Biomechanical Analysis of Anterior Cruciate Ligament Injury Mechanisms

Maja Rose

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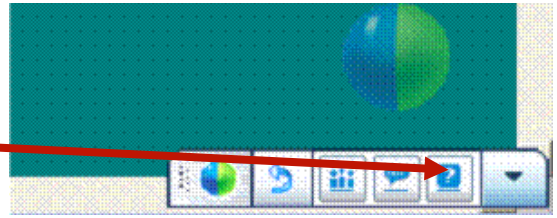

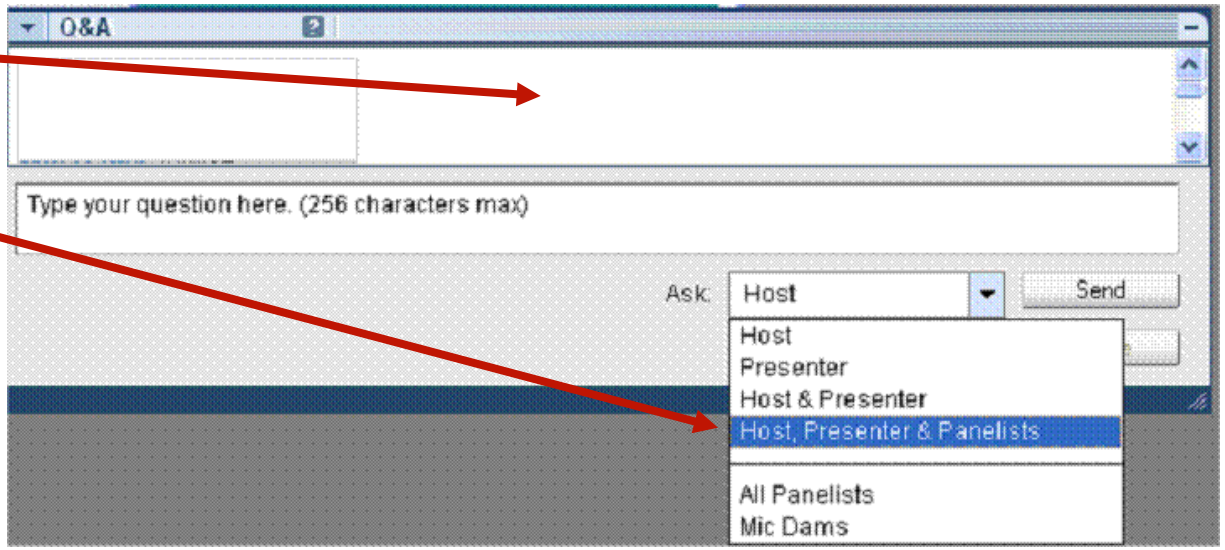

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Introduction

- Medial rotation of the tibia while the knee is slightly flexed
- Valgus trauma
- Intense deceleration
- Hyperextension trauma

Introduction

The objective is to determine which trauma mechanisms have the potential to rupture the anterior cruciate ligament by quantifying the strain in the ligament during both voluntary and forced movements.

The injury mechanisms were studied with four musculoskeletal models made with *The AnyBody Modeling System*.

- Lunge model
- Runner model
- Sagittal model
- Knee model with multiple degrees of freedom

