Bracing and rotation, part 2: ACL injuries

By Cary Groner

This two-part series explores the role of rotational forces in athletic injuries and the extent to which bracing can help control those forces and, in turn, prevent those injuries. This second installment examines rotation as a contributor to anterior cruciate ligament injury.

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As described in Part 1 (see "Rotational mechanics: Bracing's next frontier"), rotational forces play a role in a variety of athletic injuries, from foot and ankle sprains right up the kinetic chain. With regard to ligamentous injuries of the knee, clinicians and trainers are still deciphering how bracing strategies may contain or modify those forces to prevent injuries or help them heal once they've occurred.

Most clinicians express reservations about using knee braces to prevent knee injuries. For one thing, even though valgus positioning is most closely associated with problems such as anterior cruciate ligament (ACL) tears,[1] it's very difficult to control a medial problem with a lateral solution.

"If we're targeting the ACL for assistance, putting a brace on the outside of the leg to try to duplicate the function of a structure on the inside, at the axis of rotation, cannot possibly do as good a job as anyone would like," said Jonathan Chang, MD, clinical associate professor of orthopedics at the University of Southern California.

There's also what might be called the tissue issue; there's so much muscle (and sometimes fat) above and below the joint that it compromises the effect of braces, which tend to slip around before they exert any meaningful effect on the biomechanical forces playing out beneath them.

"There is always soft tissue movement that decreases the effectiveness of the brace, particularly on the thigh," said Richard Willy, PT, PhD, an assistant professor of physical therapy at Ohio University. Accurate measurement is a related problem.

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“The surface markers used by gait labs don’t measure lower extremity rotation very well,” Willy said. “As a result, we don’t completely understand these transverse plane motions, which makes it hard to design a brace to control them.”

Research supports professional reluctance to prescribe braces. A literature review of prophylactic bracing in football players found no significant benefits.[2] Another study reported that functional knee bracing failed to alter lower limb mechanics in a way that would reduce forces on the ACL.[3] One review found that bracing wasn’t even effective after ACL reconstruction.[4] And a 2008 study in the *American Journal of Sports Medicine* found that a neoprene sleeve was just as effective as a functional brace after ACL surgery, supporting those who think braces affect proprioception more than biomechanics.[5]

Examining the mechanism

Research are beginning to elucidate the biomechanical forces involved in ACL injuries, however, which may eventually offer hope for preventive or therapeutic measures. For example, last year a team in Norway used computer modeling based on video images of 10 ACL injuries to describe a process that begins with valgus loading, which tightens the medial collateral ligament (MCL) and increases lateral tibiofemoral compression. This, in turn, leads to displacement of the lateral femoral condyle, anterior tibial translation, and tibial internal rotation. These forces join to rupture the ACL.[6]

In a case study reported this year, the same researcher used the technology to support those findings, noting rapid knee valgus and internal knee rotation within 30 ms of initial foot-to-ground contact, followed by external rotation.[7]

“We think the valgus moment comes first, which causes the compression of the lateral compartment, leading to [tibial] internal rotation and anterior translation,” said author Hideyuki Koga, MD, PhD, an assistant professor in the Section of Cartilage Regeneration at Tokyo Medical and Dental University. (Koga collaborated with the Norwegian researchers on the earlier study.) “Valgus motion is probably not enough to tear the ACL; however, combined with internal rotation and anterior translation, increasing the force, it could be torn.”

A 2008 study from another Japanese investigator reported that ACL injuries were more likely under certain conditions: deceleration and acceleration with excessive quadriceps contraction and reduced hamstring contraction at or near full knee extension.[8] Most pertinent to the subject was that higher ACL loading was associated with knee internal rotation. And a study just published in *AJSM* reached a similar conclusion—that the primary ACL injury mechanism was valgus collapse resulting from tibial abduction rotations combined with anterior tibial translation or either external or internal tibial rotations.[9]

The question is, what to do about it? Researchers have not yet been able to reliably determine the extent to which braces effectively control rotation, said Tim Hewett, PhD, professor and director of research at the Ohio State University Sports, Health, and Performance Institute, and director of the Sports Medicine Biodynamics Center at Cincinnati Children's Hospital.

