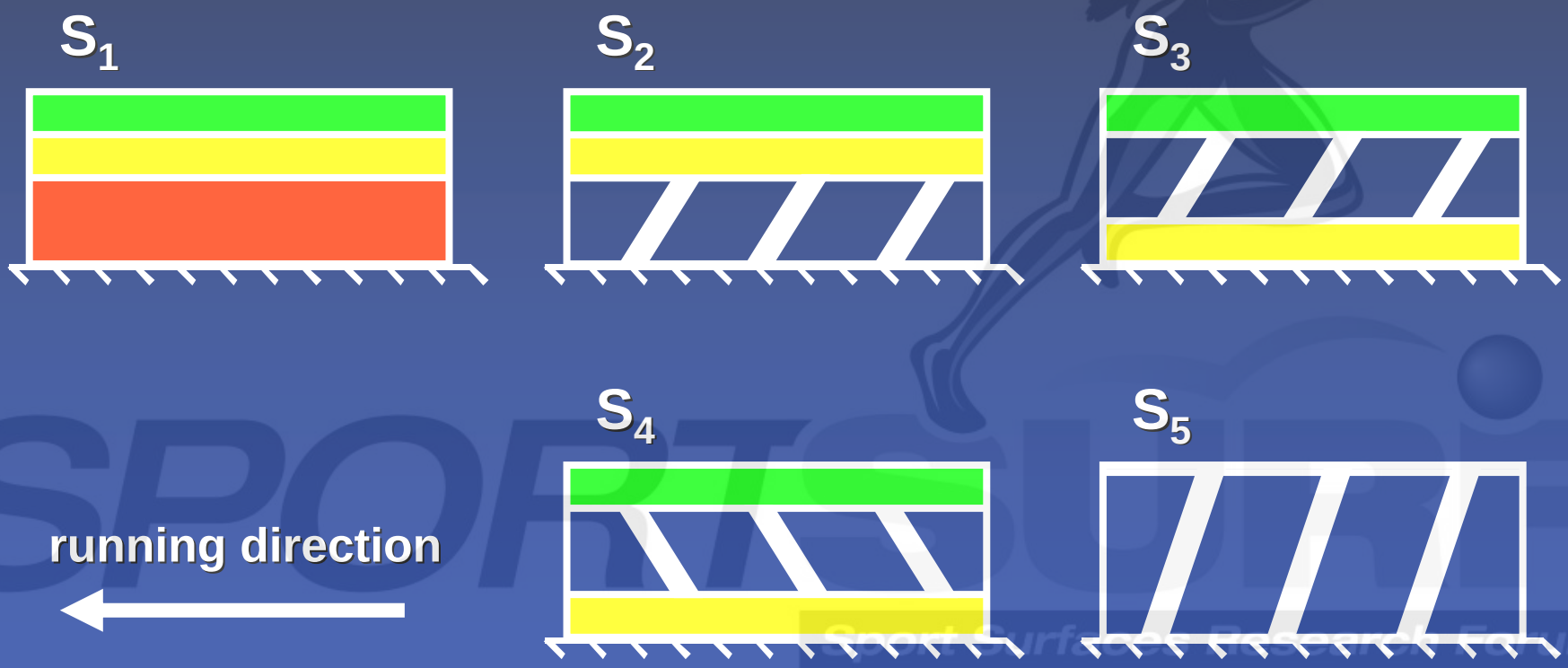