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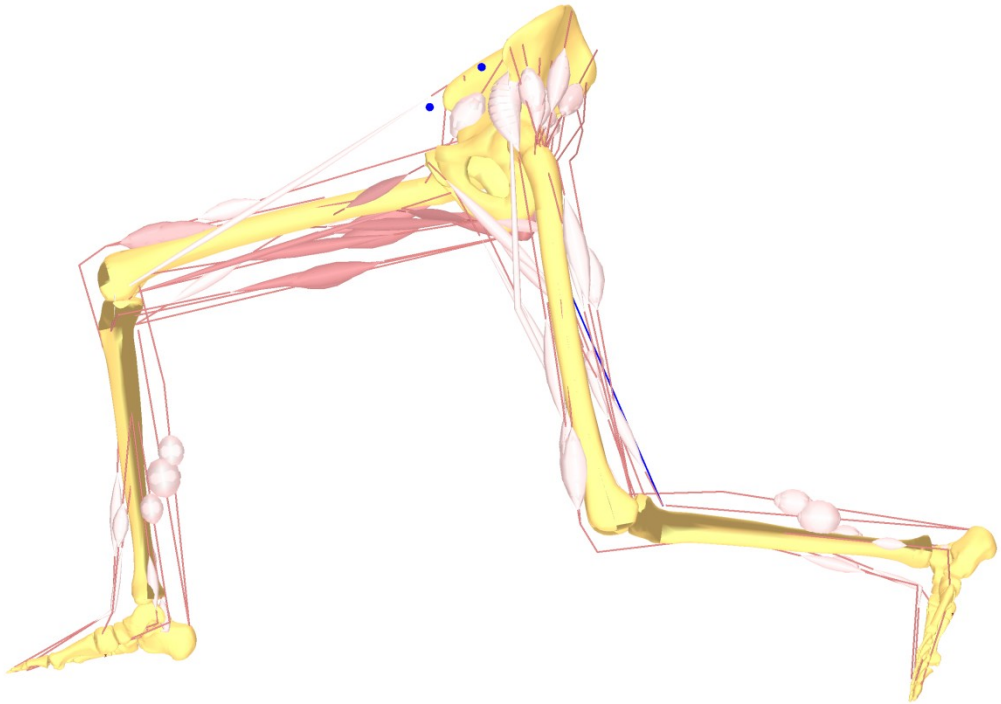
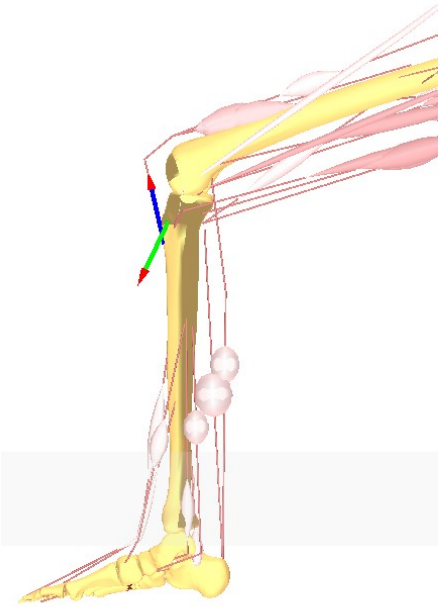
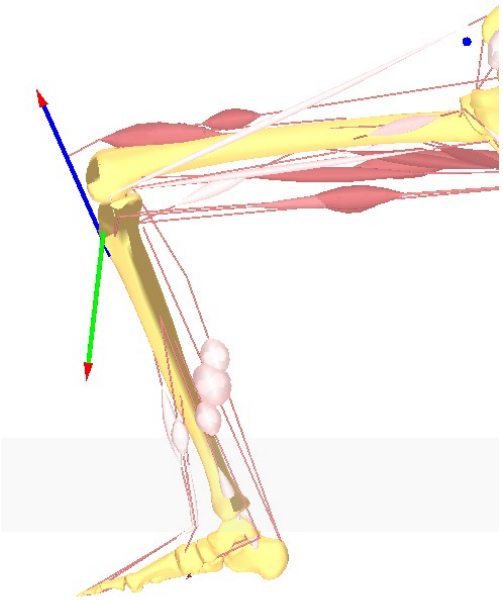
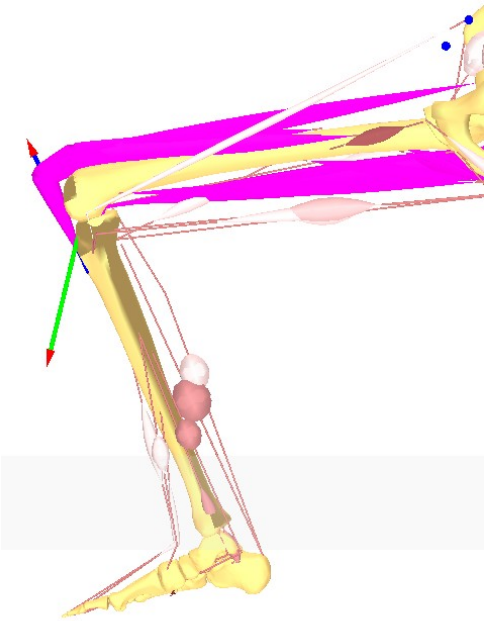
Lunge model