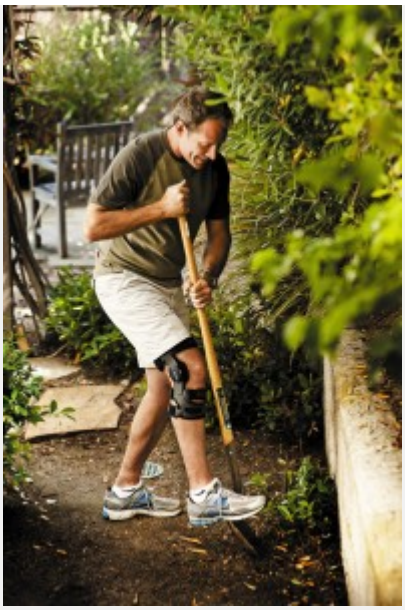
"I would say there is not much data suggesting that an ACL brace or any other brace is seriously going to alter or inhibit internal or external rotation around the knee joint," Hewett said. "I think with our current tools we can't tell. That's an area we have to move into, where more has to be done. I think there's potential there, but it hasn't been really studied too well, and I don't think the tools are there yet to really record it."

Hewett and his colleagues study braces using three methods: in vivo data from healthy individuals or patients, cadaveric testing, and computer modeling.

"I think this approach is the most likely to give us useful answers," he said. "We can validate cadaveric results in vivo, and validate in vivo results with the computer, and validate that modeling data with cadaveric data."

Hewett suspects that braces have multiple potential benefits, particularly by increasing joint position sense via increased skin input.

"The study I'd love to do would look at the effect of braces on injured athletes who are afraid to return," he said. "Postoperatively, the biggest reason patients want these braces is to feel safer. That's the study that might show the most significant effects."



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Some studies suggest that knee bracing may be effective against certain risk factors. For example, a 2010 paper from researchers in Singapore found that a brace with an anterior-sloped joint attenuated anterior tibial translation and axial tibial rotation during landing in 10 healthy male participants.[10] Another study, published this year, reported that bracing decreased tibial rotation in activities involving increased translational and rotational forces.[11] And bracing significantly reduced total range of motion in the frontal and transverse planes during running in 11 patients with ACL-deficient knees.[12]

When rotational forces interact with other factors to put ligaments at risk, bracing may help as well, according to some practitioners.

“If we can slow somebody down as they’re going into extension, force them to work against a brace and keep them flexed at the knee, we may be able to minimize ACL risk,” said Terry Malone, PT, PhD, a professor of physical therapy at the University of Kentucky. “If you look at valgus collapse, it’s a rotation that occurs in extension. If you keep the person out of extension, that collapse is minimized. The question is whether that creates an abnormal pattern and actually increases risk, and we don’t have that answer.”

Orthoses, rotation, and timing

Some sports medicine practitioners and trainers report that they get the best results in controlling rotational forces and preventing the injuries that accompany them, not with knee braces, but with foot orthoses.

“Whether someone has plantar fasciitis, shin splints, or knee tendonitis, it’s all rotation related,” said Robert Weil, DPM, who practices in Aurora, IL.

Weil has observed, as have many others, that women are more prone to ACL injuries than men.[13] Nevertheless, the female athletes he works with—many of whom are figure skaters—wear custom orthoses, and he rarely sees ACL problems.

Statistics about ACL injuries in skaters are hard to come by, however, and the injury appears rare. One paper reported that of the 25% of junior female figure skaters who reported acute injuries over a four-year period, ankle sprain was the most common; ACL injury rates weren’t reported in the abstract.[14] Another article on skating injuries didn’t include ACL injuries in its text or tables, reinforcing the impression that they don’t occur very often.[15] Nevertheless, Weil believes that orthoses can only help, given the tremendous forces involved in figure skating and the stresses they put on the body.

“You’re talking about femoral rotation, spin forces that can pull the kneecap medially, and other factors,” he said. “We want the orthosis to control the aggressiveness of those forces in the foot, the ankle, the lower leg, the knee, and the upper leg.”

Timing is a key component of these natural processes, Weil emphasized.

“If you’re looking to do a triple jump on the ice, and if you’re pushing off of pronated feet, you’re a step slow and unstable,” he said. “The lever apparatus that lets us push off is associated with the external rotation. You don’t want the posterior tibial muscle overworking because the foot is collapsing. An orthosis may not be a panacea, but it’s a major weapon to maximize efficiency in those timings of pronation/supination.”

Athletes should combine orthotic treatment with strengthening of the muscles that surround the joints as well as proprioceptive and balance training, Weil noted. In combination, these approaches not only prevent injuries but also improve performance.

“The athlete tells me she’s edging better, jumping higher, landing softer, and that’s about alignment,” he said. “If the orthotic helps with resupination, you’re going to push off with more authority than with a pronated foot that’s jerking around and collapsing.”