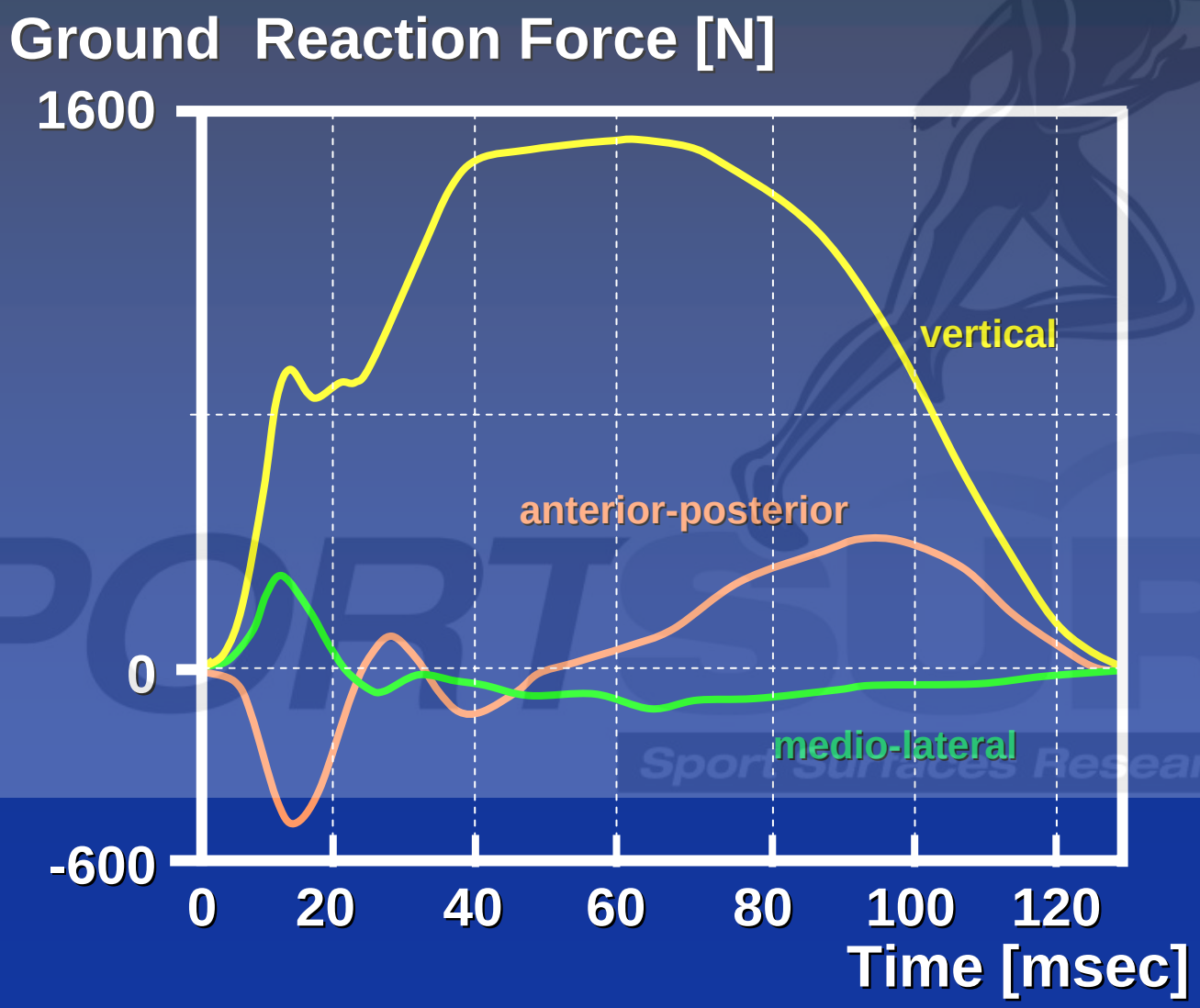