Lunge model

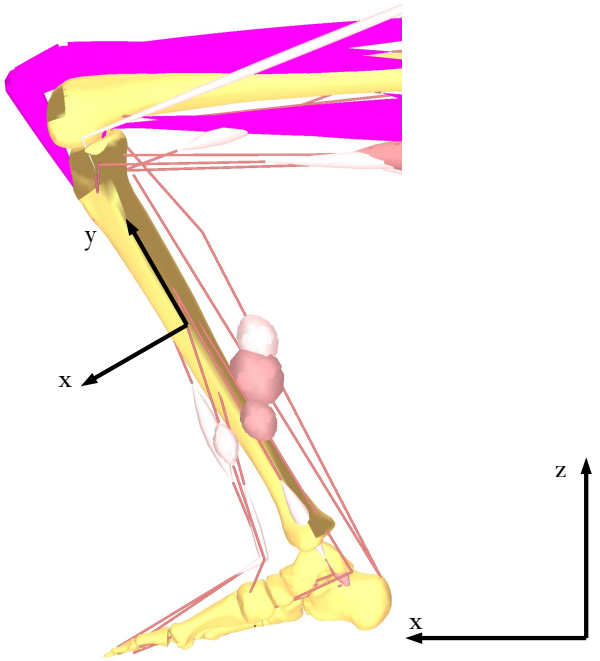


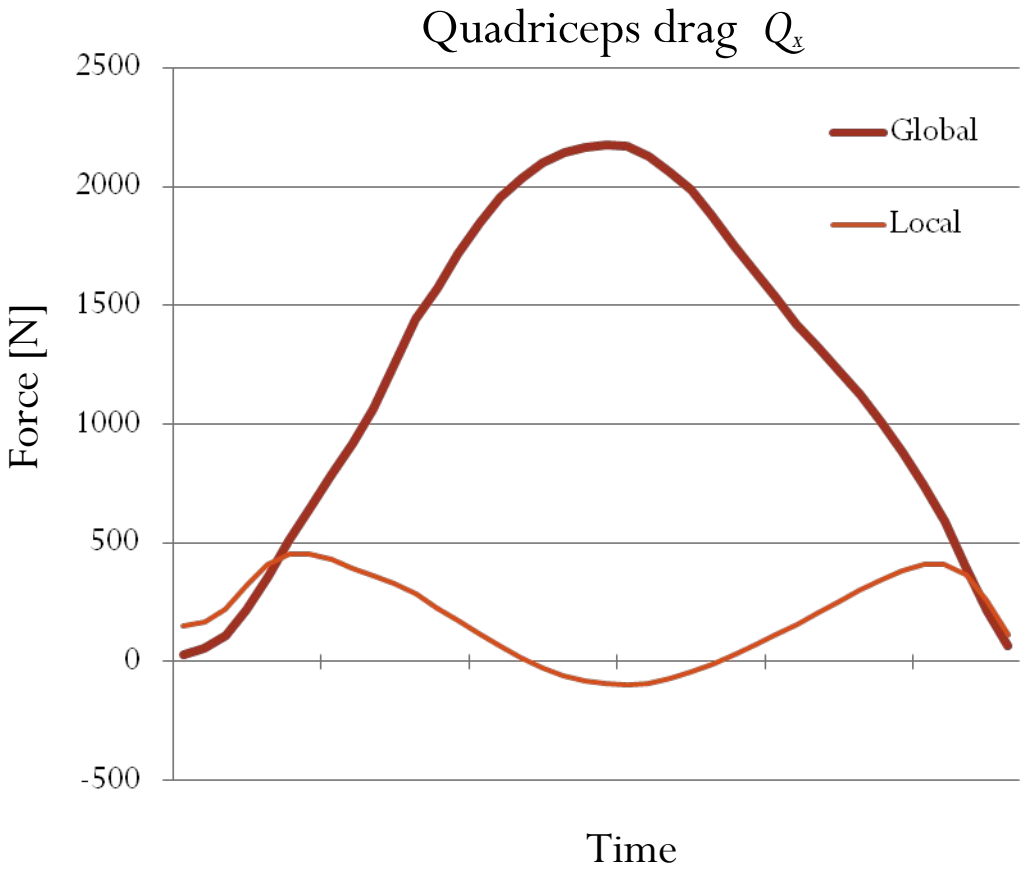




See video…

Lunge model


y
x
z
x


Quadriceps drag Q_x
2500
2000
1500
1000
500
0
-500
Force [N]
Time
Global
Local

Runner model

Runner model

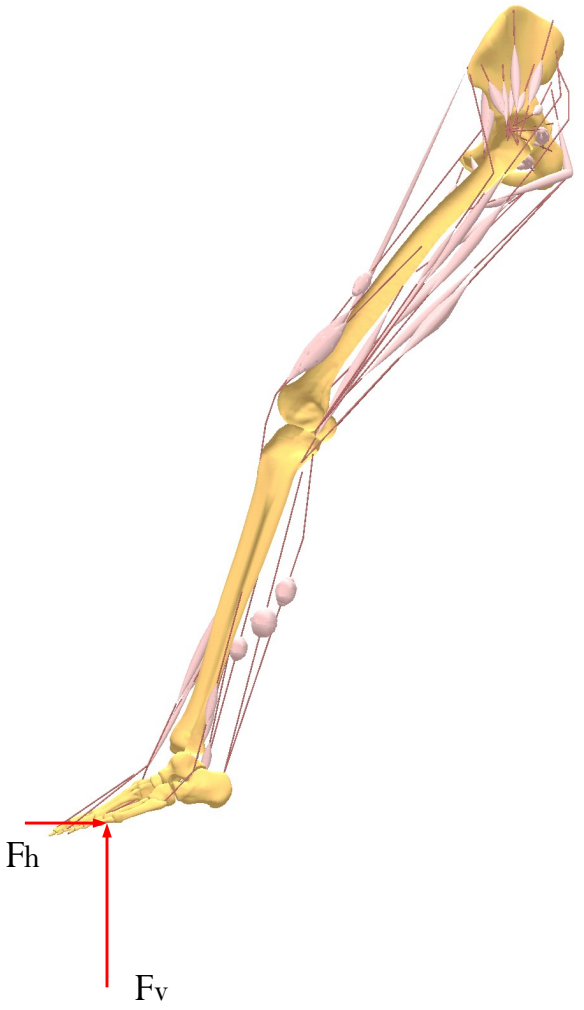
- Sprint is probably one of the most intense sagittal plane movements.
- $R_x = -943\ N$
- The ultimate tensile strength of the ligament is *1725 -2195 N*
- It appears that voluntary contraction is insufficient to injure a healthy anterior cruciate ligament.

Sagittal model

Sagittal model

The following parameters were varied systematically:

- Hip flexion angle [0 – 80 º]
- Knee flexion angle [0 – 80 º]
- Ankle plantar/dorsal flexion [-30 – 30º]
- Point of action of the ground reaction force
- Magnitude of the ground reaction



