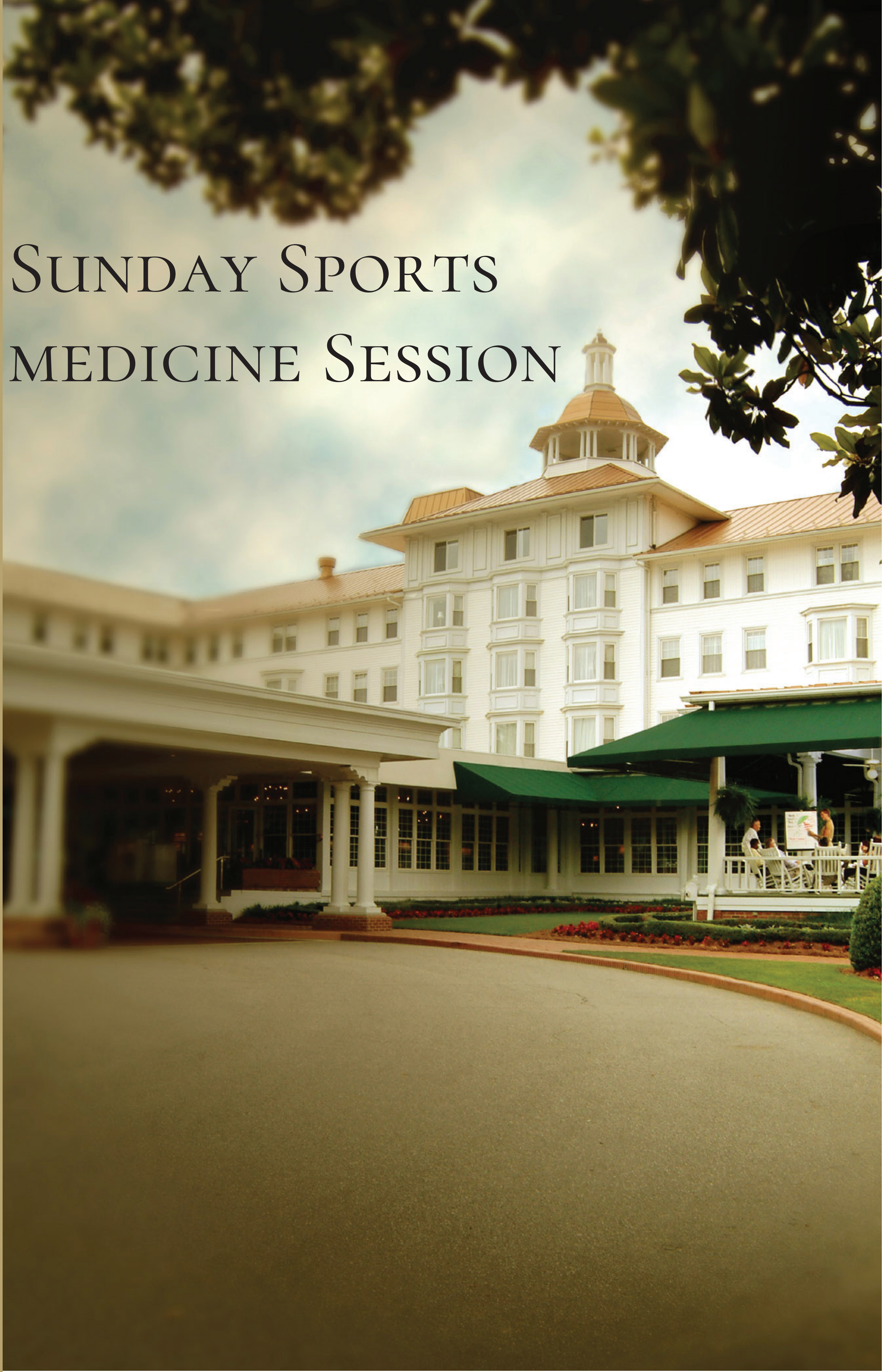
2016 NCOA Annual Meeting

Sunday Sports medicine Session



Wake Forest® School of Medicine

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Comparison of Hip Electromyographic Patterns During Overground vs. Treadmill Gait in Healthy Females

Alexis A Wright, Kevin R Ford, Nicholas S Pritchard, Steven L Dischiavi, Ian M Al'Khafaji, Allston J Stubbs

Disclosures

None

Background

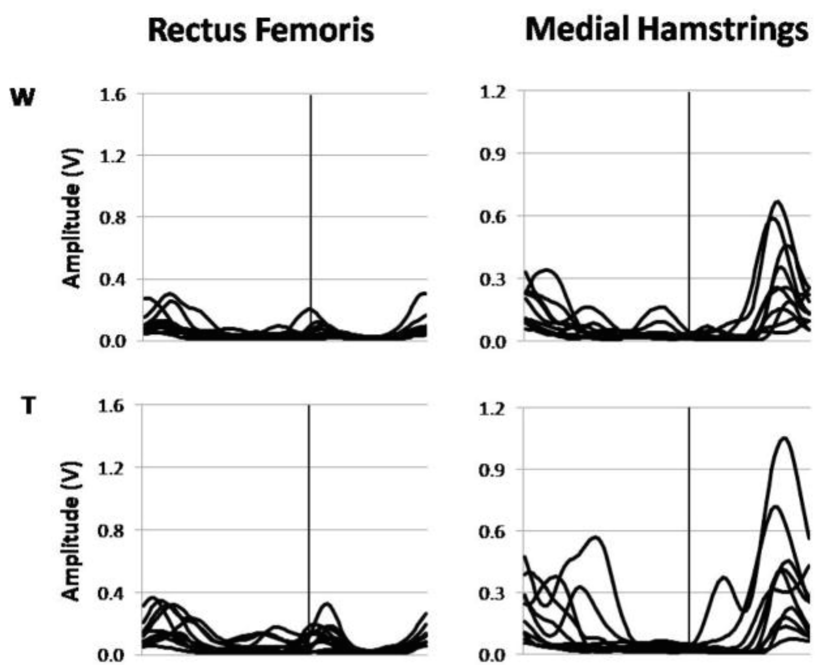
There is a common goal in lower extremity rehabilitation to improve walking ability

Training devices, such as treadmills, assist with muscle strengthening, improve muscle activation, and reproduce muscle activity patterns

There is a lack of understanding of muscle activity during treadmill and overground gait which is required to optimize post-operative hip rehabilitation protocols

Background

- Prosser et al. Gait Posture 2011
  - 10 healthy adults (6 male, 4 female)
  - Surface EMG treadmill vs overground walking
    - Measured rectus femoris (RF) and semitendinosus (ST)
  - Results
    - Activation time:
      - RF- T>W
      - ST- T=W
    - Activation amplitude:
      - RF & ST- T>W



Purpose

Compare hip muscle activity patterns during overground and treadmill walking gait in healthy female individuals

Hypothesis: There will be a significant difference in muscle activation pattern between overground and treadmill walking gait

Methods

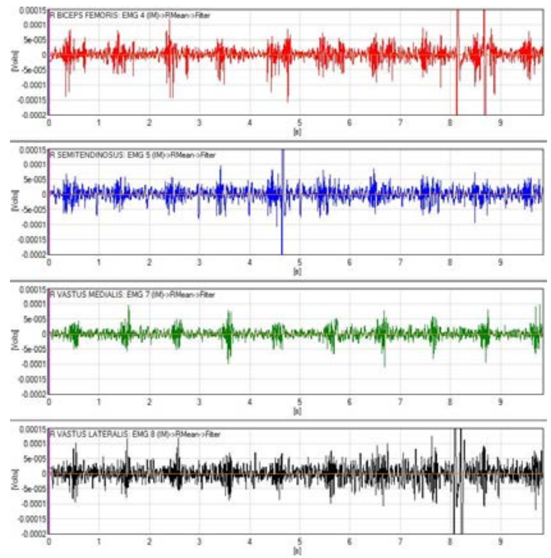
- Study subjects
  - 13 females participants
  - Mean age 20.4 years (+/- 1 year)
  - BMI 22.8 kg/m^2 (+/- 4.0)
  - No history of of lower extremity surgery or musculoskeletal pathology