(Baroud, Nigg and Stefanyshyn, 1999)

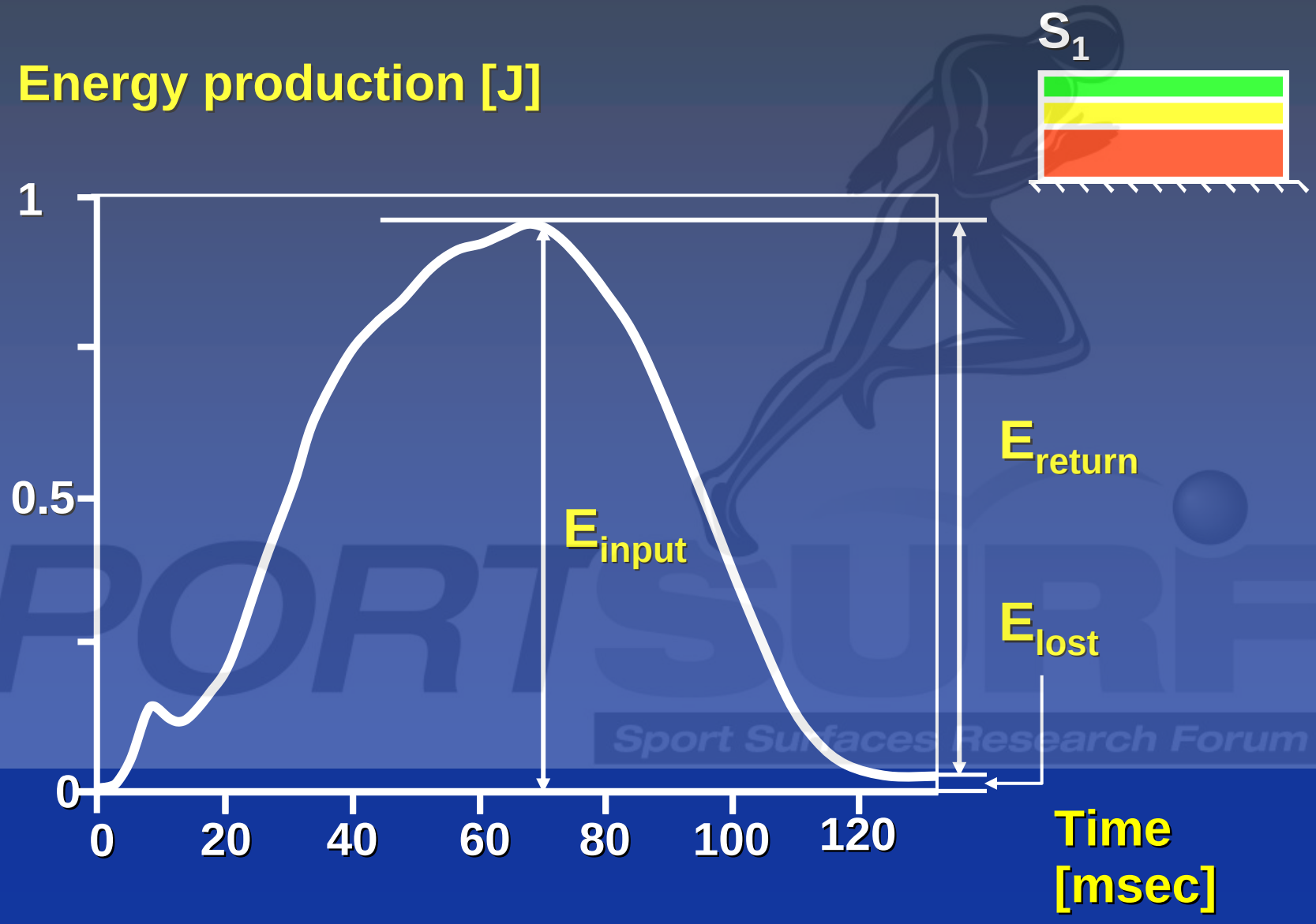
Input Forces



Conventional Surface