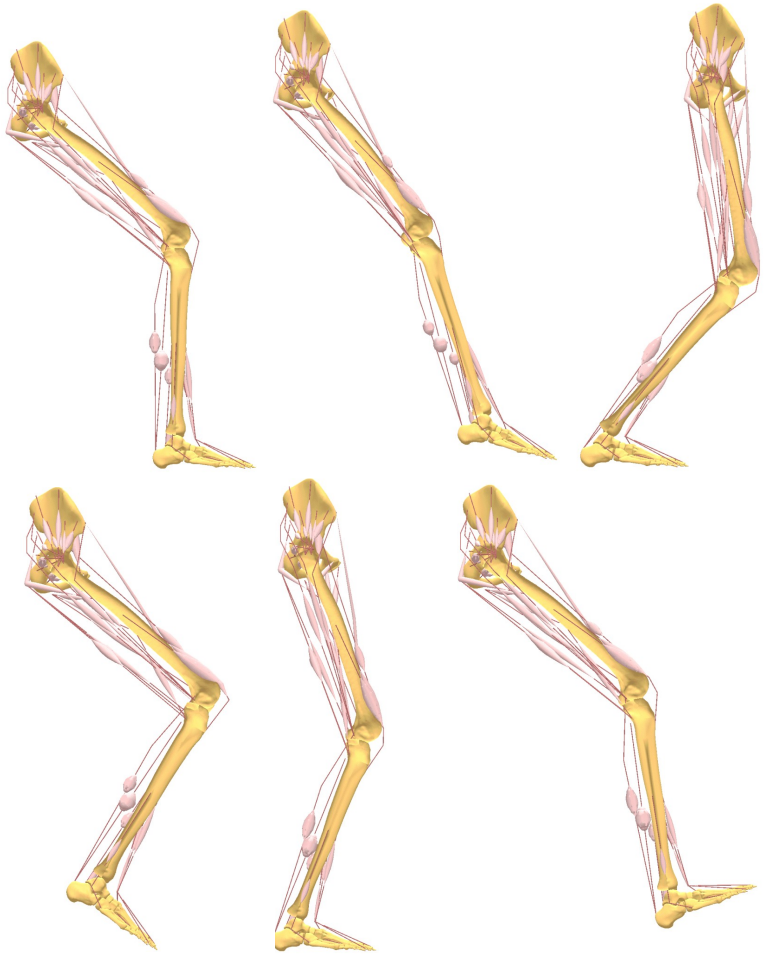
Sagittal model

Two different muscle models were applied:

- *AnyMuscleModel*
- *AnyMuscleModel3E*

Regardless of the chosen muscle model the knee joint reaction force R_x was above *-1000 N*

The analysis demonstrated that it is unlikely that sagittal plane mechanisms will rupture the anterior cruciate ligament.



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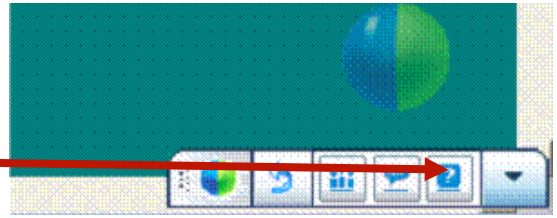

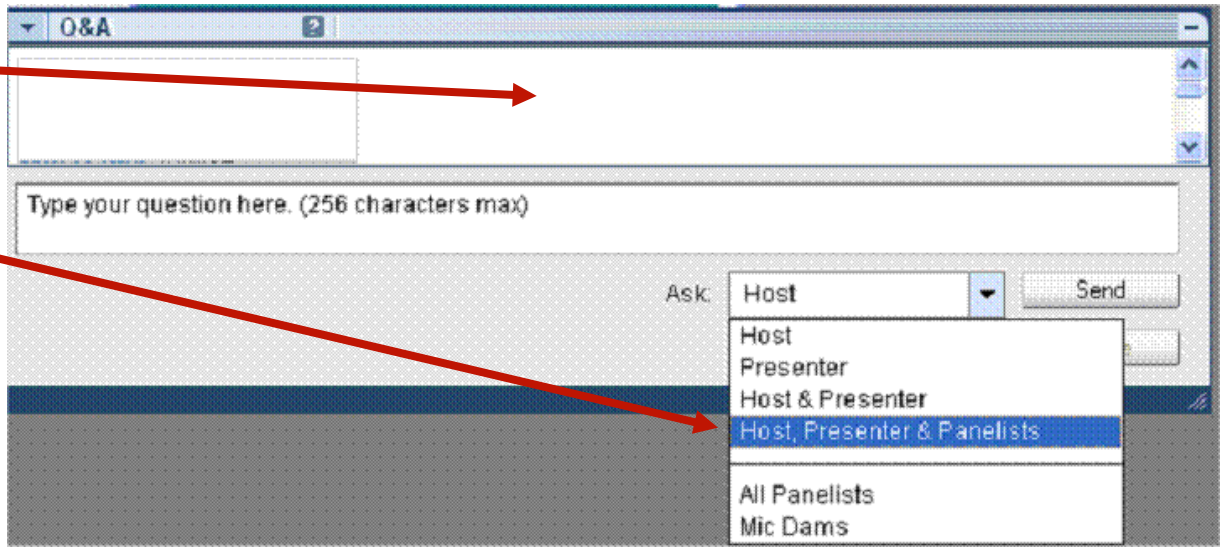

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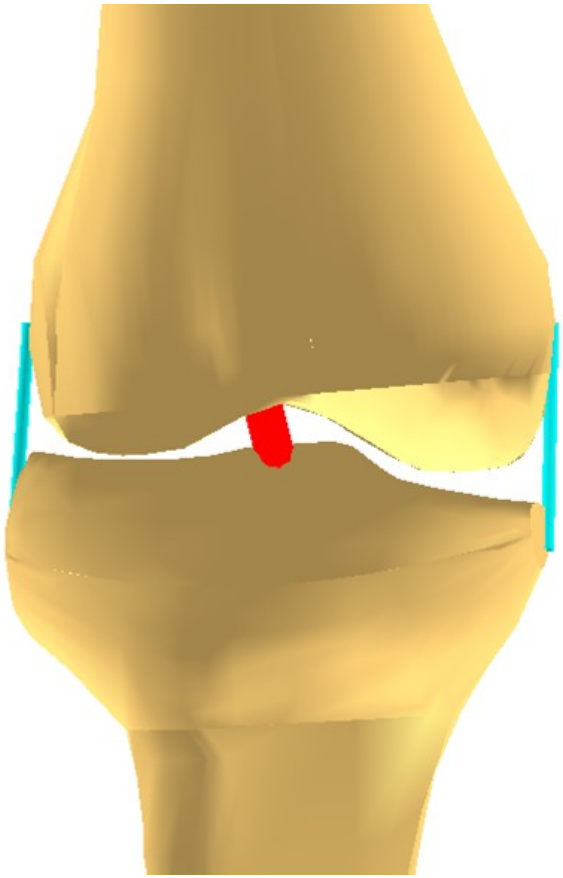
Knee with multiple degrees of freedom