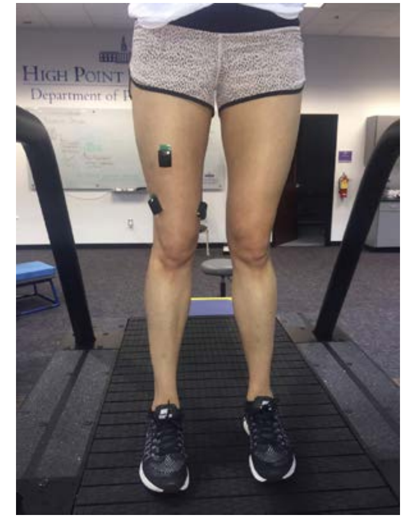
Methods

- Subjects performed overground and treadmill walking gait with surface EMGs (Delsys Trigno Wireless) measuring muscle activity
  - Signal amplitude
  - Activation time over gait cycle (0-100%)
- Average overground walking speed for each subject calculated and matched on treadmill before EMG recordings

Methods

- EMG data recorded on dominant leg
  - Glutues Maximus
  - Gluteus Medius
  - Tensor Fasciae Latae
  - Rectus Femoris
  - VMO
  - VLO
  - Biceps Femoris
  - Semitendinosus





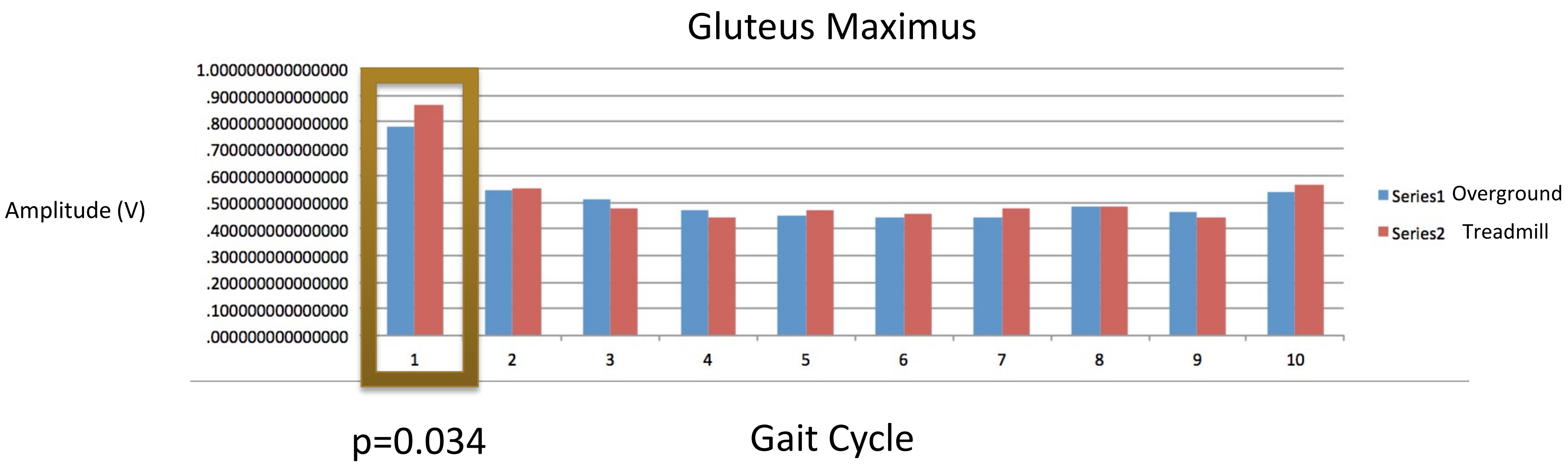
Methods

- Order (treadmill vs overground) randomized
  - Average of 3 trials
  - Overground- 10 m
  - Treadmill- 30 seconds
- Paired sample t-Test

Results

- Average walking speed 1.4 m/s (+/- .2)
  - Matched with treadmill speed

Results



All other muscle groups showed no difference between overground vs treadmill during entire gait cycle

Limitations

- Small study size
- Unable to access deep hip flexors & hip adductors
- No Male subjects

Conclusion

- Significant increase in gluteus maximus activation during treadmill walking gait compared to overground
- Treadmill could possibly cause post operative muscle imbalance and impairs appropriate hip neuromuscular function
- Findings could possibly be one etiology of hip pain during rehabilitation
- Caution should be taken with the use of treadmill during post operative protocols

Thank you

Active vs Passive Motion after Hip Arthroscopy for Symptomatic Femoroacetabular Impingement: A Prospective, Comparative Trial

Authors: Cunningham, D; Lewis, B; Hutyra, C; Mather, C; Olson, S

DukeMedicine

Disclosures

- **Daniel Cunningham**
  - none
- **Brian Lewis**
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- **Carolyn Hutyra**
  - none
- **Chad Mather**
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- **Steven Olson**
  - Orthopaedic Trauma Association: Board or committee member
  - Synthes: Research support
- No one that could potentially benefit monetarily from the outcomes of the study (e.g. CPM manufacturer or distributor) was involved in the design or conduct of the study

Hip arthroscopy for symptomatic FAI

- Hip arthroscopy
  - Minimally invasive treatment of femoroacetabular impingement and labral tear [1,2]

Early passive vs. active range of motion

- Promising pre-clinical results for CPM
  - Effective for joint healing in pre-clinical rabbit joint injury model [3]
- Disappointing clinical results
  - Only small transitory gains in ROM for total knee arthroplasty [4]
- Other indications not studied in detail

Why is CPM used after hip arthroscopy?

- Surgeon preference
  - Extensive capsular injury
  - Motion may reduce adhesion formation
  - Buy-in from patient to perform some rehabilitation
  - May be less painful in early post-operative period than active motion
- At our institution
  - 1 uses and 1 does not

Rehabilitation recommendations

- Post-operative rehabilitation protocols
  - Mostly clinician recommendations and lack clinical data [5-8]
- Barriers to CPM
  - Expense sometimes not covered by insurance [9]
  - May not be universally available

Active vs. passive motion comparison

- Primary study outcome
  - Pain
- Secondary study outcomes
  - Function
  - Pain medication usage
  - Swelling resolution
  - Hip ROM
  - Pre-operative pain complaint resolution

Methods

- IRB-approved, prospective, comparative study
  - Duke IRB protocol 00066195
- Standardized surgical and post-operative protocols
  - Active motion
    - Graduated program of active movement
  - Passive motion
    - Kinetec® Spectra™
    - 4-6 hours/day for 3-4 weeks
- Inclusion criteria
  - Patients ages 18 or older undergoing hip arthroscopy for symptomatic FAI
  - 1 of 2 hip preservation specialists at our institution

Study measures

Pre-op covariates

- Rehabilitation strategy
- Age
- Gender
- Pre-operative pain medication usage
- iHOT-12
- VAS pain
- Pain catastrophizing scale
- Patient health questionnaire

2-week and 6-week post-op outcomes

- Pain
- iHOT-12
- Hip flexion
- Pre-operative pain complaint resolution
- Swelling resolution

VAS pain and iHOT-12 outcomes MCID’s

- Recommended to use minimal clinically important difference when evaluating treatment benefits [10]

VAS Pain

- Defined >10% decrease in VAS pain from pre-operative pain since no MCID previously defined for FAI [11]

iHOT-12

- Defined >2.2 point increase from pre-operative value scaled from iHOT-33 MCID [12]

Statistical analysis

- Power calculation based on primary study outcome (pain decrease)
  - >=30 patients per rehabilitation arm
- Univariate analysis
  - Effect of each covariate on each outcome
  - If $p < 0.1$, included in multivariable model
- Multivariable analysis
  - Statistical significance if $p < 0.05$

Baseline characteristics by rehabilitation strategy

Baseline characteristic	***Passive ROM*** **average (lower 95%CI, upper 95% CI) or proportion (n=31)**	***Active ROM*** **average (lower 95%CI, upper 95% CI) or proportion (n=31)**
PHQ score (out of 24)	4.24 (2.72, 5.76)	6.65 (4.65, 8.64)
PCS score (out of 52)	12.65 (8.30, 16.99)	19.06 (13.36, 24.77)
Pre-op pain (out of 10)	4.70 (3.93, 5.47)	5.88 (5.06, 6.71)
iHOT-12 (out of 100)	36.12 (29.83, 42.40)	29.01 (22.13, 35.88)
Opioid	6 / 31 (19.4%)	9 / 31 (29.0%)
Anti-inflammatory	**9 / 31 (29.0%)**	**22 / 31 (71.0%)**
Gender	22 / 31 (71.0%)	26 / 31 (83.9%)

2-week outcomes by rehabilitation strategy (univariate)

