Unlocking the mechanisms of ACL injury

By Jennie McKee

Recent studies have shed new light on the mechanism of injury for anterior cruciate ligament (ACL) sprains and tears, paving the way for developing new preventive strategies. AAOS Now spoke with Barry P. Boden, MD, principal author of “Noncontact Anterior Cruciate Ligament Injuries: Mechanisms and Risk Factors,” a review article that appears in the September issue of the Journal of the AAOS (JAAOS).

AAOS Now: What mechanisms have traditionally been believed to cause ACL injuries?

Dr. Boden: One popular but unproven theory was that ACL impingement against the intercondylar notch caused the injury. Another popular theory is that the quadriceps causes an anterior vector on the knee, stressing and potentially disrupting the ACL, whereas the hamstrings cause a posterior vector, thereby protecting the ACL. However, when the knee is close to full extension—the position in which most noncontact ACL injuries occur—both tendons insert into the tibia at low angles. Therefore, both muscles increase the compressive force on the knee and have a more minor anterior or posterior vector. If the angle of insertion was greater than 45 degrees, the opposite would be true.

I believe the quadriceps may play a role in ACL injury, but more likely because of the compressive vector rather than the anterior vector. It’s also likely that cocontraction of the hamstrings contributes to tibiofemoral joint compressive forces, but only has minor posterior protective forces.

AAOS Now: What is now known about the mechanism of injury?

Dr. Boden: The major breakthrough in understanding the mechanism of injury came when Joseph S. Torg, MD, and colleagues identified axial compressive forces as a potentially important component in an article published in 2006. This seemed plausible because the bone bruises seen on magnetic resonance images (MRI) of ACL injuries are consistent with an impaction injury. During the last 5 years, several articles and studies have confirmed that axial compressive forces play a critical role in noncontact ACL injuries.

AAOS Now: How do ground reaction forces (GRFs) cause compressive forces that injure the ACL?

Dr. Boden: GRFs are the forces that must be absorbed by the body when the foot contacts the ground. When a person walks, the GRFs are approximately equal to body weight. When an athlete lands after jumping high into the air, the GRFs may be greater than 8 times body weight. The greater the GRFs, the more forces the body needs to absorb and the greater the likelihood of ACL injury.

My coauthors and I demonstrated the impact of GRFs on the ACL in a videotape analysis published in 2009. In comparing the landing position of noncontact ACL-injured subjects with controls, we found that athletes with ACL rupture all landed on the hindfoot or in a flat-footed position, whereas the control subjects all landed on the forefoot. The injured athletes also reached the flat-footed position 50 percent sooner than the controls.

These two factors reduced the ability of the calf muscles to absorb the GRFs. Consequently, the GRFs were transmitted to the knee, which is responsible for absorbing the larger forces.

AAOS Now: Did the study find other differences between injured and uninjured athletes?

Dr. Boden: Athletes with ACL rupture had significantly higher hip flexion angles at initial contact. To help determine the significance of this finding, I took several radiographs of my leg in different positions and found that several anatomic factors may also contribute to the injury.

When the leg is flexed in front of the body, it increases the effective posterior tibial slope, making it more vertical. If the femoral condyle impacts the tibial plateau in this position, the condyle is more likely to slide posteriorly down the tibial plateau, causing ACL rupture.

Additionally, when the leg is in the provocative position, the portion of the lateral femoral condyle that contacts the tibial plateau is its flatter anterior surface rather than the rounder posterior portion. When the two flat surfaces come into contact on the lateral side of the joint, it increases the probability of sliding, rather than rolling or flexing at the knee. Both of these theories have been substantiated with recent MRI and cadaveric studies.

AAOS Now: Why do female athletes have a significantly higher risk of ACL injuries than male athletes?

Dr. Boden: I believe that the main reason women have a higher incidence of ACL injury than men is their higher Q angle, or knee abduction moments (ie, valgus torque). The higher valgus position increases the built-in compression on the lateral side of the knee, which lowers the compressive force or GRF necessary to cause an ACL injury. Therefore, women may require a lower GRF (eg, 5 times body weight rather than 7 times body weight) in combination with the faulty leg and body position for ACL injury to occur.

AAOS Now: How can proper landing technique help athletes avoid noncontact ACL injuries?

Dr. Boden: The proper landing position simply reverses the injury or provocative position (Fig. 1). The athlete must land on the balls of the feet, with the trunk over the feet. Although an athlete will instinctively land in the proper position when possible, it may be difficult to land properly in the heat of competition. Even though it may be difficult for athletes to always land in the safe position, educating them about the importance of proper landing technique may help prevent these injuries.

Disclosure information: Dr. Boden—National Institutes of Health, Amgen Co., Johnson & Johnson, and Healthy Learning. References for studies cited in this article are available in the online version at www.aaosnow.org

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