Knee with multiple degrees of freedom

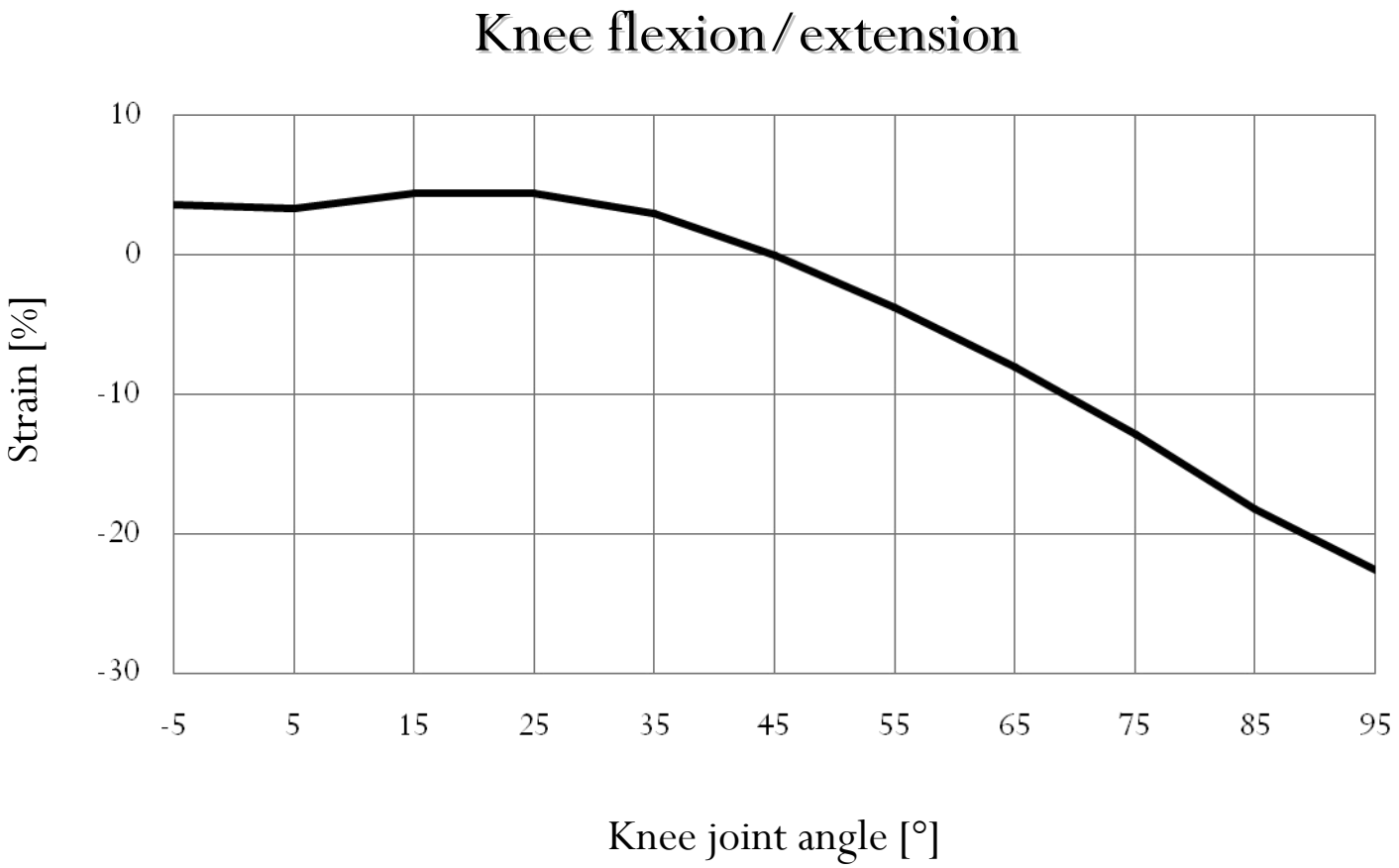
The relative movement between femur and tibia, natural or forced, is related to a complicated interaction between muscles, ligaments and bones.

The purpose of this knee model was to improve the imitation of the movement of a real knee and thereby investigate the length of the ligament when it wraps around the bones.