2-week outcome	***Passive ROM*** **average (lower 95%CI, upper 95% CI) or proportion**	***Active ROM*** **average (lower 95%CI, upper 95% CI) or proportion**	Univariate p-value
Decreased pain at least 10% from pre-operative	26 / 31 (83.9%)	24 / 31 (77.4%)	0.5195
Hip flexion change from pre-op	1.40 (-1.22, 4.02)	.-2.93 (-8.57, 2.71)	0.173
Swelling resolved	**24 / 31 (77.4%)**	**20 / 30 (93.3%)**	**0.0721**
Opioid usage	19.25 (10.09, 28.41)	25.50 (17.79, 33.21)	0.3106
Pre-operative pain complaint improved	27 / 30 (90.0%)	26 / 31 (83.4%)	0.4761
Patient-reported rehab helpfulness (out of 100)	91.91 (70.62, 113.19)	72.24 (62.10, 82.38)	0.2697
Patient-reported adherence (out of 100)	84.03 (73.92, 94.14)	80.69 (72.74, 88.64)	0.6125

6-week outcomes by rehabilitation strategy (univariate)

6-week outcome	***Passive ROM*** **average (lower 95%CI, upper 95% CI) or proportion**	***Active ROM*** **average (lower 95%CI, upper 95% CI) or proportion**	Univariate p-value
Decreased pain at least 10% from pre-operative	28 / 31 (90.3%)	24 / 31 (77.4%)	0.1622
iHOT-12 increased >2.2 points	20 / 31 (64.5%)	22 / 31 (71.0%)	0.5866
Hip flexion change from pre-op	**13.70 (10.73, 16.67)**	**4.56 (-1.95, 11.08)**	**0.0153**
Opioid usage	**23.82 (12.81, 34.83)**	**39.43 (25.84, 53.03)**	**0.0850**
Swelling resolved	27 / 31 (87.1%)	28 / 31 (90.3%)	0.6878
Pre-operative pain complaint improved	25 / 30 (83.3%)	28 / 31 (90.3%)	0.4170

Effect of rehabilitation strategy

- None retained significance in multivariable analysis

Effect of pre-operative opioid usage in multivariable analysis

Outcome	Average (lower 95%CI, upper 95% CI) or proportion with covariate	Average (lower 95%CI, upper 95% CI) or proportion without covariate	P-value
Patient-reported rehab helpfulness at 2 weeks (out of 100)	63.48 (45.59, 81.08)	88.63 (73.96, 103.30)	**0.0248**
Patient-reported adherence at 2 weeks (out of 100)	72.04 (55.61, 88.47)	85.80 (79.45, 92.14)	**0.0279**
2-week opioid usage	49.77 (35.19, 64.35)	14.80 (10.19, 19.41)	**<0.0001**
6-week opioid usage	72.38 (52.22, 92.55)	20.35 (13.19, 27.52)	**<0.0001**

multivariable outcomes if multiple univariate p-values <0.1

Effect of pre-operative anti-inflammatory use in multivariable analysis

Outcome	Average (lower 95%CI, upper 95% CI) or proportion with covariate	Average (lower 95%CI, upper 95% CI) or proportion without covariate	P-value
Decreased pain at least 10% from pre-operative to 2 weeks	28 / 31 (90.3%)	22 / 31 (71.0%)	**0.0368**
Swelling resolved at 2 weeks	29 / 30 (96.7%)	23 / 31 (74.2%)	**0.0296**

multivariable outcomes if multiple univariate p-values <0.1

Effect of depression scale in multivariable analysis

6-week outcome	Covariate	Odds ratio (lower 95% CI, upper 95% CI)	P-value
Pre-operative pain complaint improved at 6 weeks	Increased PHQ score	12.86 (0.94, 179.73)	**0.0096**

multivariable outcomes if multiple univariate p-values <0.1

Discussion

- Passive vs active motion
  - Passive
    - Increased 6-week hip flexion in univariate analysis
    - Trend towards decreased 6-week opioid usage
  - Active
    - Trend towards decreased 2-week swelling in univariate analysis
  - Multivariable analysis
    - No significant correlations of either rehab strategy with pain, function, swelling, perceived helpfulness, adherence, or pre-op pain complaint resolution

Discussion, continued

- Pre-op opioid usage
  - Increased 2-week and 6-week opioid usage
  - Lower patient-reported rehab helpfulness
  - Lower patient-reported adherence
- Pre-op anti-inflammatory usage
  - Greater proportion with MCID pain relief at 2 weeks
  - Greater proportion with swelling relief at 2 weeks
- Increased pre-op PHQ score (more depressed)
  - Greater report of pre-op pain complaint improvement

Conclusions, strengths and limitations

- Passive motion did not provide much benefit in this study
- Limitations
  - Controlled for known potential confounders
  - Potential for unknown, unmeasurable confounders

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  - Carolyn Hutyra, BS
  - Chad Mather, MD, MBA
  - Steven Olson, MD
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Carolinas HealthCare System

Cortical Button Suspensory Fixation: A Better Patellar Tendon Repair?

Gabriella Ode MD; Dana Piasecki, MD; Nahir Habet, MS; Richard Peindl, PhD

NCOA Annual Meeting, Pinehurst, NC
October 9-11, 2016

One

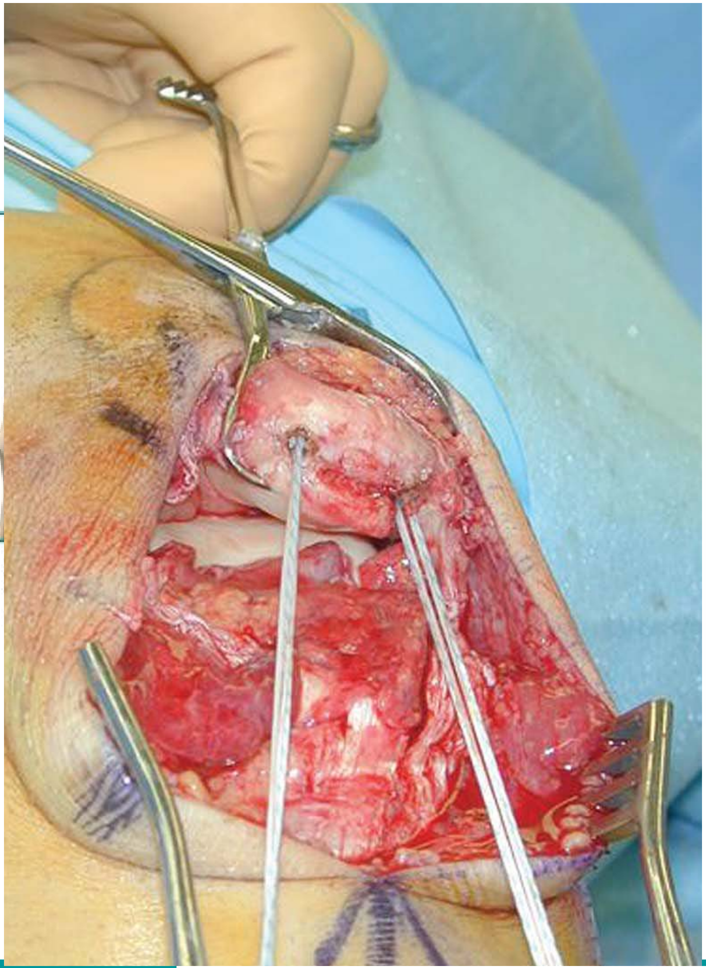
Disclosure Statement

- My co-authors and I have no financial disclosures.
  – All devices were donated in-kind by Arthrex, Inc

Patellar Tendon Rupture

- **Debilitating injury in <40 yo population**
  - Acute repair mandatory for restoration of extensor mechanism
- **No consensus repair technique**
  - **Suture alone** (end to end)
  - **Trans-osseous Suture Tunnels**
    - +/- augmentation (suture, wire, cable, hamstring autograft)
  - **Suture Anchor**
    - Capiola et al, Arthroscopy 2007
    - Gaines et al, JOT 2009
- **Post-Op Rehab**
  - Early ROM vs Immobilization
  - **Balances strength of repair vs risk of symptomatic hardware/wound complications**

- **Cortical button repair**
  - **Recent use in ligament/syndesmotic repair**
  - **No studies in large tendons**



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2. Gaines et al; J Ortho Trauma 2009

