

# Posterior Inferior Tibial Slope and Its Association with ACL Tears

The ACL Study Group 2004

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# Risk Factors for ACL Rupture



- Notch Width
- Generalized Ligamentous Laxity
- Female Gender
- Elevated BMI in Females
- Hormonal
- Static posture

# Do Other Risk Factors Exist?



# What About Slope?



# Slope and the ACL

- Dejour H, Bonnin M. *J Bone Joint Surg.* 1994; 76B:745-749.
  - Tibial translation after anterior cruciate ligament rupture. A radiological study.

# Slope and the ACL

- Full weight bearing lateral monopodal stance test
- Lateral roentgenogram at 20° knee flexion
- Tibial translation measured as change in relative position of posterior medial tibial and femoral condyles

# Slope and the ACL

## ■ Results

- Highly significant correlation between Posterior-Inferior Tibial Slope (PITS) and anterior tibial translation
- Every 10° increase in PITS causes a 6 mm increase in anterior tibial translation.
  - Intact and ACL-insufficient knees had increased anterior translation
  - Total anterior translation greater in ACL insufficiency

# Slope and Arthrosis

- Hernigou PH, Medevielle D, Debeyre J, Goutallier D. *J Bone Joint Surg* 1987;69-A(3):332-354.
  - Proximal tibial osteotomy for osteoarthritis with varus deformity.

# Slope and Arthrosis

- Long-term (10-13 yr.) f/u of HTO for varus knees with medial compartment OA.
- Radiographic changes compared pre-op vs post-op.

# Slope and Arthrosis

## ■ Pre-op Results

- 12 knees with medial tibial bone erosions
  - 8 in the middle portion-PITS  $10^{\circ}$ - $15^{\circ}$
  - 4 in the posterior portion-PITS  $18^{\circ}$ - $25^{\circ}$

# Slope and Arthrosis

## ■ Conclusions

- Increased PITS results in increased posterior medial tibial plateau bony erosions
- Posterior medial tibial plateau bony erosions correlates with anterior tibial subluxation

# Slope and Arthrosis

- Jiang CC, Yip KM, Liu TK. *J Formos Med Assoc* 1994; 93(6): 509.
  - Posterior slope angle of the medial tibial plateau.

# Slope and Arthrosis

- Retrospective review
- Study group
  - N=50 (21M, 29F)
  - Knee arthrosis patients presenting for eventual TKA
- Negative control group
  - N=50 (28M, 22F)
  - Patellofemoral pain patients
  - Exclusion criteria: tibiofemoral arthrosis

# Slope and Arthrosis

## ■ Results

- Female arthrosis:  $12^{\circ} \pm 5^{\circ}$  PITS
- Female neg control:  $10^{\circ} \pm 4^{\circ}$  PITS
- Male arthrosis:  $9^{\circ} \pm 4^{\circ}$  PITS
- Male neg control:  $10^{\circ} \pm 4^{\circ}$  PITS

# Slope and Arthrosis

## ■ Conclusion

- No statistically significant difference in PITS between cases and controls
- No significant side-to-side difference in PITS
- The difference between female and male cases was not analyzed

# Slope and the ACL

- Meister K, Talley MC, Horodyski MB, Indelicato PA, Hartzel JS, Batts J. *Am J Knee Surg.* 1998;11:217-219.
  - Caudal slope of the tibia and its relationship to noncontact injuries to the ACL.

# Slope and the ACL

- Retrospective review
- Study group
  - N=49 patients (50 knees) (24M, 25F)
  - Non-contact ACL injury
- Negative control group
  - N=39 patients (50 knees) (17M, 22F)
  - Patellofemoral pain

# Slope and the ACL

## ■ Results

- Study group (ACL insufficiency)
  - Mean PITS  $9.7^{\circ} \pm 1.8^{\circ}$
- Negative control group (PFPS)
  - Mean PITS  $9.9^{\circ} \pm 2.1^{\circ}$

# Slope and the ACL

## ■ Conclusions

- No correlation between degree of PITS and risk of ACL tear in this patient population.

# Slope and the ACL

## ■ Problems with this study

- Uneven percentage of males and females between groups
- The number of control patients was insufficient for statistical significance
- Multiligamentous injuries included
- Knee arthrosis included. This would alter the measured PITS (Hernigou, et al).

