



Female Patellofemoral Biomechanical Function

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Patellofemoral Pain in Women

- ▣ More common in young female athletes
- ▣ Most common orthopaedic concern among active young women
- ▣ Symptoms include peripatellar pain during repetitive knee flexion associated with weightbearing activities
 - Running, jumping, and climbing stairs

Factors Influencing Patellofemoral Pain in Women

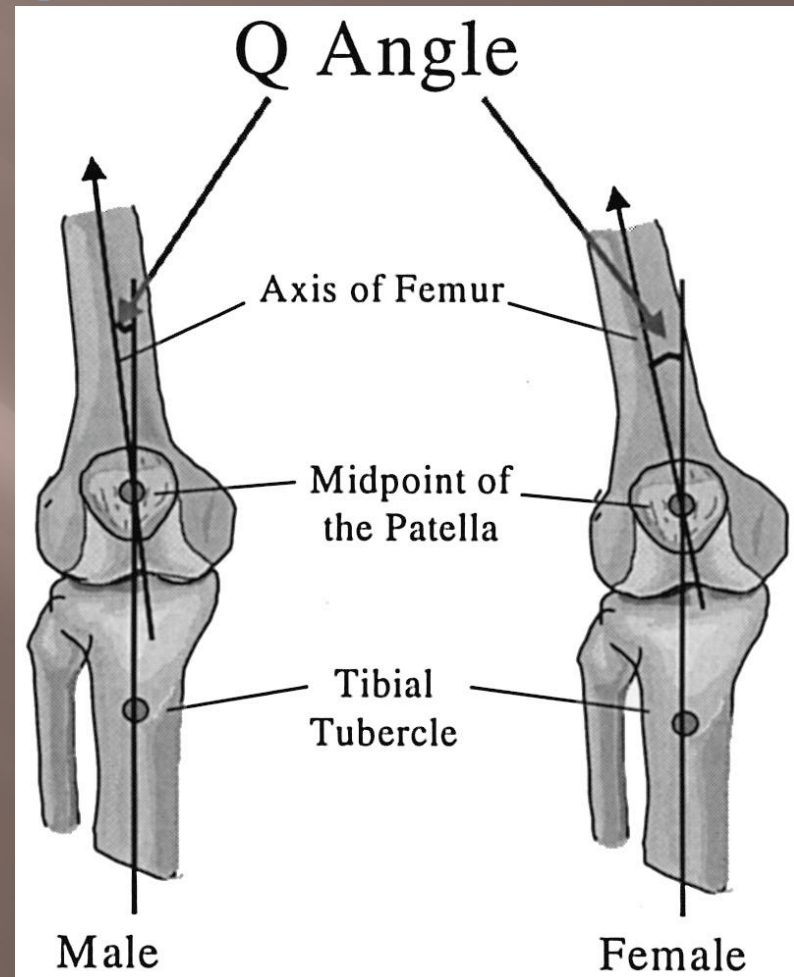
- ▣ High pelvis width (distance between anterior superior iliac spines) to femoral length ratio
- ▣ Imbalance of vastus medialis and vastus lateralis
- ▣ Tibiofemoral abduction angular impulse
- ▣ Studies suggest that individuals with malalignment related anterior knee pain may be more likely to develop patellofemoral osteoarthritis later in life
- ▣ Abnormally large “Q” uadriceps angle was initially thought to cause patellofemoral pain; however is currently debated

Factors Influencing Patellofemoral Pain in Women

- Difference in trochlear groove orientation and tibia rotation
- Hip and trunk muscle weakness may also increase retropatellar stress
- Decreased hip abductor, hip external rotator, and trunk lateral flexor strength causes hip adduction or internal rotation during weightbearing
 - Such rotations in cadaveric studies have been linked to increased retropatellar stress
- Femoral internal rotation has been shown to be associated with decreased patellofemoral joint contact area in individuals with malalignment related anterior knee pain

Q angle

- ▣ Normal Q angle in men: 8° - 14°
- ▣ Normal Q angle in women: 11° - 20°



Csintalan RP, Schulz MM, Woo J, McMahon PJ, Lee TQ. Gender differences in patellofemoral joint biomechanics. Clin Orthop. 2002; 402: 260-269.