running direction

Conventional Surface

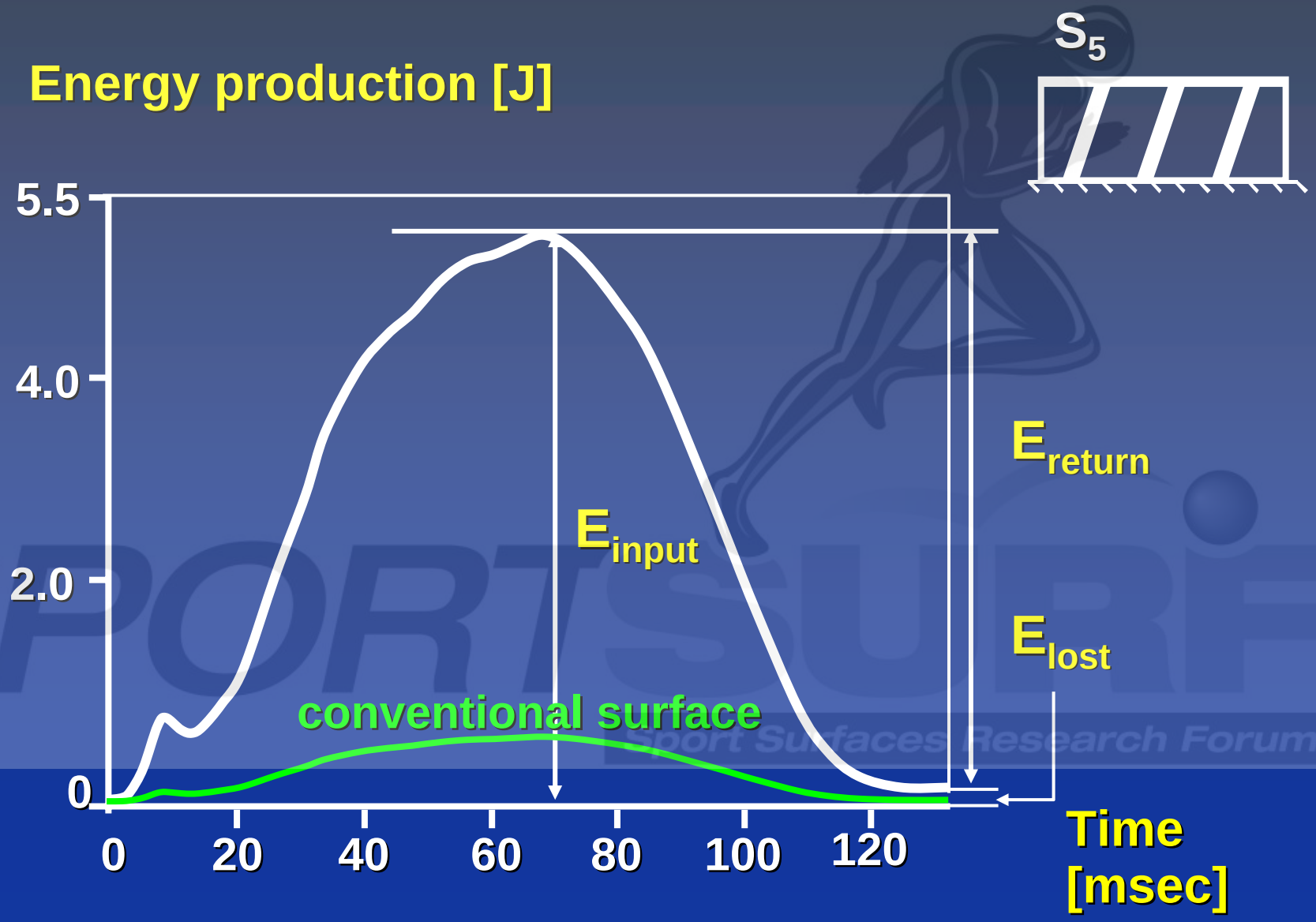


Structured Surface

S_5

running direction