# Slope and the ACL

- Giffin JR, Vogrin TM, Zantop T, Woo SLY, Harner Cl. *Am J Sp Med*. 2004; 32(2):376-382.
  - Effects of increasing tibial slope on the biomechanics of the knee.

# Slope and the ACL

- Anterior opening wedge high tibial osteotomy
- Cadaveric model
- Increasing PITS an average of  $4.4^\circ$  ( $8.8^\circ$  to  $13.2^\circ$ )
- 200 N axial compression at  $30^\circ$  &  $90^\circ$  knee flexion

# Slope and the ACL

## ■ Results

- 30° knee flexion
  - statistically significant decrease in PCL strain
  - 34 +/- 14 N pre-osteotomy to 19 +/- 15 N post-osteotomy
- 90° knee flexion
  - PCL strain decreased by increasing the PITS, but not statistically significant
- Osteotomy resulted in no statistically significant change in ACL strain at 30° or 90° of flexion.
- 4.4° of increased PITS significantly increased anterior tibial translation 2.0 mm and 1.9 mm at 30° and 90° of flexion, respectively.

# Changing Slope as a Therapeutic Option for ACL Insufficiency?

# So Far Only In These Guys



# And These Guys



# Slope in Dogs

- Slocumb B, Slocumb TD. *Vet Clin North Am Small Anim Pract.* 1993; 23(4): 777-795.
  - Tibial plateau leveling osteotomy for repair of cranial cruciate ligament rupture in the canine.

# Slope in Dogs

- Retrospective review of 394 cases
- extreme amount of PITS seen in canines (mean of  $22^{\circ}$ ) with Cranial Cruciate Ligament (CrCL) ruptures
- axial loading in the CrCL-deficient canine stifle joint-> shear forces on axial load-> cranial tibial translation

Slocumb B, Slocumb TD. Vet Clin No Am Sm  
Anim Prac 1993

# Slope in Dogs

## ■ Procedure

- closing anterior wedge HTO for total correction of PITS to a neutral slope angle of  $0^{\circ}$

## ■ Results

- Good objective results (anterior drawer test: 88% + pre-op; 23.2% + post-op)
- subjective owner satisfaction scores (93% satisfied)

# Is Increased PITS a Risk Factor for ACL Rupture?

## ■ Hypothesis

- Increased PITS is a risk factor for ACL tears
- Women have greater PITS than men
- Increased PITS would correlate with increased pivot shift grades

# Is Increased PITS a Risk Factor for ACL Rupture?

- Retrospective radiographic review
- Study Group
  - N=100 patients (66M, 34F) with ACL insufficiency
  - Exclusion Criteria: multiligamentous knee injury, capsular injury, contact injury, tibiofemoral arthritis.
- Negative Control Group
  - N=100 patients (49M, 51F) with patellofemoral pain syndrome
  - Exclusion Criteria: ligamentous knee injury, capsular injury, meniscal injury, patella instability, tibiofemoral arthritis.

# Does PITS Correlate with Pivot Shift?

- Isolated ACL insufficient patients
  - Multi-center follow-up study
  - N=87
  - PITS measured and compared to pivot shift scores
  - 2 sub groups
    - Low grade pivot shift (0-1+) (n=43)
    - High grade pivot shift (2-3+) (n=44)
  - Exclusion criteria: meniscal injury, capsular injury, multiligamentous injury, knee arthrosis.

# Is Increased PITS a Risk Factor for ACL Rupture?



- Measurement of PITS
  - The difference of  $90^\circ$  minus the angle of intersection of the A-P slope of the medial tibial plateau and the longitudinal axis of the tibia
  - The measured PITS is  $15^\circ$ .