Q angle

- ▣ Huberti and Hayes: increases and decreases in the Q angle were associated with increased peak patellofemoral pressures and unpredictable patterns of cartilage unloading
- ▣ A 10-degree increase in the Q-angle resulted in increased peak pressures (up to 45% at 20 degrees of flexion)

Q angle

- ▣ Increased external rotation increases the Q angle of the knee
 - Places tibial tubercle in a more lateral position
 - Both men and women have increased pressures on the lateral patellar facet with external rotation of the tibia
 - ▣ Especially at lower flexion angles

Q Angle Debate

- ▣ The Q angle was assumed to predispose an individual to patellofemoral pain due to increased lateral patellar position
- ▣ Q angle was associated with a more medially and inferiorly located patella in a study conducted by Sheehan et al comparing dynamic MRI findings of symptomatic and asymptomatic subjects
- ▣ The data supported a correlation between the Q-angle and medial, not lateral, patellar displacement

Quadriceps Atrophy and Weakness

- ❑ Leads to imbalance and maltracking of the patella with resultant pain, instability or both
- ❑ Line of pull of the quadriceps muscle parallels the shaft of the femur
- ❑ Quadriceps muscle is in relative valgus with respect to the axis of the tibia
 - Favors lateral deviation of the patella
- ❑ Vastus medialis has an important role as a medial stabilizer of the patella
 - Aids in normal tracking of the patella

Vastus Medialis

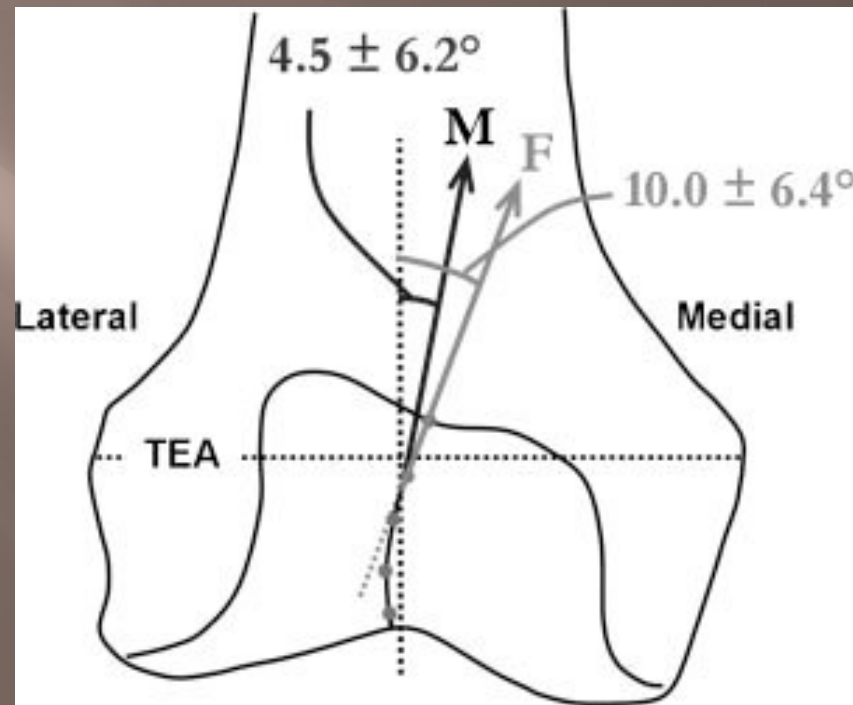
- ▣ Typically the weakest of the quadriceps group
- ▣ First muscle to atrophy and last to rehabilitate
- ▣ Short arc quadriceps strengthening exercises, emphasizing the vastus medialis are part of the initial treatment of patellofemoral disorders

Trochlear Groove Orientation and Rotational Kinematics

- ▣ Varadarajan et al. evaluated 12 male and 12 female subjects with healthy knees to perform a single leg lunge while images of the knee were recorded by two fluoroscopes
 - Females showed:
 - ▣ Greater external tibial rotation at 0° flexion
 - ▣ Smaller internal rotation at 30° flexion
 - ▣ Greater range of tibial rotation