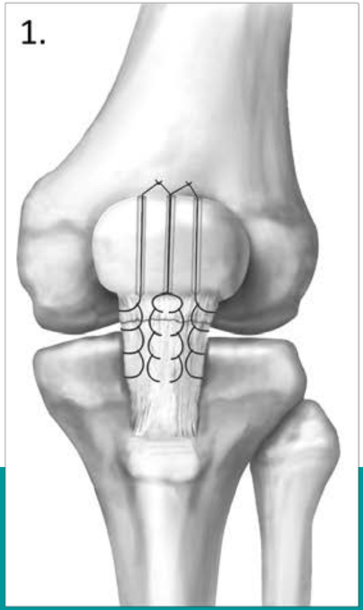
Study Design

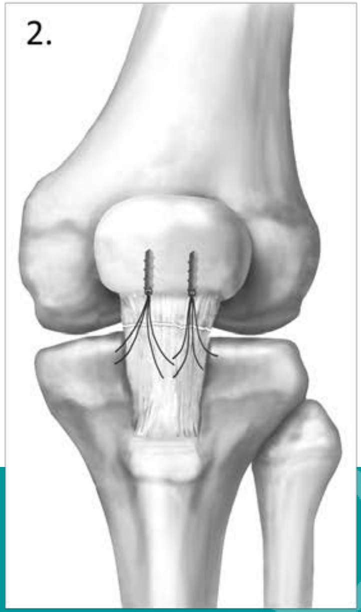
<u>Purpose:</u>

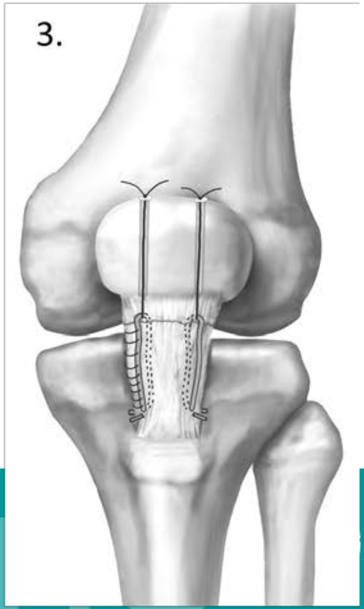
- **To evaluate a novel patellar tendon repair technique using cortical button fixation.**

<u>Design:</u>

- 22 fresh frozen cadaveric knees (mean age = 63 $\pm$ 10 yrs)
  - Simulated patellar tendon rupture at inferior pole of patella
- **Three repair techniques**
  1. **SO** = Standard Krackow suture only repair w/ #2 Fiberwire* (n=7)
  2. **SA** = 4.5mm PEEK anchor repair* (n=7)
  3. **CB** = Cortical button fixation w/ ACL Tightrope*(n=8)







Cortical Button Repair

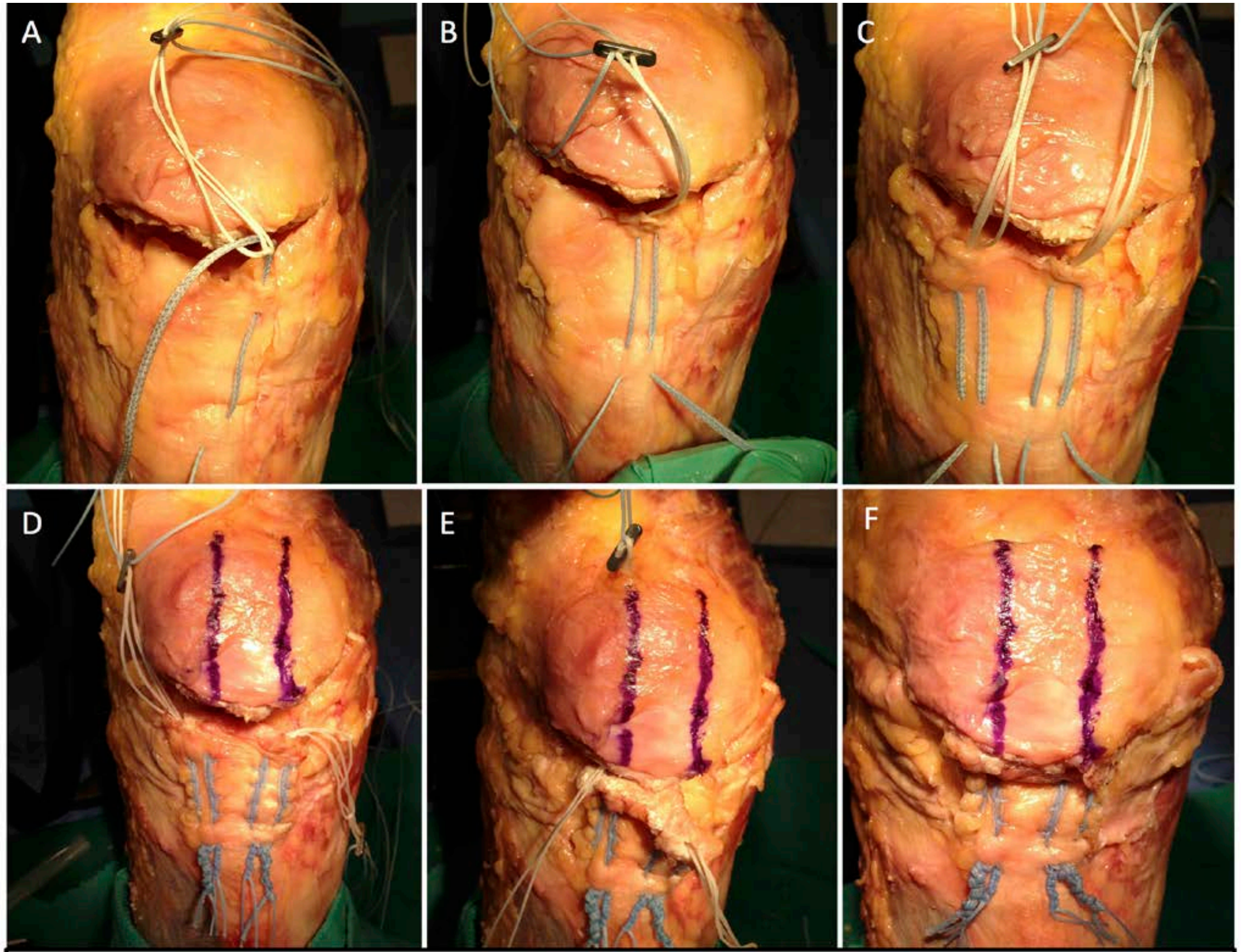


Figure. 1 – Cortical Button Repair: (A) Suture tape is looped through the mid-substance of the proximal edge of the patellar tendon on either side. **(B)** Each CB construct is passed through the suture tape loop. **(C)** The construct is then buried within the tendon edge; **(D)** Then augmented with suture. **(E)** The CB constructs are passed through drilled transpatellar tunnels; **(F)** And tethered to the superior pole of the patella

Study Design

- **Cyclic Load Biomechanical Model**
  - Established model that simulates cyclic open kinetic chain quadriceps contraction from extension to 90^{o} flexion.
    - Ravalin (AJSM 2000); Bushnell (AJSM 2006)