# Is Increased PITS a Risk Factor for ACL Rupture?



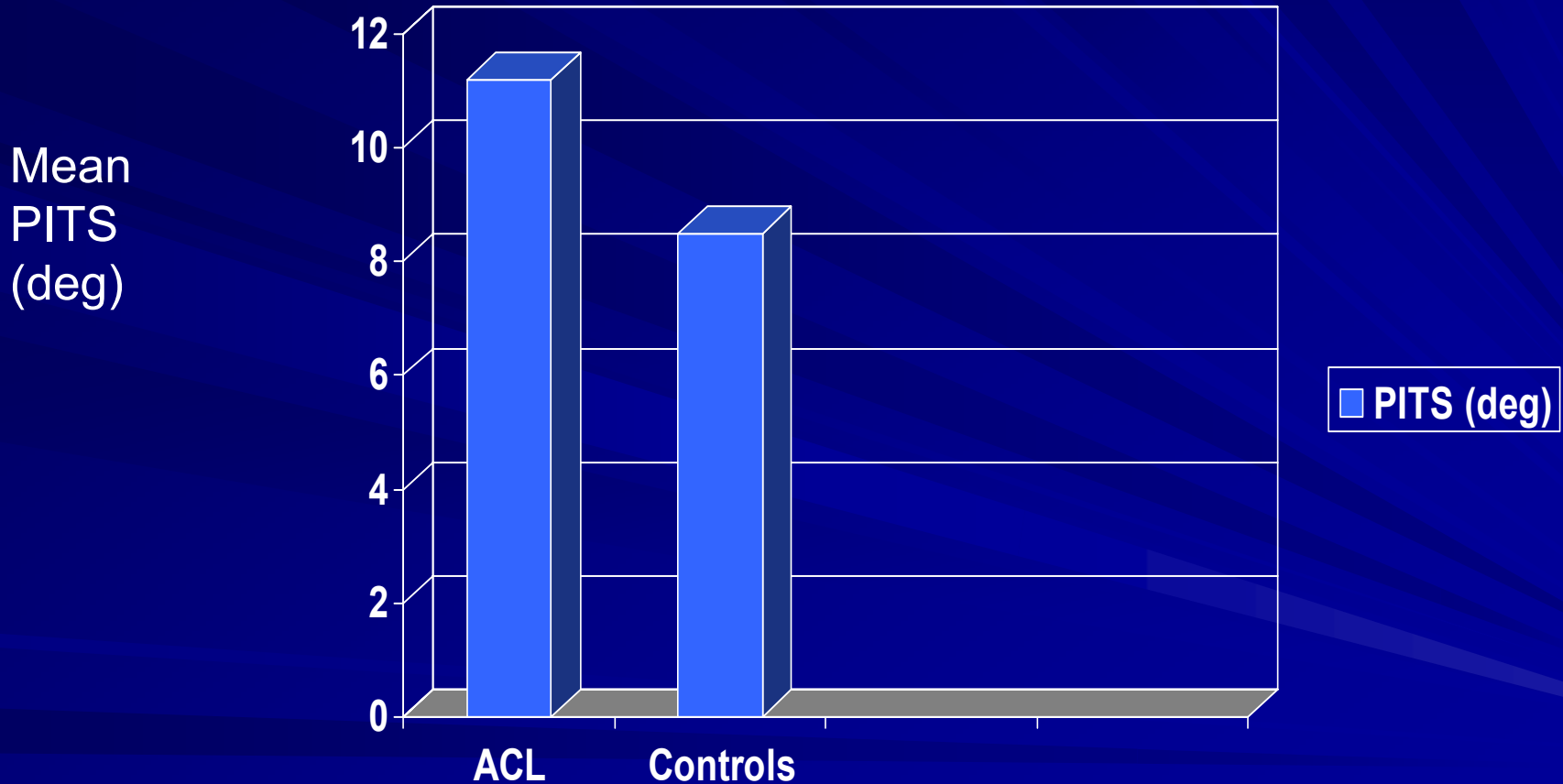
- Lateral radiograph of the left knee of an ACL-insufficient female patient
- The measured PITS is  $16^{\circ}$