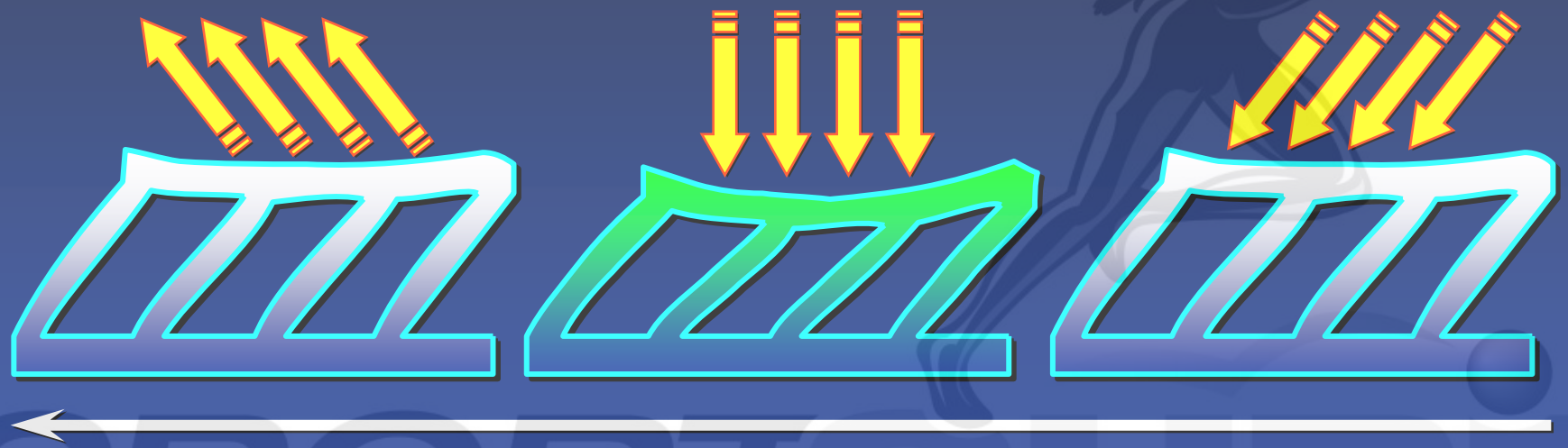
Structured Surface



Energy Return [J]

(Baroud, Nigg and Stefanyshyn, 1999)