Trochlear Groove Orientation and Rotational Kinematics

- ▣ Female knees had a more medially oriented proximal trochlear groove



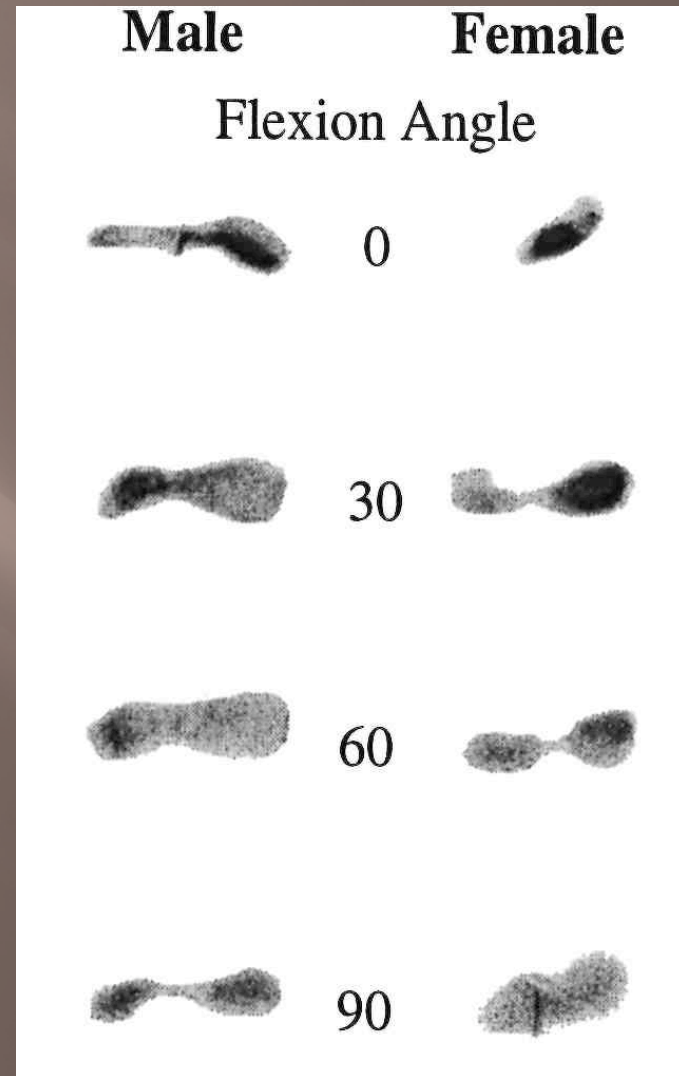
Varadarajan KM, Gill TJ, Freiberg AA, Rubash HE, Li G. Gender differences in trochlear groove orientation and rotational kinematics of human knees. *J Orthop Res.* 2009; 27: 871-878.

Csintalan et al.: Evaluation of Gender Differences in Patellofemoral Joint Biomechanics

- ▣ Twelve fresh-frozen knees from cadavers were tested
- ▣ Anatomic multiplane loading of the extensor mechanism was used with varying vastus medialis loads
- ▣ Study measured patellofemoral contact area and pressure
- ▣ Comparison was made between female and male specimens

Contact Pressures

- ▣ Patellofemoral contact areas are smaller in women at all knee flexion angles greater than 30°
- ▣ Difference increased with greater angle
- ▣ Measured contact area differences are significantly larger than the size difference between female and male knees



Effects of Tibial Rotation

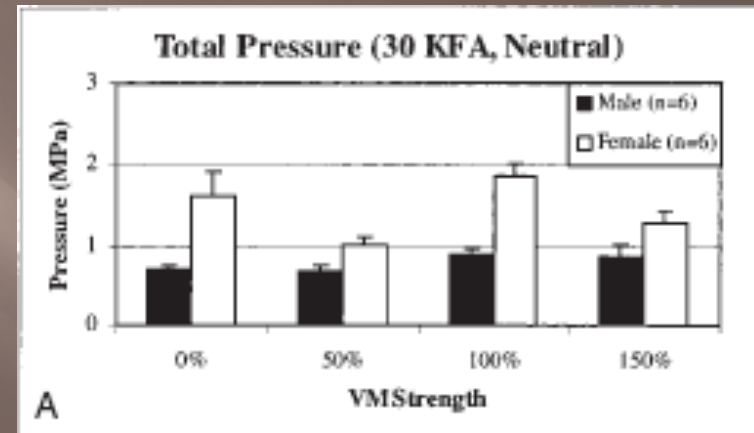
- ▣ Csintalan et al concluded that patellofemoral contact areas were larger in men in neutral, internal rotation and external rotation positions
- ▣ No significant contact difference was seen within a gender with respect to tibial rotation

Csintalan Study

- ▣ Csintalan noted a statistically significant difference in contact area when varying vastus medialis loads between 0% and 50%, and 50% and 150% at the 0 ° angle in both genders
- ▣ Contact area increased with increasing vastus medialis load
- ▣ No significant difference between genders when varying vastus medialis load

Csintalan Study

- ▣ Significant increase in total patellofemoral contact pressure in knees from women compared to men at lower knee flexion angles of 0 ° and 30 ° with the tibia in neutral
- ▣ Possibly explained by larger Q angle (valgus vector at the knee)



Csintalan RP, Schulz MM, Woo J, McMahon PJ, Lee TQ. Gender differences in patellofemoral joint biomechanics. Clin Orthop. 2002; 402: 260-269.