Diagram from Bushnell, AJSM 2006

Study Design

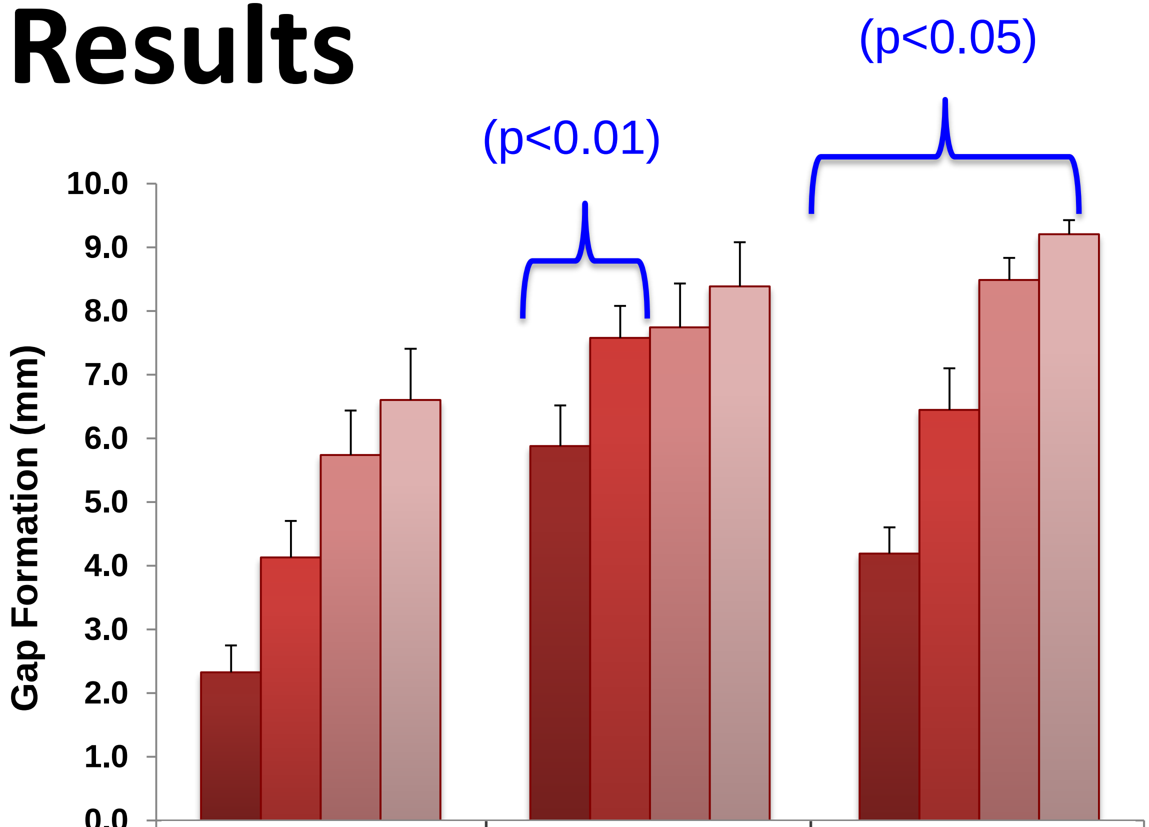
Outcomes of Interest

- **Cyclic Gap Formation (GF) up to 250 cycles →**
  - 230-320N at 0.25Hz
- **Maximum Load to failure**
- **Mode of Failure**
- **Estimated bone volume**
  - Estimated in mean Hounsfield units (HU) acquired from CT scan of each patella

Results

Gap Formation (GF)

- CB vs SA
  - Less GF through 20 cycles
- CB vs SO
  - Less GF through 250 cycles



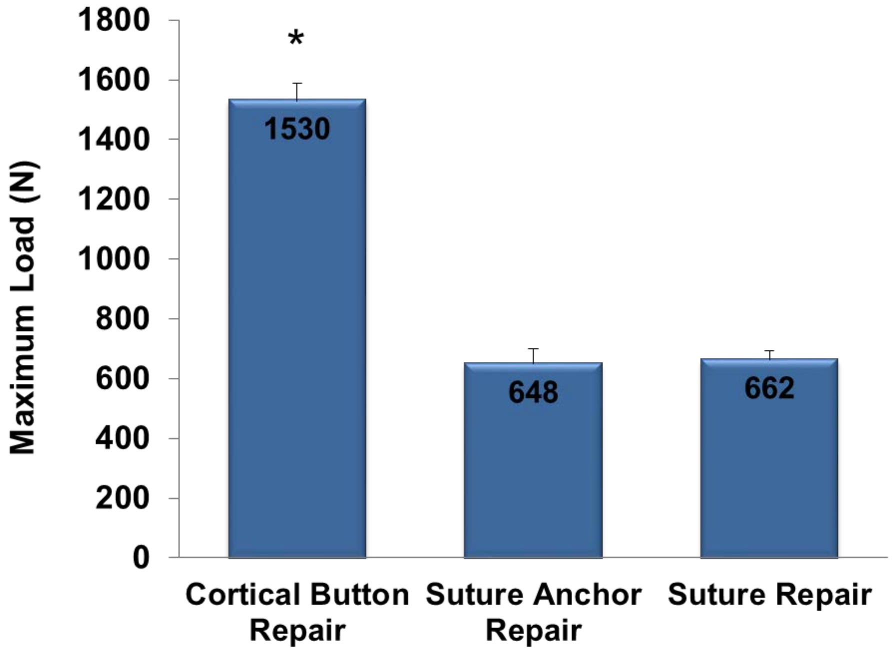
	Cortical Button Repair	Suture Anchor Repair	Suture Repair
1 Cycle	**2.3** ± 0.4mm	**5.9** ± 0.6mm	**4.2** ± 0.4mm
20 Cycles	**4.1** ± 0.6mm	**7.6** ± 0.5mm	**6.4** ± 0.7mm
100 Cycles	**5.7** ± 0.7mm	**7.7** ± 0.7mm	**8.5** ± 0.3mm
250 Cycles	**6.6** ± 0.8mm	**8.4** ± 0.7mm	**9.2** ± 0.2mm

Results

Load to Failure

- CB repairs → significantly higher loads to failure than SA repair and SO repair.

Figure 3: Maximum Load to Failure



* Cortical button repair significantly different from suture anchor and suture repairs (p<0.001).

Results

Mode of Failure

- All SO repairs failed through the suture.
- SA repairs failed at sutureanchor eyelet interface (n= 4) or by anchor pullout (n=3).
- CB repairs either failed through the suture (n=4), secondary failure of the patella tendon (n=2) or pullout of the button through the anterior cortex of the patella

Bone Volume:

- No significant correlation between failure load and mean HU or bone volume for all three groups.
- Anchor pullout in the SA group did occur at 3 of 4 lowest bone volumes for that group.
- CB construct that failed through the patella had the lowest bone volume (10.3 cm^3) of that group.

Discussion

Cortical Button Fixation

- Less gap formation
  - Early cycling vs. Anchor
  - Up to 250 cycles vs. suture only repair
- Withstood at least 2x load to failure of construct.

Limitations:

- Cadaveric study – cannot confirm clinical success
  - Clinical studies needed
- No comparison vs. suture + augmentation

Clinical Relevance

- **Less gap formation**
  - Potentially favors accelerated rehab protocols without repair attenuation
- **Higher load to failure**
  - High resistance to catastrophic repair failure during healing period (sudden quad contraction from stumble or fall)
- **Potentially lower risk for pullout with osteoporotic bone**
- **Not technically challenging.**
- **Cost difference (implants only):**
  - Fiberwire Suture (2)= $37
  - PEEK Anchors (2) = **$570**
  - ACL TightRope + FiberTape (2) = **$677**

Conclusion

Patellar tendon repair using CB fixation has mechanical advantages over both suture and suture anchor repair, which may justify its potential use in clinical practice.

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Comparison of Male vs. Female Knee Kinematics during Anterior Cruciate Ligament Injury

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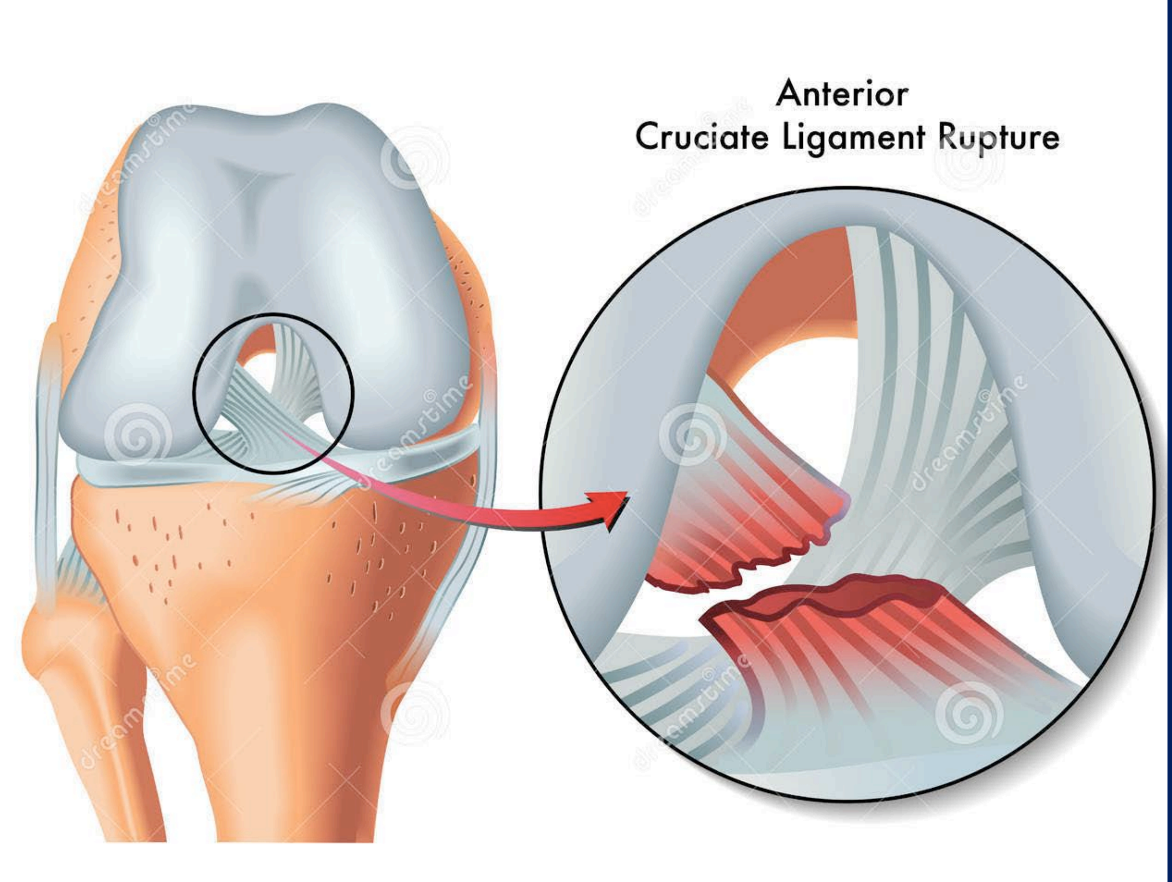
- Disclosures: None

