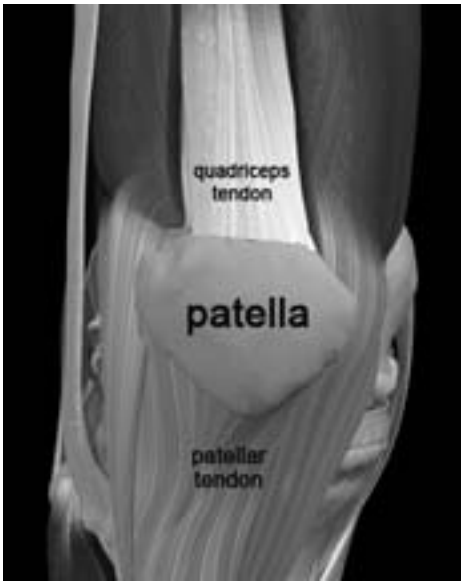
# CLINICAL BIOMECHANICS:
# Patellofemoral Biomechanics

By Christopher MacLean, Ph.D.

## INTRODUCTION

The knee is the most common site of overuse running injury. Specifically, anterior knee pain (PFPS, patellar tendinopathy, patellar instability, fat pad impingement) is the most common injury sustained by runners. Because of this, biomechanists have focused research efforts on investigating coupling mechanisms in the lower extremity, variability in movement patterns and the influence of various therapeutic interventions on knee dynamics. The current *Clinical Biomechanics* will focus on these three areas.




## COUPLING DYNAMICS

With the running boom that emerged in the late 1970s came a plethora of research trying to identify the mechanisms underlying overuse running injuries. Initially, it was proposed that excessive subtalar joint (STJ) pronation was a potential etiological factor. We have learned that the story underlying running injury mechanisms is not so simple. It is much more complex and what defines *excessive pronation* has yet to be determined. In fact, STJ pronation is an essential movement pattern that allows the lower extremity to attenuate the forces associated with weight acceptance.

Bates et al. (1979) were among the first to suggest that during the initial part of the stance phase, the rotations of subtalar joint pronation, tibial internal rotation and knee flexion are coupled. At approximately midstance, these rotations should reverse in a somewhat synchronous manner. These authors proposed that it may be deleterious if the subtalar joint: 1) continues to pronate while the knee begins to extend or 2) begins to supinate while the knee continues to flex. It was thought that these mechanisms would produce a series of antagonistic counter rotations that might lead to injuries of the soft tissue about the ankle and knee.

This idea led to a number of theoretical models on how the movement of the foot influences knee dynamics and, specifically, patellofemoral tracking. In 1987, Tiberio proposed that with prolonged or greater degrees of pronation, the leg would be delayed in external rotation and thus the femur would have to internally rotate in order to facilitate knee extension. This scenario would certainly facilitate knee extension but might be deleterious in terms of patellofemoral tracking increasing the compression between the infrapatellar surface and lateral femoral condyle.

More recently, Powers (2003) has reviewed how dynamic Q-angle (Figure 1, left) may be influenced by transverse and frontal plane rotations of the femur and tibia. On its own, tibial internal rotation may decrease the dynamic Q-angle and lateral force vector (Figure 1, right).

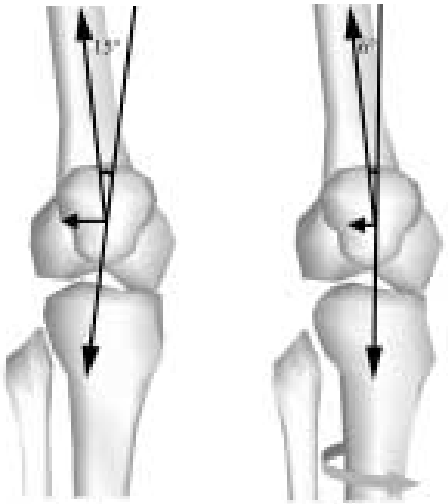


Figure 1: (from Powers, 2003)

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# CLINICAL BIOMECHANICS:
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However, when coupled with internal rotation of the femur (Figure 2, left) and/or knee abduction (Figure 2, right), dynamic Q-angle will increase. Thus, increasing the lateral force vector.