Research supports Weil’s experience in terms of biomechanics, at least. One study found that both rigid plastic and accommodative orthoses significantly reduced tibial internal rotation;[16] another reported that foot hyperpronation appeared to increase the risk of ACL injury.[17] In 2008, researchers from the University of Massachusetts reported that custom foot orthoses decreased maximum ankle inversion moment and increased maximum knee external rotation moment.[18] The same year, an article in *AJSM* reported that, in female athletes completing a jump, medial posting decreased ankle pronation and knee valgus at contact.[19]

Patient profiling

In some cases, apparently, efficacy depends on patient profile. A study published in 2006, for example, found that in low-arched runners, motion-control shoes decreased tibial internal rotation compared with cushioning shoes, whereas in high-arched runners, the cushioning shoes reduced tibial shock versus the motion-control shoes.[20] By contrast, a study published this year—notable mainly for going against the grain of these other findings—reported that semicustom orthoses had no effect on tibial internal rotation.[21]

At East Carolina University in Greenville, Walter Jenkins, PT, DHS, LATC, says that his ideas about elevated ACL injury risk in female athletes have evolved over time. Jenkins chairs the university’s physical therapy department, and a brief chronological tour of a few of his papers is instructive.

In 1996, Jenkins and his colleagues reported that a combination of knee hyperextension with excessive subtalar joint pronation was a strong discriminator between women who’d had ACL injuries and those who had not.[22]

In 2008, Jenkins reported in the *Journal of the American Podiatric Medical Association* that of 155 collegiate women basketball players studied over several years, those who did not wear foot orthoses were 1.72 times more likely to suffer a collateral ligament injury and 7.14 times more likely to sustain an ACL injury than those who wore orthoses.[23]

As he noted in the discussion section of that paper, “An increase in subtalar joint pronation leads to an increase in the amount of tibial internal rotation and knee joint valgus [which] increase the tension on the ACL….If orthoses decrease tibial internal rotation and improve the timing of pronation, the potential for ACL injuries may decrease.”

Then, in 2009, Jenkins reported that over-the-counter foot orthoses decreased internal rotation at the hip joint, and that custom orthoses decreased tibial internal rotation, in wearers compared with individuals who did not wear orthoses.[24]

“These days, we’re looking more at motion studies than at posture,” he told *LER*. “Factors that affect motion include strength, neuromuscular movement patterns, and the ability to fire muscles in a balanced fashion so that there’s no longer dysfunction.”

According to Jenkins, women may be more prone to ACL injury than men because they tend to be quadriceps dominant when landing after a jump, whereas men have more of a balance between quadriceps and hamstrings. The differences in men's and women's hips play a role, as well.

"Women tend to have more internal rotation of the femur at the hip joint on landing," he said. "That adduction is decreased when they wear a foot orthotic, but that's not the case for men."[25]

Getting hip

Regardless of the pelvic differences between men and women, researchers and clinicians are paying increasing attention to the role of the hips when assessing lower extremity problems, for pelvic and lumbar rotation both reflect and influence torque forces in the knee and ankle joints.

As noted in an influential 2010 literature review and clinical commentary published in the *Journal of Orthopaedic & Sports Physical Therapy*, hip muscle weakness has been associated with knee injury, and impaired trunk proprioception and control are predictors of knee injury in female athletes.[26] Abnormal femur motion can strain the soft tissues at the tibiofemoral joint, and the excessive valgus already noted as a risk factor for ACL rupture is related to diminished hip muscle strength.

Moreover, clinicians increasingly agree on the importance of assessing lower trunk and pelvic rotation as a factor in knee problems.

"If the low back and pelvis region is not well stabilized, it could put you at a disadvantage for controlling lower segment motion," said Bryan Heiderscheit, PT PhD, associate professor of orthopedics and rehabilitation, and codirector of the Neuromuscular Biomechanics Laboratory at the University of Wisconsin.

Failing to consider this aspect of an injury may compromise the effectiveness of therapy, Heiderscheit said.

"You may treat the injury but not what caused it initially," he said.

Because Heiderscheit has studied hamstring injuries extensively, he's convinced of the importance of such factors in healing them and believes that the same variables may affect ACL rehabilitation as well.

"Making sure that neighboring muscles are strong enough, and that you have adequate control of the pelvis and low back, is crucial to recovery," he said. "If you don't control hip and pelvis rotation, you'll never get full recovery and you will probably reinjure yourself."

The long view

As researchers and clinicians continue to refine their understanding of the role played by rotational forces in both normal biomechanical function and abnormal pathology, they will ideally more cogently define the roles to be played by strengthening, bracing, and strapping. With time, such investigations may lead to more holistic and thorough approaches to dealing with the biomechanical effects of rotation.

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