Background

- Anterior cruciate ligament (ACL) rupture common ligamentous injury of the knee
- Estimated incidence 100-250,000 annually (Giugliano 2007)
- Associated healthcare cost $1-2 billion (Silvers 2007)



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Female Predominance

- Rate of ACL rupture is 2-8 times higher in female athletes compared to male counterparts
- Proposed contributing factors
  - Morphology (increased tibial slope, higher Q angle)
  - Hormonal Differences (Liu 1996)
  - Neuromuscular control/Biomechanics

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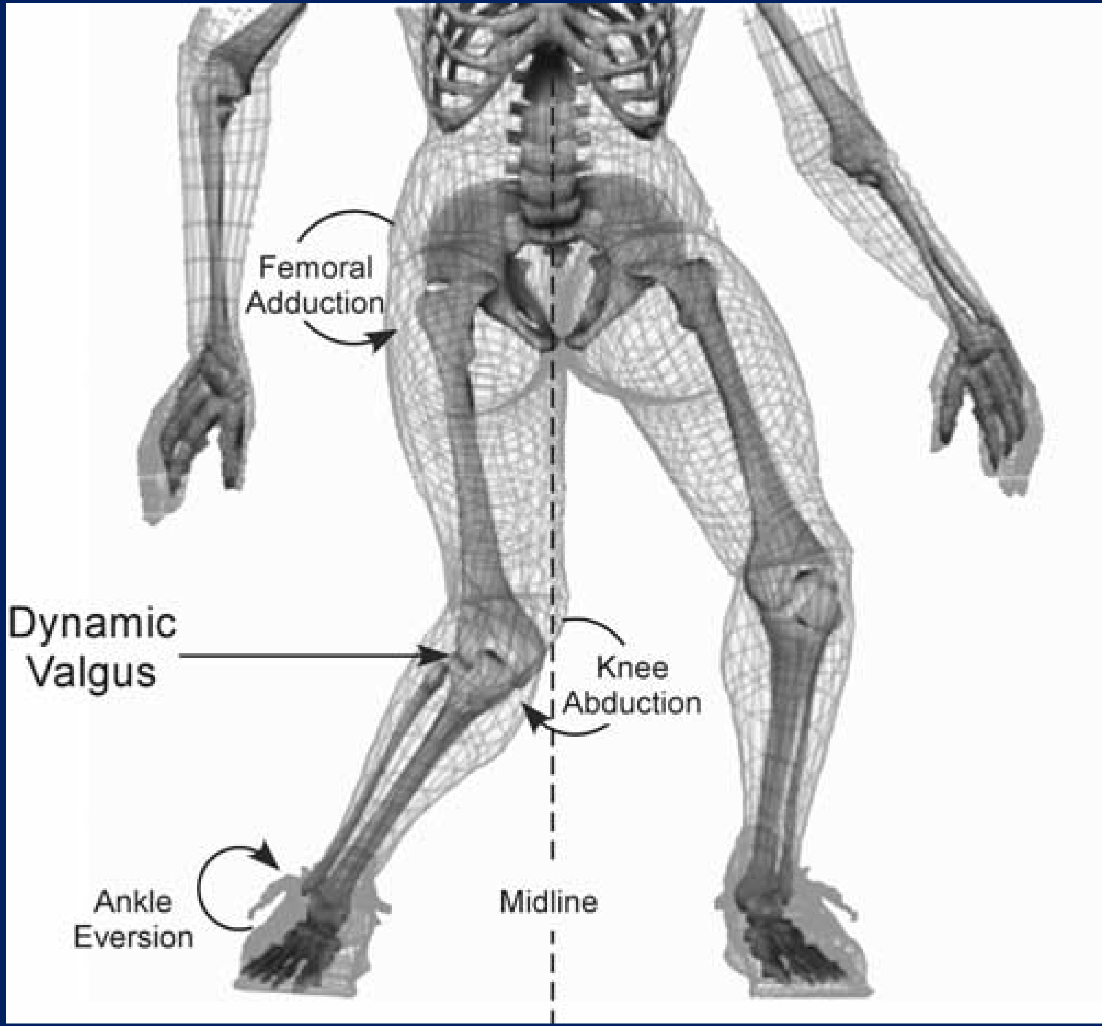
Difference in Kinematics

- Previously proposed higher degree of “valgus collapse” in female athletes
- Prospective 3-D investigation of female athletes prior to season demonstrated knee abduction moment as 73% specific and 78% sensitive for injury (Hewett 2005)
- Further studies show a higher amount of knee abduction in female athletes



Differences in Kinematics II

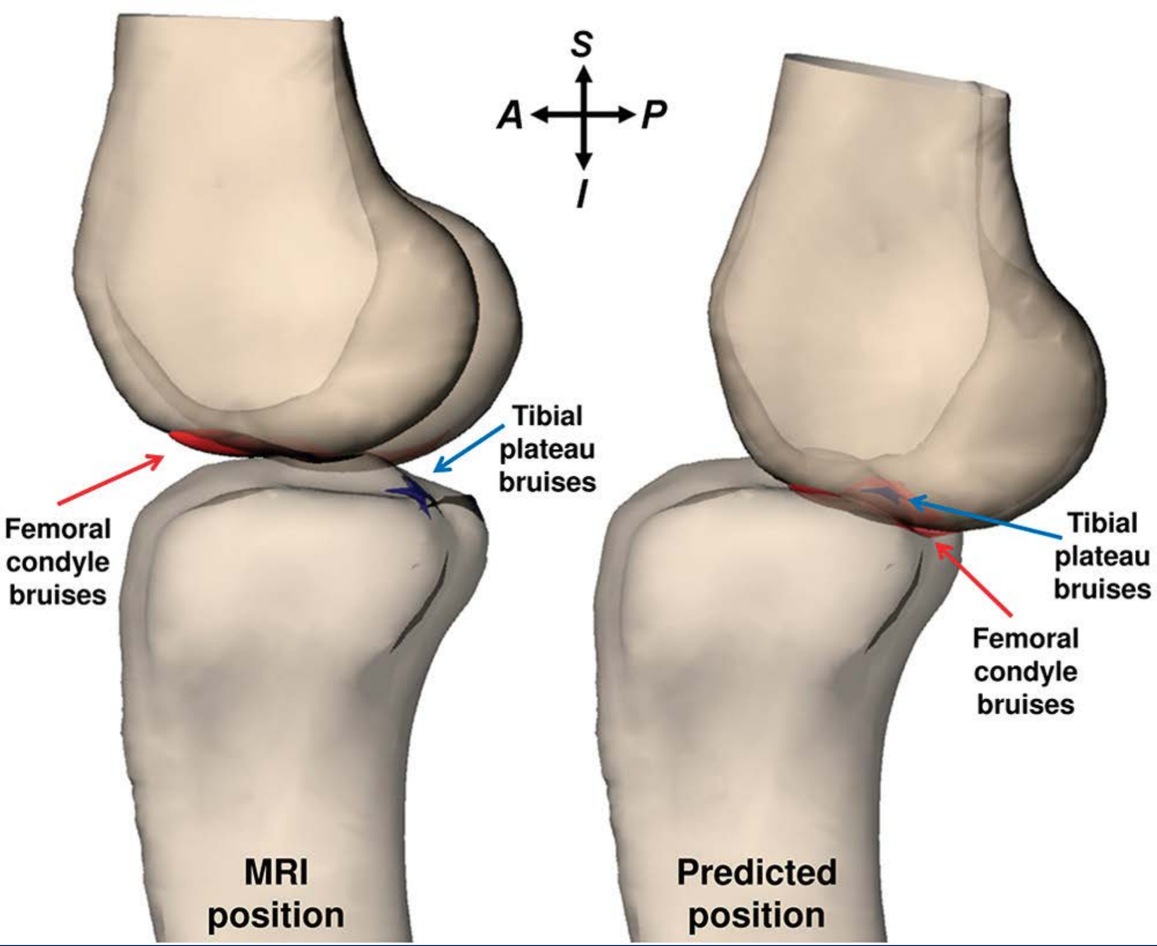
- Video investigations at the time of injury suggesting valgus collapse mechanism (Boden 2009)
- Limitation of this method is 2D analysis of injury occurring in 3 dimensions
- Limited evidence that neuromuscular training has decreased the female predominance of injury (Stevenson 2015)