# Is Increased PITS a Risk Factor for ACL Rupture?



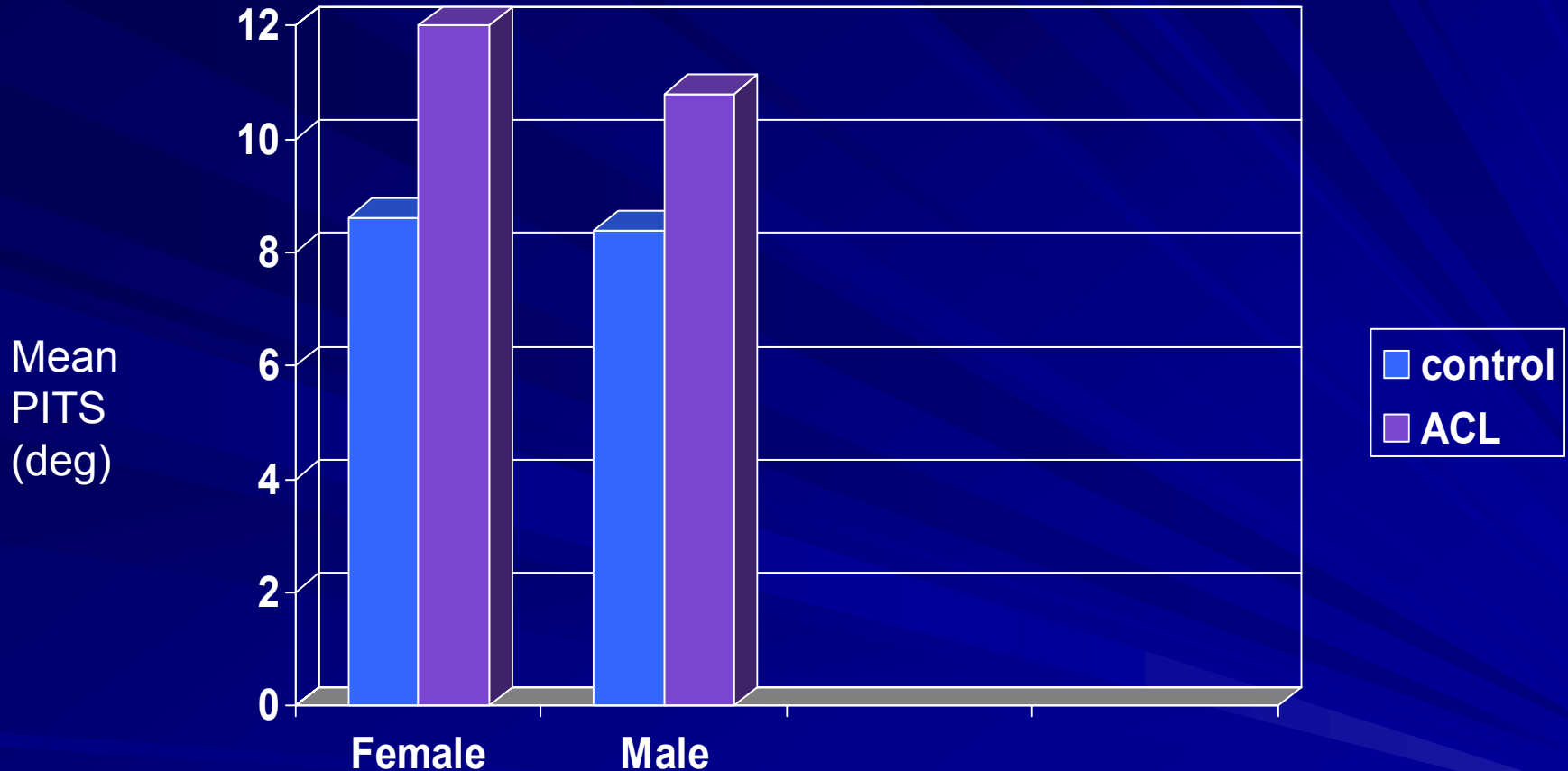
- Lateral radiograph of the right knee of a patellofemoral pain male patient
- The measured PITS is 9°

# Results



The ACL insufficient patients (11.20°) had statistically significant greater degrees of PITS than the control group (8.50°) ( $p < 0.001$ ).