Csintalan Study

- ▣ Women had significant increase in total pressures when compared to men at 30° knee flexion with the tibia in internal and external rotation
- ▣ Both genders had higher pressures with external rotation of the tibia at lower knee flexion angles

Csintalan Study

- ▣ Vastus medialis load
 - Women showed a greater change in patellofemoral contact pressures to varying vastus medialis loads from 0-50% and 50-150%
 - ▣ Pressure changed inversely to vastus medialis load at 0°, 30°, and 60°
- ▣ Peak Pressure
 - Women had statistically significantly higher peak values at 0°, 30°, and 60° of knee flexion with the tibial in neutral

Hip Muscle Function in Relation to Females with Malalignment Related Anterior Knee Pain

- ▣ Baldon et al and Willson et al have demonstrated weaker hip abductor and external rotator muscles in women with malalignment related anterior knee pain



Baldon RM, Nakagawa TH, Muniz TB, Amorim CF, Maciel CD, Serrao FV. Eccentric hip muscle function in females with and without patellofemoral pain syndrome. *J Ath Training*. 2009; 44: 490-496.

Hip Muscle Function in Relation to Females with Malalignment Related Anterior Knee Pain

- ▣ Baldon et al evaluated females with and without malalignment related anterior knee pain
 - Females with malalignment related anterior knee pain demonstrated:
 - ▣ 28% lower eccentric hip abduction mean peak torque
 - ▣ 15% lower eccentric hip adduction mean peak torque
 - No difference in the normalized eccentric hip external or internal rotation peak torque

Hip Muscle Function in Relation to Females with Malalignment Related Anterior Knee Pain

- ▣ Malalignment related anterior knee pain has been related to poor hip adduction and internal rotation control during weight-bearing activities
- ▣ Excessive femoral adduction and internal rotation may increase the dynamic quadriceps angle and lead to greater lateral patellar contact pressure
- ▣ During weight-bearing, females with malalignment related anterior knee pain demonstrate internal rotation of the femur underneath the patella
- ▣ Greater hip external rotation during walking, squatting, running and jumping has been reported to compensate for a larger Q angle

Jumping Mechanics of Female Athletes

- ▣ Willson et al evaluated 20 women with patellofemoral pain and compared them to 20 healthy female controls
- ▣ Women participated in an exertion protocol of repetitive single-legged jumps
- ▣ Examined the effect of exertion on variables thought to increase retropatellar stress in women with and without patellofemoral pain during repetitive single-legged jumping

Jumping Mechanics of Female Athletes

- ▣ Women in Willson's jumping mechanics study with patellofemoral pain when compared to controls had:
 - 24% less lateral trunk flexion strength
 - 13% less hip abduction strength
 - 14% less hip external rotation strength

Jumping Mechanics of Female Athletes

- ▣ When performing single-leg jumps, women with patellofemoral pain when compared to controls demonstrated:
 - Increased hip adduction
 - Increased hip flexion
 - Decreased hip internal rotation
 - Greater hip abduction angular impulse

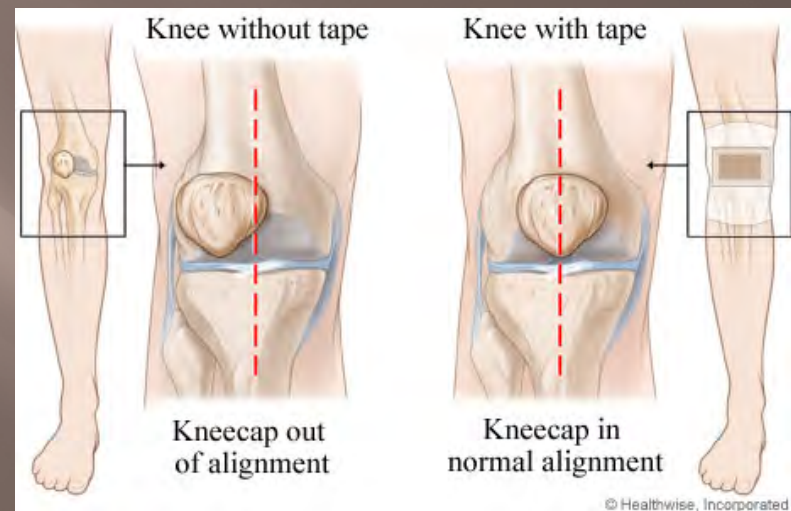
Risk Factors in Developing Patellofemoral Pain