Bone Contusion and ACL Rupture

- Characteristic bone contusions at the time of ACL rupture on the tibia and femur
- Bone contusions related to impact at time of injury (Viskontas)
- Review of male and female bone contusions patterns demonstrated no difference in location or intensity
- 80% demonstrated injury both compartments, implying anterior translation (Wittstein)

Numerical Optimization of Bone Bruise Locations

- Kim et al utilized numerical optimization of bone bruise overall in 8 subjects with non-contact ACL ruptures
- Mathematical estimate of knee position with bone bruise maximal overlap
- Flexion angle 4 degrees higher, valgus 5 degrees; internal tibial rotation and anterior tibial translation 22 mm
- Support anterior translation as principle injury mechanism rather than valgus collapse



Objectives

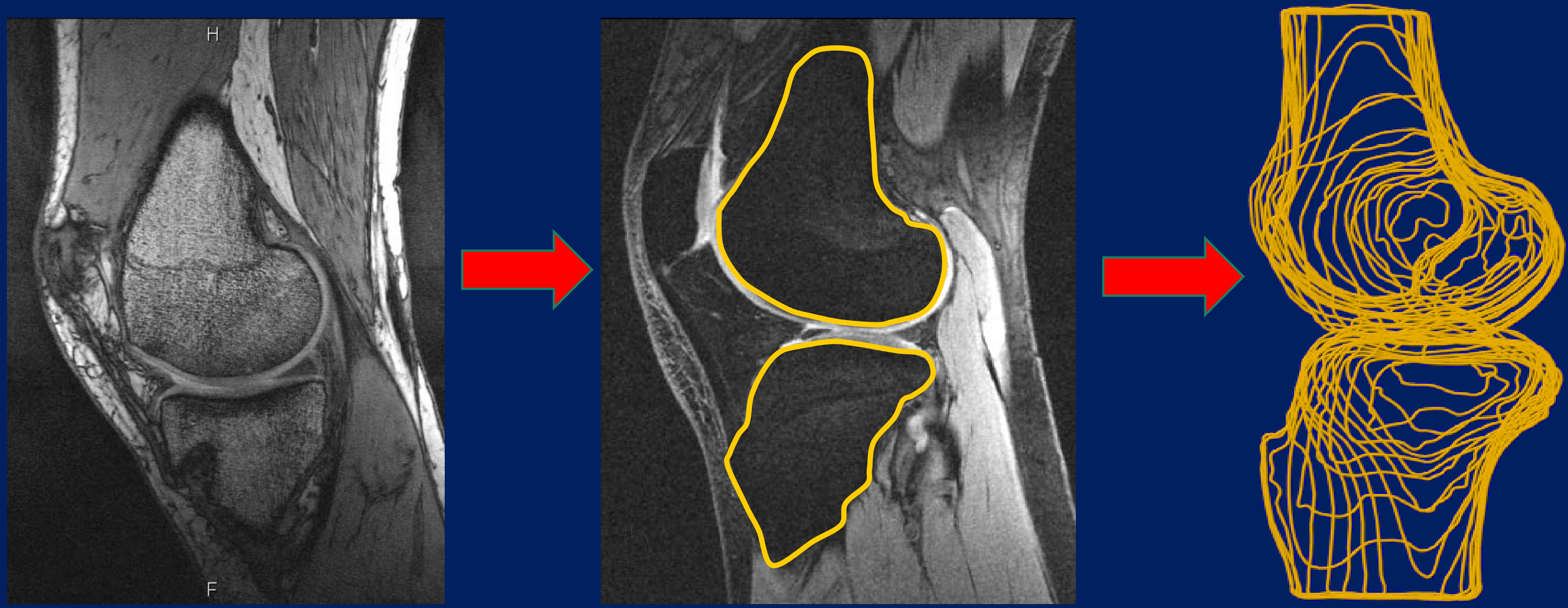
- Utilize numerical optimization of bone bruise overlap to compare male and female position of injury at time of ACL rupture
- Hypothesis: There will be little difference between the kinematics at the time injury between sexes

Methods

- MRI of patient with noncontact ACL ruptures retrospectively reviewed
- Subjects with bone bruising in all 4 locations (Medial and lateral femur/tibia) selected (Kim)
- 12 male and 12 female subjects selected
- MRI obtained within 4 weeks of injury

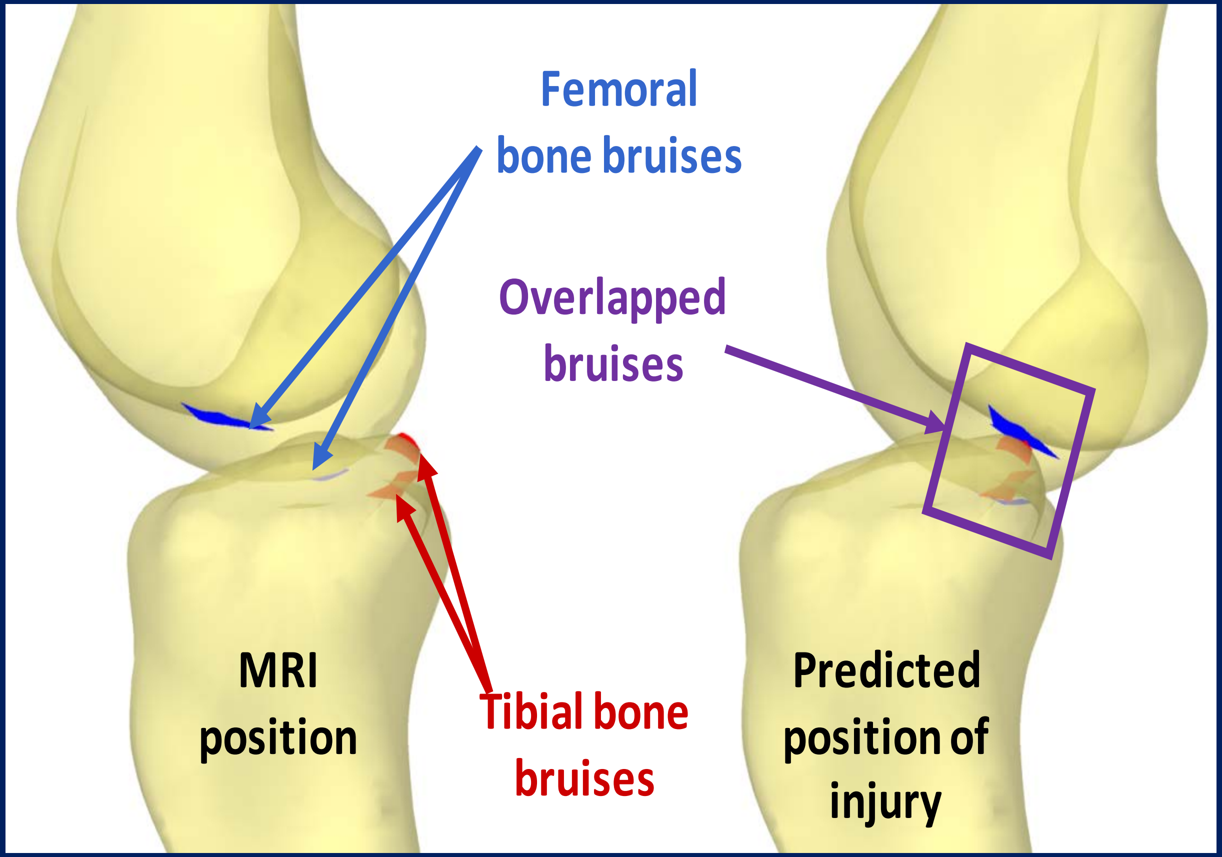
Model Creation

- Sagittal MRI images segmented manually for bony, articular surfaces and bony contusions (Kim)
- Sagittal images stacked to create 3D models of each knee (Rhinoceros 4.0; Robert McNeel and Associates)