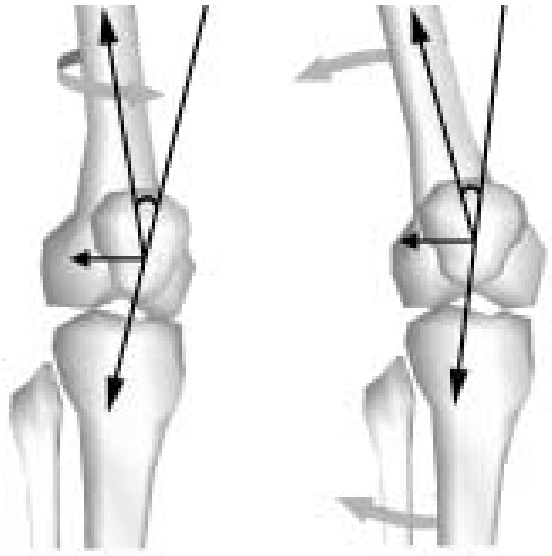

Figure 2: (from Powers, 2003)

## COUPLING VARIABILITY

Investigating the angular rotations of segments and joints is certainly one method of studying coupling, another method is to analyze the variability of movement patterns. Hamill et al. (1999) suggested that decreased coordination or coupling variability may be an etiological factor for, or the result of, orthopaedic injury. The idea here is that there is a healthy degree of variablilty in the coordinated movement patterns between joints and/or segments. A decrease in variability may lead to localized tissue stress with repetitive joint/segment actions. This is not unlike the idea that it may be healthier running on variable surfaces (i.e. trail running) versus on a treadmill.

There is a great deal of work that remains to study the relation between movement variability and etiology of injury. However, there is some evidence to suggest that runners with PFPS exhibit decreased variability in some couplings. Whether this is the cause or the result of the injury remains unknown.

## CUSTOM FOOT ORTHOSES

It is generally accepted in the literature that custom foot orthotic (CFO) intervention leads to an improvement in symptoms in patients with anterior knee pain (Saxena & Haddad , 2004; Johnston & Gross, (2004). At the University of Massachusetts Amherst, we investigated a number of dynamic variables to see how custom foot orthoses influenced joint and segment angular rotations, and variability of movement patterns.

In our studies, subjects reported an improvement in knee symptoms of ~75% and a significant decrease in pain. However, we did not find that the orthoses influenced femoral internal rotation or knee angle in the frontal plane. This is consistent with other studies who have also reported little to no change in knee kinematics with CFO intervention (Mundermann et al., 2003) or shoe modifications (Hamill et al., 1992).

During running the knee goes into adduction (increased genu varum) until about midstance and then abducts until toe-off. Williams et al., (2003) showed that CFO intervention led to increases in knee adduction angle. This may be viewed as beneficial to some and deleterious to others depending on knee alignment (frontal plane) prior to heel strike.

Our laboratory has also looked at how CFO intervention influences movement variability. Our studies have analyzed healthy and injured runners. Our results suggest that healthy runners maintain a level of variability throughout the course of a prolonged run (30-minutes) when running in a shoe only condition whereas injured runners exhibit significant decreases in variability. When performing the run with orthoses in their running shoes, our results revealed the variability is maintained in a pattern that resembles the healthy runners. This was specifically the case for the coupling between the foot (frontal plane) and tibia (transverse plane).

In conclusion, there is a lot of work that still remains to determine the biomechanical cause of patellofemoral pain and how different interventions influence that cause. What may be the cause of injury and response to intervention in one patient/subject may be very different from the next.

*For cited references, please contact Christopher MacLean at cmaclean@parisorthotics.com.*