- ▣ The Joint Undertaking to Monitor and Prevent ACL Injury (JUMP-ACL) prospectively investigated risk factors for patellofemoral pain
 - 1597 participants enrolled from the United States Naval Academy
 - Followed for 2.5 years
- ▣ Risk Factors
 - Decreased quadriceps and hamstring strength
 - Increased hip external rotator strength
 - Increased navicular drop
 - ▣ Difference in navicular tuberosity height in a nonweightbearing subtalar joint neutral position and a weightbearing position
 - During jump-landing task
 - ▣ Decreased knee flexion angle
 - ▣ Decreased vertical ground-reaction force
 - ▣ Increased hip internal rotation angle

Nonoperative Treatment of Patellofemoral Dysfunction

- ▣ NSAIDS (however not significant inflammation involved)
- ▣ Simple bracing with elastic patellar cut-out brace
- ▣ McConnell taping technique
- ▣ Stretching quadriceps mechanism
- ▣ Straight-leg exercises with weights on the ankle
- ▣ Exercises within a pain-free arc
- ▣ Vocational Rehabilitation
- ▣ Orthotics

McConnell Taping



Rehabilitation Recommendations Based on Willson's Study

- ▣ Kinematic retraining of landing from jumping
- ▣ Eccentric Hip Strengthening
- ▣ Trunk Strengthening

Recommendations of the Joint Undertaking to Monitor and Prevent ACL Injury (JUMP-ACL) Regarding Patellofemoral Pain

- ▣ Strengthening of the quadriceps and hamstring musculature
- ▣ Teaching proper technique for performing dynamic tasks
 - Decrease hip internal rotation angle
 - Increase knee flexion

References

1. Baldon RM, Nakagawa TH, Muniz TB, Amorim CF, Maciel CD, Serrao FV. Eccentric hip muscle function in females with and without patellofemoral pain syndrome. *J Ath Training*. 2009; 44: 490-496.
2. Boling MC, Padua DA, Marshall SW, Guskiewicz K, Pyne S, Beutler A. A prospective investigation of biomechanical risk factors for patellofemoral pain syndrome: The joint undertaking to monitor and prevent ACL injury (JUMP-ACL) cohort. *Am J Sports Med*. 2009; 37: 2108-2116.
3. Conley S, Rosenberg A, Crowninshield R. The female knee: anatomic variations. *J Am Acad Orthop Surg*. 2007; 15: S31-S36.
4. Csintalan RP, Schulz MM, Woo J, McMahon PJ, Lee TQ. Gender differences in patellofemoral joint biomechanics. *Clin Orthop*. 2002; 402: 260-269.
5. Draper CE, Besier TF, Santos JM, Jennings F, Fredericson M, Gold GE, Beaupre GS, Delp SL. Using real-time MRI to quantify altered joint kinematics in subjects with patellofemoral pain and to evaluate the effects of a patellar brace or sleeve on joint motion. *J Orthop Res*. 2008: 571-577.
6. Escamilla RF, Zheng N, Macleod TD, Edwards WB, Imamura R, Hreljac A, Fleisig GS, Wilk KE, Moorman CT, Andrews JR. Patellofemoral joint force and stress during the wall squat and one-leg squat. *Med Sci Sports Exerc*. 2009: 879-888.
7. Huberti HH, Hayes WC. Patellofemoral contact pressures. *J Bone Joint Surg* 1984; 66A: 715-723.
8. Horton MG, Hall TL. Quadriceps femoris muscle angle: normal values and relationships with gender and selected skeletal measures. *Phys Ther* 1989; 69: 897-901.
9. Macintyre NJ, Hill NA, Fellows RA, Ellis RE, Wilson DR. Patellofemoral joint kinematics in individuals with and without patellofemoral pain syndrome. *J Bone Joint Surg* 2006; 88A: 2596-2605.
10. Sheehan FT, Derasari A, Fine KM, Brindle TJ, Alter KE. Q-angle and J-sign: indicative of maltracking subgroups in patellofemoral pain. *Clin Orthop Relat Res*. 2010; 468: 266-275.
11. Varadarajan KM, Gill TJ, Freiberg AA, Rubash HE, Li G. Gender differences in trochlear groove orientation and rotational kinematics of human knees. *J Orthop Res*. 2009; 27: 871-878.
12. Willson JD, Binder-Macleod S, Davis IS. Lower extremity jumping mechanics of female athletes with and without patellofemoral pain before and after exertion. *Am J Sports Med*. 2008; 36: 1587-1596.