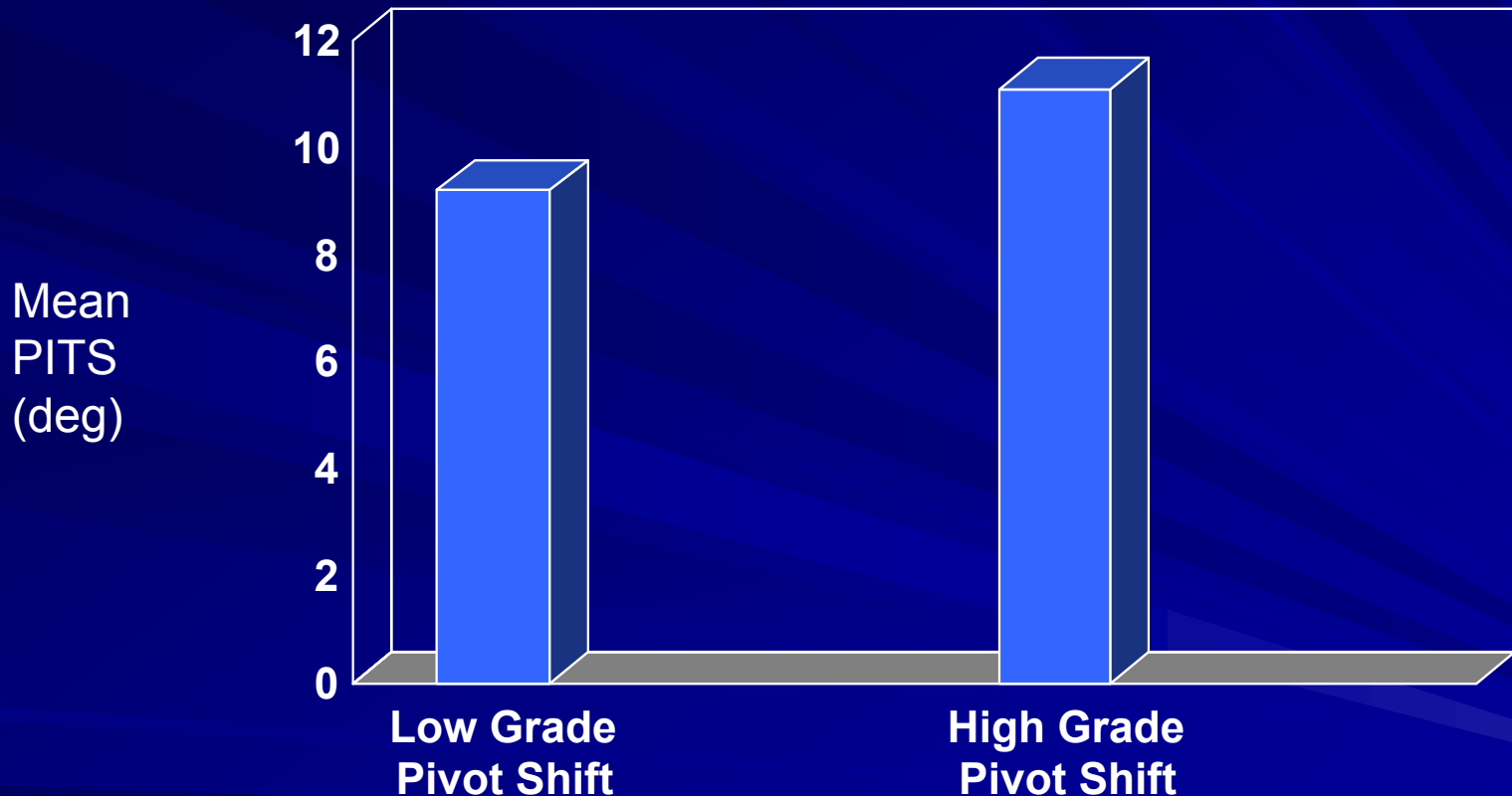
# Results



Female and male ACL insufficient patients had statistically significant greater PITS than their respective negative controls ( $p < 0.001$  and  $p < 0.001$ ).

Female ACL- patients had greater PITS ( $12.0^\circ$ ) than male ACL- patients ( $10.8^\circ$ ), but not statistically significant ( $p = 0.1$ ).

# Results of Isolated ACL PITS & Pivot Shift



High grade pivot shift group ( $11.10^{\circ}$ ) had a statistically significant greater degree of PITS than the low grade pivot shift patient group ( $9.19^{\circ}$ ) ( $p=0.03$ ).

# Is Increased PITS a Risk Factor for ACL Rupture?

## ■ Conclusion

- Increased PITS is a risk factor for ACL tears in both males and females.
- A higher pivot shift grade is associated with an increased degree of PITS.

# The Future

- Further studies are needed to determine whether an increased degree of PITS correlates with
  - Greater subjective knee instability
  - A greater risk of meniscal or chondral injuries
  - The results of ACL reconstructions

# The Future

- How does changing the tibial slope influence kinematics and contact pressures?
- Is a PITS-reducing sagittal plane high tibial osteotomy a potential therapeutic option for treatment of ACL insufficiency?

# Thank you



“Never leave the girl who loves you.” -Dr. Ben Sherman