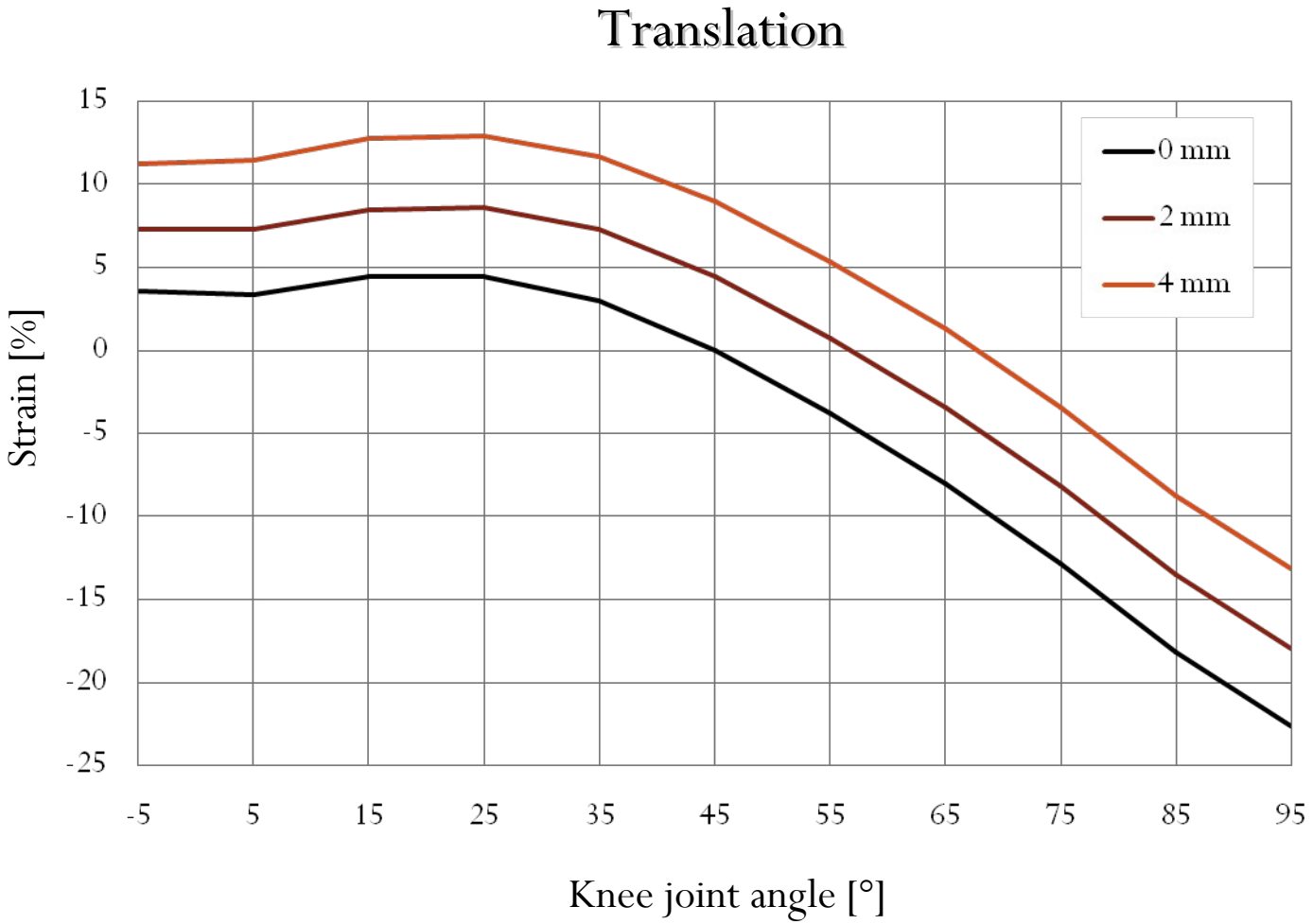
- Knee ligaments.
- Contact condition between the segments.
- Change the way the model was driven.

