The Role of Dynamic Hamstring Activation in Preventing Knee Ligament Injury

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Anterior cruciate ligament (ACL) injuries result primarily from a non-contact mechanism and often occur during movements that require a sudden deceleration or change of direction. Athletes whose sports involve jumping, cutting, and pivoting maneuvers are particularly susceptible to these injuries. In order to adequately counteract the joint forces inherent in these activities, the knee musculature plays a critical role in joint stabilization. Given the position of the hamstring muscles relative to the knee joint, their function in stabilizing the tibia to prevent excessive anterior and rotary tibial translation is particularly important to anterior cruciate ligament protection.

Therefore, training the hamstring muscle group to respond quickly and effectively to sudden joint stress may be an important factor in dynamic joint stabilization and ligament protection. To that end, our purpose in this article is to identify factors that can influence dynamic hamstring activation and to discuss the implications of these factors on training and rehabilitation techniques.

What is Dynamic Stability?
Dynamic stability refers to the ability to maintain joint equilibrium and prevent excessive motion through appropriate neuromuscular responses when dynamic forces and disturbances are detected at the joint (McClanahan & Williams, 1986). One of the primary causes of knee ligament injury is the large mechanical forces imposed on the knee joint during sport activity. These forces can cause excessive joint motion to the point at which the ACL becomes stretched and ultimately torn. To counteract these forces, the knee joint has both static (ligament, capsule) and dynamic (muscle) stabilizers.

While the anterior cruciate ligament provides about 86% of the static resistance to pure anterior tibial translation (Butler et al., 1980), the forces incurred in sport go well beyond the capacity of the ligament and require the addition of the active musculature to “stiffen” the joint and thus prevent joint deformation and ligament strain. If the quadriceps act alone, they can pull the tibia forward on the femur, which can place strain on the ACL. However, if the hamstrings are activated at the same time (i.e., co-contraction), their action can counteract the anterior pull of the quadriceps and help stabilize the knee. In fact, research has demonstrated that timely co-activation of the hamstrings with the quadriceps can significantly reduce ACL strain by reducing anterior and rotary tibial translation (shear) (Hirokawa et al., 1999).
Factors That Influence Dynamic Hamstring Activation

Optimal training is desirable for maximizing the protective role of the hamstrings in preventing ACL strain by counteracting anterior shear forces and rotary tibial translation. The following factors have been found to influence hamstring activation and should be considered when designing training programs that maximize their response.

Joint Angle and Body Position

In order for the hamstring muscles to be effective in reducing anterior and rotary shear forces at the knee joint, it appears the knee must be flexed to at least 15–30° (Hirokawa et al., 1991; Renstrom et al., 1986). At flexed knee positions, the contracted hamstrings line of pull is more parallel to the joint surface and will pull the tibia in a posterior direction. Conversely, when the knee is hyperextended, straight or only slightly flexed, the hamstrings line of pull is more perpendicular to the joint. This position will act to stabilize and compress the joint, but will not pull the tibia posteriorly to counteract an anterior tibial translation force (Figure 1).

In addition to knee joint angle, the position of the trunk and hip in relation to the knee can also affect hamstring activation. This was demonstrated by Wilk et al. (1996), who compared hamstring activity during isotonic squat, leg press, and leg extension (open chain) exercises. Hamstring co-activation was found to be significantly greater in the squat compared to leg press and leg extension exercises which demonstrated high levels of quadriceps activation but minimal hamstring activity. Hamstring activity was greatest during the concentric phase of the squat between 40 and 70° of knee flexion.

These differences in hamstring co-activation were thought to be influenced by the position of the trunk relative to the knee, with greater activation noted when the trunk was positioned directly over the knee (squat) versus behind the knee (leg press and leg extension). Hip flexion angle while standing was thought to be a related factor, as this position creates a forward lean of the trunk which reduces quadriceps activation and increases hamstring activation.

Prior Training

Specificity of training and level of conditioning can also affect hamstring function during activity. Hamstring co-activation during knee extension forces has been shown to be diminished in athletes with hypertrophied quadriceps who do not routinely train their hamstrings (Baratta et al., 1988). Training of the quadriceps and not the hamstrings may result in neural adaptations that inhibit hamstring activity in favor of more efficient quadriceps function (Baratta et al., 1988; Enoka, 1994). Clearly, this training imbalance would be counterproductive to the hamstrings' ability to stabilize the tibia during extension forces.

Additionally, how the hamstrings are trained can also influence the speed of muscular activation. Wojtys et al. (1996a) compared the effects of various exercise regimens on neuromuscular performance. Time to peak torque (via isokinetic testing) and muscle reaction time were measured in the quadriceps, hamstring, and gastrocnemius muscles in subjects following either agility, isokinetic, or isotonic training. The agility-trained group had significantly more improvement in muscle reaction time than the isokinetic- or isotonic-trained groups. They also had the greatest decrease in time to peak torque for both quadriceps and hamstring muscles while the isotonic-