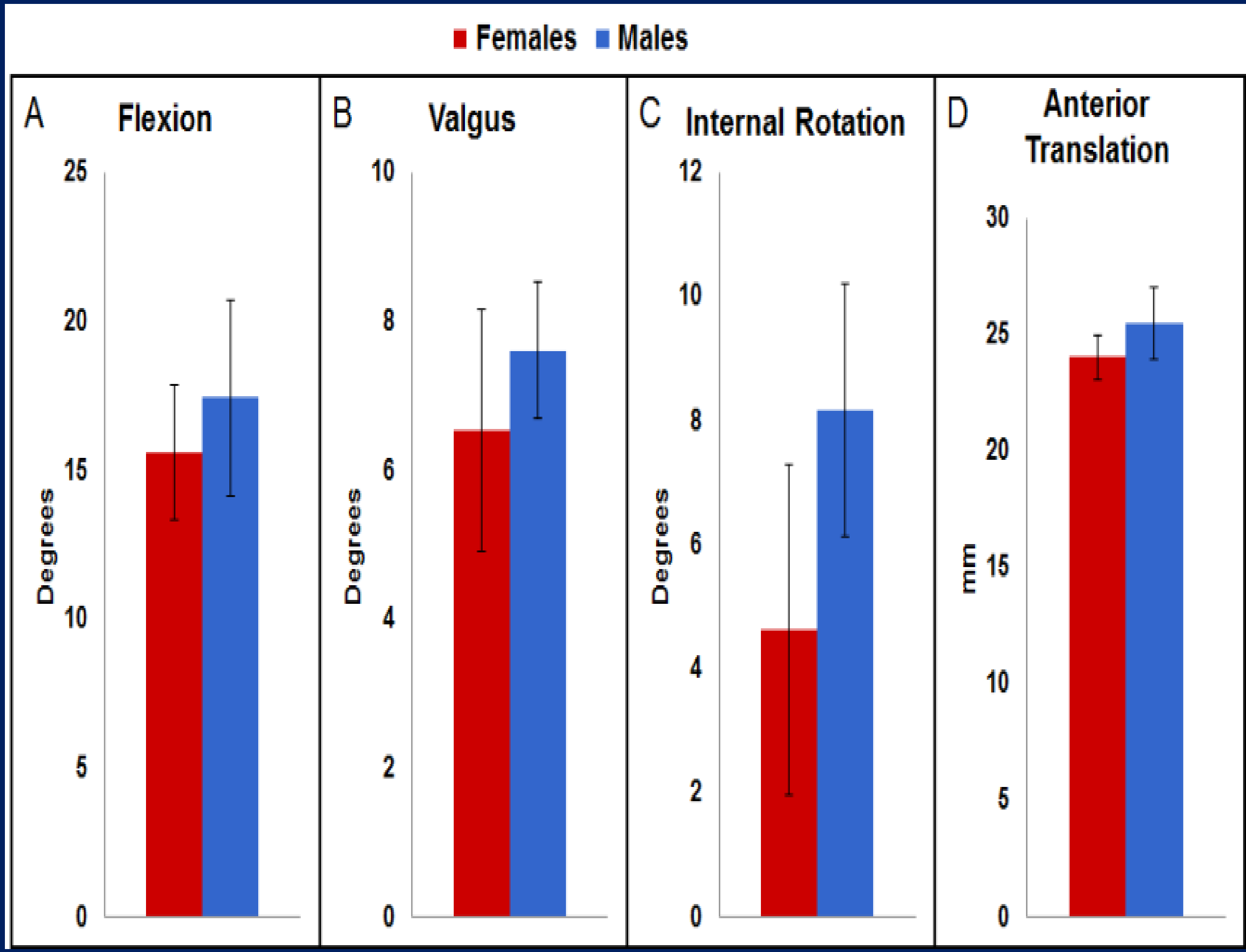
Calculation of Knee Position

- Numerical optimization used to maximize the distance between femoral and tibial bone bruises
- Position of femur translated relative to femur
- Position of femur and tibia measured in 6 degrees of freedom before and after optimization
- Difference in flexion, valgus, internal tibial rotation and anterior tibial translation measured



Results

- No difference in age (p=0.87); time from injury to MRI scan (p=0.94) or frequency of MCL sprain (p=0.66)
- No statistically significant difference between male and female predicted position of injury
- Males slightly greater flexion (1.9 degrees p=0.24); valgus (1.1 degrees p=0.07); internal tibial rotation (3.7 degrees p = 0.40); anterior tibial translation (0.9 mm p=0.13)

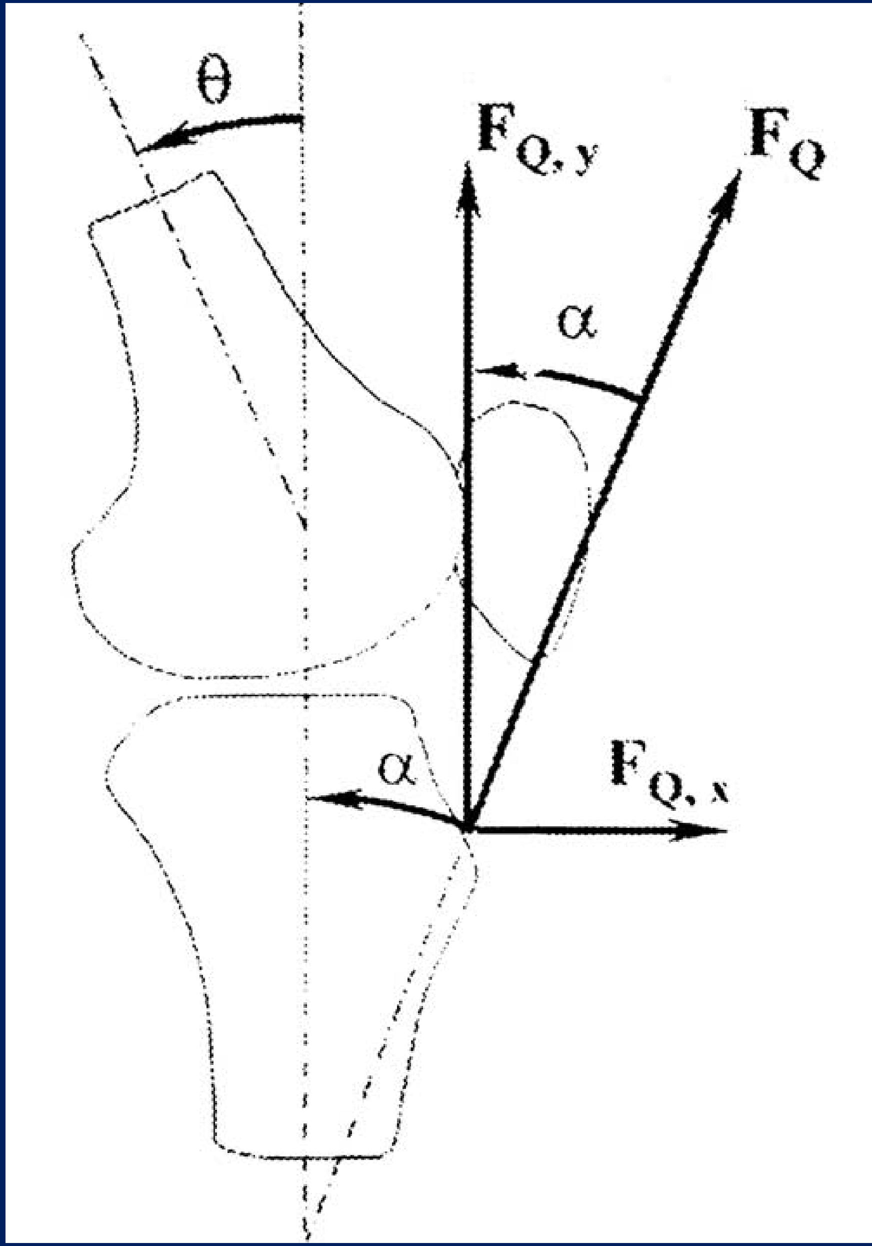


Discussion

- No significant difference between sexes in knee position at time of ACL rupture
- Supported by previous review of bone bruising location/intensity showing no difference (Wittstein 2014)
- Does not support valgus collapse theory, or high degree of knee abduction in female subjects (Kim, Viskontas)

Discussion

- Low flexion angle demonstrated as high risk for injury
- Previous studies demonstrating maximal ACL strain at low flexion with walking and jumping (Taylor 2013)
- Knee flexion directs the quadriceps force on the knee in maximal anterior shear
- Supported by large anterior translation moment demonstrated in this model



Significance & Further Direction

- Further information about the knee kinematics at injury may contribute to improving prevention and rehabilitation
- Findings suggest less effort attribute to knee abduction, increased emphasis on knee stiffness when landing in all athletes
- Further prospective investigation of knee kinematics at the time of injury needed to improve our understanding

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