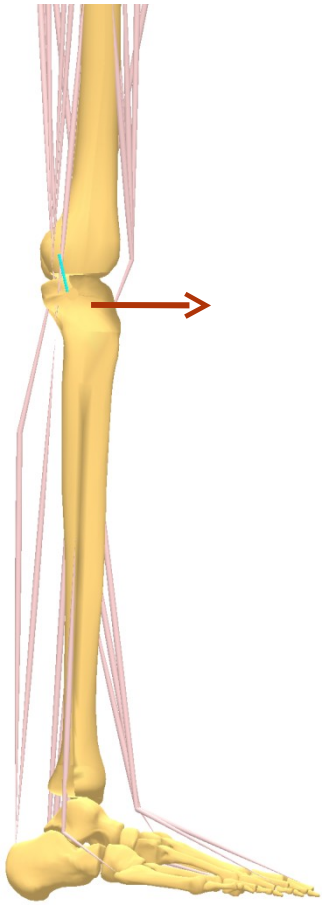


Knee model

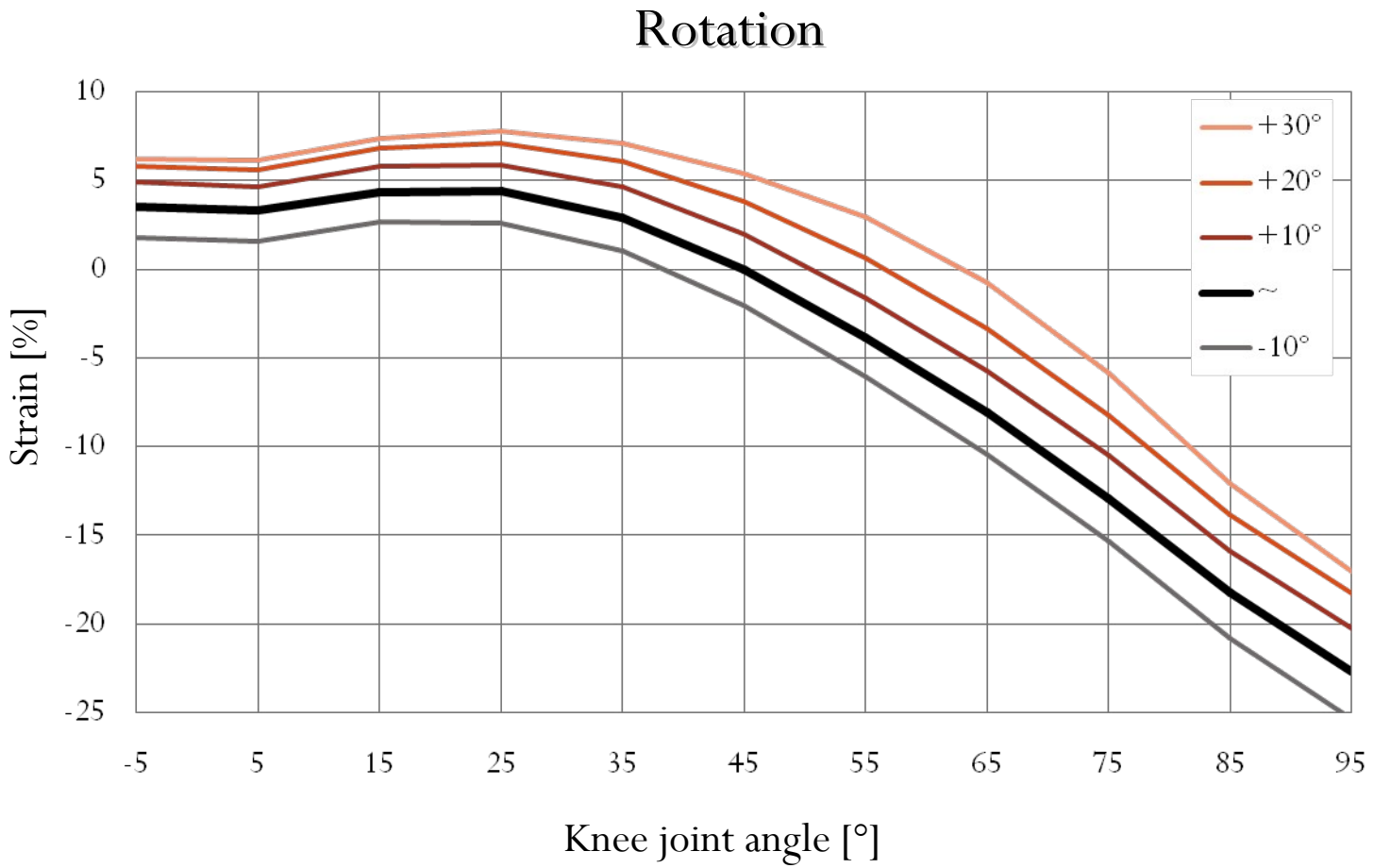

Knee flexion/extension
Strain [%]
10
0
-10
-20
-30
-5
5
15
25
35
45
55
65
75
85
95
Knee joint angle [°]