Right Direction



Maximizing Energy Return

Energy transfer in sports

body → foot → shoe → surface

and eventually

surface → shoe → foot → body

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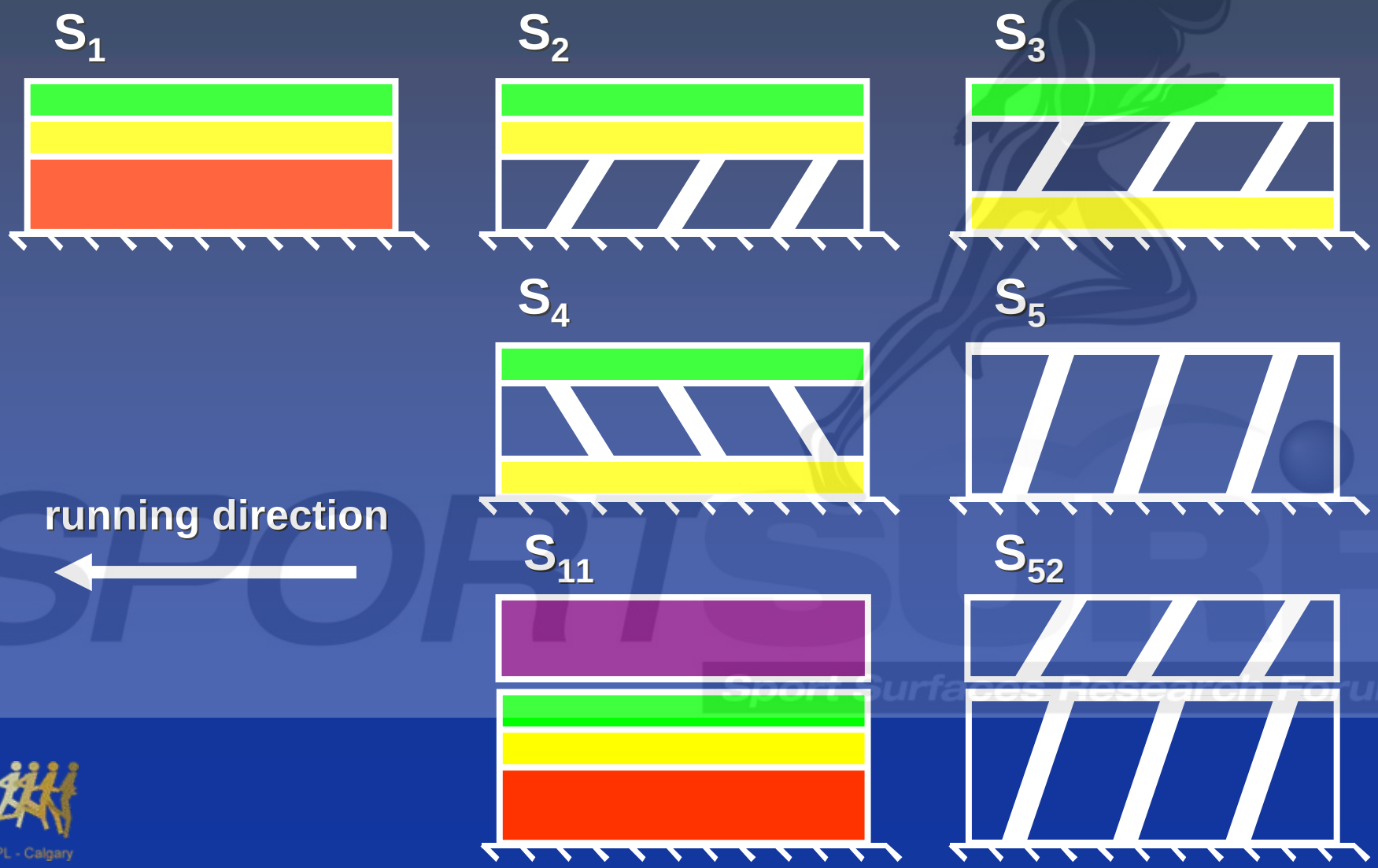
Surfaces and Shoes



Energy Return [J]

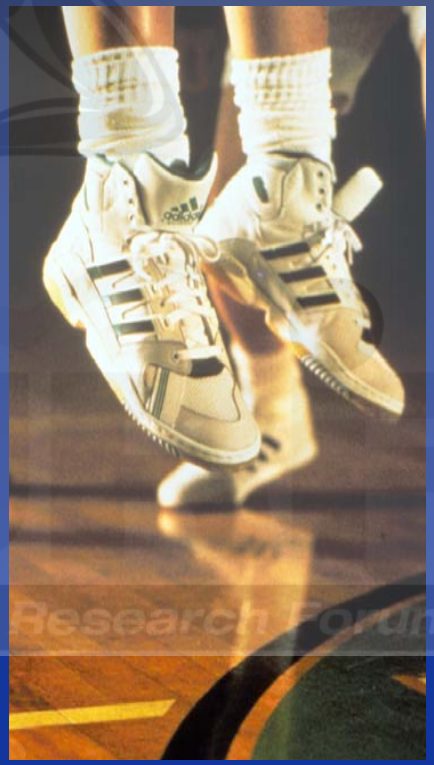
FE Model Limitations

- Linear material model
- Only one material
- Only one set of input forces
- Arbitrarily selected structural shapes
- Not validated

Energy Return

- Large enough to influence performance

- Returned at the
  - right location
  - in the proper direction
  - at the appropriate time
  - with the right frequency

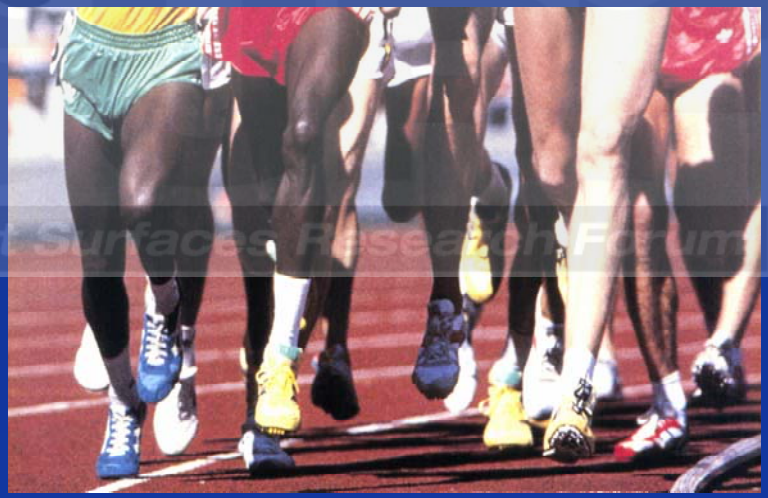


Nigg and Segesser, 1988

Energy/Performance in Surfaces

Relevant in:

- Tumbling floors
- Gymnastics
- Indoor tracks
- Outdoor tracks



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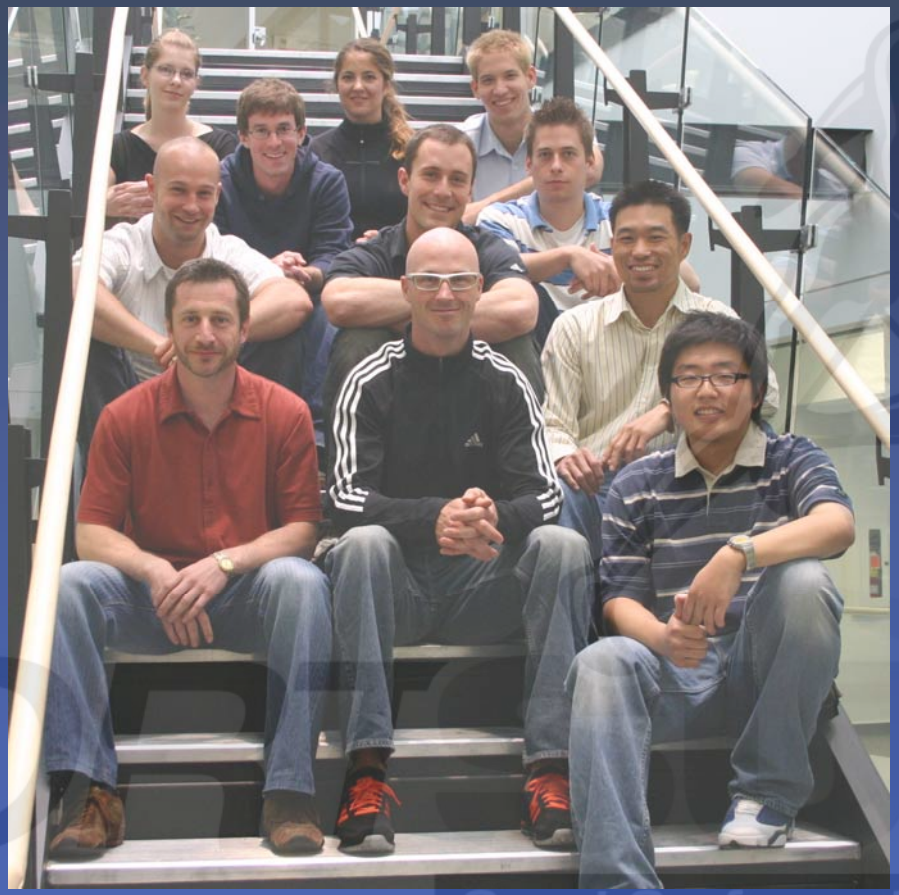
Acknowledgements



Sport Surfaces Research Forum

Thank you

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