Knee model

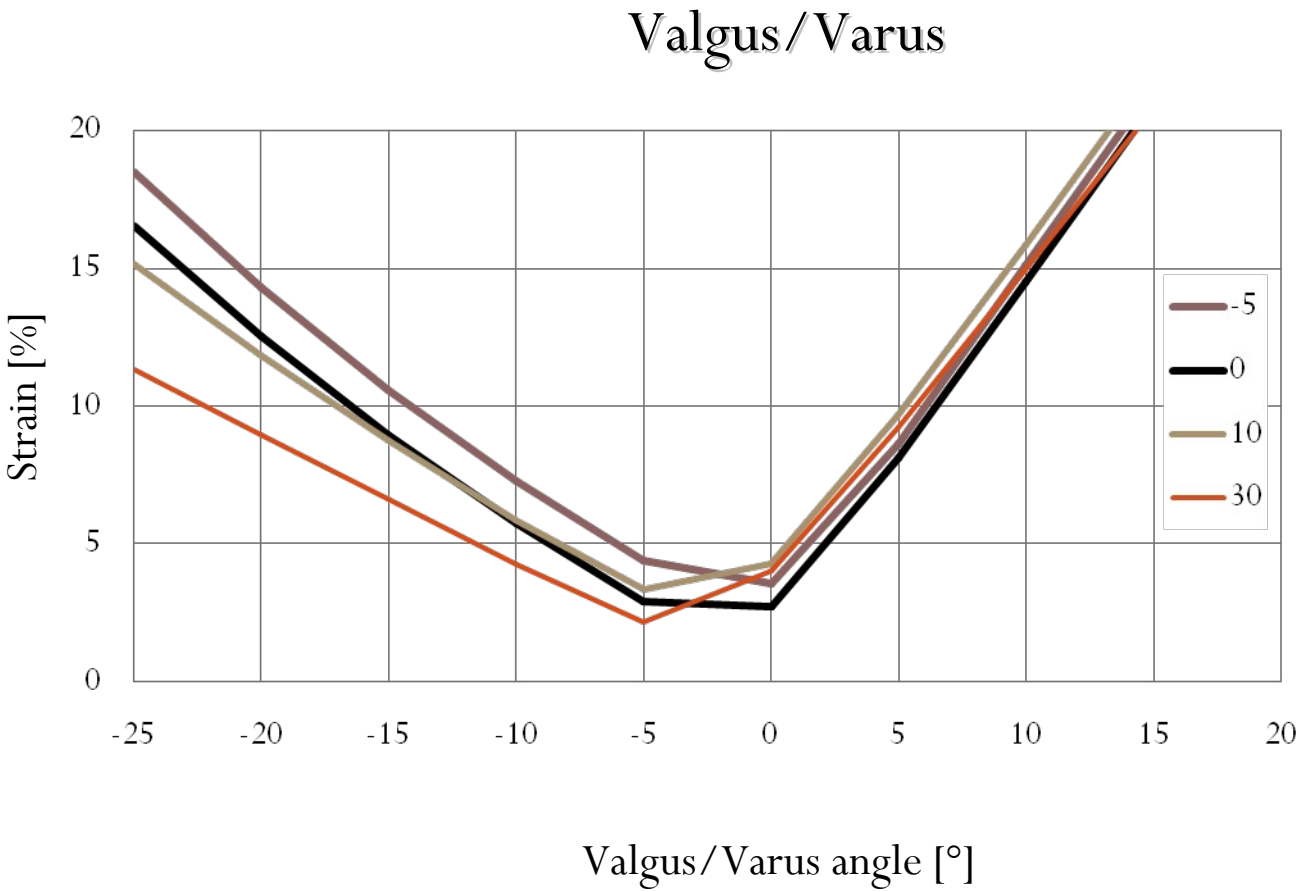

Translation
15
10
5
0
-5
-10
-15
-20
-25
Strain [%]
-5
5
15
25
35
45
55
65
75
85
95
Knee joint angle [°]
0 mm
2 mm
4 mm



Knee model


Rotation
Strain [%]
10
5
0
-5
-10
-15
-20
-25
-5
5
15
25
35
45
55
65
75
85
95
Knee joint angle [°]
+30°
+20°
+10°
~
-10°

Knee model


Valgus/Varus
20
15
10
5
0
Strain [%]
-25
-20
-15
-10
-5
0
5
10
15
20
-5
0
10
30
Valgus/Varus angle [°]

Knee model

- The ligament is strained the most when the knee is slightly flexed.
- Valgus and especially varus positions can increase the strain considerably.
- Rotation of tibia about its longitudinal axis produce minor strain.
- Anterior translation of the tibia increases the strain significantly.

Video Analysis

TABLE 4
Information on Each Case Based on Analysis of the Videotapes (n = 20)

		Knee Position (degrees)				
Activity	Speed	Flexion	Tibia Rotation[a]	Valgus	Weight Distribution: Percentage on Injured Leg	Contact[b]
Plant-and-cut	High	5	5	5	100	No
	Moderate	5	–10	10	100	Indirect
	High	15	–10	20	80	No
	High	15	–5	15	65	No
	High	10	–5	15	100	Indirect
	High	15	–10	15	100	No
	Moderate	15	–10	15	90	No
	High	10	10	20	80	No
	High	10	10	10	100	No
	High	20	–15	15	100	No
	High	20	10	15	100	No
	Moderate	20	10	15	100	Indirect
One-leg landing	High	20	10	10	100	Indirect
	Very high	15	10	15	100	No
	Very high	25	15	15	100	No
	Very high	15	5	10	100	No
Deceleration[c]	Moderate	25	10	10	100	No
	High	20	10	10	100	Indirect
Running	High	20	10	10	100	Indirect
Collision						Direct

Table from **Olsen et al**. 2004 Injury Mechanisms for Anterior Cruciate Ligament Injuries in Team Handball

Injury Mechanisms

- Intense deceleration
- Valgus trauma
- Medial rotation of the tibia while the knee is slightly flexed

Q&A Panel

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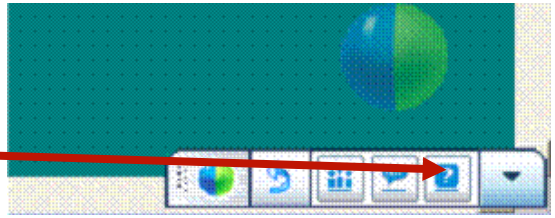

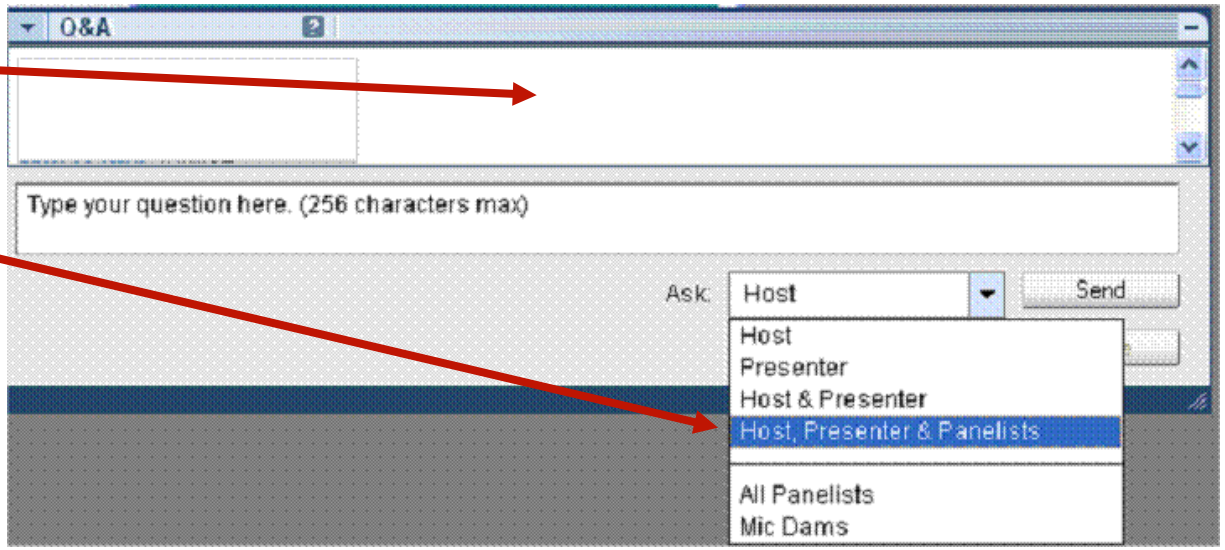

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